Brief Introduction to the NASEM (formerly known as NRC) 8th Revised Edition of the Nutrient Requirements of Dairy Cattle

W. P. Weiss
Department of Animal Sciences
Ohio Agricultural Research and Development Center
The Ohio State University, Wooster

Introduction

After 20 years, a new "Dairy NRC" was released in 2021 albeit with new name. The 8th revised edition of the Nutrient Requirements of Dairy Cattle will now be designated as a product of the National Academies of Science, Engineering, and Medicine (NASEM). The Academies have always been the governing unit of the NRC. Although the name has changed, the procedures related to development of the revised edition remained the same. A committee of experts are chosen by the Academy that represents a broad range of expertise and geography, and the committee is vetted for potential conflicts of interest. The final committee was comprised of Rich Erdman (co-chair), Bill Weiss (co-chair), Mike Allen, Lou Armentano, Jim Drackley, Jeff Firkins, Mary Beth Hall, Ermias Kebreab, Paul Kononoff, Helene Lapierre, and Mike Vandehaar.

The main charge of the committee was "to (conduct) a comprehensive analysis of recent research on the feeding and nutrition of dairy cattle, including research on the amounts of amino acids (AA), lipids, fiber, carbohydrates, minerals, vitamins, and water needed by preweaned calves and growing, reproducing, and lactating dairy cattle. . . and to … evaluate new information to improve the accuracy of predicting animal performance from nutrient input and of predicting nutrient input when animal performance is known." The committee was also charged with developing a computer model that reflected the discussion and equations in the text. To meet the last objective, large databases need to be constructed, mostly from published data. Those databases are then used to derive equations to estimate both nutrient supply and requirements. For most vitamins and minerals, inadequate data to generate statistically based equations. In these situations, equations generated from single studies, means from a few studies, and expert interpretation of committee members were used.

It is far beyond the scope of this paper to discuss everything that has been revised (the final book exceeds 500 pages). Rather this brief review will discuss some major revisions from NASEM (2001) and their implications and will be limited to lactating cows even though the chapters on transition cows, calves and heifers have been modified extensively. Some of this will be discussed by other speakers at this conference. Minerals and vitamins were discussed separately at this conference. In addition, areas that need more research to improve equations and incorporate more effects of various nutrients on animal productivity and well-being will be discussed. The amount of text dedicated to different sections does not reflect the importance or magnitude of the changes made, but rather reflects this author's areas of expertise.

Estimating Dry matter Intake

The dry matter intake (DMI) equation in NRC (2001) used only animal factors (milk production, body weight, and days in milk). Because milk yield is strongly related to DMI, the equation was fairly accurate when production measures were known. The equation did not work as well when a diet was formulated without knowing actual production. NASEM (2021) includes an improved animal factor only equation (based on more data and data from higher producing cows) and an animal and diet factor equation. Primary dietary factors that influence DMI are forage NDF (negatively related to DMI), in vitro NDF digestibility (positively related to DMI) and the primary source of fiber in the diet estimated using the ADF/NDF ratio (high ratio indicates a legume-based diet and a lower ratio indicates a grass-based diet). The new equations will be more accurate with today's higher producing cows and reflect the impact of diet on DMI. Users are cautioned that when using the diet factor equation, entered milk yields must be reasonable because milk yield is still the major driver of DMI. Equations to estimate DMI for dry and prefresh cows, calves and heifers were also updated and include dietary NDF (except for the calf equations).

Future improvements. The current feed-animal factor equation is too dependent on milk yield. An accurate equation based mostly or solely on diet factors would allow nutritionists to better determine the production potential of various diets before actually feeding them. The equation estimating DMI during the dry period is much better than the equation in NRC(2001) but it only accounts for one source of dietary variation (NDF concentration). Digestibility of NDF, starch, and source of NDF likely affect DMI prepartum but more data are needed to generate equations to account for that variation. Data with Jersey cows are needed.

Energy

The NRC (2001) was the first revision of the Dairy Requirements series that calculated energy values (i.e., net energy for lactation, NEL) from the nutrient composition of the feeds. Prior to that revision, NEL values of feeds were fixed. In the 2001 system, digestible energy (DE) was calculated for feeds by estimating the energy provided by digestible portions of NDF, CP, fatty acids (FA), and nonfiber carbohydrate (100 – NDF – CP – FA – ash). The DE of the diet was calculated as a weighted mean from feed values, and the diet DE was then discounted based on DM intake (DMI) and TDN concentration of the diet. TDN concentration was essentially a proxy for diet starch concentration. One issue that was identified regarding NRC (2001) was that energy balance (NEL supply minus NEL requirements for maintenance, milk, growth, and reproduction) was underestimated for high producing cows. Because it was a problem with high producing, high DMI cows, the source of the error was assumed to be an overestimation of lactation NEL requirements and/or an underestimation of NEL concentration of the diet likely caused by the discount factor.

Research published after NRC (2001) indicated that the greatest source of error was indeed the discount factor. Dry matter digestibility did not decrease as much with increasing

DMI and diet TDN as the NRC 2001 equation calculated. In NASEM (2021), the digestibility of NDF and starch are reduced as DMI increases but much less than the discount in NRC (2001) (Figure 1). One reason for the error is that NRC (2001) used a cow fed at maintenance (approximately 7 kg of DM) as the base and discounted from there. This resulted in substantial extrapolation and assumed linearity starting at a very low and restricted DMI. The data used by NASEM (2021) was with mostly lactating cows (DMI ranging from about 1.7 to 4.6% of BW with a mean of 3.5% of BW). Because increased dietary starch can depress NDF digestibility, its effect was also included (the base was set at 26% starch which was mean concentration in the dataset used). This approach is much more theoretically accurate than using TDN as done previously. The improved discount equation should correct most of the underestimation of NEL balance in high intake cows by NRC (2001).

Other changes made to the energy prediction equation would be considered fine-tuning. The NFC fraction was replaced with starch and residual organic matter (ROM; i.e., NFC – starch) as outlined by Weiss and Tebbe (2018) and Tebbe et al. (2017). This allows better estimation of the energy provided by a variety of starch sources (e.g., different grind sizes of corn grain, high moisture vs dry corn, different maturities of corn silage). The true digestibility of ROM was set at 96% (Tebbe et al., 2018) and starch digestibility values are constants based on the feed (Table 1). Users can choose to use a lignin-based equation as in NRC (2001) or 48 h in vitro NDF digestibility. An equation is used to convert in vitro digestibility into estimated in vivo digestibility.

Another change was to the true digestibility coefficient used for FA. In NRC (2001) the true digestibility of FA was assumed to be 100% at maintenance DMI (92% for a typical lactating cow). This was based on very limited data because at that time, FA was not commonly measured. Over the past 2 decades a substantial database of FA digestibility was developed and allowed better estimation of the true digestibility of FA. Two meta-analyses have been conducted (Weiss and Tebbe, 2018, Daley et al., 2020) and both derived essentially the same true digestibility value (73%) with no metabolic fecal FA (i.e., intercept was not different from 0). In the NASEM (2021), digestible FA are calculated as 0.73* FA (% of DM). This is substantially lower than the 0.92*FA (% of DM) used in NRC (2001) but the difference is not as great as it appears because in NRC (2001), FA contributed to metabolic fecal energy but not in NASEM (2021). However, the DE concentration of feeds with appreciable concentrations of FA will be lower in NASEM (2021) than in NRC (2001).

In NRC (2001), metabolizable energy (ME) was calculated directly from DE using an equation that was developed several decades ago. That equation did not correctly account for the effect of protein or fat on ME. NASEM (2021) estimates methane using a published equation based on DMI and dietary concentrations of FA (negative effect on methane) and digestible NDF (positive effect on methane). Urinary energy is estimated by estimating urinary N excretion (g/d) and multiplying that value by 0.0143 Mcal/g (Morris et al., 2021). Both methane and urinary energy are calculated for a diet, not a feed. Therefore, feeds will not have ME or NEL values. The change in the method to calculate ME will result in higher ME values for diets with high FA concentrations and lower ME values for higher fiber diets and diets with excess CP. In the previous NRC, NEL was approximately .64*ME. Based on a re-analysis of Beltsville calorimetry data, Moraes et al. (2018) determined that 0.66 was more accurate and that value is used to convert diet ME into NEL concentrations of diets.

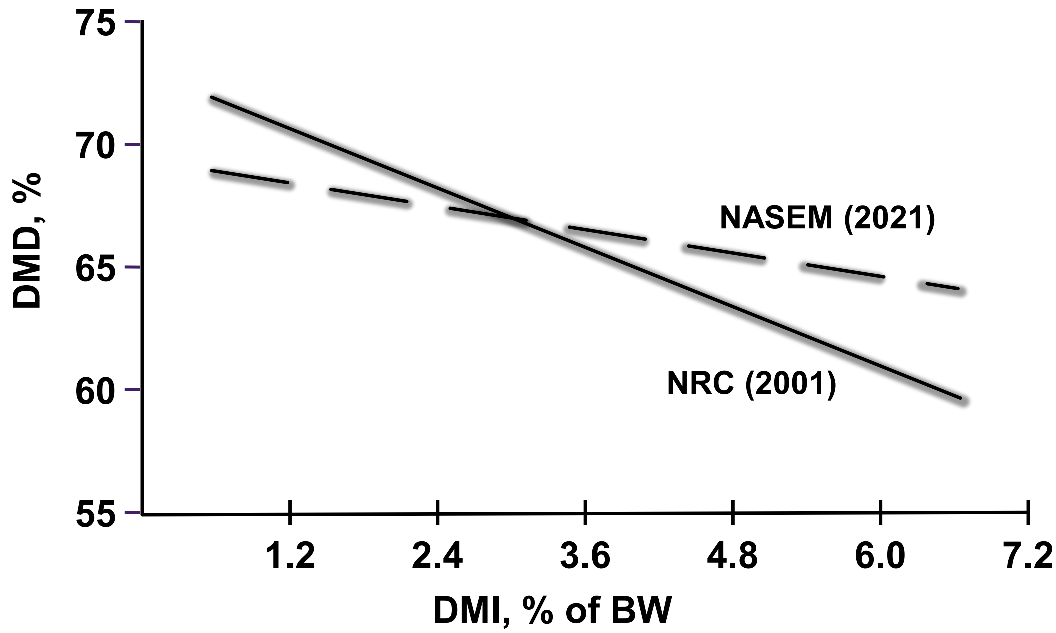

Figure 1. The effect of increasing dry matter intake (DMI) expressed as % of body weight (BW) on dry matter digestibility (DMD) using the NRC (2001) discount equation and the discount equation in NASEM (2021) model. For NRC (2001) diet TDN was set at 72% and for the NASEM line, dietary starch was set at 26%. Overall, the effect of DMI on digestibility (i.e., digestible energy) is about 3 times greater using NRC (2001) than in the updated NASEM.

Energy requirements were also evaluated and modified as necessary. The greatest change was in the maintenance requirement. Several papers published over the past 15 years determined that the standard equation for maintenance (which has been used for more than 30 years) underestimated the maintenance requirement of modern dairy cows. Using an average from several newer studies, the maintenance requirement was increased from 0.08*MBW to 0.10*MBW (where MBW is metabolic body weight in kilograms). This change is a 25% increase in maintenance or about 2.5 Mcal of NEL/day for a 650 kg cow). The equation to calculate gestation energy requirements changed to better model fetal growth but the change did not appreciably alter gestation NEL requirements. Lactation energy requirements changed slightly because the efficiency coefficient (0.66) changed from 0.64. Equations to estimate NEL requirements for grazing cows were updated based on newer data and generally activity requirements will be less when calculated using NASEM (2021) than when using NRC (2001).

Table 1. Starch digestibility coefficients used in NASEM (2021) for selected feeds (not all feeds are shown).

Feed	Starch digestibility
Default	0.91
Corn grain, dry, fine grind (<1250 μm)[2]	0.92
Corn grain, dry, medium grind (1500 um to 3250 μm)	0.89
Corn grain, dry, coarse grind (>3500 μm)	0.77
Corn grain, high-moisture, fine grind (<2000 μm)	0.96
Corn grain, high-moisture, coarse grind (>2500 μm)	0.90
Corn grain, steam flaked	0.94
Sorghum grain, dry, ground	0.83
Sorghum grain, steam flaked	0.94
Corn silage <30% DM	0.91
Corn silage 32 – 37% DM	0.89
Corn silage >40% DM	0.85
Barley, ground	0.91
Wheat	0.93

Future improvements. If laboratory measures can be developed to estimate total tract starch digestibility, they should be incorporated into the energy supply equation. The energy coefficient for NDF is too high based on very recent data from Nebraska. Perhaps incorporating fatty acid composition data will increase the accuracy of estimating fatty acid digestibility resulting in more accurate estimates of DE. On the requirement side, going back to an ME system will be simpler and probably just as accurate as the NEL system unless we can develop specific NEL/ME efficiencies for nutrients. Including body condition in the maintenance equation should improve accuracy (a fat cow will have a lower maintenance requirement than a thin cow at the same BW). More data with Jersey cows are needed.

Carbohydrates

NASEM (2021) has a chapter on Carbohydrates but did not establish requirements or 'adequate intakes' for the different carbohydrate fractions. The major fractions discussed are total NDF, forage NDF, starch, and various measures of 'effective' NDF. A major change from NRC (2001) was the replacement of nonfiber carbohydrate (NFC) with starch. Recommendations provided by NASEM (2021) follow the same basic relationships as did NRC (2001) but now as concentrations of forage NDF decrease, recommended concentrations of starch decrease (previously concentrations of NFC decreased). The text includes increased discussion of both dietary and management factors that can affect the optimal concentrations of forage NDF, total NDF, and starch in diets. In addition, recommendations for effective NDF as measured by the method of Zebeli (2012) are provided. Zebeli et al. (2012) defines effective NDF as the NDF in the top 2 screens of the Penn State Particle Size box (PSPS) expressed as a percent of diet DM. NASEM (2021) discusses a new concept called physically adjusted NDF. This approach uses several nutrient fractions along with particle size and some cow factors to estimate the optimal amount of diet DM that should be on the 8 mm screen of the PSPS. Because of the uncertainty around the values, this was not included in the software but is discussed in detail in the text.

Future improvements. This is an area that needs substantial research if we are going to change from 'recommendations' to more quantitative optimal concentrations or intakes. Appropriate analytical measurements and identification of meaningful response measures are major limitation to progress. The committee identified several issues including the need to measure both DM and NDF concentrations in various particle size fractions. Usually, particle size fractions are assumed to have the same concentrations as the total diet which is clearly wrong. Rumen pH is often used as the response measure but that has questionable value. Do we use mean pH, hours below a certain pH, lowest pH, etc? The fermentability of starch should affect the optimal concentration of effective NDF needed but data do not exist to quantify that relationship.

Protein and Amino Acids

This section underwent the greatest change as compared to NRC (2001) and the complexity of the model precludes a detailed discussion in this paper. Microbial protein is estimated based on estimated rumen digested starch and fiber (these are estimated based on diet composition, not digestion rates). Rumen undegradable protein is based on the A, B, C fraction scheme described in NRC (2001); however rather than estimating rate of passage based mostly on intake as done in NRC (2001), constant rates of passage are used (one for concentrates and one for forages). Significant improvements were made in the estimates for the digestibility of the rumen undegraded protein because the data base was much larger allowing greater screening for spurious values. Supplies of metabolizable protein (MP) and metabolizable AA are the sum of digestible microbial AA or true protein and digestible rumen undegraded AA or true protein. In NRC (2001) endogenous protein was included in MP supply; however, this was an error because endogenous protein does not cause a net increase in MP supply. Therefore, endogenous protein is considered a requirement rather than a supply function in NASEM (2021).

For lactating cows, maintenance requirements are based on both net protein (NP) and amino acids. The requirement for metabolic fecal protein was changed markedly and is now a function of dietary fiber. The calculation for endogenous urinary CP was also changed. In addition, rather than using a classic requirement model for milk protein (e.g., to produce 1200 g of milk protein you need X grams of MP or specific AA) a response model is used (based on AA and energy supplies, the cow should be able to produce X grams of milk protein). The response function for milk protein yield is based on DE supply (the DE is from components other than CP) and supply of lysine, methionine, leucine, isoleucine, histidine, and total essential AA. The equation to estimate milk protein yield illustrates that an almost infinite array of AA profiles can result in similar milk protein yields. The efficiency of converting MP to NP for maintenance function is 0.68. Efficiency of converting metabolizable AA to milk protein is not fixed as it was for MP in NRC (2001). The function includes a quadratic term for total essential AA which means efficiency decreases as supply of essential AA increases. The software calculates 'target efficiencies' which help users determine which AA are mostly likely limiting and it also calculates expected response in milk protein yield if supply of certain AA change.

Future improvements. The equation used to calculate microbial protein does not include important sources of variation (e.g., high moisture corn will produce the same microbial protein as dry corn) and needs to be expanded. The AA composition of digestible RUP is assumed to be the same as the feed which may or may not be true. More data on AA requirements for maintenance functions are needed. The equation used to estimate milk protein yield is empirical and based on data generated several years ago. More data are needed to validate its accuracy with high producing cows.

Minerals and Vitamins

These nutrients are discussed in another paper in these proceedings; therefore, this section will concentrate on future improvements.

Future improvements. Much less research is published on minerals and vitamins than for macronutrients such as AA, protein, and energy and therefore we have more uncertainty associated with mineral and vitamin requirements or adequate intakes. A major limitation to the current system is the lack of absorption data for most minerals. For most minerals we have almost no data on their true absorption by cows, and the data we do have is often more than 60 years old. Measuring true absorption is very difficult and expensive (it usually requires the use of stable isotopes) which is why data is so limited. In addition, we know antagonistic relationships exist among many minerals but in general we do not have adequate data to quantify the effects. For example, increased dietary sulfur reduces copper absorption but we do not know exactly how much. We have virtually no information on absorption of vitamins or factors that affect absorption. For many minerals and vitamins, we do not have sensitive status indicators so we cannot develop recommendations based on optimal status. Currently we often rely on clinical health data (e.g., reduction in incidence of mastitis) but these studies are expensive and require lots of cows. This limits most experiments to just 2 treatments which is inadequate to fine tune recommendations. Lastly the factorial method used to establish requirements for minerals does not include everything minerals do. For example, several trace nutrients are needed to elicit strong immune responses, but the factorial method does not include a requirement for health.

Conclusions

The 8th revised edition of the NASEM (formerly NRC) Nutrient Requirements of Dairy Cattle reflects the current state of knowledge for applied dairy nutrition. All facets of nutrition for calves, heifers, dry cows, and lactating cows were reviewed and changes in requirements were made when appropriate. The book also contains up to dates reviews on numerous topics relevant to feeding dairy cattle. The new revision is an improvement over NRC (2001), but the new revision also identified areas where improvements are still needed, and the book should be used to focus research on those areas.

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Fat in dairy diets and relationship to NRC 8 energy system

Lou Armentano

Dairy Science Emeritus Professor
University of Wisconsin

I have previously compared how the NRC 8 derivation of fat contribution to energy differs from the previous NRC 7. One of the major advantages (my opinion) of NRC 8 handling of fatty acids is it is much simpler without "exceptions" for fat as a diet component and integrates more seamlessly with the energy system as a whole. Given that, explaining the complexities of the previous model that are not carried over into NRC 8 is probably not the best use of time or effort.

The new NRC deals with fatty acids per se and not gravimetrically determined ether extract or crude fat measurements. Fatty acids are measured individually, but in NRC 8 they are really handled as a sum of FA in most cases. Remember, that even when total FA is reported and FA shown as a proportion of total FA, the 'wet chemistry' analysis is done by measuring individual FA and then summing them. The 5 major individual fatty acids found in feeds (palmitic, C16:0; stearic, C18:0; oleic, C18:1; linoleic, C18:2 and linolenic, C18:3 are reported) and should be useful in evaluating and formulating diets even though they are not used in any of the model equations. When dealing with FA in diets, it is important to remember that when feeding a triglyceride, the mass of FA and glycerol released is greater than the original mass of triglyceride. FA content of feeds should be reported as the free fatty acid (protonated) weight regardless of its form in the feed, so the reported FA and glycerol released from a pure triglyceride is more than 100% of the original triglyceride weight. Also when adding or removing fat to a diet, other components (usually mostly starch) are altered reciprocally, and their effect in both the model equations and the cow must be recognized.

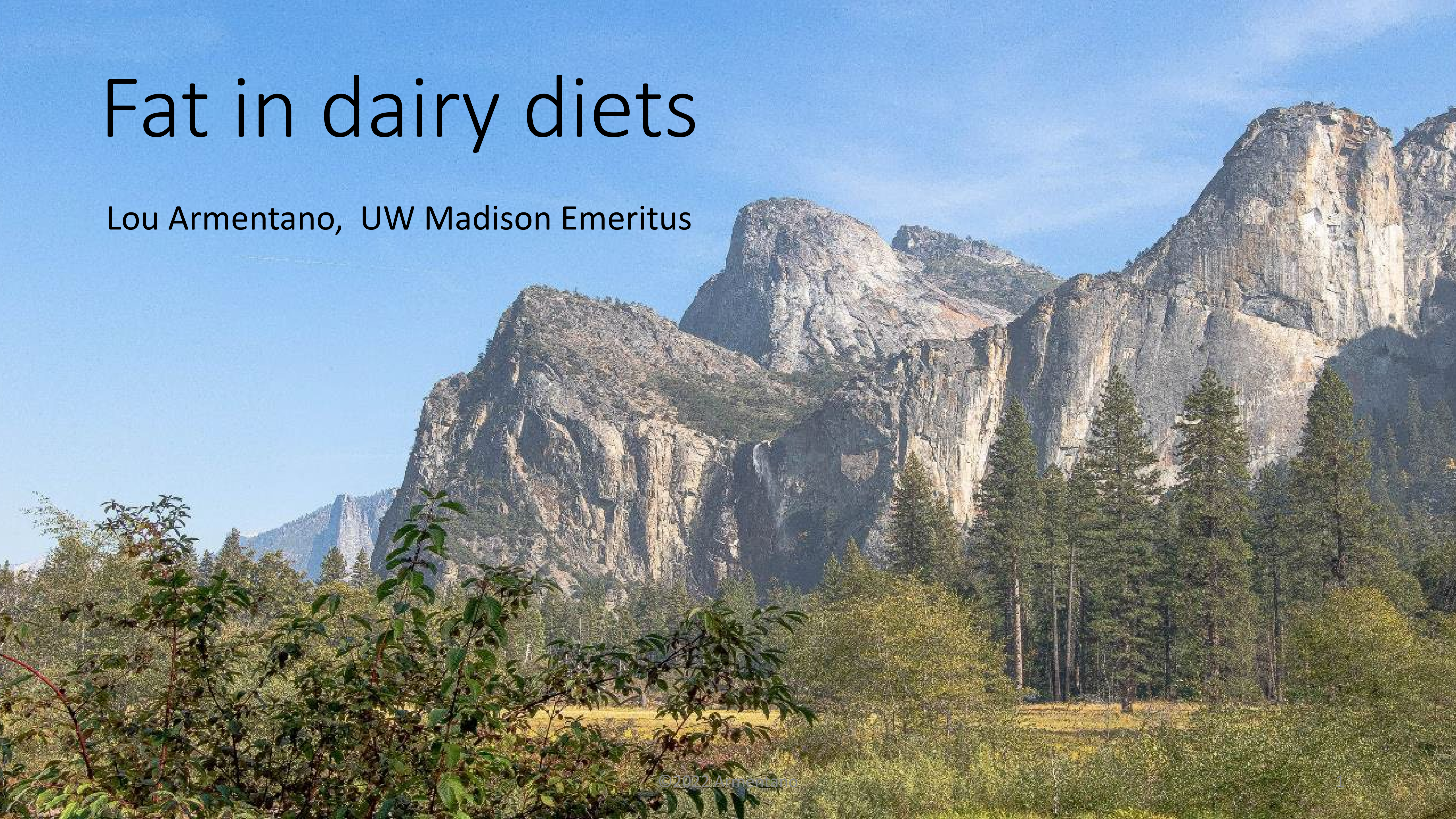
In the updated NRC, FA contribution to DE is slightly less than in NRC 7. Decreasing FA digestibility at higher levels of FA in the diet is ignored by the NRC 8 model even though evidence exists to show that it clearly exists for some FA sources. As increased diet FA usually relies on added fat supplements (both in research data and field use) some of this digestibility decline is captured implicitly in the (generally lower) digestion of FA supplements based on empirical measurement, but the model may underestimate FA digestion in lower level of a given FA supplement compared to higher levels of the same FA supplement. Nevertheless, a linear, 0 intercept model of FA digestion (including the ten classes of FA supplements formed according to their reported FA profile) fit the data well without bias for FA concentration or DM intake. This straight line (class adjusted) model also is consistent with a 0 intercept signifying no endogenous fecal FA secretion and subsequently true digestion equal to apparent digestion. FA effect on ME obtained from DE is through the combined diet methane production equation, and diet FA has a large negative effect in this equation which greatly enhances the DE to ME conversion efficiency when adding FA to a diet. While there are data to support a higher conversion of ME to NE for FA compared to other energy sources, however the effect is very small over the range of FA actually fed and the model converts diet ME to NE with the same efficiency (0.66) for all dietary energy source, including FA. Therefore some of the simplifications of the model may be slightly disconcerting in theory, but provide a simple model that fits the data as well as more complex constructions and with deviations in calculated energy supply that are not likely to be of a magnitude that is impactful, or even measurable, in practice.

I believe it is useful to pay attention to the 5 main individual fatty acids in the diet, and also to use milk infrared analysis that separates the shorter de novo milk fatty acids from exogenous dietary FA (sum of C4 to C14 milk fatty acids, C16 total milk, and C18 total milk fatty acids). Future nutrient models may better predict total FA digestion by directly measuring dietary fatty acids. In the current model FA composition is only incorporated by the classification of fat supplements. This probably helps account for possible detrimental effects of high levels of stearic and low levels of oleic acid to some extent, but not directly. The profile of diet FA is important also in differing effects on milk fat yield. In general adding any of these fatty acids to the diet results in partial transfer to the absorbed C16 or C18 to those FA secreted in milk (mostly as C16:0, C18:0 and C18:1) . But, adding linoleic acid to diets reduces de novo milk FA synthesis. Adding oleic or linolenic also reduces de novo milk fatty acid secretion. It is not really clear what stearic acid does, but adding palmitic acid does not reduce the combined mass of C4 to C14 secreted (although profile within that group changes, and more milk C16 is now derived from the exogenous C16:0 fed and less from synthesis of C16:0 by the mammary gland). At least part of the effect of linoleic is clearly due to production of bioactive FA with trans bonds in the rumen which are absorbed and inhibit milk fat synthesis. Some knowledgeable investigators believe that the effect of exogenous dietary FA to reduce shorter chain fatty acids in milk solely a substitution effect where the mammary gland is regulating total milk fat secretion so that longer chain exogenous FA displace de novo fatty acids. While this possible substitution effect cannot be totally discounted, in my opinion it does not fully explain the effect of oleic and linolenic acids, but I could be wrong. In any event, the effect of depressing mammary de novo FA is stronger for dietary linoleic than oleic and linolenic, not clear for stearic, and not existent for palmitic. To the extent that stearic acid would show the same effect as oleic and linolenic, the substitution model would make most sense, if dietary oleic and linolenic have stronger depressing effect than stearic, some sort of bioactive FA effect may explain that as it does the greater effect of linoleic over oleic and linolenic. While it is important to avoid extreme high levels of linoleic acid, both linoleic and linolenic are essential as absorbed nutrients and less that 10% of these dietary FA actually make it to the cow's tissues. I would be cautious of intentionally reducing linoleic acid much below 1% of diet dry matter.

Because adding dietary fat generally increases milk fat and milk lactose yield, not all of the increased energy density from adding fat contributes to improving energy balance in the cow. Also, any reduction in intake cause by fat addition (but not incorporated into model estimates of intake) will impact the benefit of FA to improved energy balance.

Fat in dairy diets

Lou Armentano, UW Madison Emeritus



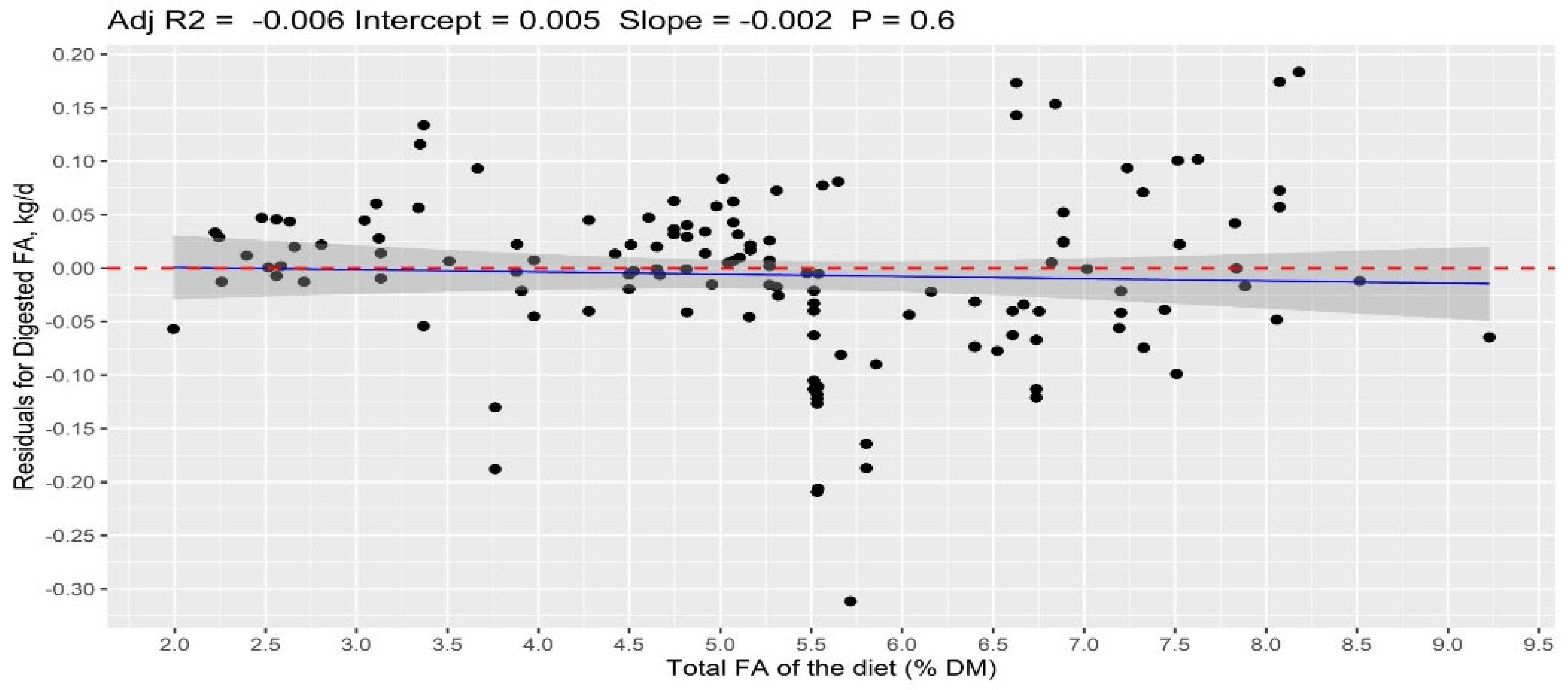
Major changes in NRC 8 vs. 7 (for your records)

	NRC 7	NRC 8	
Fat amount	Ether Extract (crude fat)	Fatty Acid – as COOH	In 8
FA content calculation	EEx-1	FA by measurement or regression from EEx	FA content a user variable in "new" feeds
FA Digestibility in basal	True dig. Set to 100% at maintenance DMI	Estimated by regression to be 73% true digest.	FA digestibility also a user variable for any new feed
FA Class (supplements)	TDN class – FAT or FAT with Glycerol	Can call FA nonesterified to calculate rOM correctly	
True vs Apparent Digestibility	TDN and DE are apparent Endogenous fecal energy	True=Apparent (no endogenous FA)	
Digestibility of FA supplements	5 supplements Included (digestibility <100%)	10 FA rich feeds included	
Fat on DE to ME efficiency	DE to ME increased for EEx over 3%	ME of diet increased with FA due to less Methane	All FA same from 0% up
Fat on ME to NE efficiency	80% for EEx > 3%, vs 70%	Same as all other ME	NE=.66*ME

FA as energy source greatly simplified in NRC 8

- FA not Ether extract or crude fat
- No endogenous FA used so apparent and true digestibility are same
- 'native' FA digestion <u>variable</u> set at 73% <u>in library</u> to get DE (digestible energy)
- Supplements classified by FA content and grouped into classes
- DE to ME uses diet methane production
  - Fat reduces diet methane
  - Therefore higher FA diets have increased DE to ME by that diet methane prediction
- ME to NE efficiency same for FA as all other energy sources (.66)
- Dry matter intake
  - Diet adjusted DM Intake equation does not reduce intake with FA in diet
  - Increased DM Intake does not reduce FA digestibility
  - Increased FA in diet does not reduce FA digestibility
  - adding FA no direct effect on NDF digestion (but removing starch increases NDF digestion)

Model with no DMI or FA concentration induced depression of FA digestibility fits data well



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- In 7 DMI affected all DE, in 8 no effect of DMI on FA digestion
- Amount of FA (or EEX) does not alter FA digestion in either model

Basal

Feed Ingredient	% of DM	
Corn Grain, fine grind	37.4%	
Corn Silage	24.2%	
Corn Oil, 70% dig FA	0%	
Grass-Legume	24.2%	
Soy Bean Meal	10.0%	
Salt	4%	
[FA]	(2.6%)	
[EEX-1]	(1.8%)	

24.75 kg DM/day

	Mcal/kg DM	% of GE	% of DE	% of ME
NRC 8				
DE	3.01	72.0		
ME	2.61	62.5	86.7	
NE	1.72	41.2	57.2	66.0
NRC 7				
TDNd?	*61.1*			
DE(?)	*2.46*			
ME	2.37		*96.5*	
NE	1.57		*61.1*	63.3

Corn Oil replaces **Salt**

Feed Ingredient	% of DM
Corn Grain, fine grind	37.4%
Corn Silage	24.2%
Corn Oil, 70% dig FA	4.0%
Grass-Legume	24.2%
Soy Bean Meal	10.0%
Salt	0%
[FA]	(6.1%)
[EEX-1]	(6.2%)

	Mcal/kg DM	% of GE	% of DE	% of ME
		NRC 8		
DE	3.28	72.2		
ME	2.94	64.7	89.5	
NE	1.94	42.7	59.1	66.0
		NRC 7		
TDNd?	*69.0*			
DE?	*2.87*			
ME	2.66		*92.6*	
NE	1.71		*59.6*	64.3

Oil for salt substitution (**Δ = delta = effect of added FA)**

	Δ FA%	Δ DE	Δ ME	Δ NE	Δ ME/Δ DE)	Δ NE/Δ ME
		---------Mcal/kg DMI--------				
Corn Oil – NRC 8	**3.5**	**0.27**	**0.33**	**0.22**	**1.22**	**0.67**
Corn Oil – NRC 7	**4.4**	*0.42*	**0.29**	**0.21**	*.70*	**0.72**

Methane (Mcal/d) = + .294 * Dry Matter Intake kg
- .347 * %Fatty acid in DM
+ .0409* %digest NDF in DM

Methane loss is ~7 Mcal/d, so -.347 is a **big** coefficient

This is the only non-additive effect of FA addition on any Energy intake fraction

Note: NRC 7 feed library data changed feed Fat to equal Crude Fat reported in NRC 8

Why did I replace salt?

- Not what you would do in practice
- To show model results without associative effects of OTHER components that are reduced when replaced by FA
- Energy system in NRC 8 and associative digestion effects:
  - Dry matter intake and Starch cause loss of disgestion
  - It is only NDF digestion that is reduced

Oil or starch substitution for salt in NRC 8

	Δ FA%	Δ DE	Δ ME	Δ NE	Δ ME/Δ DE)	Δ NE/Δ ME
		---------Mcal/kg DMI--------				
Corn Oil for salt	**3.5**	**0.27**	**0.33**	**0.22**	**1.22**	**~0.66**
Starch for salt	**0**	**0.13**	**0.13**	**0.09**	**1.00**	**~0.66**

Diet	NDF digestion	Gas energy (Mcal/d)
Salt	45.67%	6.86
Oil	45.67%	5.62
Starch	43.29%	6.83

Regression Model ttNDFd

	ΔttNDFd (%)			
Fat Supplement Type	Δ	Δ3	SE	P-value
C12/C14	-2.7	-8.0	0.4	**<0.001**
Oil	-0.6	-1.9	0.2	**0.01**
C16	-0.3	-0.9	0.4	0.47
Animal – Vegetable	-0.1	-0.2	0.3	0.87
Tallow	-0.1	-0.3	0.3	0.66
Calcium Salts Palm	0.5	1.6	0.3	0.12
Calcium salts LCFA	0.3	0.8	0.3	0.32
Saturated	0.4	1.3	0.3	**0.09**

ME to NE conversion: should it be higher for FA? And would it matter?

- By my calculation using NE = .8 x ME for pure FA:
  - at 1% FA NE/ME= .658
  - at 7% FA NE/ME= .666
  - NRC 8 uses .66 constant
  - Difference negligible over practical range

Intake?

- No direct FA effect on dry matter intake in NRC diet adjusted DMI
  - Given a 2 “random” diets, FA content does not help you predict DMI
  - Best general intake equation mostly driven by fiber and forage but includes Milk Yield
- Restricting analysis to only studies where FA was added, FA decreased DMI
  - Given two related diets, adding (some kind) of FA can reduce intake
- Measure herd intake when changing FA in diet
- Remember intake affects associative effects on fiber and starch digestion and also methane production

Effect of 1% or 3% added FA on DM Intake

	ΔDMI in kg/d			
Fat Supplement Type	Δ1	Δ3	SE	P-value
C12/C14	-1.1[c]	-3.2	0.2	**<0.001**
Oil	-0.3[abc]	-0.9	0.1	**0.01**
C16	-0.1[ab]	-0.4	0.2	0.45
Animal – Vegetable	-0.2[ab]	-0.6	0.2	0.31
Tallow	-0.3[abc]	-1.0	0.1	**0.01**
Calcium Salts Palm	-0.4[abc]	-1.2	0.2	**0.02**
Calcium salts LCFA	-0.6[bc]	-1.8	0.1	**<0.001**
Saturated Fat	0.2[a]	0.7	0.1	**0.09**

Weld and Armentano 2017

Looking forward

- Cows are fed (mostly) 5 fatty acids:
  - C16:0 Palmitic
  - C18:0 Stearic
  - C18:1 Oleic
  - C18:2 Linoleic
  - C18:3 Linolenic
- These are included in feed library
- You can count them on one hand !
- Pay attention to them <u>individually</u>

Effect of different diet FA on total Milk FAT yield

Milk FA class	Diet C16:0	Diet C18:0	Diet C18:1 & C18:3	Diet C18:2
<C16	No effect	No effect?	Decreases	**Decreases**
C16	**Increases**	No effect?	Decreases	**Decreases**
C18	No effect	Increase?	**Increase**	Increase?
Total	Increase	Increase?	Decrease	Decrease

Milk	Intercept (±SE)	P-value	FA as % of Diet	Slope (±SE)	P-value	AIC
<C16, g/d	340.8 (±19.1)	<.001	∑C18:1,2,3	-30.1 (±2.18)	<.001	970
<C16, g/d	**346.7 (±19.5)**	**<.001**	**C18:1**	**-27.1 (±4.6)**	**<.001**	**968**
			C18:2	**-36.7 (±3.9)**	**<.001**	
			C18:3	**-26.0 (±3.9)**	**<.001**	
<C16, g/d	346.5 (±20)	<.001	C16:0	0.39 (±7.60)	0.95	973
			C18:0	0.39 (±25.2)	0.98	
			C18:1	-27.2 (±4.8)	<.001	
			C18:2	-36.7 (±4.0)	<.001	
			C18:3	-26.0 (±4.0)	<.001	

Best fitting model, C18:2 gets bigger negative effect

2019 data set

Milk	Intercept (±SE)	P-value	FA as % of Diet	Slope (±SE)	P-value	AIC
C16, g/d	453.0 (±25.4)	<.001	∑C18:1,2,3	-35.8 (±3.4)	<.001	1040
C16, g/d	461.7 (±26.1)	<.001	C18:1	-31.2 (±7.3)	<.001	1037
			C18:2	-45.8 (±6.2)	<.001	
			C18:3	-29.6 (±6.3)	<.001	
C16, g/d	414.0 (±21.3)	<.001	C16:0	79.0 (±7.1)	<.001	969
			C18:0	-15.2 (±23.6)	0.52	
			C18:1	-41.6 (±4.4)	<.001	
			C18:2	-51.8 (±3.7)	<.001	
			C18:3	-26.5 (±3.8)	<.001	

Milk FA yield	Intercept (±SE)	P-value	Diet % Variable	Slope (±SE)	P-value	AIC[3]
C18 total, g/d	307.9 (±25.3)	<.001	C18:1,2,3	26.0 (±3.39)	<.001	1037
C18 total, g/d	320.6 (±25.4)	<.001	C18:1	31.9 (±7.0)	<.001	1033
			C18:2	11.8 (±5.9)	0.05	
			C18:3	35.4 (±6.0)	<.001	
C18 total, g/d	309.6 (±25.8)	<.001	C16:0	6.8 (±10.9)	0.53	1030
			C18:0	82.4 (±36.2)	0.02	
			C18:1	27.5 (±6.95)	<.001	
			C18:2	8.2 (±5.8)	0.16	
			C18:3	32.6 (±5.8)	<.001	

2019 data set

	Intercept (±SE)	Diet Variable	Slope (±SE)	P-value	AIC[3]
Milk FA[1], g/d	1099.3 (±59.1)	∑C18:1,2,3	-38.5 (±6.4)	<.001	1165
Milk FA[1], g/d	1127.6 (±60.1)	C18:1	-24.7 (±12.7)	0.05	1157
		C18:2	-70.2 (±10.8)	<.001	
		C18:3	-18.0 (±10.9)	0.10	
Milk FA[1], g/d	**1070.1 (±57.2)**	**C16:0**	**83.7 (±17.8)**	**<.001**	**1137**
		C18:0	**68.9 (±59.2)**	**0.25**	
		C18:1	**-39.8 (±11.2)**	**<.001**	
		C18:2	**-79.5 (±9.4)**	**<.001**	
		C18:3	**-19.0 (±9.5)**	**0.05**	

2019 data set

Effect of different diet FA on total Milk FAT yield

Milk FA class	Diet C16:0	Diet C18:0 ???	Diet C18:1 & C18:3	Diet C18:2
<C16	No effect	No effect?	Decreases	**Decreases**
C16	**Increases**	No effect?	Decreases	**Decreases**
C18	No effect	**Increase**	**Increase**	Increase?
Total	Increase	Increase?	Decrease	Decrease

De novo inhibition vs. substitution

- Substitution theory (wrong one?)
  - adding dietary FA into milk fat displaces shorter chain FA
  - Implies that milk fat secretion is regulated not FA synthesis and transport
  - Why doesn't palmitic do this? Only C18 FA do this? Stearic too?
- De novo inhibition (what I think)
  - Unsaturated FA form bioactive FA in rumen to reduce de novo FA synthesis in Mammary
  - Also provide exogenous C18 FA for milk fat
  - Later compensates for former
  - Definitely true for linoleic; Linoleic even inhibits its own transfer into milk fat
  - Lessor effect for oleic and linolenic (for sure) / no effect for stearic(?)
- Could be all of oleic and linoleic effect and part of linoleic effect is substitution
  - But then stearic should do same as oleic and linoleic
- Remember biological mechanisms should work on a molar basis

	Intercept (±SE)	Diet Variable	Slope (±SE)	P-value	AIC[3]
Milk FA[1], mol/d	4.80 (±0.25)	∑C18:1,2,3	-0.21 (±0.03)	<.001	197
Milk FA[1], mol/d	**4.91 (±0.25)**	**C18:1**	**-0.15 (±0.05)**	**0.008**	**190**
		C18:2	**-0.35 (±0.04)**	**<.001**	
		C18:3	**-0.13 (±0.04)**	**<.001**	
Milk FA[1], mol/d	4.70 (±0.25)	C16:0	0.32 (±0.08)	<.001	175
		C18:0	0.27 (±0.27)	0.31	
		C18:1	-0.21 (±0.05)	<.001	
		C18:2	-0.40 (±0.04)	<.001	
		C18:3	-0.14 (±0.04)	0.001	

2019 data set

Current and future FA digestion

- Current model uses classes of FA for digestibility of "FA" in that feed
  - These are user adjustable variables with library defaults
- These are then summed linearly by feed for diet
- Cannot measure digestion of the 4 individual C18:? FA
  - eg: C18:2 consumed – C18:2 in feces could be absorption or luminal biohydrogenation
- Can measure digestion of combined C18 FA (ΣC18 eaten–ΣC18 in feces)
- And also C16 (separately from C18)
- Future models may predict effect of 5 individual diet FA on digestion of C18 and C16
  - Something like this:
  - C16 dig = B0 + B1*C16 + B2*C18:0 + B3*C18:1 + B4*C18:2 + B5*Diet C18:3
  - C18 dig = B6 + B7*C16 + B8*C18:0 + B9*C18:1 + B10*C18:2 + B11*Diet C18:3
  - Quadratic and interaction terms might be needed

Measuring DE is doable

- DE is a large and variable loss
- Diet DE can be measured DIRECTLY by most research laboratories
  - Need a shovel, scale, and a bomb calorimeter (students useful too!, plus some cows)
  - Actual is always better than predicted
- Then use NRC model predictions to get at <u>predicted</u> ME and NE
  - better (I think) than going from diet chemistry to predicted DE then predicting ME then predicting NE
  - NRC 8 much more transparent about this process
- So measure digestible Organic Matter fractions <u>PLUS</u> direct DE
  - Combustible energy (bomb calorimeter)
  - Starch, N, NDF, OM
  - C16 and C18 FA digestibility

FA effect on methane?

- Do all FA affect methane equally?
- Especially FA we feed, and not C12 or C14

NASEM 2021: What's New for Minerals and Vitamins for Dairy Cows

W. P. Weiss
Department of Animal Sciences
Ohio Agricultural Research and Development Center
The Ohio State University, Wooster

Summary

The NASEM (2021) dairy committee conducted a thorough review of mineral and vitamin nutrition of dairy cattle. Requirements and recommendations for most minerals and vitamins were changed although for several the changes were quite modest when applied to average cows fed typical diets. However, many of the equations are more biologically correct which means that they should be more accurate over a wider range of cows and when fed in a wider diversity of diets. For most minerals requirements for absorbed mineral are estimated and then divided by an absorption coefficient to obtain dietary requirements. Magnesium and manganese dietary requirements changed the most and on average they are about twice as high as those estimated by NRC (2001). Copper requirements were substantially increased for dry cows but decreased substantially for high producing cows. Vitamin A recommendations increased for high producing cows and vitamin D recommendations increased for lactating cows. Although no recommendations were established for water-soluble vitamins, the vitamin chapter contains a thorough review of expected responses when they are supplemented. The mineral chapter contains up to date information on factors that can affect absorbed requirements and absorption of minerals. Many of these factors are not included in equations; therefore, the book will be helpful to nutritionists to finetune diets.

Introduction

The NASEM (2021) committee evaluated the previous (NRC, 2001) requirements for all essential minerals and vitamins and reviewed scientific papers published since about 2000 to determine whether updates were needed. Based on that review, requirements were revised for almost every essential mineral and vitamin. Although for many minerals and vitamins, previous recommendations were accurate for average lactating cows fed typical midwestern diets, they were less accurate for higher producing cows and dry cows and when cows were fed less typical diets. For several minerals, dietary requirements changed only slightly compared with NRC (2001) even though many of the equations changed markedly. A major aim of the committee was to make equations more biologically correct so that they would work better for cows that were not average and not fed typical diets. No changes were made to iron and selenium recommendations, and phosphorus and iodine recommendations changed very little from NRC (2001) and these will not be discussed. Mineral and vitamin recommendations for pre-weaned calves underwent substantial updates but those also will not be discussed. Lastly, very little research is conducted on the vitamin and mineral needs of growing heifers and either recommendations from beef (2016) or extrapolation from dairy cow experiments are used. Growing heifers will only be discussed briefly.

Requirement vs. Adequate Intake vs. Response

The NASEM (2021) uses two terms to describe the quantitative needs for minerals and vitamins: requirements and adequate intake (AI). Requirements are established when the committee had enough data to be highly confident in the equations. A requirement will meet the needs of the average cow in a defined population (e.g., 1500 lbs. Holstein cow producing 80 lbs./day of milk). Requirements were established for calcium (Ca), phosphorus (P), magnesium (Mg), sodium (Na), chloride (Cl), sulfur (S), copper (Cu), and zinc (Zn).

The term AI means that in the committee's expert opinion, cows fed this much mineral or vitamin will not be deficient and that the AI elicited a positive response above that when a lesser amount was fed. Adequate intake is similar to a requirement except that it means the committee did not have the same degree of confidence because of limited data. To establish an AI (or requirement), the first criteria was a clinical deficiency must have been shown in cattle. For examples a vitamin D deficiency can cause rickets in cattle, but no clinical deficiency signs have been shown for biotin, so an AI was established for vitamin D but not for biotin. An AI was used when titration data were lacking (i.e., most studies only used two treatments, a control with no supplemental mineral or vitamin and one treatment with some level of the nutrient of interest), when data on basal intakes were limited or lacking, or when very few experiments were conducted on the mineral or vitamin.

Vitamin E will be used to show how an AI could be set. Several studies with dry cows have been conducted using 2 treatments (an unsupplemented control and a treatment diet providing about 1000 IU of supplemental vitamin E/d). Most of those studies found that 1000 IU/d of supplemental vitamin E reduced mastitis, metritis, and/or retained placenta. Using that data, the committee set the AI at 1000 IU/d for dry cows. However, 500 IU/d might have been adequate, or 2000 IU/d might have been better, but the available data would only support setting an AI at 1000 IU/d for dry cows.

For diet formulation a requirement and an AI can usually be considered the same thing. An AI was established for cobalt (Co), iodine (I), iron (Fe), manganese (Mn) selenium (Se) and vitamins A, D, and E.

Some minerals and vitamins can increase milk production when supplemented; however, this does not necessarily mean that the supplementation rate is the requirement or AI. Primary examples are chromium (Cr), biotin, rumen-protected choline and dietary cation anion difference (DCAD). Cows require Cr and milk production often increases when diets are supplemented with about 0.5 mg/kg of Cr (Lashkari et al., 2018). However, a clinical deficiency of Cr has not been described, perhaps because basal concentrations of Cr are usually adequate to prevent them, Although supplemental Cr often increases milk production it is not a requisite to high production. Diets contain biotin and rumen bacteria can synthesize it so clinical deficiencies do not occur. However, supplementing biotin at rates between 10 and 20 mg/day can increase production and improve hoof health (Lean and Rabiee, 2011). Supplemental protected choline at rates of 10 to 15 g of actual choline can increase milk production and reduce fatty liver (Sales et al., 2010). There is a minimum requirement for DCAD based on requirements for K, Na, Cl, and S but exceeding that requirement (approximately 175 mEq/kg) often increases milk, milk fat, and

DMI (Iwaniuk and Erdman, 2015). Conversely feeding reduced DCAD to dry cows reduces hypocalcemia. The responses to these nutrients are discussed in the text but AI or requirements were not derived by the committee. Feeding K or Na above requirements increase urine output which will increase water intake and this may be beneficial during heat stress. Production responses to increased intake of various minerals and vitamins are discussed in the text (NASEM, 2021) but they are not included in the software.

Calculation of Requirements or AI

Requirements or AI for most minerals were calculated using the factorial approach. The exceptions are Co, Se, and S. Cobalt and S are bacterial requirements, not cow requirements and are therefore expressed as a dietary concentration (0.2 mg/kg and 0.2%, respectively). The concentration of supplemental Se in diets is regulated by FDA; therefore, its AI is expressed on dietary concentration basis (0.3 mg/kg diet). The factorial approach estimates the amount of absorbed (not dietary) mineral needed for maintenance plus the amount of mineral secreted in milk (lactation requirement) and accreted in tissue (growth requirement) or conceptus (gestation requirement). Maintenance requirement is estimated as the sum of endogenous fecal and urinary losses; however, except for electrolytes, endogenous urinary losses are either set to 0 or are very small. The total absorbed requirement is divided by an absorption coefficient (AC) to obtain the dietary requirement. For most minerals (Ca and P are exceptions), the same AC is used for all basal ingredients but the AC for the mineral supplements can vary. All mineral requirements or AI are for total, not supplemental minerals. Users should include the minerals provided by basal ingredients in all supply calculations. Lastly requirements or AI are for the average cow in a defined population which means that the requirement may underfeed about 50% of the cows. Appropriate safety factors should be applied when formulating diets. In my opinion (this is not NASEM, 2021) increasing supply of minerals by 1.2 times NASEM average requirement or AI is a reasonable safety factor. However, a safety factor is not needed for P, S, and Se. Because moderately excess sulfur can cause several problems (discussed below), it should be fed at about the NASEM requirement (i.e., 0.2% of diet DM). The requirements for P are very well defined and because of recycling within the cow, P deficiencies are extremely unlikely when the average cow in the pen is fed to meet NASEM (2021) average requirements. A safety factor is not needed. A safety factor often cannot be applied to Se because supplementation may be limited by regulation. In most areas of the world, nutritionists should formulate dairy diets to the maximum legally allowable Se concentration.

Requirements or AI for most minerals and vitamins are on a milligram, gram, or IU/day basis, not on a dietary concentration basis. However, expressing requirements on a concentration basis can be useful when evaluating diets if estimated dry matter intake is reasonable. Table 1 contains dietary concentrations of minerals that will meet the requirement or AI for an average Holstein cow producing about 80 lbs. of milk per day assuming the cow is eating about 54 lbs. of dry matter.

All vitamins and minerals that have a requirement or AI will be discussed briefly; however the most substantial changes in dietary requirements (or AI) were made for Mg, Co, Co, and Mn.

Calcium

Two major changes were made to Ca and they are related. In NRC (2001) endogenous fecal Ca (i.e., maintenance requirement) was a function of body weight; however, it should be a function of dry matter intake (DMI). The more a cow eats that greater the loss of endogenous fecal Ca should be, and the new maintenance requirement is estimated based on DMI. This will result in an increased maintenance requirement for high producing, high DMI cows. The second change was to the AC. The AC for Ca from all Ca supplements were reduced from a range of about 70 to 95% to 45 to 60%. The AC for Ca from basal feeds either were not changed or increased slightly. The net result is the dietary Ca concentrations to meet the requirements will need to be slightly higher than previously and the less basal Ca in the diet the greater the increase.

Electrolytes (Na, K, Cl)

A large database was assembled to estimate AC and endogenous fecal excretion for K, Na, and Cl. The AC for K and Na was set at 100% and 92% for Cl compared with 90% used for all three in NRC (2001). The maintenance requirements for electrolytes can include endogenous fecal and urinary excretion. Total maintenance requirements did not change greatly for K and are slightly greater for Na and Cl compared with NRC (2001). The greatest change was in the route of excretion (urinary or fecal), and the new equations better reflect measured excretion data. For example, very little Na is excreted in urine when cows are fed at requirements whereas urinary K is quite high and the 2021 equations reflect those differences. Conversely using NRC (2001) equations, urinary Na was high, but K was low. Lactation requirements for Na and Cl were reduced substantially reflecting the lower concentrations of those two minerals in milk produced today compared with milk produced 50 years ago (the source of data used in NRC, 2001). This is likely because mastitis is much less today than 50 years ago and cows with mastitis secrete milk with elevated Na and Cl concentrations. The change in maintenance and lactation requirements mostly cancel out and total requirements for Na, Cl, and K are about the same as in NRC (2001).

Sulfur

The S requirement did not change (0.2% of diet DM) but the discussion regarding S was substantially updated and expanded. Most of the discussion regards all the potential negative effects that are associated with feeding excess S. These include reduced absorption of Cu, Se, Mn and maybe Zn. High S usually is associated with lower DCAD which can reduce DMI, milk and milk fat. High S can reduce fiber digestibility and although unlikely with dairy cows, high S increases the risk for polioencephalomalacia. If the S concentration in water is high (generally greater than about 300 mg sulfate-S/L), that should be included when determining whether S intake is great enough to cause problems.

Magnesium

The requirement for Mg changed the most of any micromineral. The amount of data available to estimate AC and requirements increased markedly after the NRC (2001) was published which allow the committee to make several changes. First, maintenance (endogenous fecal Mg) is estimated from DMI, not bodyweight. This resulted in about a doubling of absorbed maintenance requirement. The other big change was to the AC. In NRC (2001), the calculated AC for basal ingredients was about 30% but because of the high variability of that estimate, the committee reduced the AC by 1 standard deviation to 16%. Presumably the AC for Mg supplements were calculated using a basal AC of 16% rather than 30% and this resulted in overestimating the AC for the supplements. Using a larger database, the same AC was obtained for basal ingredients (30%) but rather than reducing that by 1 standard deviation, the committee incorporated an equation that reduced AC as dietary K increases. Dietary K is a major antagonist to Mg absorption and a major source of variation in the AC of Mg. Using 30% AC for basal ingredients (standardized to 1.2% K), magnesium oxide and magnesium sulfate have AC of 23 and 27% compared with 70 and 90% used by NRC (2001). The change in maintenance along with change in AC means that the dietary requirement for Mg is about 1.5 to 2 times greater than NRC (2001). The potential benefit of excess Mg during the prefresh period is not included in the requirement calculations (it is considered a response).

Cobalt

Different biomarkers can be used to assess adequacy of Co including liver vitamin B-12 concentrations and serum concentrations of homocysteine. Experiments published since 2000 indicated that the NRC (2001) requirement of about 0.11 mg/kg of diet was not optimal for beef cattle based on common biomarkers. Based on that experiment the AI for Co was about doubled to 0.2 mg/kg of diet DM. Measuring Co in feeds is difficult, but it is likely that many diets contain enough Co in basal ingredients to meet the AI.

Copper

Because of increasing concerns about Cu toxicity, Cu requirements underwent an especially rigorous review. Two major changes were made to requirement calculations. Inadequate data were available to calculate endogenous fecal excretion of Cu as a function of DMI and it remained a function of body weight. A study using isotopic Cu was used to develop a new equation to estimate absorbed maintenance requirement and it about doubled from NRC (2001). However, the value used to estimate endogenous fecal Cu affects calculation of the AC and the AC for Cu increased by 25%. The net effect was about a 60% increase in dietary maintenance requirement. This means that for growing heifers and dry cows, total dietary Cu requirement has increased about 50% compared with NRC (2001). The other substantial change was in lactation requirement. The Cu concentration of milk used in NRC (2001) was 0.15 mg/kg, but a review of data published during the last 20 years found that milk averages only about 0.04 mg Cu/kg. The lactation requirement decreased by about 70%. For a Holstein cow producing about 80 lbs. of milk, the total requirement for dietary Cu is about the same as NRC (2001) but as production increases the total requirement for dietary Cu calculated using NASEM (2021) will become less than that calculated by NRC (2001).

Manganese

A study with pregnant beef heifers (Hansen et al., 2006) demonstrated that the NRC (2001) Mn requirement was too low. Very little research is conducted on Mn with dairy cattle, so the committee set an AI rather than a requirement. Based on a single study published after NRC (2001), the NASEM (2021) increased the absorbed maintenance requirement by about 30%. A study was also found that measured absorption of Mn by dairy cattle resulting in a substantial lowering of its AC. The net result of these two changes was that dietary requirements for Mn are slightly more than twice as great as they were in NRC (2001).

Zinc

An equation was developed to estimate the maintenance requirement for absorbed Zn from DMI and the resulting values are greater than those calculated by NRC (2001). Other requirements (growth, lactation, gestation) did not change. The AC for Zn were also modified using the new estimate for endogenous fecal losses. Overall, total dietary requirements for Zn will be 10 to 15% greater for heifers, dry cows, and lactating cows than NRC (2001) estimates.

Vitamin A

Inadequate data were available to estimate requirements; therefore, the committee established an AI for supplemental vitamin A. No new data was available to bring into question the requirement (i.e., 50 IU/lbs. of bodyweight) set in NRC (2001). However, the experiments used to generate that requirement were conducted long ago and maximum milk production was only about 75 lbs./day. Milk contains about 450 IU of vitamin A (as retinol)/lb. The AI for vitamin A of 50 IU/lb. of body weight was used for dry cows and cows producing less than 75 lbs. of milk/day and to cover the loss of vitamin A in milk, the AI is increased by 450 IU/day for every pound of milk produced that is greater than 75 lbs. For example, a 1500 lbs. cow producing 70 lbs. of milk would have an AI of 1500 x 50 = 75,000 IU/day but the same cow that produced 85 lbs. of milk would have an AI of 75,000 + ((85-75) x 450) = 79,500 IU/day.

Vitamin D

Because of limited data, supplemental vitamin D has an AI. Previously the requirement for vitamin D was based almost exclusively on Ca metabolism; however, we now know that vitamin D is involved in a multitude of function well beyond Ca metabolism. The AI for vitamin D for dry cows and heifers was not changed from NRC (2001) and remains at about 14 IU/lbs. of body weight (approximately 23,000 IU/d for a dry Holstein cow). For lactating cows, the AI was based on how much vitamin D is needed to maintain the concentration of 25-OH vitamin D in the blood at 30 ng/ml or greater (Nelson et al., 2016). Based on that criteria, the AI for lactating cows was set at 18 IU/lbs. of bodyweight or about 28,000 IU/d for a typical Holstein cow.

Vitamin E

The AI for supplemental vitamin E did not change for dry (0.7 IU/lbs. body weight) or lactating cows (0.36 IU/lbs. body weight). Based on experiments showing less mastitis and metritis when prefresh cows (approximatley the last 3 weeks of gestation) when additional vitamin E is fed, the AI for prefresh cows was set at 1.4 IU/lbs. body weight (about 2000 IU/day). Because pasture is usually an excellent source of tocopherol, the AI for vitamin E is reduced when cows are grazing based on how much pasture is being consumed. If more than about 50% of the diet dry matter is from fresh green pasture, the AI for supplemental vitamin becomes essentially zero.

Conclusions

- Almost all calculations used to estimate dietary mineral and vitamin requirements and AI have been revised; however total requirements for many of those nutrients did not change greatly
- Requirements or AI for Mg, Mn, Cu, Co changed the most from NRC (2001)
- The requirements (or AI) calculated by NASEM are for the average cow in a defined population. Safety factors are not included but often will need to be incorporated into diet formulation
- Several factors affect requirements and absorption of minerals. Many of these are not included in the equations. Users are encouraged to read the text to determine how specific situations affect diet formulation for minerals

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Table 1. Dietary concentrations (dry matter basis) of minerals and vitamin that should meet average requirements (or AI) of a Holstein cow producing 80 lbs. of milk per day. Assumed dry matter intake is 54 lbs./day.

Mineral	Concentrations to meet NASEM (2021)
Ca, %	0.57
P, %	0.32
Mg (1.2% K), %	0.16
Mg (2% K), %	0.20[1]
K, %	1.00
Na, %	0.20
Cl, %	0.28
S, %	0.20
Co, mg/kg	0.20
Cu (2 g/kg S and 1 mg/kg Mo), mg/kg	10
Cu (4 g/kg S and 5 mg/kg Mo), mg/kg	10[3]
Fe, mg/kg	16
I, mg/kg	0.4
Mn, mg/kg	27
Se, mg/kg	0.3
Zn, mg/kg	55
Vitamin A, IU/lb.	1430
Vitamin D, IU/lb.	500
Vitamin E, IU/lb.	10

[1] The NASEM model reduces the absorption coefficient of Mg as dietary K increases.

[2] Although increased dietary (including water) S and Mo significantly reduces Cu absorption inadequate data was available to include this effect in the NASEM equations. Users should read the text and make appropriate dietary adjustments for antagonism.

Current Concepts in Transition Cow Feeding and the NASEM Requirements

James K. Drackley, Ph.D., Professor of Animal Sciences
University of Illinois Urbana-Champaign
drackley@illinois.edu

The transition period surrounding calving remains a critical time for welfare of cows and dairy farm profitability. Many farms still struggle with a high incidence of metabolic and infectious disorders, and suboptimal milk production and fertility as a result of improper transition programs. Publication of the 8th revised edition of *Nutrient Requirements of Dairy Cattle* by the National Academies of Sciences, Engineering, and Medicine (NASEM, 2021) provides updated guidelines for nutritional management of cows during the dry period and transition period. New equations for predicting dry matter intake (DMI) were developed, which predict that cows fed lower NDF diets will have higher DMI. Conversely, high NDF diets can be used to control total DMI and limit energy intake to near requirements, which is particularly important during the far-off dry period. The equations predict that DMI starts to decrease about 2.5 wk before calving, and reach a nadir before calving at about 1.65% of DMI. Requirements for pregnancy now begin in early pregnancy and are less in the far-off period but greater in the transition cow than predicted by the last edition of NRC (2001).

Increasing prefresh energy (more starch, less NDF) increases prepartum DMI but has little impact on postpartum DMI. Most studies show no effect on milk yield. Single group dry period management can work as demonstrated by our recent research. Milk fat concentrations are lower with a single diet approach, which we have shown is related to increased *trans*-10 fatty acid intermediates. Therefore, a close-up group may have advantages in that regard. Diets should be low enough in energy density during the far-off period and make uniform steps up in energy density to the high lactation group. The requirements for energy have been revised, with the maintenance requirement being increased for all classes of cattle except newborn calves. Consequently, total requirements for net energy for lactation (NEL) are about 17-18 Mcal/kg DM for dry cows and 19-20 Mcal/kg DM for close-up cows. However, the equations that predict dietary energy supply also result in greater NEL density of diets; as a result, the balance of supply and requirement for NEL is slightly lower for the new system and more in line with observations in the field. Dry cows can easily consume more energy than they require. There is little evidence to suggest that high DMI per se prevents transition problems; rather, we should strive to meet the cows' requirements for energy and nutrients while avoiding excesses. Thus the problem is more often limiting energy supply rather than struggling to meet it.

Requirements for metabolizable protein (MP) are not changed much from the previous edition and are about 1000 g/d for typical Holstein cows. This does not include possible uses for the immune system or mammary development, and may not be optimal for first-calving heifers. The NASEM model provides estimates of amino acid supply. Typical diets based on corn silage and wheat straw likely will benefit from supplementation of rumen-protected methionine. Our research has demonstrated increases in postpartum DMI and milk yield with supplemental methionine, as well as favorable metabolic responses during the transition period.

Requirements for minerals and vitamins also have been adjusted as newer evidence has become available. A fully acidified, negative DCAD ration results in greater milk production than a partial DCAD approach. Requirements for potassium and sodium have been increased. For the trace minerals, cobalt, copper, iodine, manganese and zinc have been increased. While the NASEM committee recognized the responses to chromium and choline supplementation, no requirement or adequate intake was established. The requirement for vitamin E has been increased to about 2000 IU per day.

Publication of the new NASEM volume on nutrient requirements provides a tremendous resource for practicing nutritionists to fine-tune their approach to dairy cattle nutrition.

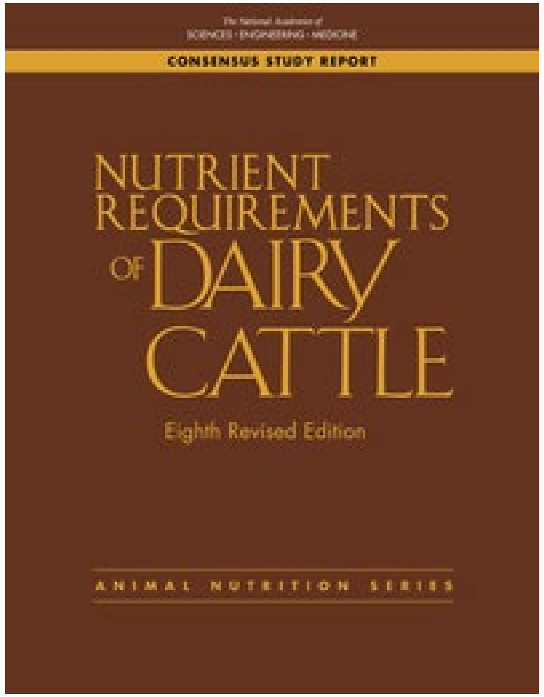
Current concepts in transition cow feeding and the NASEM requirements

James K. Drackley, Ph.D.

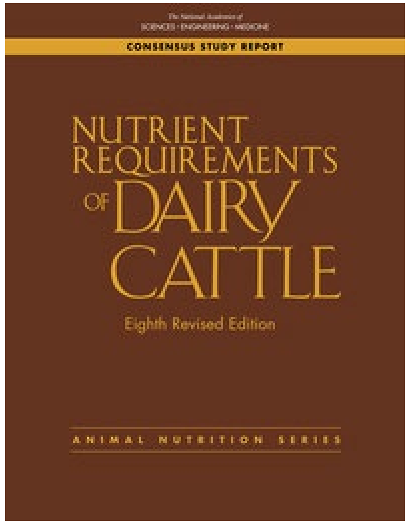
Professor of Animal Sciences
University of Illinois Urbana-Champaign

Nutrient Requirements of Dairy Cattle (8th rev. ed.) National Academies of Sciences, Engineering and Medicine (NASEM), 2021

- Replaces “NRC”, 2001
- 21 chapters, over 500 pages
- $149.95 (nap.edu)
- New computer model (similar interface), expanded outputs (free download)
- New material as well as extensively revised material from NRC 2001



Chapter 12
Dry and Transition Cows



Changes from NRC 2001

- Updated literature review
- New DMI equations
- Gestation requirement model structure
- Energy requirements and dietary energy concentrations
- Mineral requirements
- Vitamin E requirements

Estimated DMI by NASEM 2021

- Equations include parity, diet NDF, and week prepartum
  - Week used because of uncertainty of calving date
- Insufficient data for true meta-analysis
- Insufficient data to evaluate interactions among parity, diet, and time prepartum
- Data from 2001 and all newer data available were used
- Almost all experiments used high forage diets; diets with byproduct NDF sources not represented

Estimating DMI using NASEM 2021

- **Cows (% of BW):**

  $= 1.47 - [(0.365 - 0.0028 \times NDF)\ week] - 0.035 \times week^2$

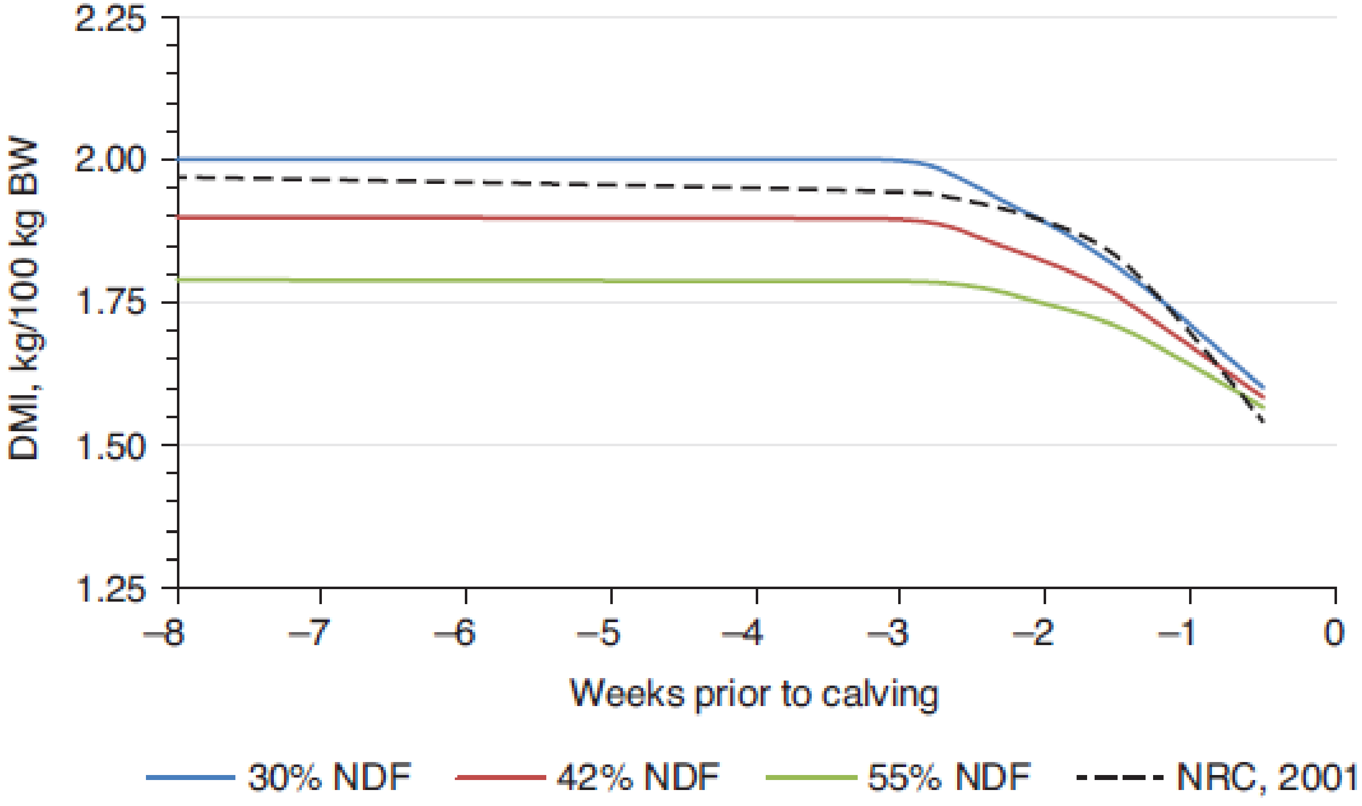
  where week = week from calving (i.e., it is negative)

  If cow > 3 wk from parturition, week = -3

- **Heifers:** Cow equation × 0.88

  Insufficient new data, therefore average parity effect from 2001 was retained

Estimated DMI by cows using NASEM 2021



New DMI equations

For far-off dry cows (>3 wk prepartum)

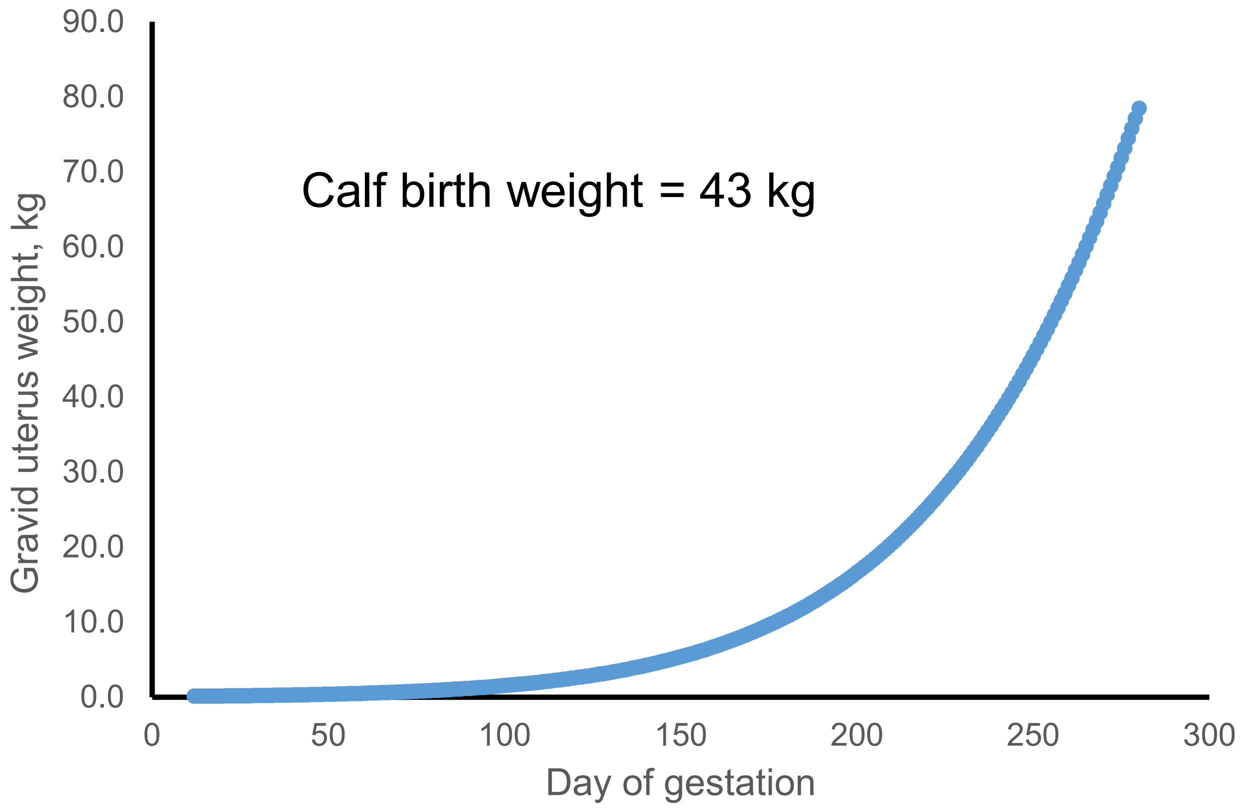
- DMI will be between 1.8 and 2% of BW
- Negatively correlated with dietary NDF

For close-up dry cows (<3 wk prepartum)

- DMI starts decreasing ~2.5 wk prepartum
- Rate of decline negatively correlated with dietary NDF
- At about wk 1 prepartum DMI about the same for all NDF (1.65% of BW)

Calculation of gestation requirements

- Mass model for conceptus starts at d 12 of gestation (compared with d 190 in NRC 2001)
- Function of maternal BW (heifer has smaller calf)
- Energy = 0.88 Mcal/kg
- CP = 125 g/kg



Gestation energy and protein requirements

	Gestation NEL, Mcal/d		Gestation MP, g/d	
Day of gestation	NRC 2001	NASEM 2021	NRC 2001	NASEM 2021
50	0	0.04	0	3
100	0	0.1	0	13
150	0	0.5	0	43
200	2.7	1.4	199	125
220	3.0	2.0	245	185
250	3.4	3.5	306	320
275	3.8	5.4	357	489

Close-up starch, fiber, and energy

- Almost impossible to separate these effects (e.g., as NDF goes up starch and NEL usually go down)
- Increasing prefresh energy (more starch, less NDF):
  - Increases prepartum DMI
  - Generally little effect on postpartum DMI
  - Most studies show no effect on milk yield

Use of pre-fresh diet to adapt rumen

- To “help rumen deal with higher starch postpartum diet”

  “Based on available data, benefits of feeding a diet of moderate starch and fiber to transition ruminal cells and rumen tissue morphology from a high-forage diet to a higher-starch lactation diet are not evident.”

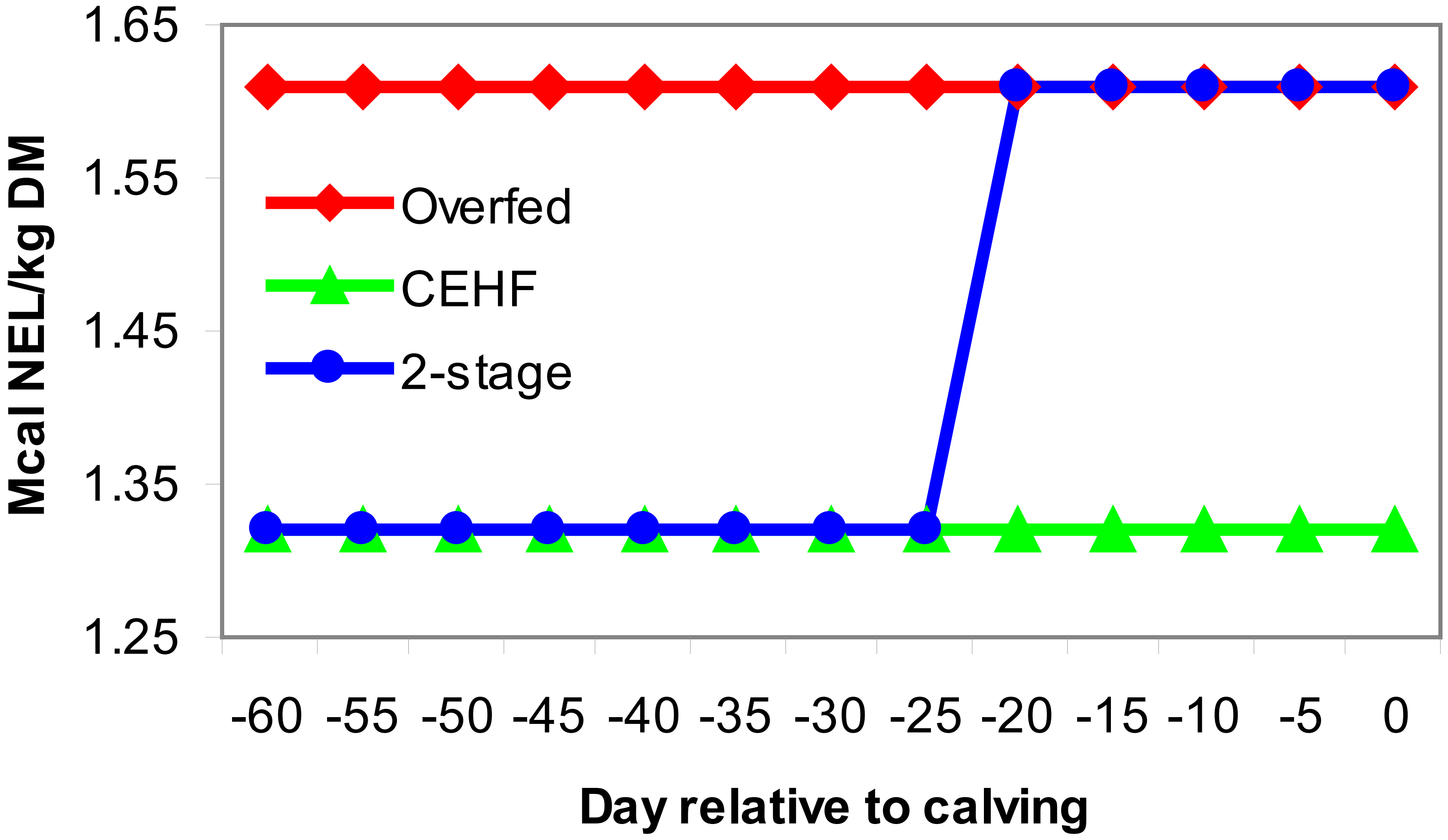
One-diet dry cow management: use of controlled energy diets

Diet composition (% of DM) – dry period

Ingredient	HE	LE
Wheat straw	0.0	40.5
Alfalfa hay, mid-maturity	6.0	3.2
Alfalfa silage, mid-maturity	17.9	9.7
Corn silage	49.9	28.3
Concentrate	26.2	18.3

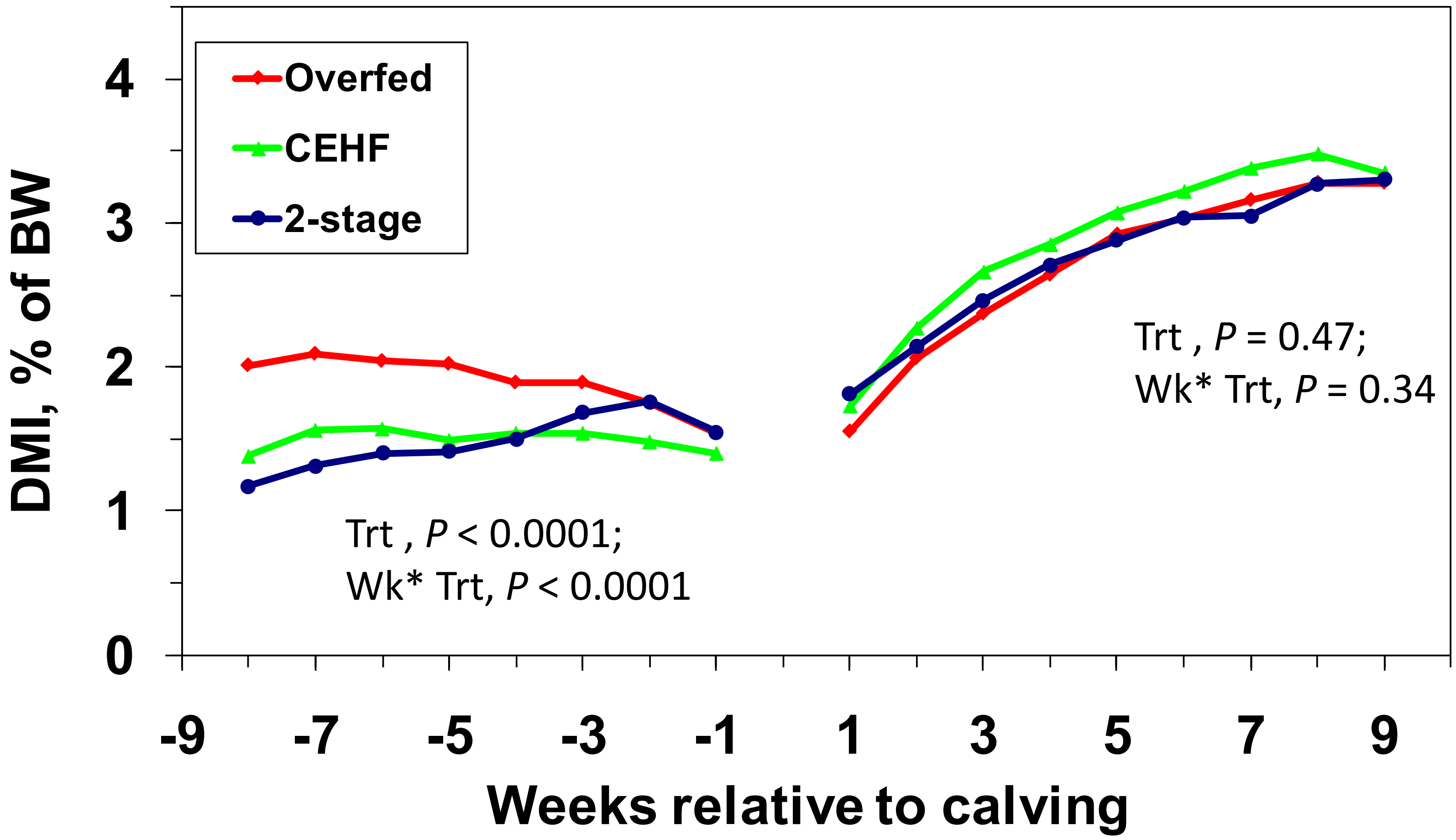
Richards et al., 2020

Dietary treatments



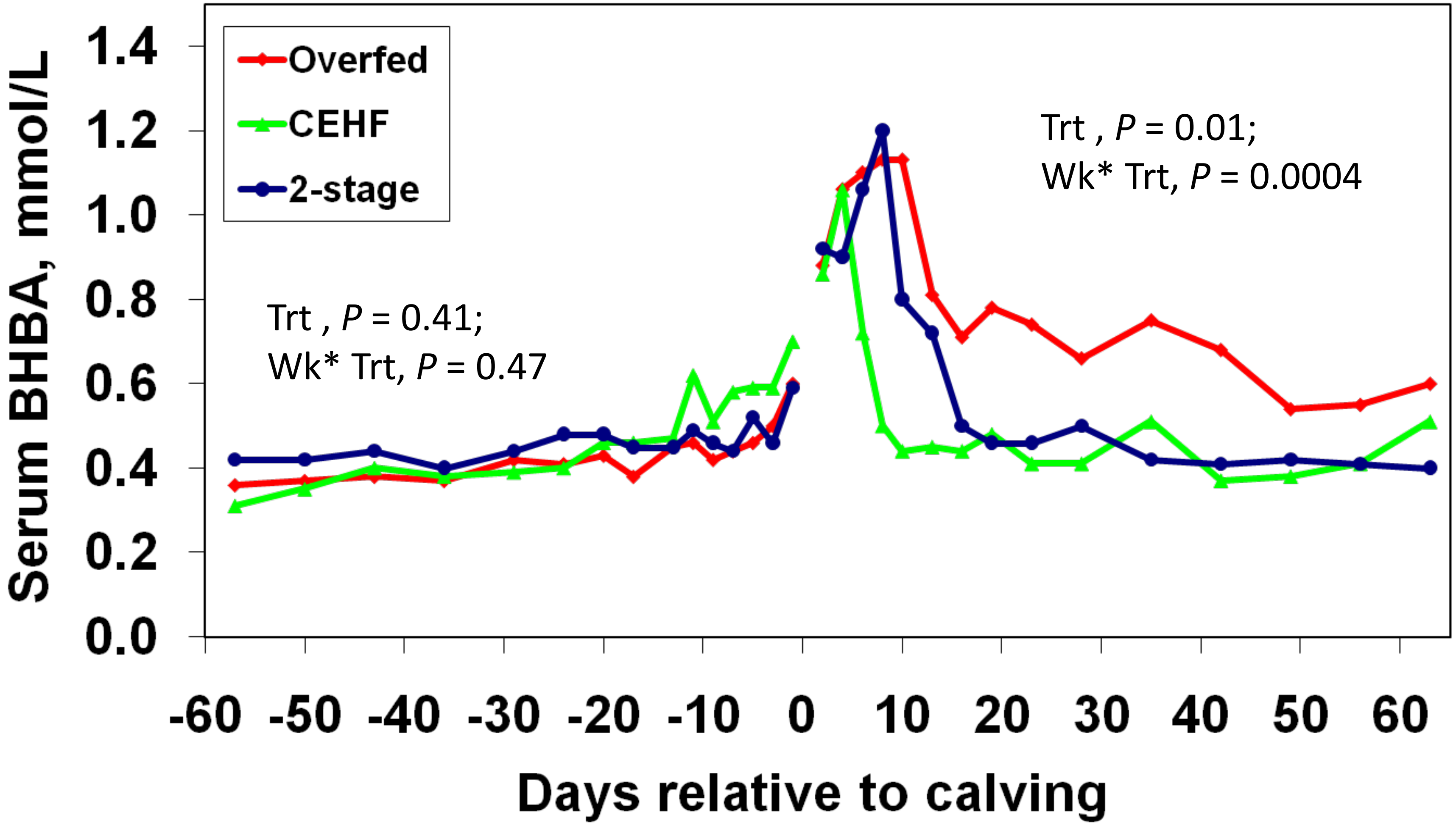
Richards et al., 2020

Dry matter intake for dry cows fed single-group or two-group diets



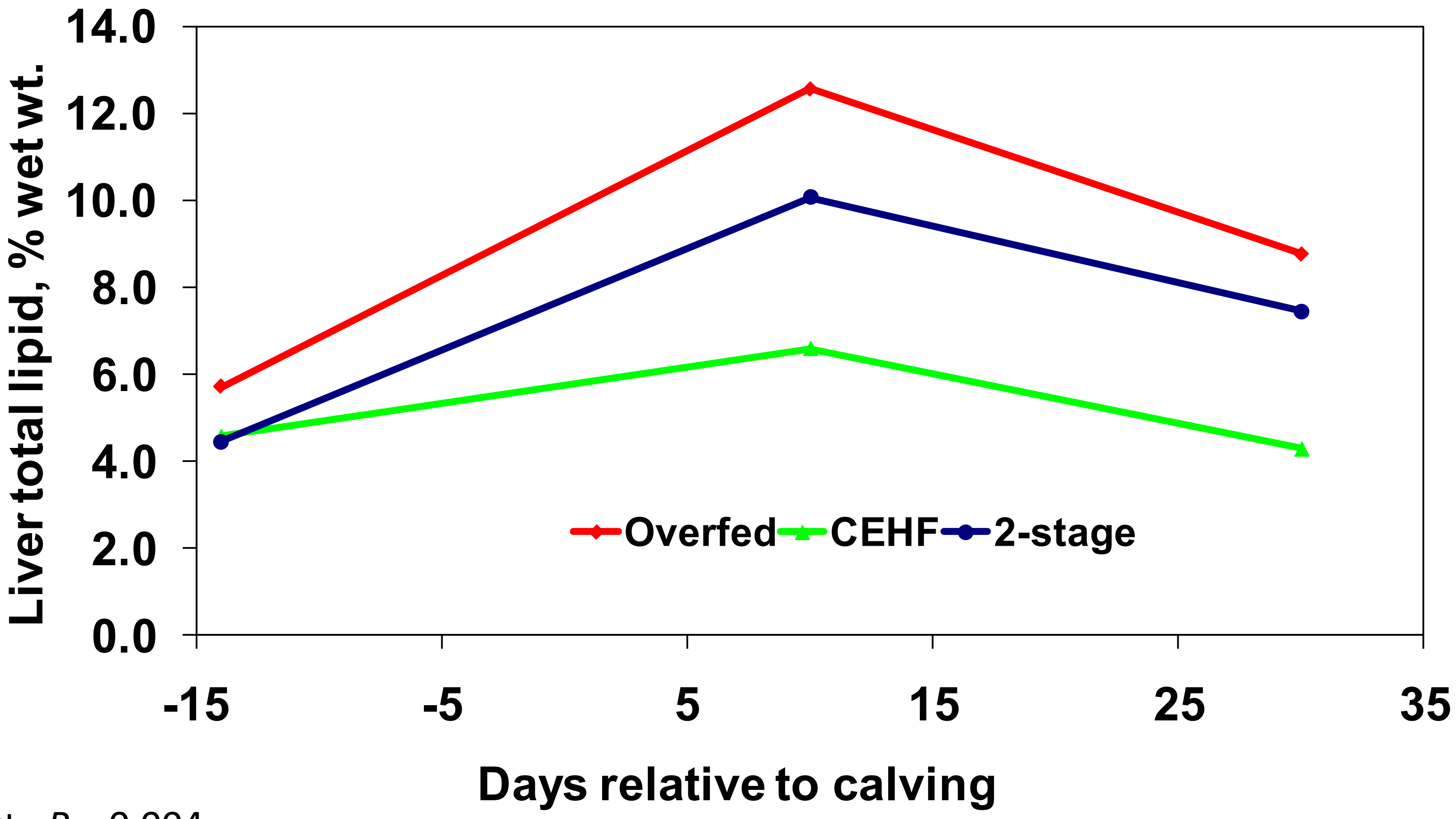
Richards et al., 2020

Controlled energy dry cow diets decreased serum BHBA



Richards et al., 2020

Controlled energy dry cow diets decreased liver total lipid



Trt , P = 0.004;
Wk* Trt, P = 0.02

Richards et al., 2020

Dry period treatment did not affect milk yield but decreased milk fat percentage and yield

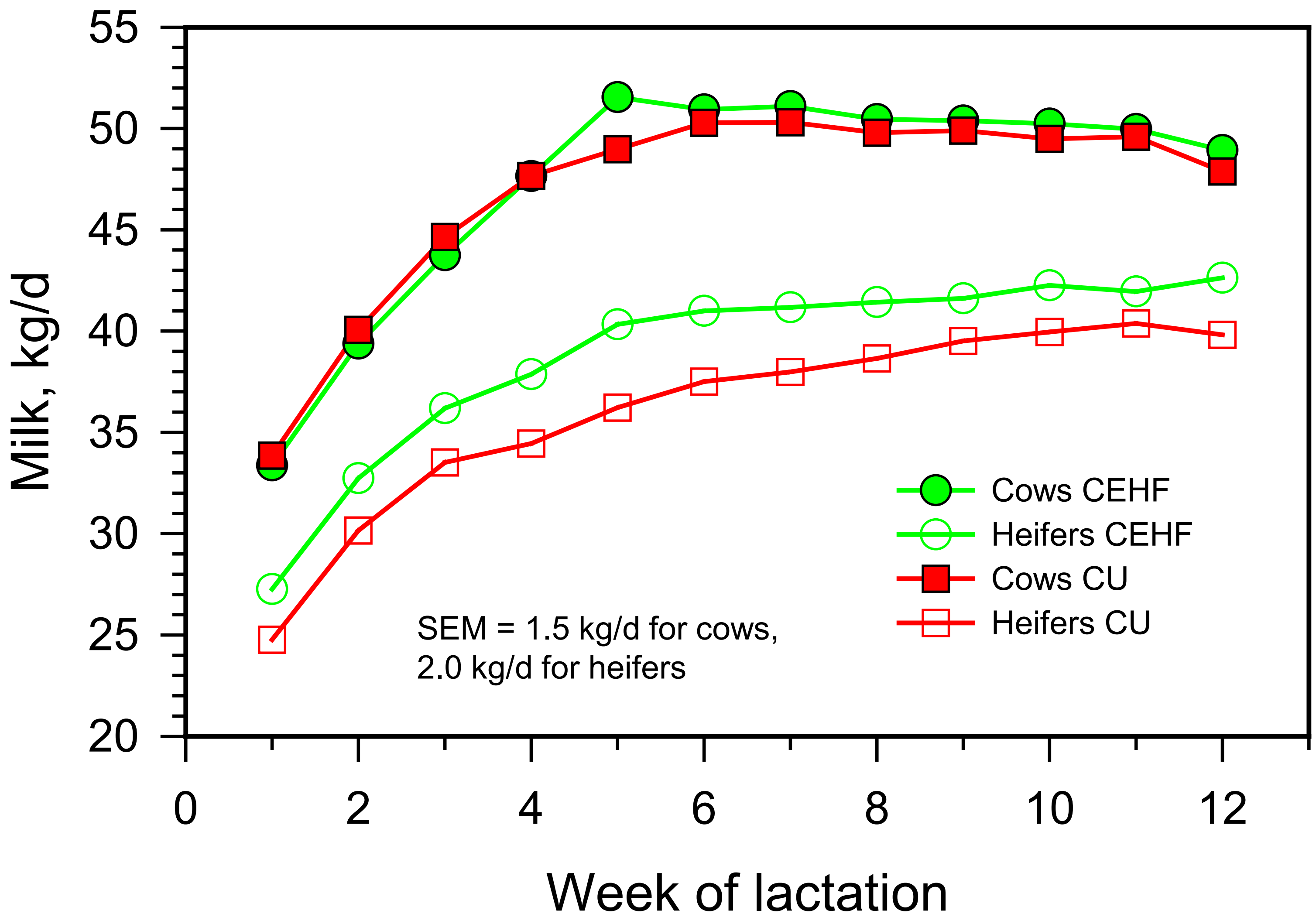
	Dry period treatment			
Variable	LE	HE	LE+HE	SE
Milk, kg/d	32.2	33.6	33.1	1.4
Milk fat, %	3.20[c]	3.87[a]	3.43[b]	0.11
Milk fat, kg/d	1.12[c]	1.41[a]	1.21[b]	0.06

Weeks 1 – 9 of lactation, first lactation cows included

[a,b,c] $P < 0.05$

Richards et al., 2020

Milk yield was not different between strategies



Vasquez et al., 2021

Dry period treatment did not affect milk yield but decreased milk fat percentage

	Dry period treatment		
Variable	CEHF	CU	SE
Milk, kg/d	43.1	41.5	1.0
Milk fat, %	3.54[b]	3.76[a]	0.07
Milk fat, kg/d	1.48	1.52	0.03
C18:1 *trans*-10, %	1.14[a]	0.66[b]	0.16

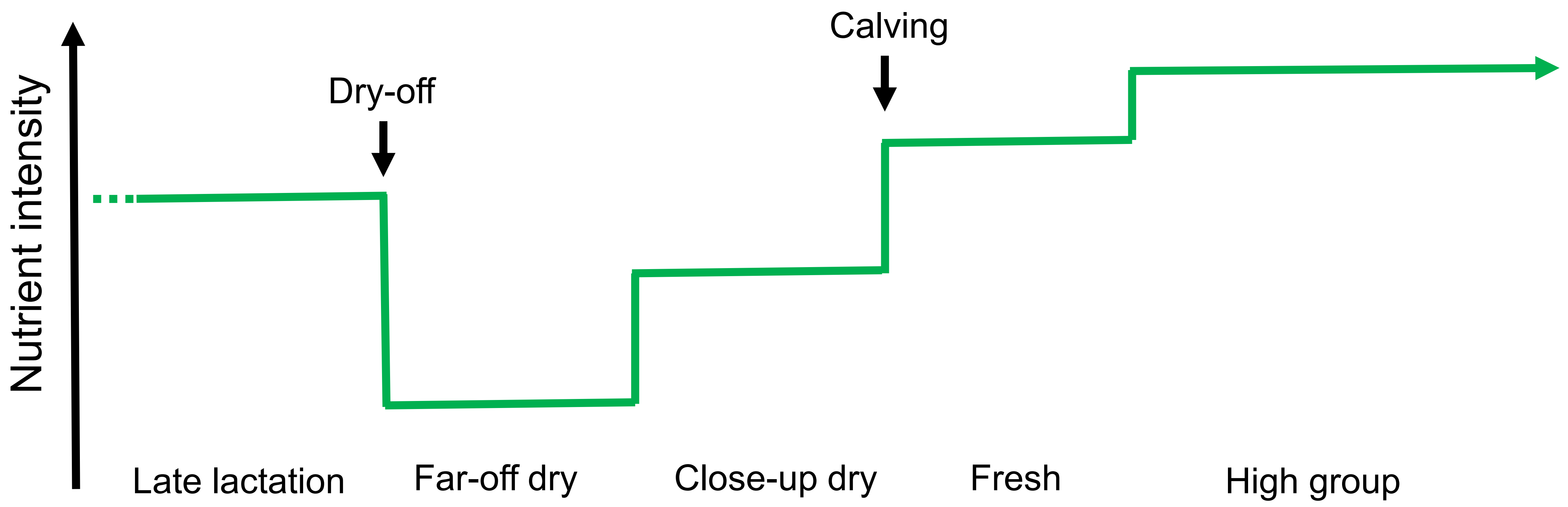
Weeks 1-12 of lactation, first lactation cows included

[a,b] $P < 0.05$

May indicate lack of rumen adaptation at calving for one-diet strategy

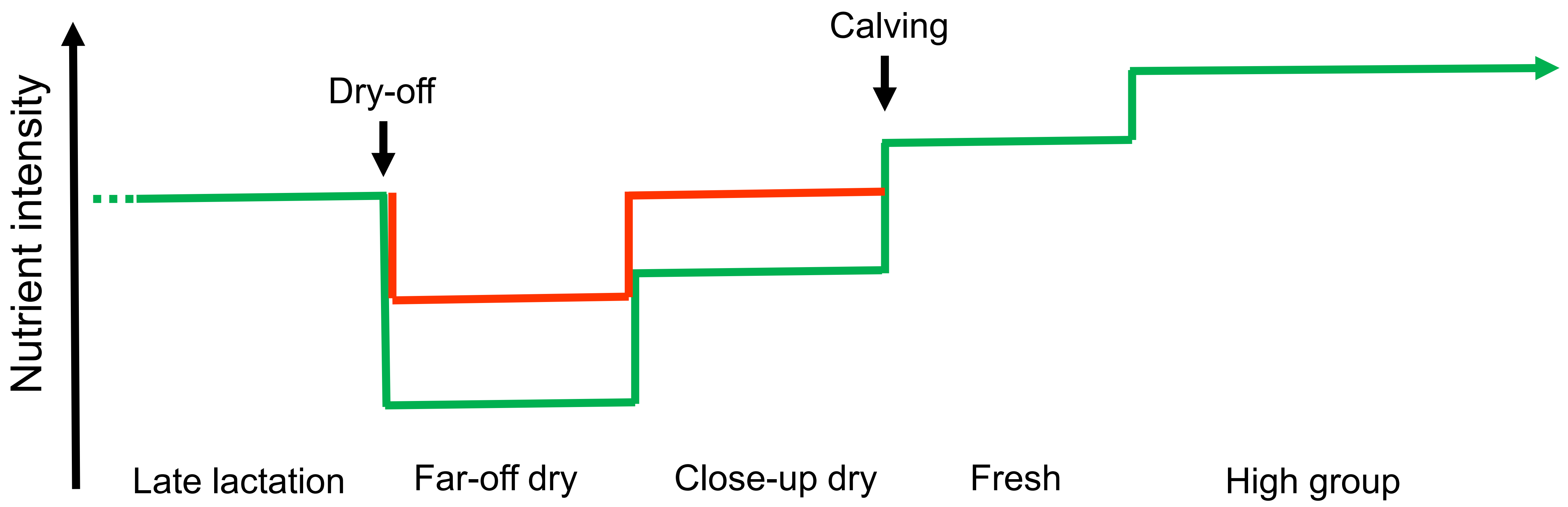
Vasquez et al., 2021

"Nutrient intensity" changes during the transition



"Nutrient intensity" changes during the transition

But don't want this…steps too small and far-off not low enough



NEL concentration of diets: dry cows

Ingredient	% of DM
Corn silage	40.0
Wheat straw	40.8
Corn gluten feed	8.05
Soybean meal	5.9
Canola meal	3.0
Urea	0.30
Minerals and vitamins	1.95

1790 lb, 240 DCC, 30.8 lb/d DMI

- NEL NRC 2001:
  0.63 Mcal/lb
  (19.5 Mcal/d)
- NEL NASEM 2021:
  0.71 Mcal/lb
  (21.8 Mcal/d)

Requirements also increase!

Comparison of energy requirements – dry cows

Ingredient	NRC, 2001	NASEM, 2021
NEL maintenance, Mcal/d	11.4	15.2
NEL pregnancy, Mcal/d	3.6	3.1
Total NEL required, Mcal/d	15.0	18.3

1790 lb, 240 DCC, 30.8 lb/d DMI

Comparison of nutrient balances – dry cows

Ingredient	NRC, 2001	NASEM, 2021
ME balance, Mcal/d	6.3	5.4
NEL balance, Mcal/d	4.5	3.6
MP balance, g/d	219	373

1790 lb, 240 DCC, 30.8 lb/d DMI

Both dietary energy prediction and energy requirements are higher with NASEM 2021.

Must use dietary NEL calculated by NASEM to be accurate!

NEL concentration of diets: close-up cows

Ingredient	% of DM
Corn silage	32.1
Wheat straw	36.3
Corn gluten feed	8.2
Soy hulls	6.6
Wheat midds	6.2
Soybean meal	5.8
Canola meal	2.6
Urea	0.25
Minerals and vitamins	1.95

1790 lb, 270 DCC, 28.6 lb/d DMI

- NEL NRC 2001:
  0.65 Mcal/lb
  (18.6 Mcal/d)
- NEL NASEM 2021:
  0.73 Mcal/lb
  (20.9 Mcal/d)

Requirements also increase!

Comparison of energy requirements – close-up cows

Ingredient	NRC, 2001	NASEM, 2021
NEL maintenance, Mcal/d	11.4	15.2
NEL pregnancy, Mcal/d	3.6	5.2
Total NEL required, Mcal/d	15.0	20.4

1790 lb, 270 DCC, 28.6 lb/d DMI

Comparison of nutrient balances – close-up cows

Ingredient	NRC, 2001	NASEM, 2021
ME balance, Mcal/d	5.0	0.5
NEL balance, Mcal/d	3.6	0.3
MP balance, g/d	240	-113

1790 lb, 270 DCC, 28.6 lb/d DMI

Both dietary energy prediction and energy requirements are higher with NASEM 2021.

Must use dietary NEL calculated by NASEM to be accurate!

NEL concentration of diets: fresh cows

Ingredient	% of DM
Corn silage	30.0
Wheat straw	1.0
Alfalfa silage	15.0
Corn gluten feed	17.0
Corn grain	25.05
Soybean meal	3.0
Soybean meal, expellers	2.0
Blood meal	2.5
Tallow	2.0
Rumen protected Lys Met	0.2
Minerals and vitamins	2.25

1375 lb, 15 DIM, 46.2 lb/d DMI, 88 lb/d milk

- NEL NRC 2001:
  0.76 Mcal/lb
  (35.1 Mcal/d)
- NEL NASEM 2021:
  0.84 Mcal/lb
  (38.8 Mcal/d)

Requirements also increase!

Comparison of energy requirements – fresh cows

Ingredient	NRC, 2001	NASEM, 2021
NEL maintenance, Mcal/d	10.0	12.5
NEL milk, Mcal/d	29.0	29.0
Total NEL required, Mcal/d	39.0	41.5
NEL balance, Mcal/d	-3.9	-3.4

1375 lb, 15 DIM, 46.2 lb/d DMI, 88 lb/d milk

Both dietary energy prediction and energy requirements are higher with NASEM 2021.

Must use dietary NEL calculated by NASEM to be accurate!

Summary – diet energy concentrations (Mcal/lb DM)

Cow class	NRC, 2001	NASEM, 2021
Far-off dry cows	0.63	0.71
Close-up dry cows	0.65	0.73
Fresh cows	0.76	0.84

Don’t mix systems!

Overall changes in energy balance are small.

Cows can consume enough energy to meet requirements during transition period from a variety of diets

Dietary NE_L (Mcal/lb)	DMI (lb) for 19 Mcal
0.70 (high straw)	27.1
0.75	25.3
0.80	23.8
0.85 (high energy)	22.3

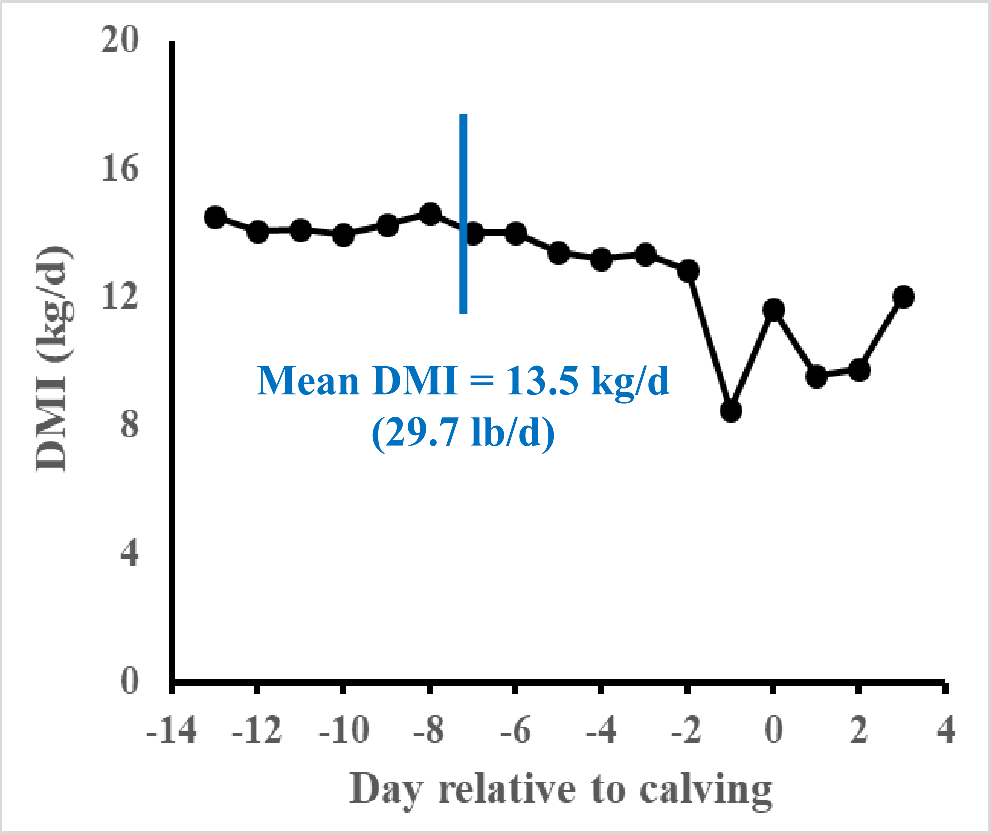
Dry cows will not stop eating once they have eaten enough energy – depends on rumen NDF fill!

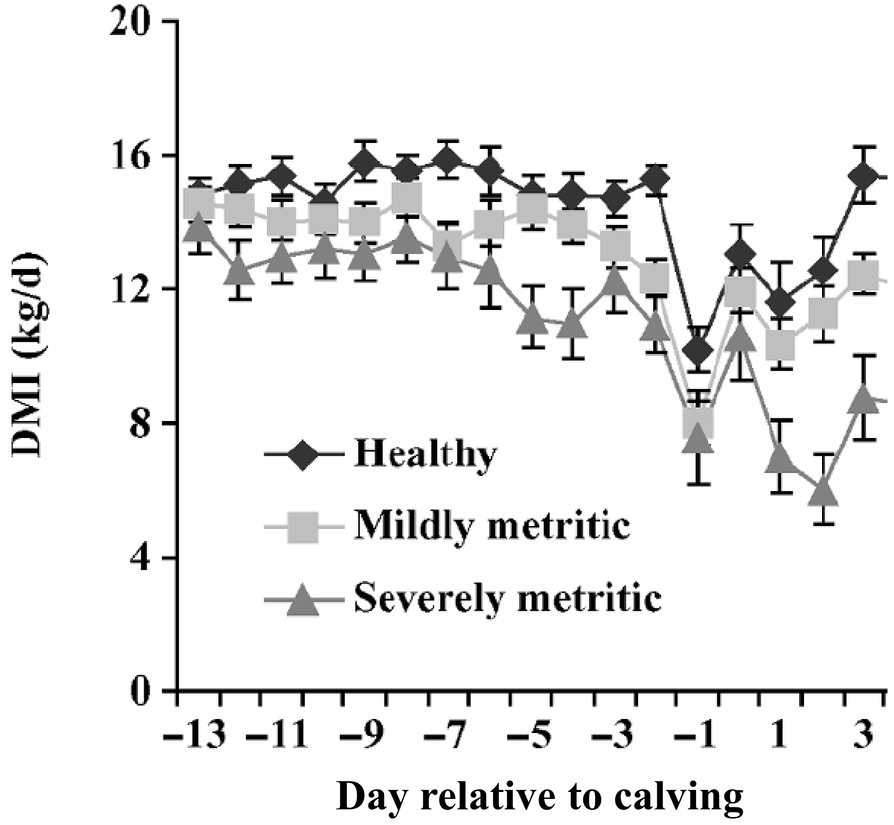
Close-up cows will easily consume more energy than they require

NE_L, Mcal/ lb DM	Forage NDF, % of DM	Predicted DMI, lb/d	NE_L intake, Mcal/d
0.70	55	25.5	18.5
0.75	50	26.4	19.8
0.80	45	27.3	21.8
0.85	40	28.2	24.0

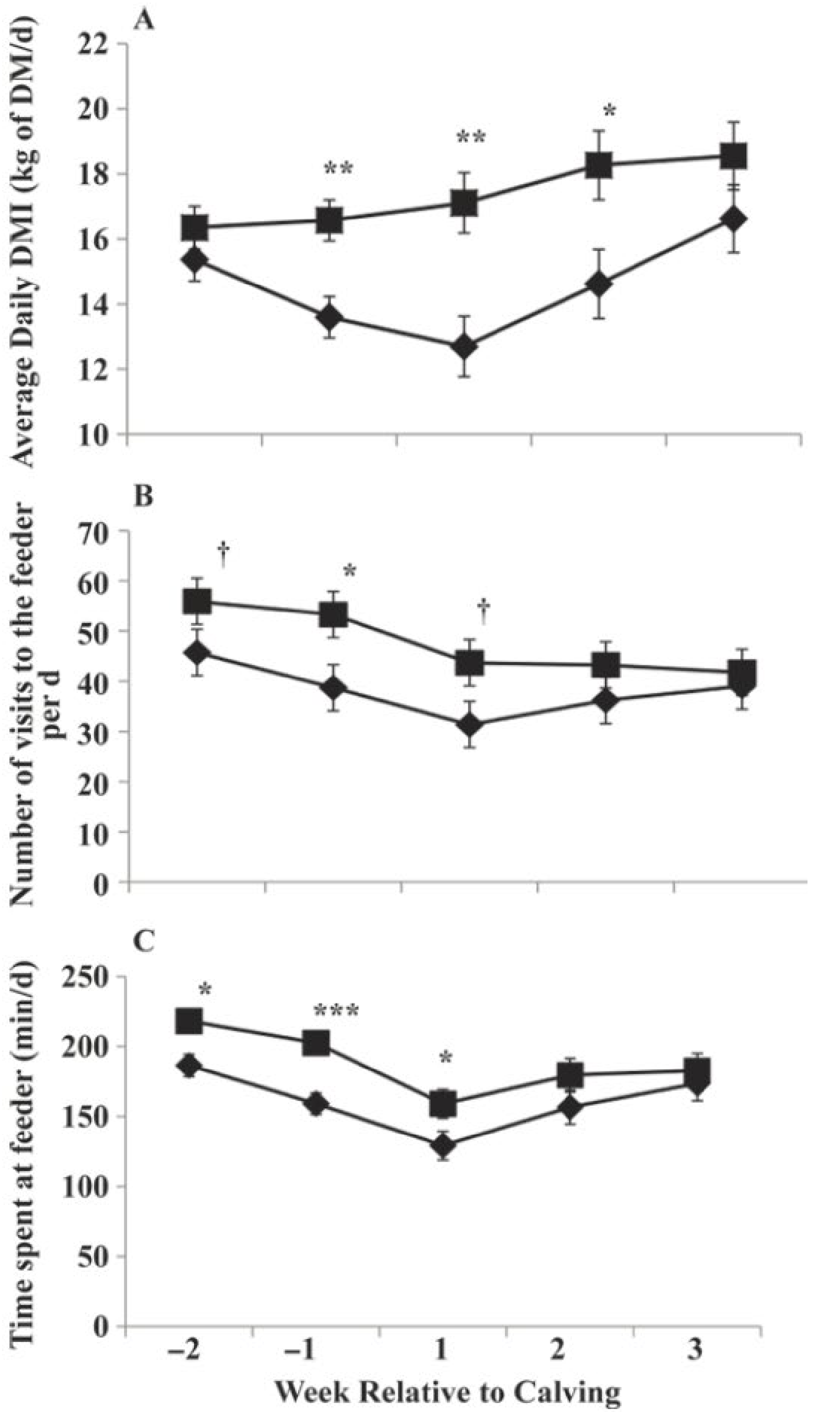
Estimated for 1540 lb Holstein cow at 265 days carried calf using NASEM (2021)

Mean DMI vs sub-groups





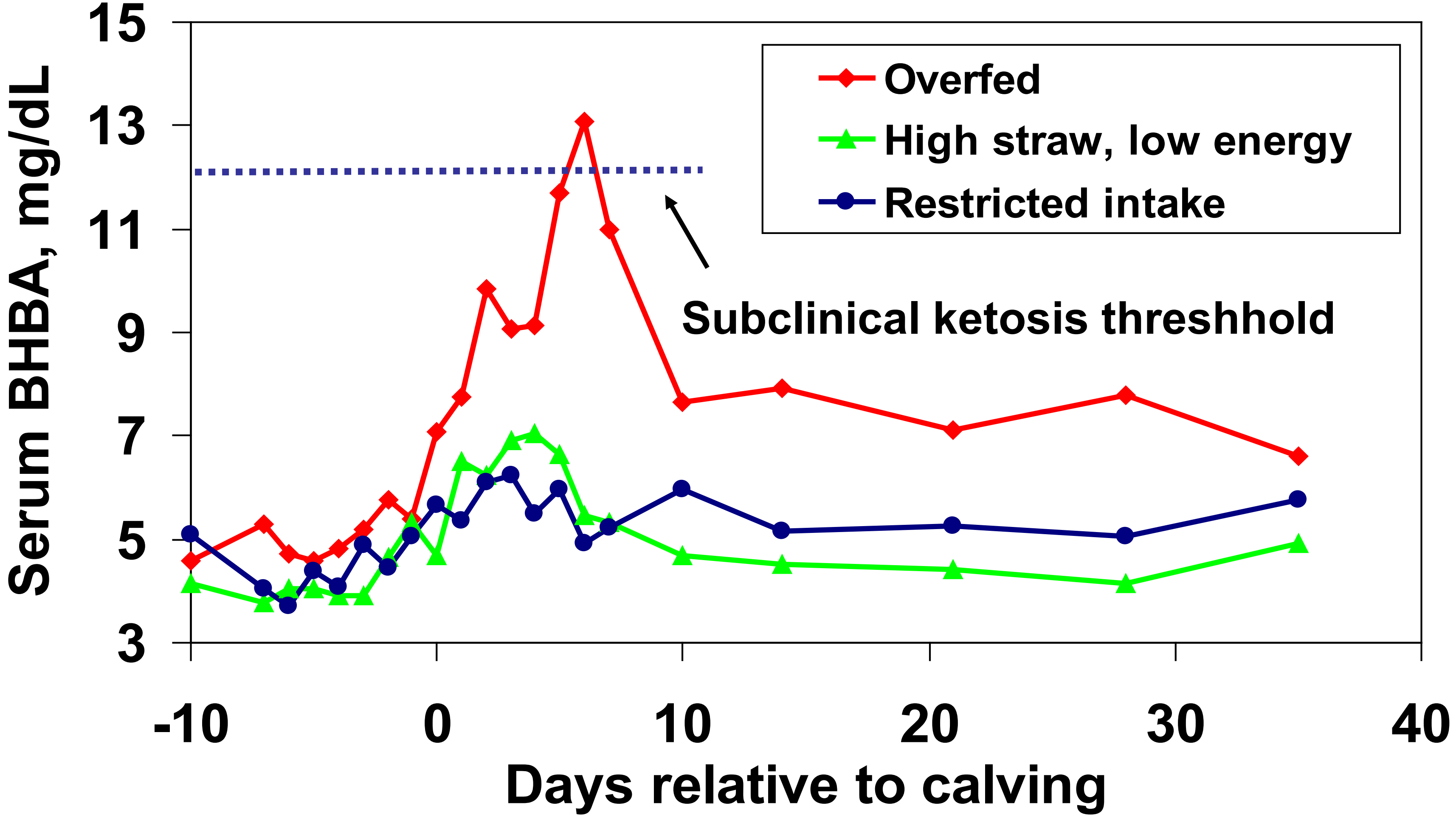
Adapted from Huzzey et al., 2007



Pre-calving DMI, visits to feed bunk, and time spent at feed bunk were lower for cows that developed subclinical ketosis postpartum

Goldhawk et al., 2009

Restricting feed intake precalving in otherwise-healthy cows does *not* cause ketosis or metritis



Janovick et al., 2011

Does high DMI in pre-fresh cows prevent health problems?

- No.
- Indicates there are fewer cows destined for problems as a result of management barriers for cows to adapt to lactation.
- *High DMI is an* ***indicator*** *of a successful program, it is not the reason for it.*

Summary - Energy

- Energy requirements for NASEM 2021 are about 17-18 Mcal/d NEL for dry cows and about 19-20 Mcal/d NEL for transition cows (mature Holstein).
- Diets will be higher in calculated energy with NASEM 2021 than with NRC 2001.
- Balances will be lower with NASEM 2021 than with NRC 2001 – closer to what is observed in field.

Dry cow dietary protein and milk production

- For NRC (2001) most studies fed treatments during entire dry period, not just pre-fresh
- Milk and milk composition during first 3 wk to 17 wk were the primary outcome variables
- In a few studies, diets were as low as 10% CP without effect on milk production (cows)
  - Diet with 10% CP prepartum remained in protein balance at d -10 (Putnam and Varga, 1998)

Dry cow dietary CP and milk production

Meta-analysis (Lean et al., 2013)

12 studies, 26 treatment comparisons

Control diets: 9.7 to 14.1% CP (avg. = 12.3)

Treatment diets: 11.7 to 23.4% CP (avg. = 15.9%)

Milk yield first 28 d to 120 d (avg = 65 DIM)

Average increase in milk for increased CP

= 0.1 kg/d (-0.6 to +1.2 kg/d)

Dry cow dietary MP and milk production

Meta-analysis (Husnain and Santos, 2019)

- 27 comparisons for heifers
- 97 comparisons for cows
- Mostly prefresh treatment comparisons

Diets: 9 to 21% CP (avg. = 14.0%)

6 to 10% MP (avg. 9.3% for cows; 6 to 13%)

MP calculated according to NRC 2001

Dry cow dietary CP and milk production

- No difference in milk yield for cows
  - ➢Milk protein increased 60 g/1000 g MP intake in cows producing >36 kg/d milk
- Increased milk and milk protein in first lactation cows

(Husnain and Santos, 2019)

Protein - NASEM 2001 model

Far-off dry cow and heifer

- ~11% CP (6.5% MP) will ~meet requirement
- 12% CP (7.2% MP) recommended because of limited data and potentially inadequate RDP
- Translates to 864 g/d (DMI 12 kg/d) to 1008 g/d (DMI 14 kg/d)

Protein - NASEM 2001 model

Close-up cow and heifer

- ~13% CP (7.8% MP) will meet requirement
- Translates to 936 g/d (DMI 12 kg/d) to 1014 g/d (DMI 13 kg/d)
- Might not be optimum for heifers
- Model ignores MP for colostrum, mammary development, and immune function (no data to model)

Higher quality MP may improve health outcomes?

	Prepartum diet		
Disorder	Low CP	High CP - SBM	Hi CP - Prolak
Retained placenta	4	6	1
n = 20			

Underwood et al., 2022

Amino acid supply – close-up cows

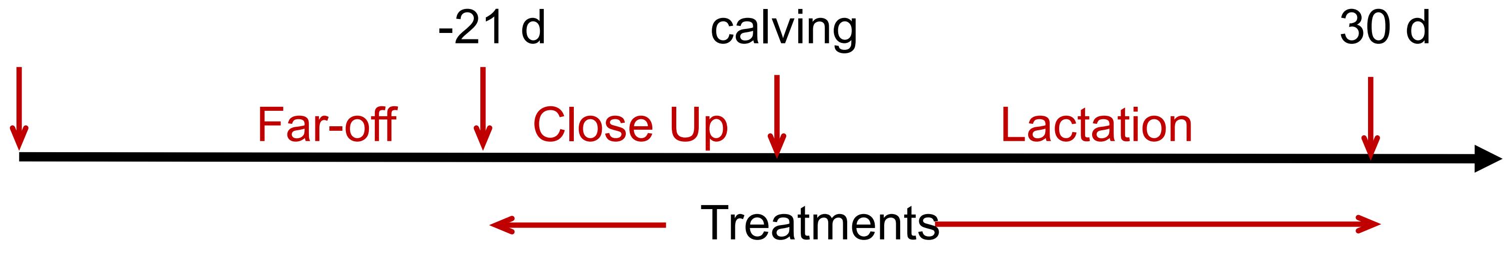
Item	Predicted Supply Mcal or g/d
DE Non-Protein	28
Arg	57
His	27
Ile	66
Leu	96
Lys	86
Met	25
Phe	62
Thr	60
Trp	14
Val	70

Lys:Met = 3.44

Targets (P. French):
Lys = 90 g/d
Met = 31 g/d
Lys:Met = 2.9:1

Would likely benefit from rumen-protected Met supplementation

Experimental design comparing the efficacy of rumen-protected methyl donors



CON: Control

MET: Smartamine (Met; 0.08% of DM)

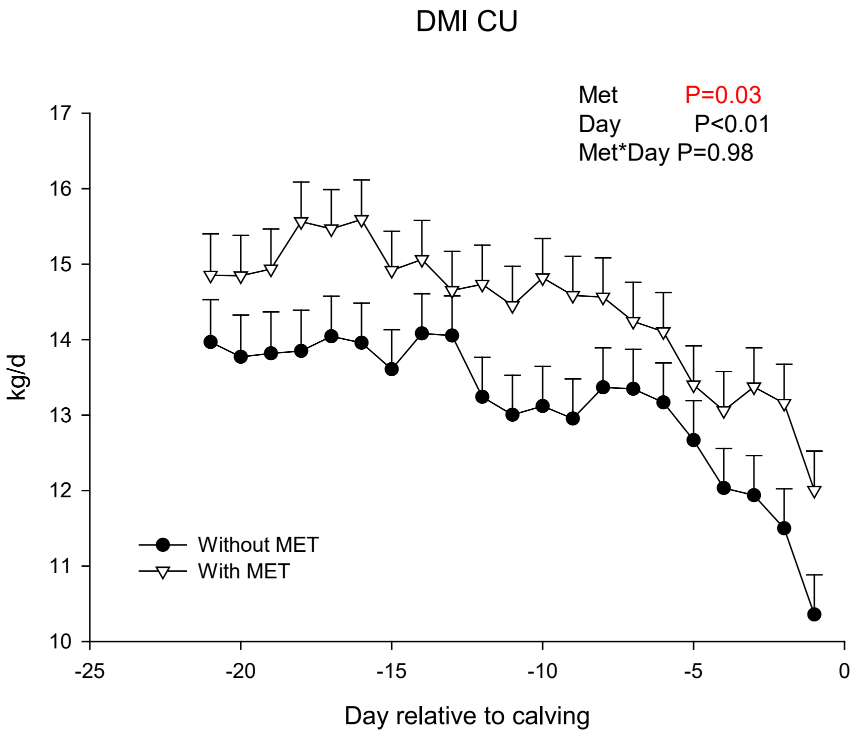
CHO: ReaShure (Choline; 60 g/cow/d)

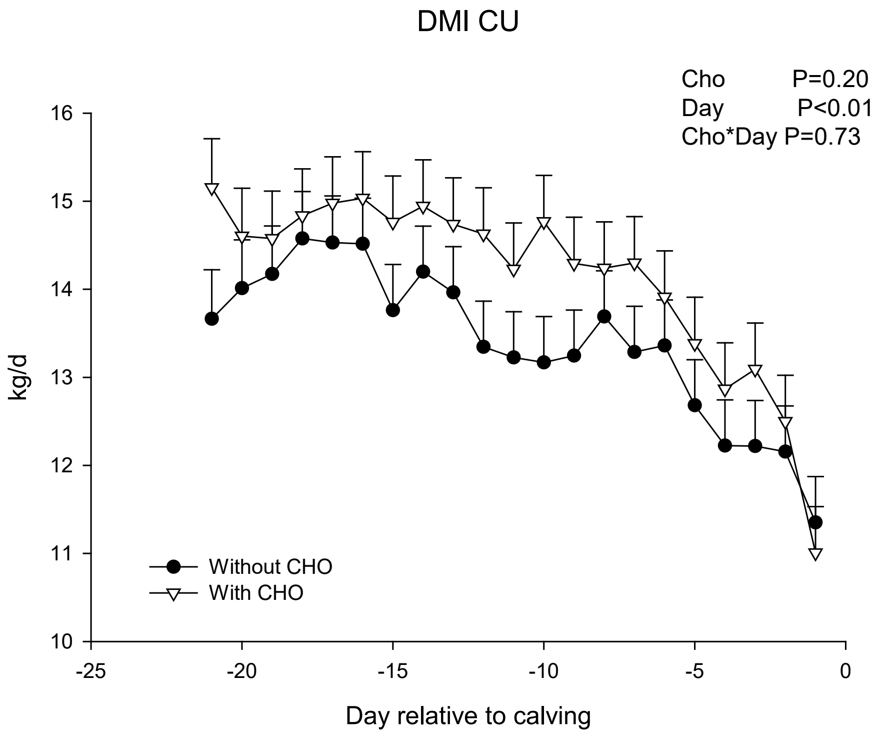
MIX: Smartamine + ReaShure

2×2 Factorial arrangement		Methionine	
		no	yes
Choline	no	CON	MET
	yes	CHO	MIX

(Zhou et al., 2015 JAM Orlando, FL, USA)

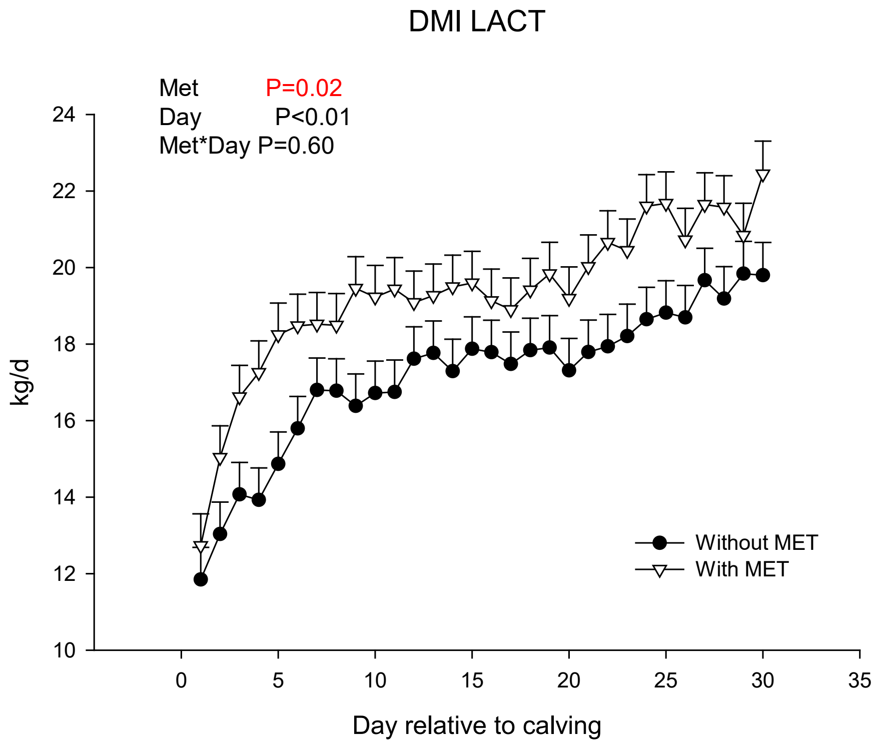
Main effects on DMI prepartum

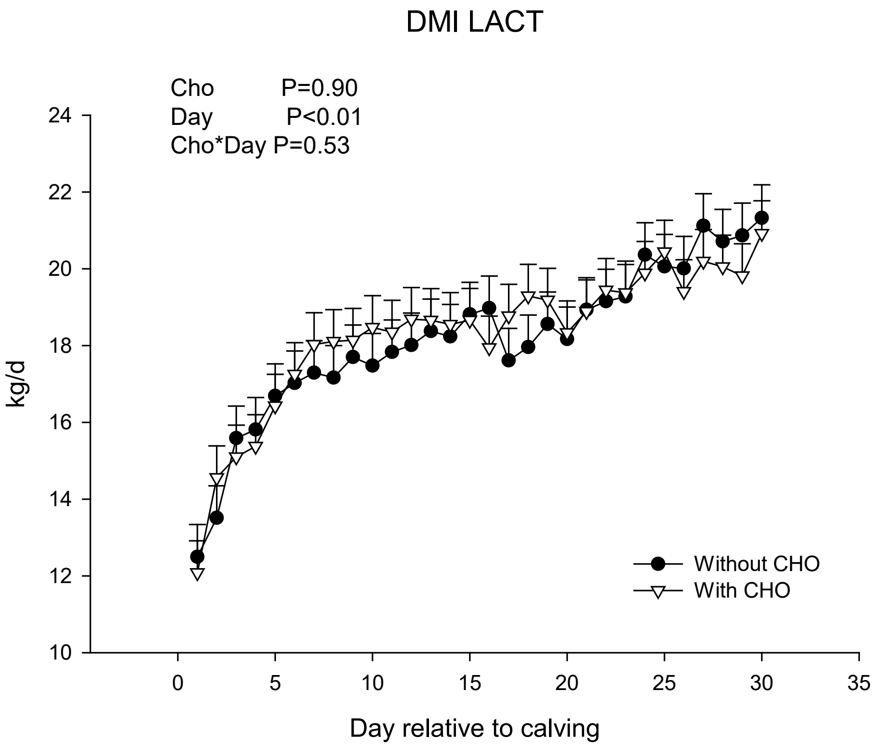




Zhou et al., 2015

Main effects on DMI postpartum





Zhou et al., 2015

Met but not choline increased milk yield and components

Variable	Met		Choline		*P* Met	*P* Cho
	+	−	+	−		
Milk, kg	44.3	40.3	41.6	43.1	**0.03**	0.41
Fat, %	3.72	3.74	3.78	3.68	0.92	0.46
Protein, %	3.32	3.14	3.27	3.19	**0.001**	0.23
Fat, kg	1.67	1.53	1.59	1.61	**0.04**	0.79
Protein, kg	1.51	1.33	1.41	1.42	**0.001**	0.67
FCM, kg	44.8	40.7	42.3	43.2	**0.001**	0.54

Main effects shown; interactions of Met and Cho were not significant.

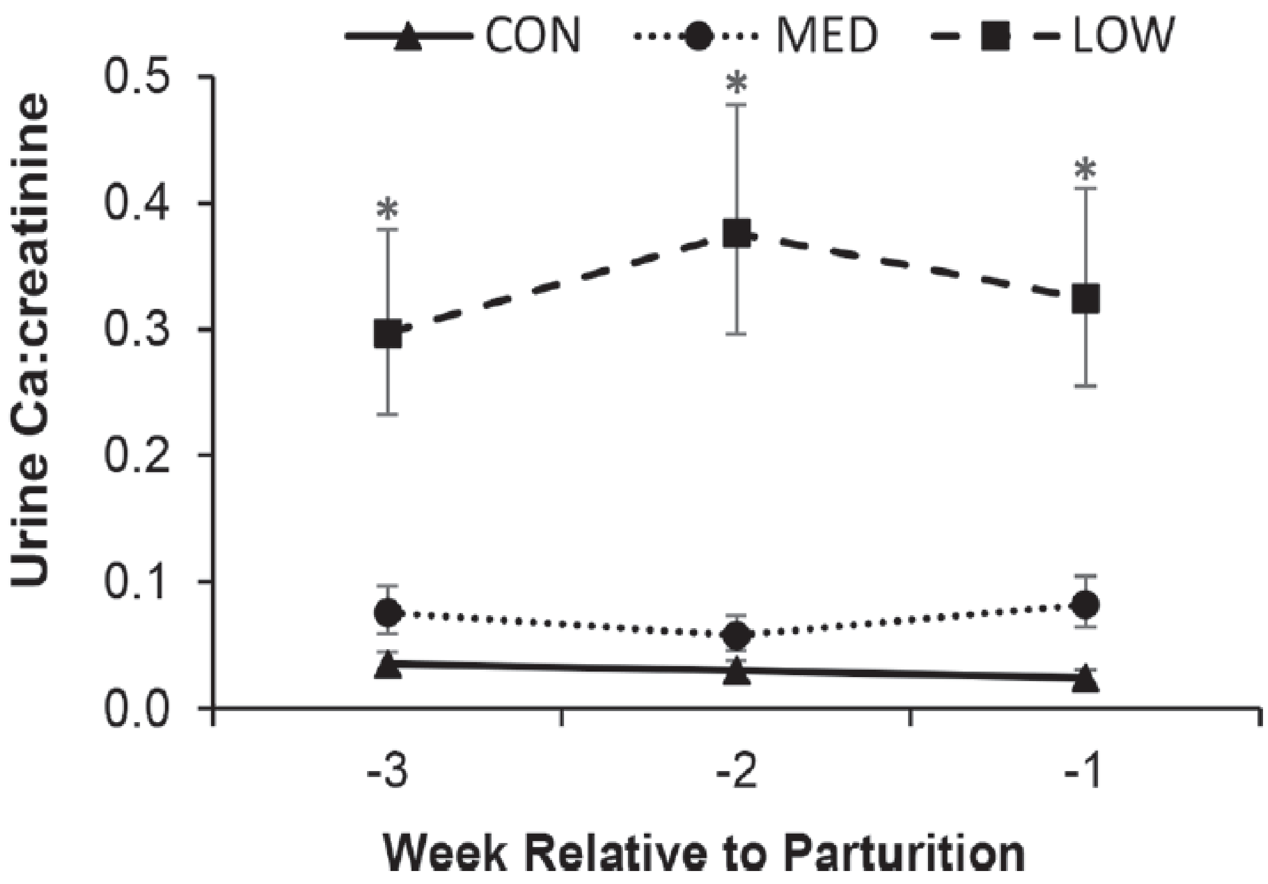
Zhou et al., 2016

Specific minerals/vitamins for transition cows

- Negative DCAD, Ca, P, Mg for hypocalcemia
- Higher vitamin E based on preventing mastitis, RP, and metritis
  - 1000 IU/d for dry cows and 2000 IU/d for prefresh cows (Holsteins)
- No other specific requirements

Metabolic acidosis caused by negative DCAD increases Ca excretion in urine

Dietary DCAD = 18.3 5.9 -7.4



Leno et al., 2017

Effects of partial or full DCAD

Variable	Diet (DCAD)			SEM	*P*
	CON	MED	LOW		
DCAD, mEq/100 g DM	18.3	5.9	-7.4		
DMI, kg/d					
wk -3 to -1	13.6	14.0	13.2	0.2	Q, 0.01
wk 1 to 3	20.2	20.9	21.3	0.5	L, 0.09
% of BW	2.88	2.98	3.07	0.06	L, 0.04
Milk, kg/d	40.8	42.4	43.9	1.0	L, 0.03

Q = quadratic effect, L = linear effect

Leno et al., 2017

Dietary concentrations (% of DM) required to meet the known requirements for macrominerals

Mineral	NRC, 2001	NASEM, 2021	Recommended[1]
Ca	0.45	0.37	1.5 – 2.0
P	0.23	0.21	0.25
Mg	0.12	0.13	0.40
K	0.52	0.65	low as possible
Na	0.10	0.16	0.16
Cl	0.15	0.13	0.7 – 0.9
S	0.20	0.20	0.20 – 0.35

[1] J. K. Drackley recommendation for full anionic program

Dietary concentrations (mg/kg of DM) required to meet the known requirements for trace minerals

Mineral	NRC, 2001	NASEM, 2021	Recommended[1]
Co	0.11	0.20	0.24
Cu	13	19	22
I	0.4	0.54	0.65
Fe	13	14	17
Mn	18	41	50
Se	0.3	0.3	0.3
Zn	22	30	36

[1] J. K. Drackley recommendation, includes 1.2X safety factor

Dietary supply (IU/d) required to meet the known requirements for vitamins

Vitamin	NRC, 2001	NASEM, 2021	Recommended[1]
A	82,610	81,500	100,000
D	22,530	22,000	26,000
E	1202	2000	2000

[1] J. K. Drackley recommendation

No requirement established

- Cr
  - Essentiality recognized but insufficient data to establish an adequate intake
  - Analytical challenges
- Choline
  - Committee acknowledges response to supplementation during transition but declined to establish a requirement
    - Endogenous synthesis
    - Variable results during lactation


drackley@illinois.edu

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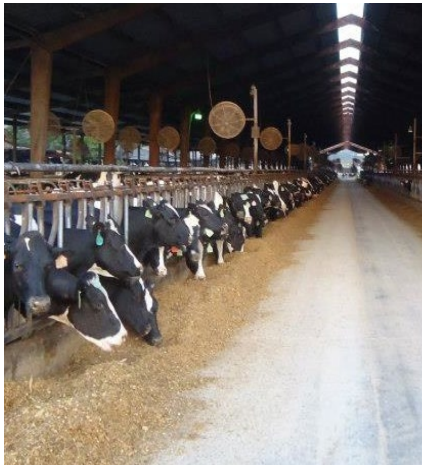
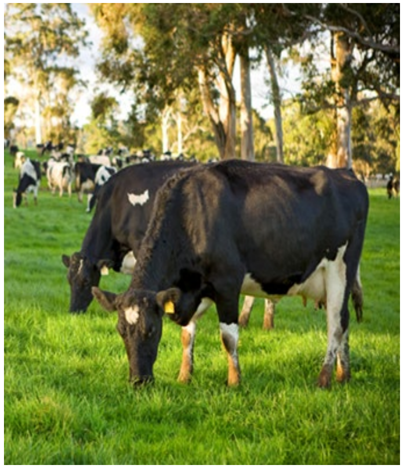
CALCIUM AND ENERGY BALANCE OF EARLY JERSEY COWS AND THE EFFECT OF AN ORAL CALCIUM SUPPLEMENTATION IN LACTATION PERFORMANCE

Paulo Menta

DVM, M.Sc, PhD student



Agenda

- Serum Ca dynamics in postpartum cows
- Key differences between breeds
- Association of blood calcium concentration in the first 3 days after parturition and energy balance metabolites at day 3 in milk with disease and production outcomes in multiparous Jersey cows
- A Randomized Clinical Trial Evaluating the Effect of an Oral Calcium Bolus Supplementation Strategy in Postpartum Jersey Cows on Mastitis, Culling, Milk Production, and Reproductive Performance

Background

3 weeks prepartum

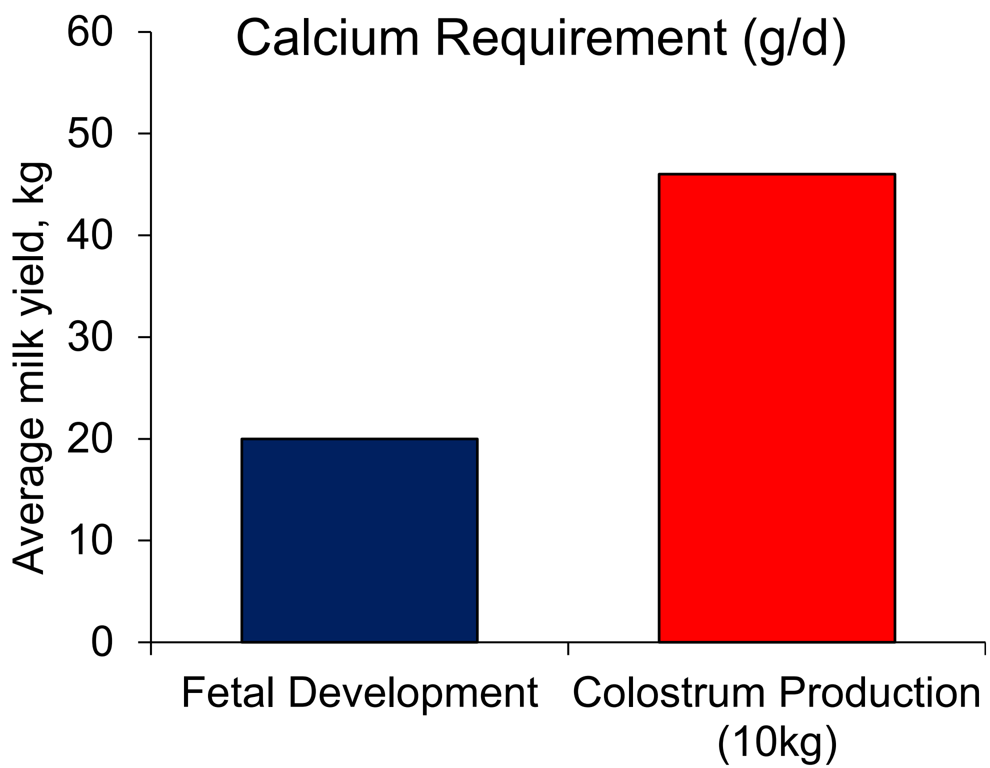
21 days in milk

Challenges:

- Change of physiological state
- Abrupt nutritional change
- Social stressors
- Inflammatory-infectious process in the reproductive tract
- 70% of the disease
- Energy demands increase by about 300%
- Calcium requirements are increased around 65%

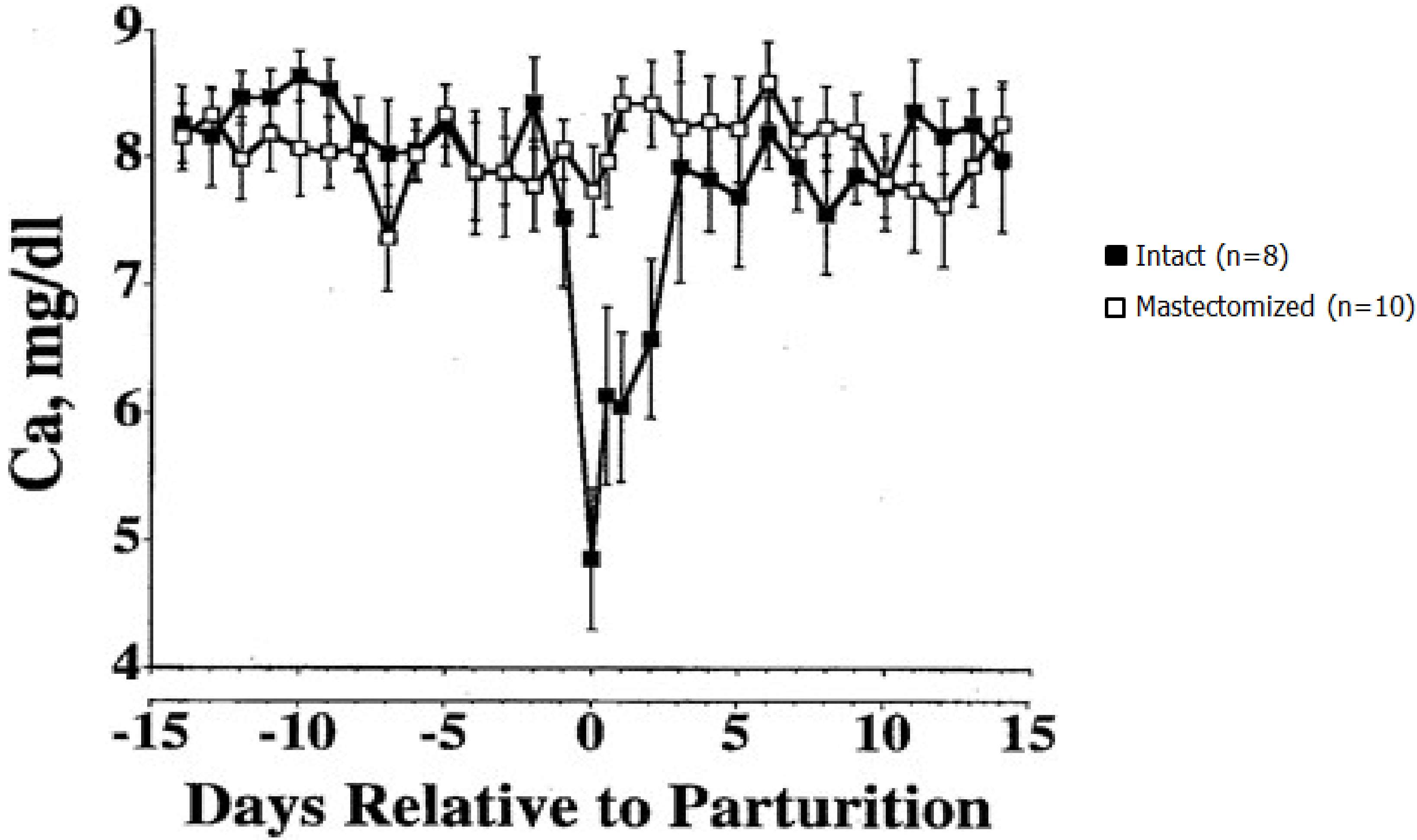
Bell, 1995; Darckely 1999

Background



- 2-4 g of Ca in the plasma pool
- Plasma pool must turnover 10+ times for colostrum production
- Adaptation requires coordination of several hormones and tissues

Background



Goff et al., 2002

Study #1

J. Dairy Sci. 104
https://doi.org/10.3168/jds.2020-19189

Association of blood calcium concentration in the first 3 days after parturition and energy balance metabolites at day 3 in milk with disease and production outcomes in multiparous Jersey cows

P. R. Menta,[1] L. Fernandes,[1] D. Poit,[1] M. L. Celestino,[1] V. S. Machado,[1] M. A. Ballou,[1] and R. C. Neves[2]*
[1]Department of Veterinary Sciences, College of Agricultural Sciences and Natural Resources, Texas Tech University, Lubbock 79409
[2]Department of Veterinary Clinical Sciences, College of Veterinary Medicine, Purdue University, West Lafayette, IN 47907

Why is it important?

J. Dairy Sci. 101:1–11
https://doi.org/10.3168/jds.2018-14587

Epidemiology of subclinical hypocalcemia in early-lactation Holstein dairy cows: The temporal associations of plasma calcium concentration in the first 4 days in milk with disease and milk production

R. C. Neves,* B. M. Leno,† K. D. Bach,‡ and J. A. A. McArt‡[1]
*Department of Veterinary Sciences, Texas Tech University, Lubbock 79409
†Department of Animal Science, and
‡Department of Population Medicine and Diagnostic Sciences, Cornell University, Ithaca, NY 14853

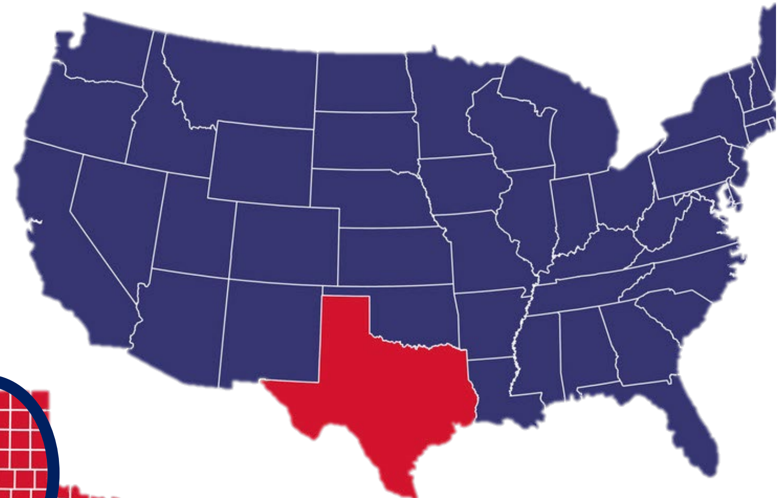
- Ca was associated with the risk of metritis at 2, 3, and 4 DIM
- Ca concentration was associated with the risk of metritis or displaced abomasum diagnosis (or both) for 2nd parity animals at 2 DIM), and at 4 DIM for 3rd and greater lactations
- ↓ Ca concentration was associated with ↑ milk production at 1 DIM in primiparous and multiparous cows
- ↓ milk production when assessed at 4 DIM in multiparous cows
- Assessments of SCH at the individual cow level must take into account the DIM of Ca concentration measurement and parity of the cow, as the epidemiology of the disorder was demonstrated to be highly dependent on these variables

Why is it important?

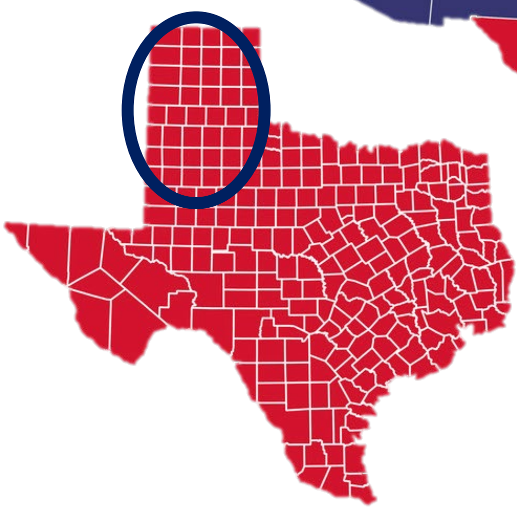
- Jersey vs. Holstein
- Calcium demands (Cerbulis and Farrell, 1976)
  - greater milk total ash content
- Calcium absorption
  - Vitamin D receptors (Goff et al., 1995)
- Negative energy balance (Friggens et al., 2007; Olson et al., 2010)
  - ↑ energy demands
  - ↓ Glucose
  - ↑ Lipolysis
- Energetic metabolism
  - FFA
  - BHB

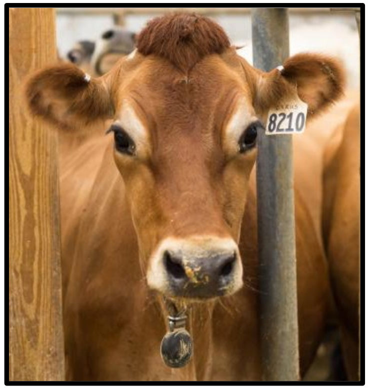
Why is it important?

- Differences between breeds can influence the ability of extrapolating results and disorder classification performed in one breed to the other



- West TX is the 2nd largest region in concentration of Jersey cattle in the U.S
    - 64,251 cows (American Jersey Cattle Association, 2017)





Study #1

- **Objetive**
  - Evaluate the associations of plasma total Ca measured at 1 through 3 DIM and FFA, BHB, and glucose measured at 3 DIM with:
    - the risk of multiparous Jersey cows being diagnosed with early-lactation diseases and culling
    - milk production in the first 9 wk of lactation
    - the risk of pregnancy in the first 150 DIM

Cut points for SCH and appropriate DIM for SCH testing to better assess this metabolic disorder in Jerseys would benefit technicians in the field

Material and Methods

- Prospective Cohort Study
  - July – April/2018
  - West Texas
  - 380 purebred Jersey cows
  - Data was extracted from the farm's DC305

Material and Methods

Data collection regarding monthly milk yield, fertility and culling

Days pospartum

0 1 2 3 4 7 10 180

tCa tCa tCa
FFA
BHB
Glu

Metritis diagnosis

Purebred
No oral Ca
No twin
DCC < 260
2 Lact
≥ Lact

- **Calving** season (**warm**: cows calving from July 19 to September 22, 2018; **cool**: calving from September 23 to December 9, 2018)
- **Calving problem**: Cows that suffered from dystocia, stillbirth or both

Material and Methods: Statistics

- Data modeling were developed in SAS (version 9.4)
  - Multivariable Poisson regression models were built to evaluate the association of the analytes with the risks of early lactation disease and culling
  - Linear mixed models were used to evaluate the association of the analytes with milk production
  - Cox Proportional hazards modeling were built to assess the risk of pregnancy
  - ROC curves were performed using MedCalc (version 9.5.2.0)
    - Metabolites were dichotomized if the AUC was significantly different than 0.5
    - Dichotomizations were based on thresholds that maximized the Sn and Sp for classification purposes

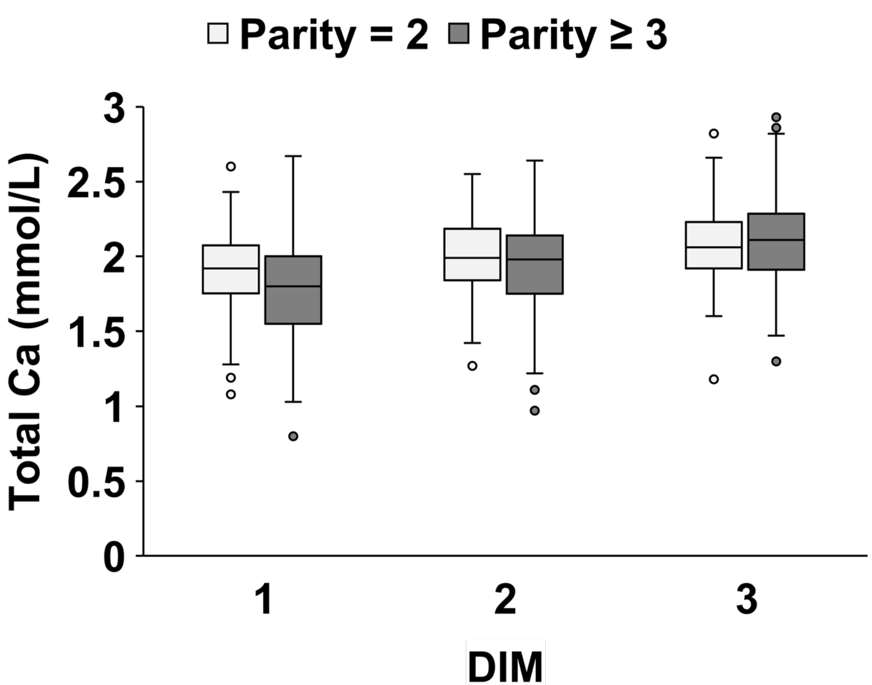
Descriptive Statistics

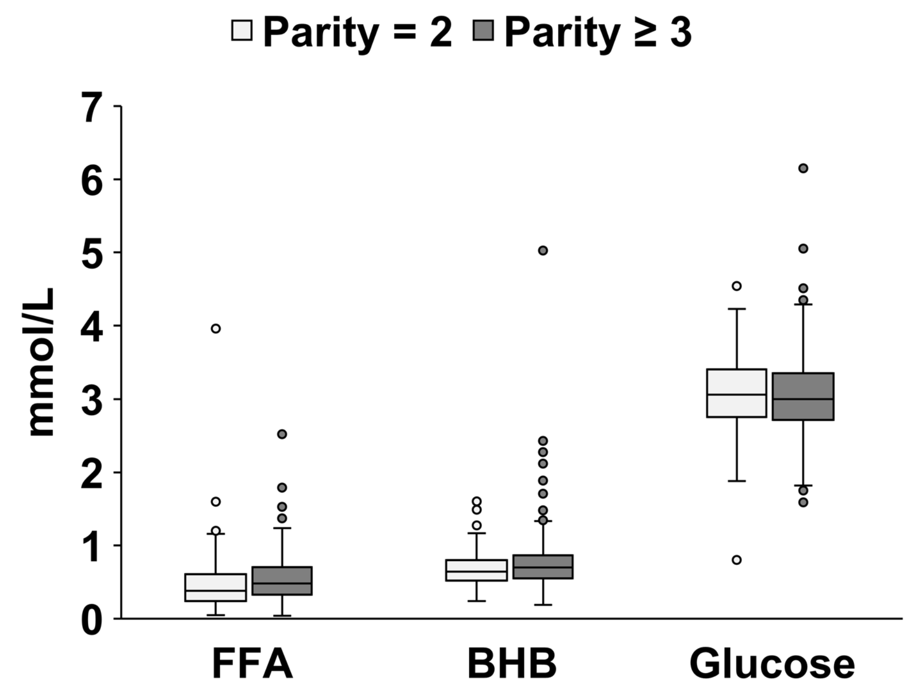
Disorder	n (%)
Stillbirth	14 (3.7)
Dystocia	11 (2.9)
Retained placenta	3 (0.8)
Left displaced abomasum	1 (0.3)
Metritis	100 (26.3)
Mastitis	46 (12.1)
Culling (sold/died)	36 (9.5)

Descriptive Statistics

	DIM		
Plasma total Ca concentration	1	2	3
1 DIM in 2nd parity cows (n = 147)			
r	1.00	0.65	0.08
P-value	-	<0.01	0.32
1 DIM in ≥3 parity cows (n = 233)			
r	1.00	0.52	0.06
P-value	-	<0.01	0.39

Descriptive Statistics





Risk of metritis

Variable	Relative risk	95% CI	P-value
Parity			
2	–	–	–
≥3	–	–	0.26
Calving season			
Cool	–	–	–
Warm	0.58	0.39 - 0.86	<0.01
Calving-related problem(s)	2.32	1.26 - 4.25	<0.01
Retained placenta	7.29	2.39 - 22.24	<0.01
FFA ≥0.43 mmol/L at 3 DIM	1.78	1.20 - 2.66	<0.01

Risk of metritis

Variable	Relative risk	95% CI	P-value
Intercept	–	–	<0.01
Parity			
2	–	–	–
≥3	–	–	0.26
Calving season			
Cool	–	–	–
Warm	0.58	0.39 - 0.86	<0.01
Calving-related problem(s)	2.32	1.26 - 4.25	<0.01
Retained placenta	7.29	2.3[illegible] - 22.24	<0.01
FFA ≥0.43 mmol/L at 3 DIM	1.78	1.20 - 2.66	<0.01

- **↓ blood Ca concentrations impair innate immunity (Kimura et al., 2006; Martinez et al., 2014)**
- **Parity dependency and temporality of Ca association (Neves et al., 2017)**
- **No correlation of Ca at 1 and 3 DIM was evidenced for our dataset**
- **Holstein vs. Jersey**
- **Consequence other than a risk factor for the disease**
- **↑ FFA can adversely affect oxidative burst and the phagocytic capacity of PMNL (Scalia et al., 2006)**

Risk of culling

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Variable	Relative risk	95% CI	P-value
Parity			
2	–	–	–
3	4.36	2.02 - 9.43	<0.01
Body condition score			
1	–	–	–
2	0.41	0.23 - 0.74	<0.01
3	0.30	0.12 - 0.72	<0.01
Glucose at 3 DIM	1.75	1.16 - 2.64	<0.01
BHB at 3 DIM	1.63	1.0 - 2.64	0.08
FFA at 3 DIM	2.18	1.03 - 4.60	0.05
Total Ca at 3 DIM ≤1.99 mmol/L	2.93	1.74 - 4.94	<0.01

Risk of culling

- **Literature is inconsistent**
  - **↓ [Ca] associated with culling in the first 2 weeks postpartum (Seifi et al., 2011; Roberts et al., 2012).**
  - **[Ca] concentration <2.00 mmol/L had increased risk of being culled in the first 60 DIM (Venjakob et al. 2018)**
  - **↓ [Ca] within 12 h after parturition tendendof increased tCa concentration and the risk of culling within 60 DIM (Neves et al., 2018)**
  - **Lipolysis before parturition is a known risk factor for metritis (Chapinal et al., 2011; Giuliodori et al., 2013)**
    - **↑ metritic cows are more likely to be culled (Wittrock et al., 2011)**
    - **↑ FFA associated with metritis and culling**

Variable	Relative risk	95% CI	P-value
Parity			
2	[illegible]	[illegible]	[illegible]
3	4.36	2.02 - 9.43	<0.01
Body condition score			
1	[illegible]	[illegible]	[illegible]
2	0.41	0.23 - 0.74	<0.01
3	0.30	0.12 - 0.72	<0.01
Glucose at 3 DIM	1.75	1.16 - 2.64	<0.01
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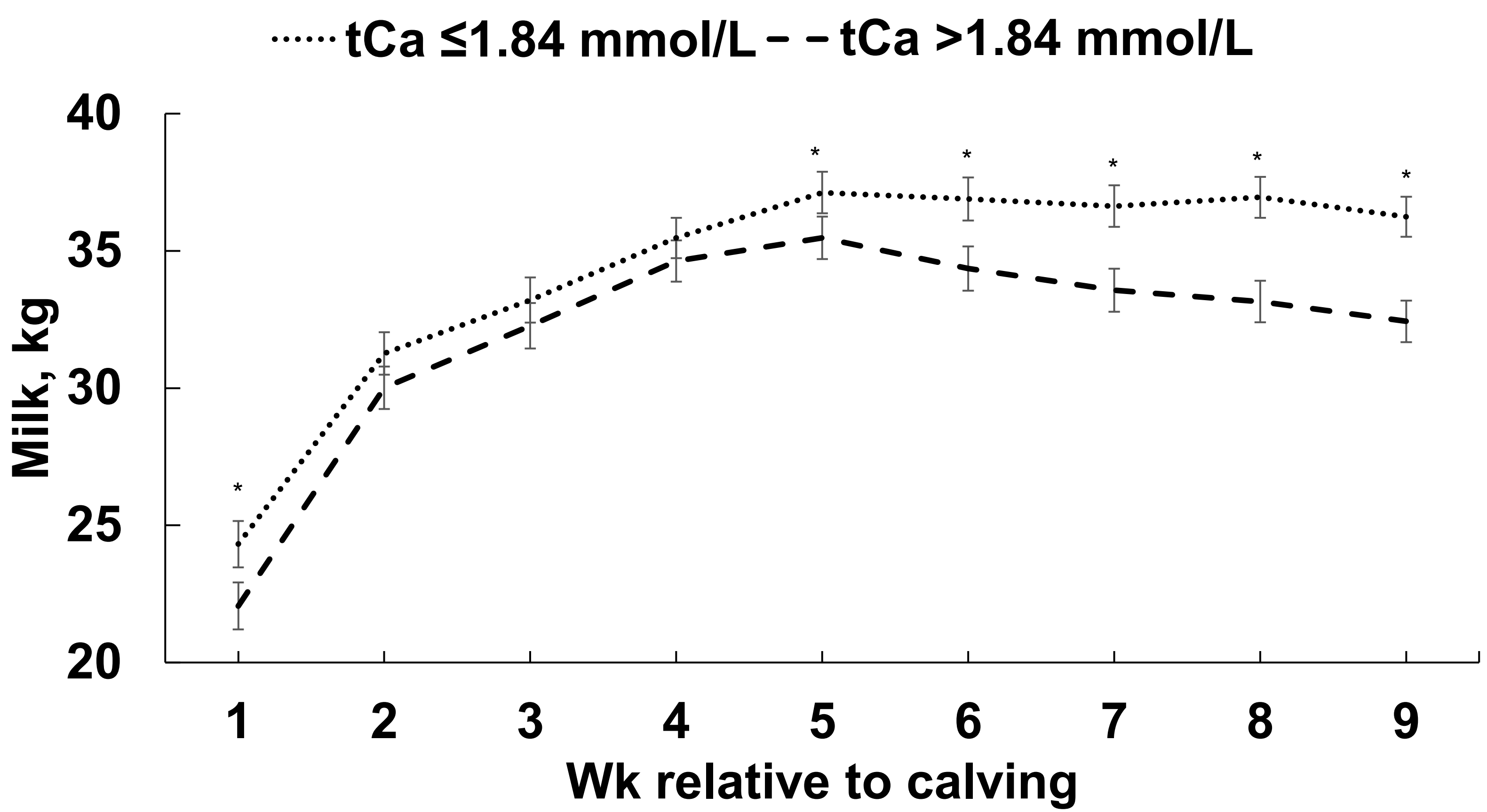
FFA at 3 DIM	2.18	1.03 - 4.60	0.05
Total Ca at 3 DIM ≤1.99 mmol/L	2.93	1.74 - 4.94	<0.01

Milk Yield

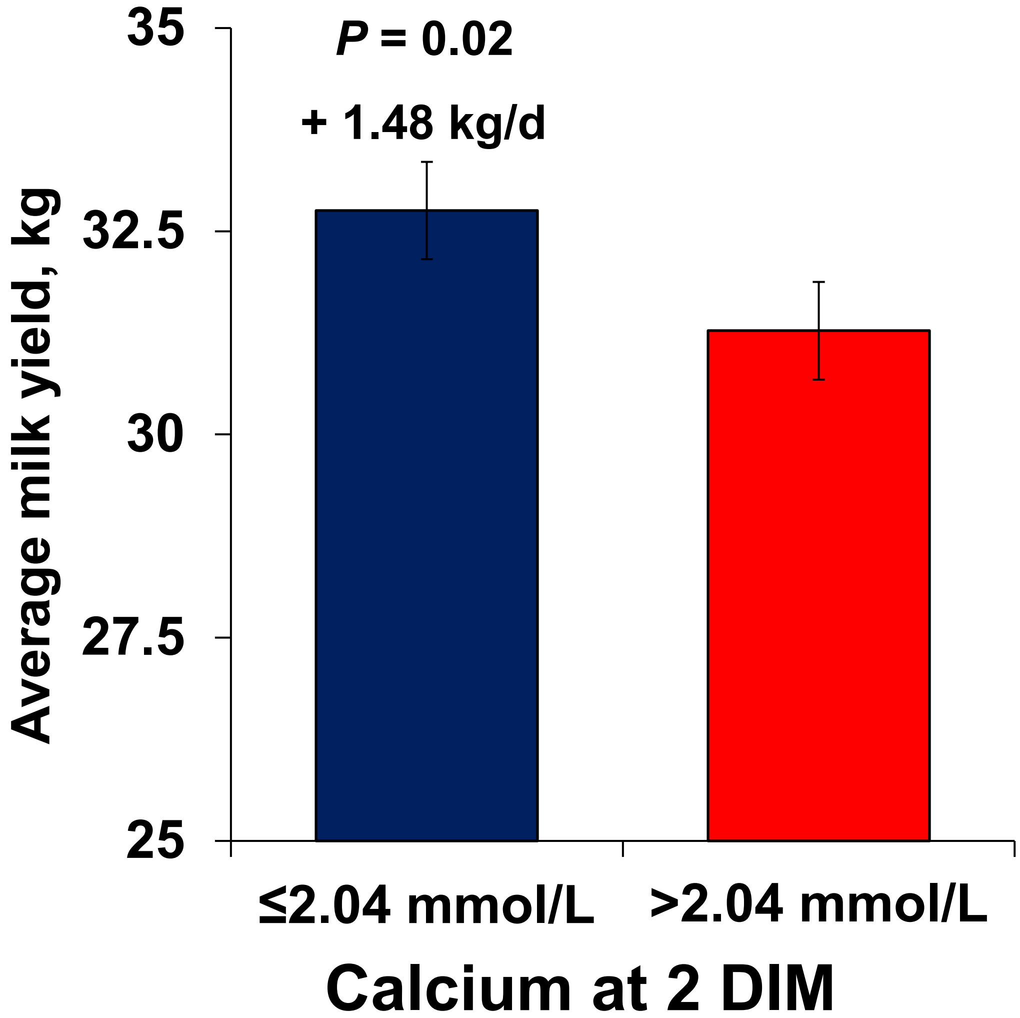
	1 DIM			2 DIM		
Variable	Estimate	SE	P-value	Estimate	SE	P-value
Parity						
2	Ref	-	-	Ref	-	-
3	-0.10	0.64	0.88	0.19	0.64	0.76
BCS Score						
1	Ref	-	-	Ref	-	-
2	2.79	0.89	<0.01	2.81	0.91	<0.01
3	4.49	1.15	<0.01	4.32	1.17	<0.01
Calving season						
Cool	Ref	-	-	Ref	-	-
Warm	1.22	0.63	0.05	1.23	0.66	0.06
Gestation length (d)	0.19	0.06	<0.01	0.20	0.06	<0.01
Metritis	-0.45	0.69	0.51	-0.52	0.70	0.46
Mastitis	-3.24	0.92	<0.01	-3.18	0.93	<0.01
Dichotomized total Ca variable	-	-	<0.01	1.48	0.66	0.02
Weekly test*Dichotomized total Ca variable	-	-	0.02	-	-	0.35

Milk Yield



tCa ≤1.84 mmol/L
tCa >1.84 mmol/L
40
35
30
25
20
Milk, kg
1
2
3
4
5
6
7
8
9
Wk relative to calving

Milk Yield

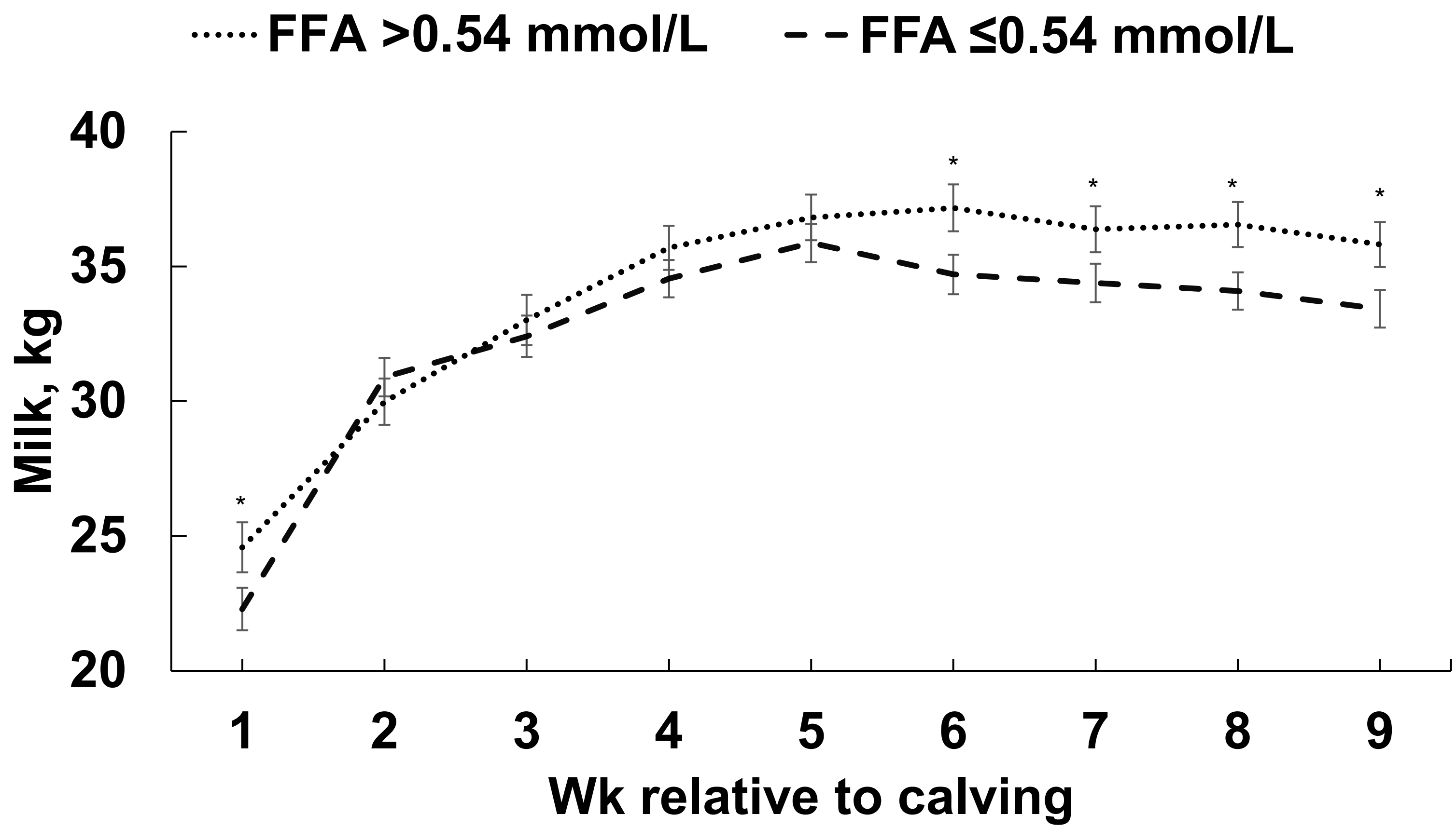


P = 0.02
+ 1.48 kg/d
Average milk yield, kg
35
32.5
30
27.5
25
≤2.04 mmol/L
>2.04 mmol/L
Calcium at 2 DIM

Milk Yield

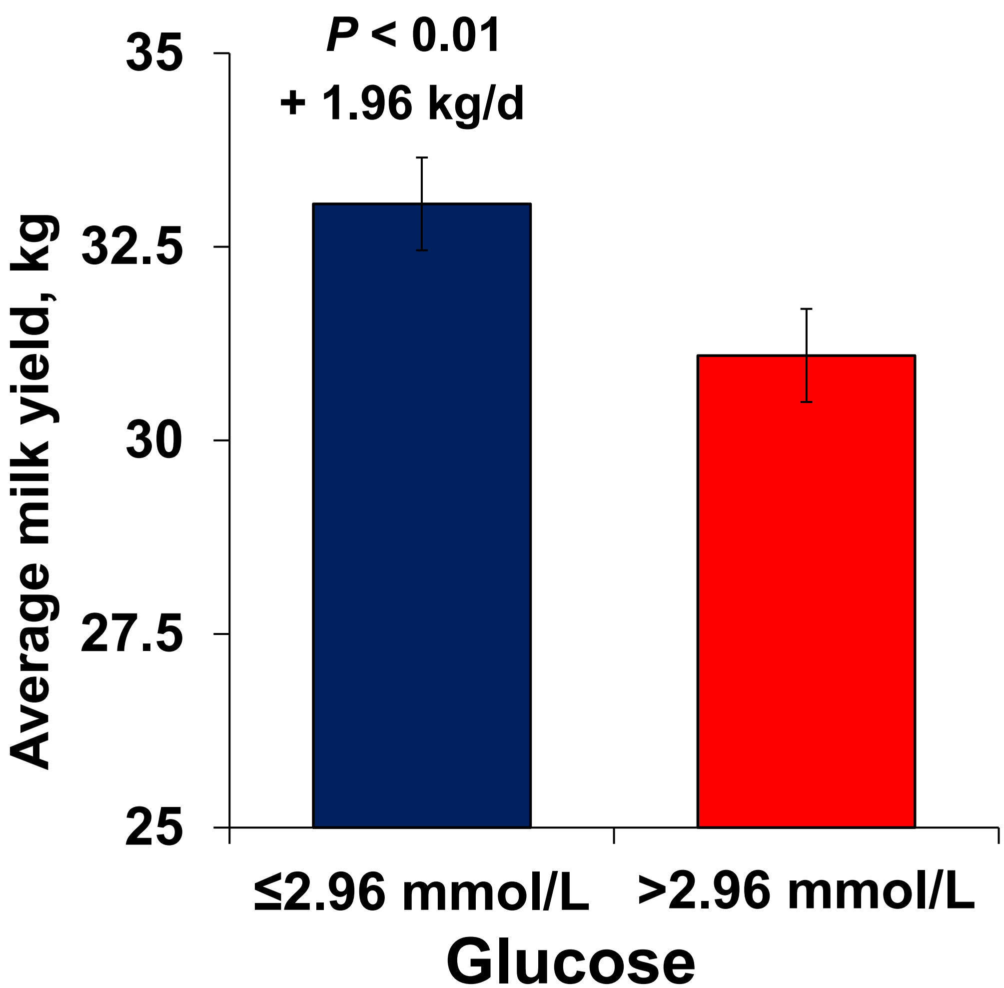
Variable	Estimate	SE	P-value
Parity			
2	Ref		
≥3	-0.24	0.63	0.70
BCS Score			
1	Ref		
2	2.38	0.90	<0.01
3	3.44	1.17	<0.01
Season			
Cool	Ref		
Warm	1.30	0.62	0.04
Gestation length (d)	0.19	0.06	<0.01
Metritis	-0.41	0.69	0.55
Mastitis	-3.12	0.92	<0.01
FFA ≥0.37 mmol/L			<0.01
Weekly milk test*FFA ≥0.37 mmol/L			0.01
Glucose ≤2.96 mmol/L	1.96	0.61	<0.01

Milk Yield



FFA >0.54 mmol/L
FFA ≤0.54 mmol/L
Milk, kg
40
35
30
25
20
*
*
*
*
*
1
2
3
4
5
6
7
8
9
Wk relative to calving

Milk Yield



P < 0.01
+ 1.96 kg/d
35
32.5
30
27.5
25
Average milk yield, kg
≤2.96 mmol/L
>2.96 mmol/L
Glucose

Milk Yield

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Association of immediate postpartum plasma calcium concentration with early-lactation clinical diseases, culling, reproduction, and milk production in Holstein cows

R. C. Neves,* B. M. Leno,† M. D. Curler,‡ M. J. Thomas,‡ T. R. Overton,† and J. A. A. McArt*[1]
*Department of Population Medicine and Diagnostic Sciences, College of Veterinary Medicine, and
†Department of Animal Science, Cornell University, Ithaca, NY 14853
‡Dairy Health and Management Services LLC, Lowville, NY 13367

Association of postpartum hypocalcemia with early-lactation milk yield, reproductive performance, and culling in dairy cows

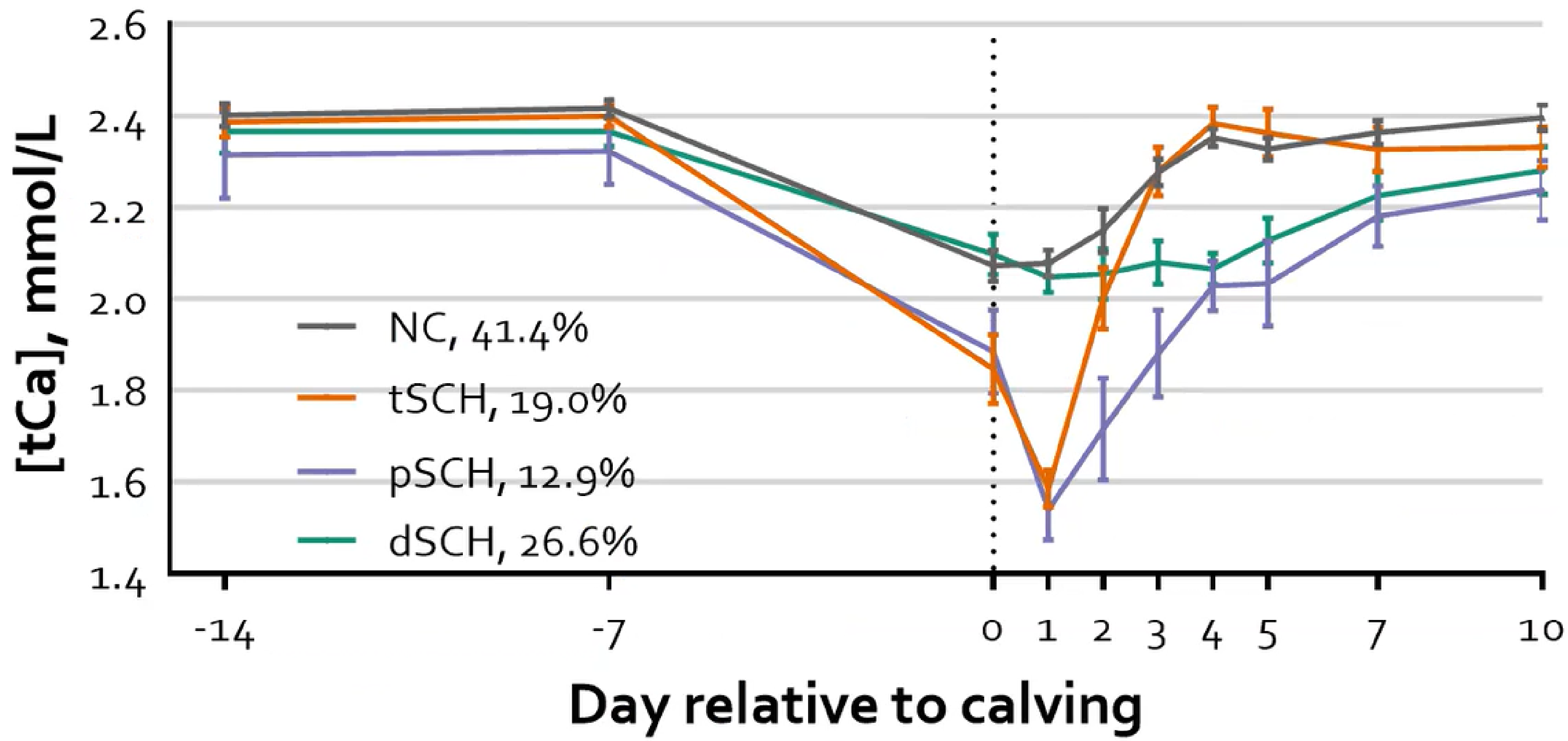
P. L. Venjakob,*† L. Pieper,‡ W. Heuwieser,*[1] and S. Borchardt*
*Clinic for Animal Reproduction, Faculty of Veterinary Medicine, Freie Universität Berlin, 14163 Berlin, Germany
†Veterinary practice G. Thiele, 15837 Baruth/Mark, Germany
‡Institute for Veterinary Epidemiology and Biostatistics, Faculty of Veterinary Medicine, Freie Universität Berlin, 14163 Berlin, Germany

J. Dairy Sci. 104:11983–11994
https://doi.org/10.3168/jds.2020-19527

Association of low serum calcium concentration after calving with productive and reproductive performance in multiparous Jersey cows

Ainhoa Valldecabres[1,2] and Noelia Silva-del-Río[1,2]*
[1]Veterinary Medicine Teaching and Research Center, Tulare, CA 93274
[2]Department of Population Health and Reproduction, School of Veterinary Medicine, University of California, Davis 95616

Discussion



McArt and Neves., 2020

Conclusions

- Multiparous Jersey cows with lower [Ca] in the first 2 DIM and reduced glucose at 3 DIM were more likely to have increased milk production across the first 9 wk of lactation

- Cows with increased concentration of FFA at 3 DIM had an overall higher milk production; however, they were also more likely to develop metritis within 10 DIM

- Reproduction was not affected by time to cure in this dataset

- More studies evaluating the association of Ca and energy balance markers during the transition period with lactation performance while including a greater number of herds are needed to best characterize subclinical hypocalcemia and hyperketonemia in Jersey cows

Study #2

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animals

MDPI

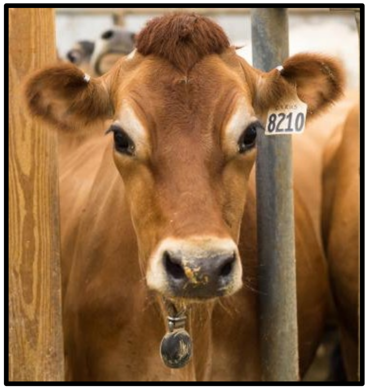
Article

A Randomized Clinical Trial Evaluating the Effect of an Oral Calcium Bolus Supplementation Strategy in Postpartum Jersey Cows on Mastitis, Culling, Milk Production, and Reproductive Performance

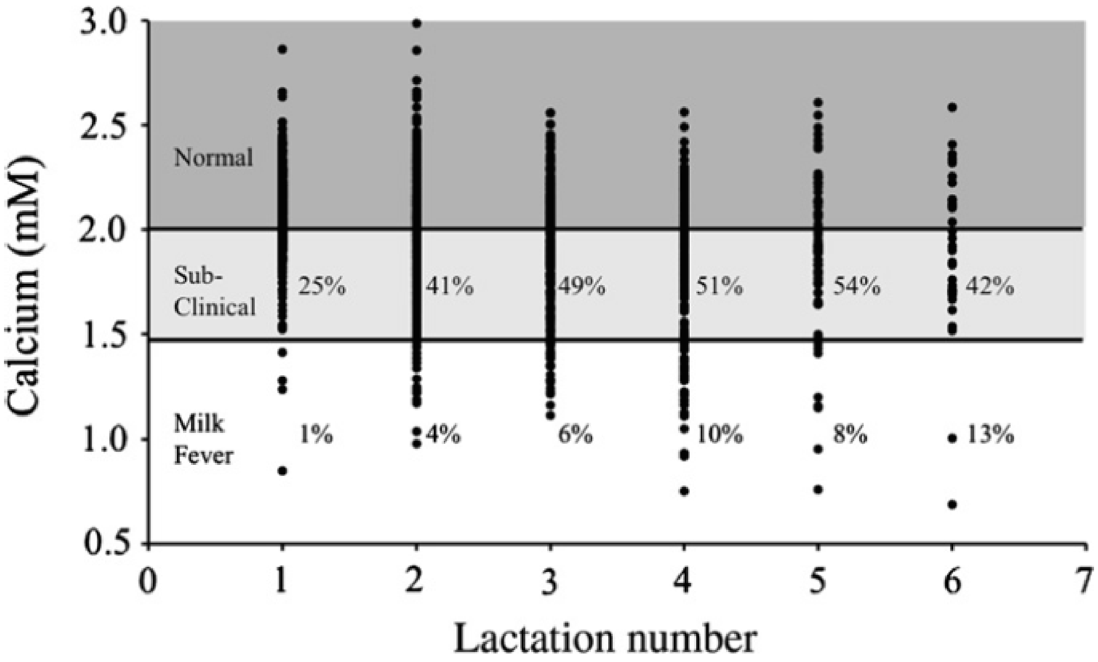
Paulo R. Menta [1], Leticia Fernandes [1], Diego Poit [1], Maria Luiza Celestino [1], Vinicius S. Machado [1] and Rafael C. Neves [2,*]

Introduction

- Cows develop clinical and subclinical hypocalcemia
  - Sequestration of Ca into mammary gland
- Jersey cows are more susceptible
  - Greater [Ca] in colostrum
  - Fewer vitamin D_3 receptor expression in the intestine



- Older cows are more susceptible
  - Greater colostrum production
  - Smaller number of vitamin D_3 binding sites in the intestine



Reinhardt et al. (2011).

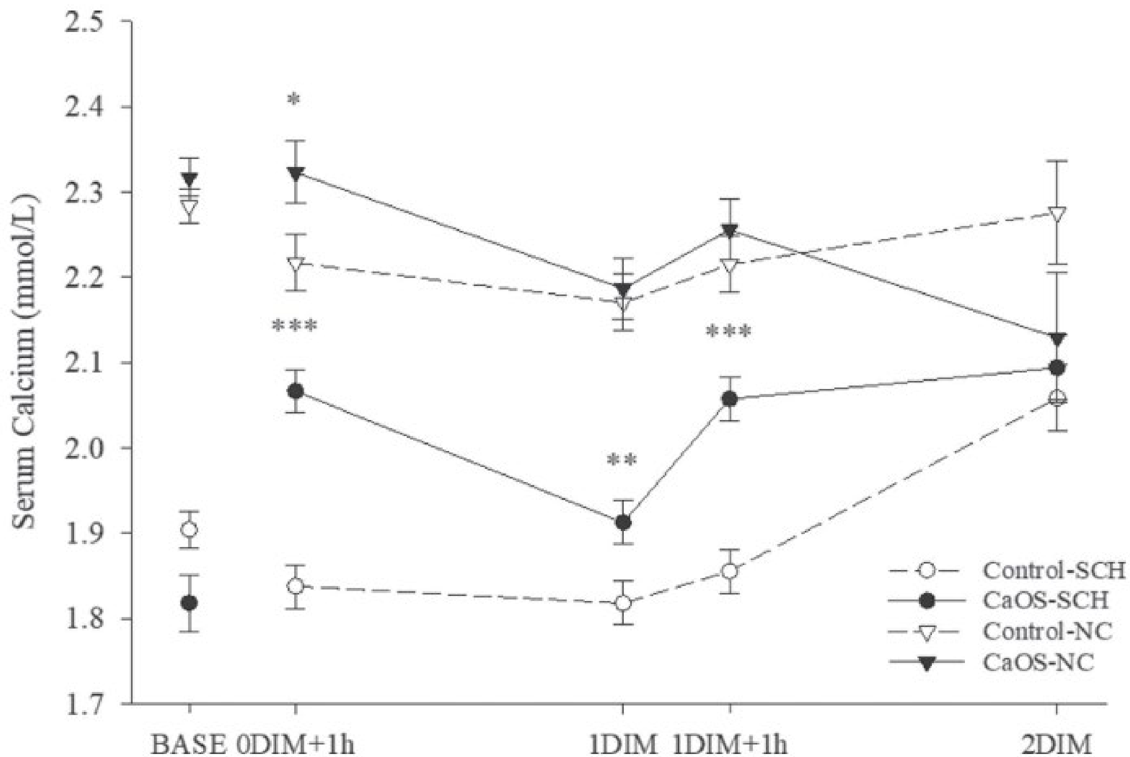
Introduction

- Acidogenic diets have not been demonstrated to be as effective for SCH prevention as for CH (Reinhardt et al., 2011)

- Strategies to mitigate the potential effects of SCH via postpartum oral Ca supplementation are still widely adopted

- In the U.S. for instance, 80% of the large farms used some combination of injectable, drench, or oral Ca as a preventative strategy to postpartum diseases (USDA, 2014)

Introduction



- Benefits are incosistent
- High milk producers
- Lame cows
- Parity
- Data limited for Jersey cows

Oetzel and Miller, (2012); Valldecabres et al., (2018); Valldecabres and Silva-del-Rio, (2020)

Introduction

VS

Objective

- **Objective**
  - Determine the effect of an oral Ca supplementation strategy applied to multiparous Jersey cows on:
    - health outcomes
    - reproductive performance
    - milk production

- **Hypothesis**
  - Postpartum oral Ca supplementation would:
    - decrease the odds of clinical diseases
    - improve milk production
    - reproductive performance

Material and Methods

- Randomized clinical trial – CTRL and TRT
  - July/2018 – April/2019
  - West Texas
  - 852 purebred Jersey cows
  - Data was extracted from the farm's DC305
    - Milk yield
    - DIM at pregnancy
    - Culling
    - Mastitis incidence
  - **TRT:** two doses of a commercial oral Ca bolus (Bovikalc®, Boehringer Ingelheim Vetmedica, Inc., St. Joseph, MO, USA)
    - calcium chloride and calcium sulfate (43 g of Ca per bolus);
  - **CTRL**: No oral Ca supplementation

Material and Methods

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Data collection regarding health events monthly milk yield, fertility and culling

Days pospartum

0 1 2 3 4 7 10 180

TRT

Metritis diagnosis

Purebred
No oral Ca
No twin
DCC < 260
2 Lact
≥ Lact

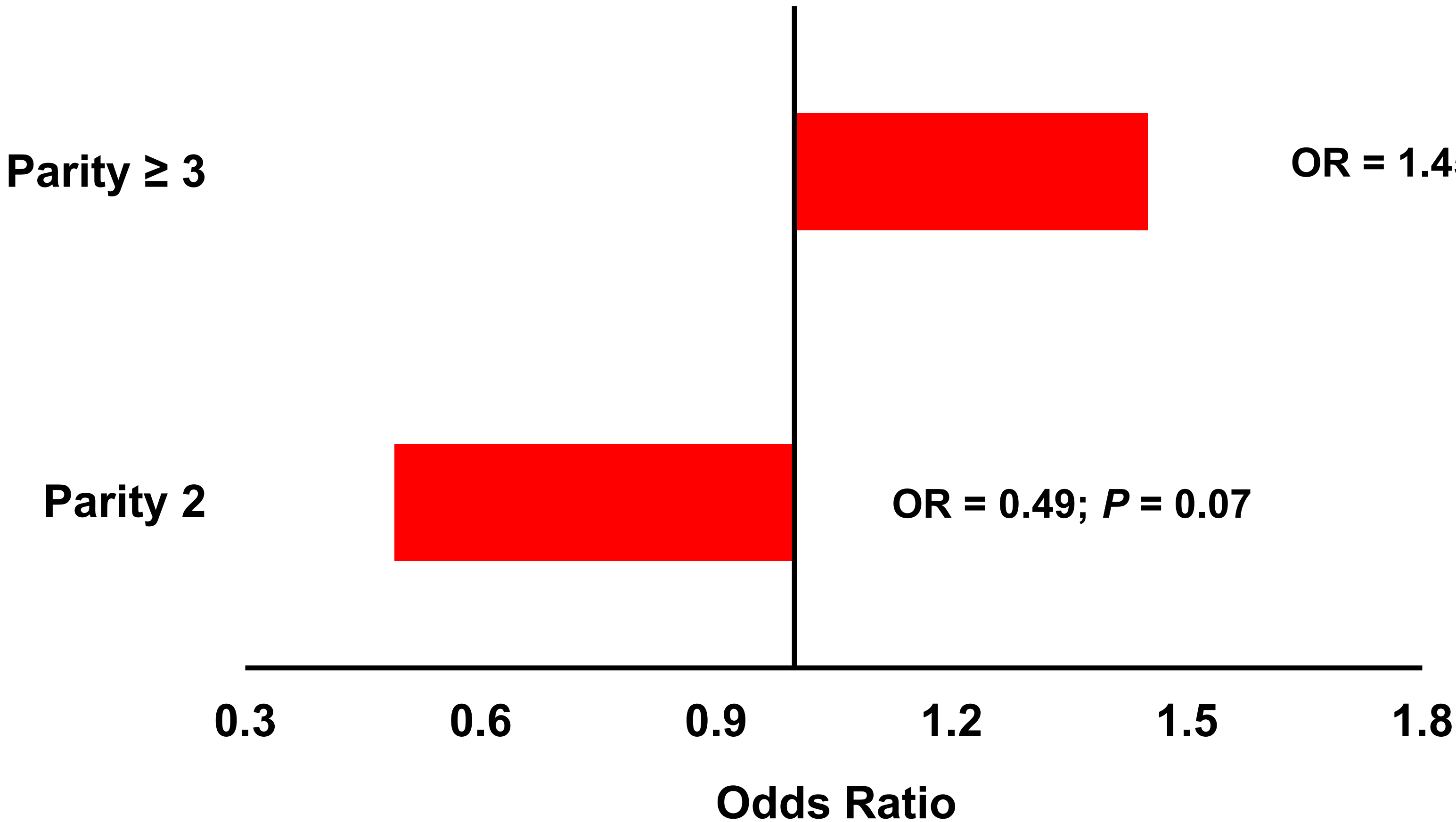
1st bolus: within 1h after calving

2nd boluses: occurred around 21 h after calving

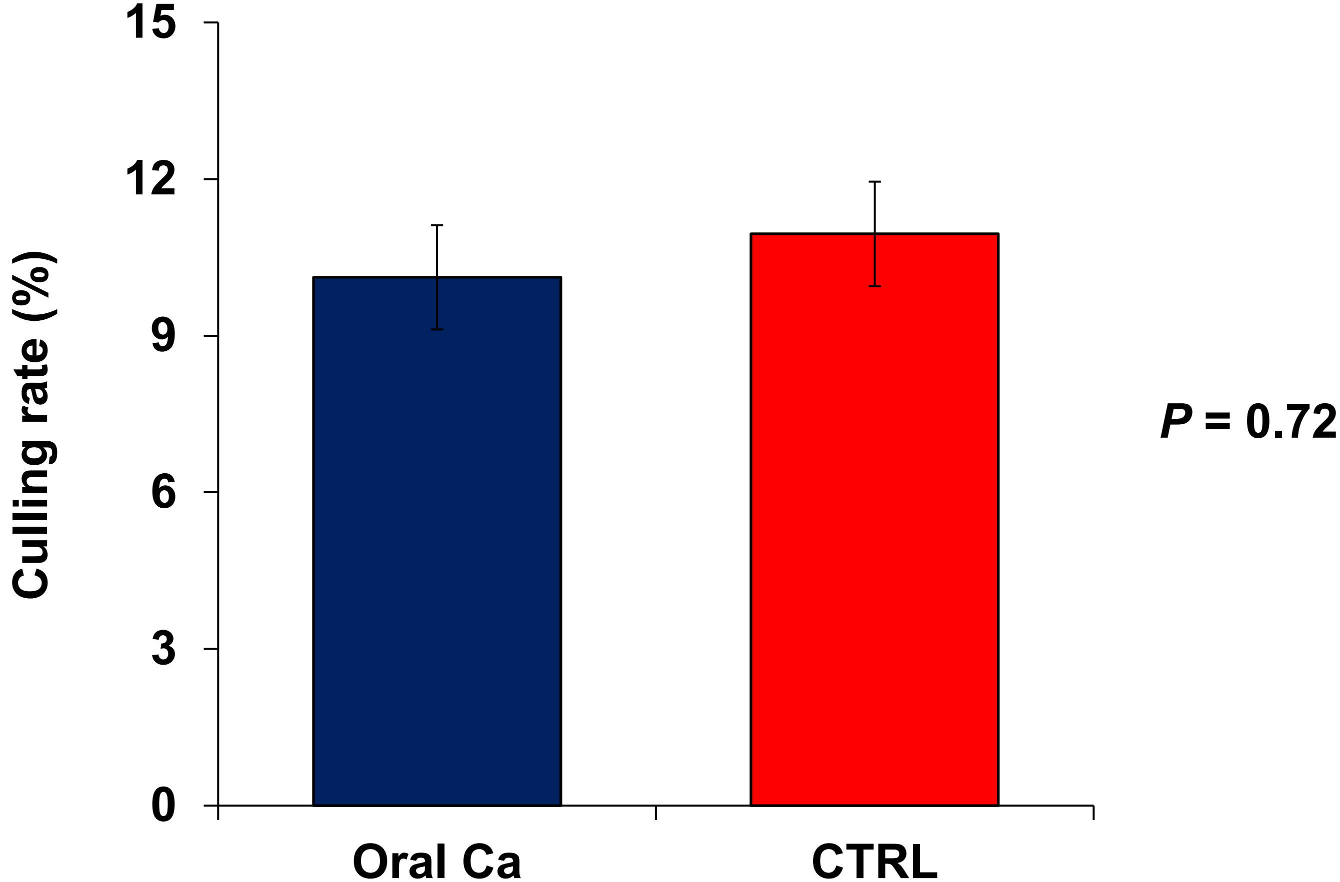
Mastitis within 60 DIM

Variable	Estimate	SE	P-value
Postpartum Ca supplementation			
Control	Ref	–	–
Treatment	-0.72	0.39	0.06
Parity			
2	Ref	–	–
≥3	-0.15	0.30	0.62
Calving problem			
No	Ref	–	–
Yes	-1.36	0.73	0.06
Parity × Treatment	1.08	0.47	0.02

Mastitis within 60 DIM



Culling within 60 DIM



Reproductive Performance

Variable	Estimate	SE	P-value	HR
Postpartum Ca supplementation				
Control	Ref	–	–	
Treatment	0.04	0.10	0.67	1.04
Parity				
2	Ref	–	–	
≥3	-0.01	0.10	0.91	0.99
Calving problem				
No	Ref	–	–	
Yes	-0.37	0.26	0.16	0.69

Milk yield

Variable	Estimate	SE	P-value
Postpartum Ca supplementation			
Control	Ref	–	–
Treatment	0.24	0.69	0.73
Parity			
2	Ref	–	–
≥3	0.50	0.41	0.22
Test number	–	–	<0.01
Calving season			
Warm	Ref	–	–
Cool	-0.97	0.40	0.02
Gestation length (d)	0.15	0.04	<0.01
Body condition score			
Thin	Ref	–	–
Normal	0.76	0.72	0.29
Over-conditioned	1.64	0.99	0.10

Conclusions

- Prophylactic postpartum Ca supplementation to multiparous Jersey cows had no effects on:
  - culling
  - milk yield
  - Reproduction

- Second parity cows that were supplemented with oral Ca boluses tended to have reduced odds of mastitis compared to non-supplemented cows

- Our data do not support blanket oral Ca supplementation in Jersey cows as the effects were minimal to none; however, targeted oral Ca supplementation for subpopulations of cows and at different times relative to parturition remain to be investigated

Acknowledgment

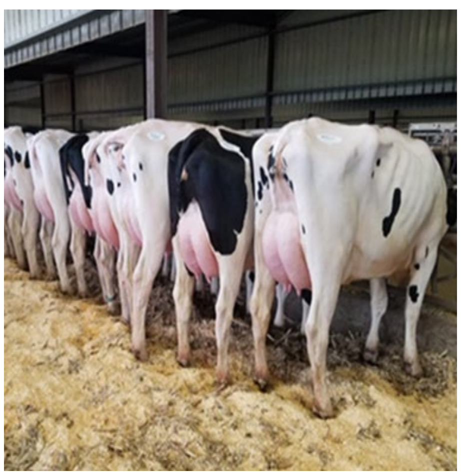
This work was funded by the Texas Animal Nutrition Council via the 2018 competitive grant funding

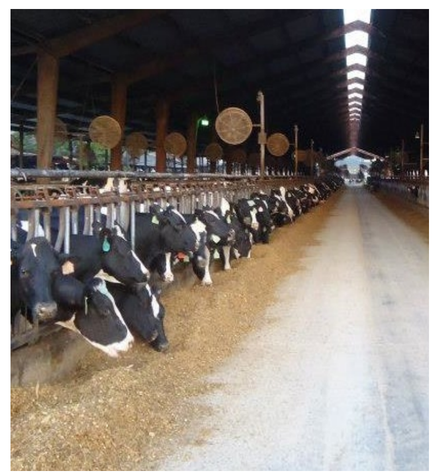
paulo.menta@ttu.edu

CALCIUM AND ENERGY BALANCE OF EARLY JERSEY COWS AND THE EFFECT OF AN ORAL CALCIUM SUPPLEMENTATION IN LACTATION PERFORMANCE

Paulo Menta

DVM, M.Sc, PhD student






Agenda

- Serum Ca dynamics in postpartum cows

- Key differences between breeds

- Association of blood calcium concentration in the first 3 days after parturition and energy balance metabolites at day 3 in milk with disease and production outcomes in multiparous Jersey cows

- A Randomized Clinical Trial Evaluating the Effect of an Oral Calcium Bolus Supplementation Strategy in Postpartum Jersey Cows on Mastitis, Culling, Milk Production, and Reproductive Performance

Background

3 weeks prepartum

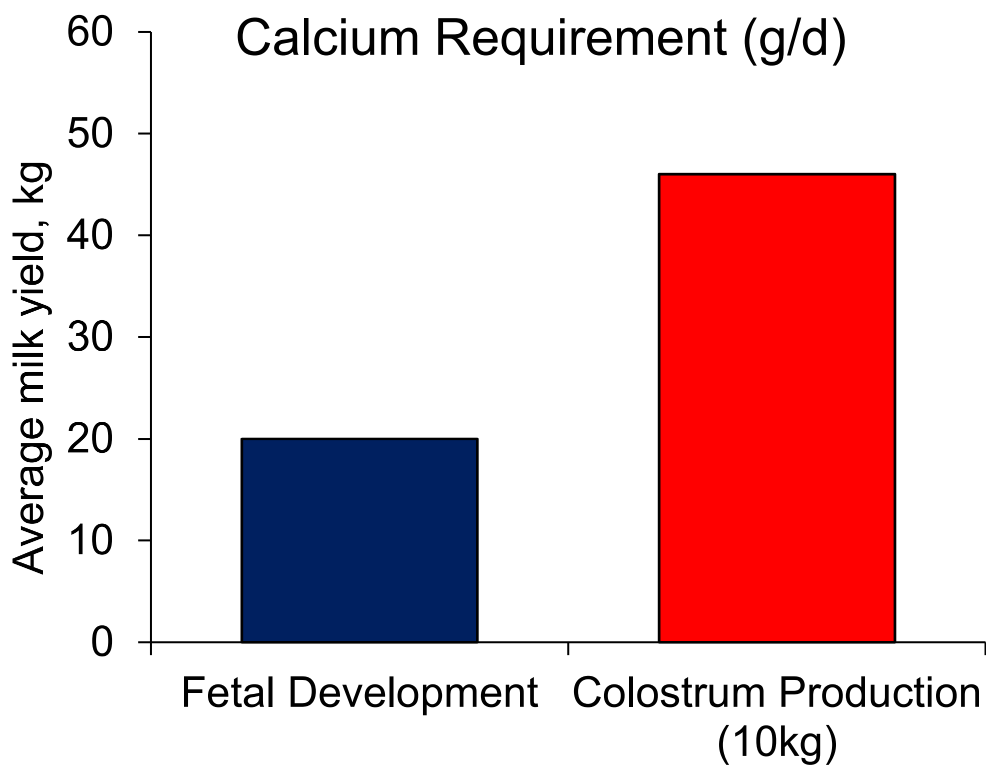
21 days in milk

Challenges:

- Change of physiological state
- Abrupt nutritional change
- Social stressors
- Inflammatory-infectious process in the reproductive tract
- 70% of the disease
- Energy demands increase by about 300%
- Calcium requirements are increased around 65%

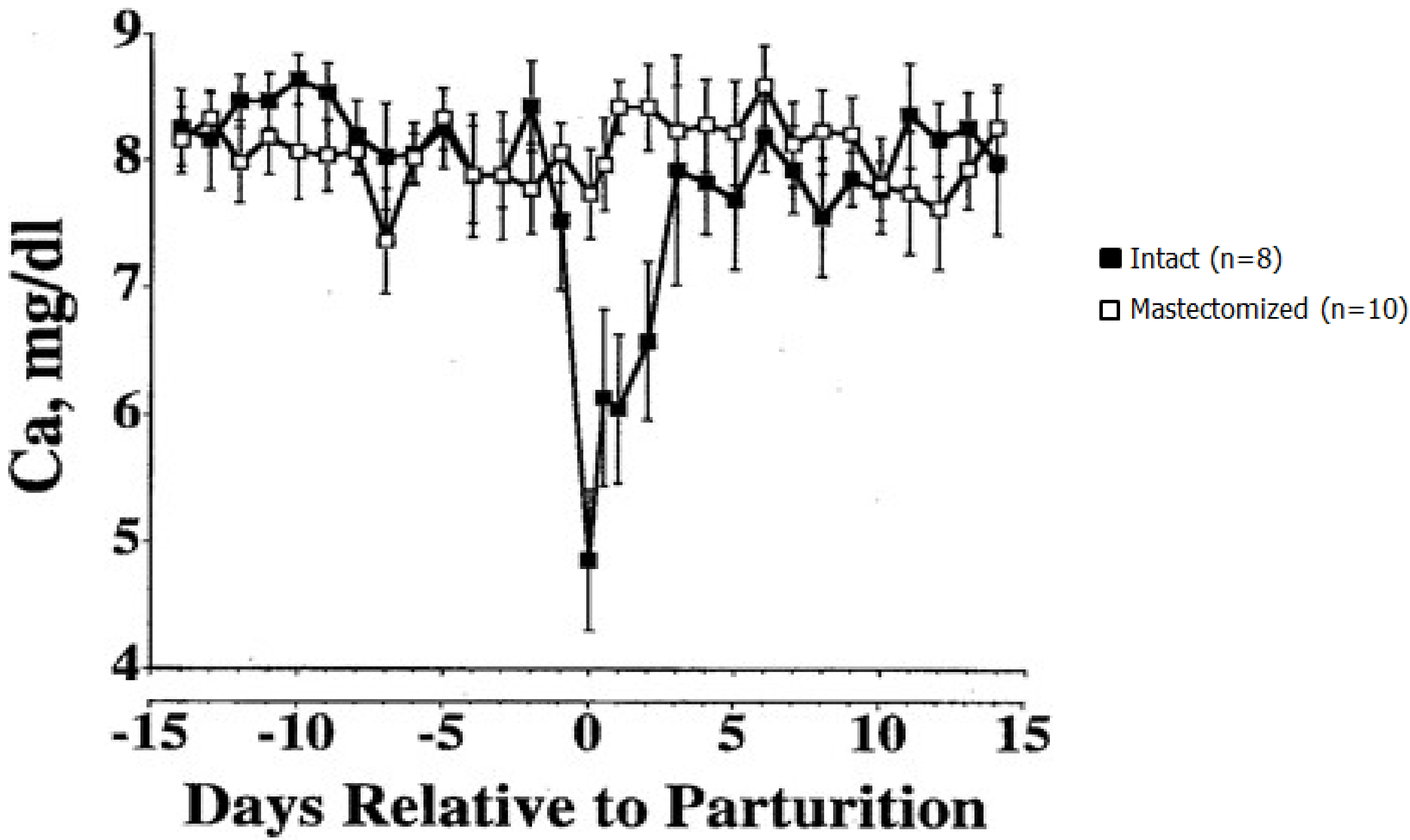
Bell, 1995; Darckely 1999

Background



- 2-4 g of Ca in the plasma pool
- Plasma pool must turnover 10+ times for colostrum production
- Adaptation requires coordination of several hormones and tissues

Background



Goff et al., 2002

Study #1

J. Dairy Sci. 104
https://doi.org/10.3168/jds.2020-19189

Association of blood calcium concentration in the first 3 days after parturition and energy balance metabolites at day 3 in milk with disease and production outcomes in multiparous Jersey cows

P. R. Menta,[1] L. Fernandes,[1] D. Poit,[1] M. L. Celestino,[1] V. S. Machado,[1] M. A. Ballou,[1] and R. C. Neves[2]*
[1]Department of Veterinary Sciences, College of Agricultural Sciences and Natural Resources, Texas Tech University, Lubbock 79409
[2]Department of Veterinary Clinical Sciences, College of Veterinary Medicine, Purdue University, West Lafayette, IN 47907

Why is it important?

J. Dairy Sci. 101:1–11
https://doi.org/10.3168/jds.2018-14587

Epidemiology of subclinical hypocalcemia in early-lactation Holstein dairy cows: The temporal associations of plasma calcium concentration in the first 4 days in milk with disease and milk production

R. C. Neves,* B. M. Leno,† K. D. Bach,‡ and J. A. A. McArt‡[1]
*Department of Veterinary Sciences, Texas Tech University, Lubbock 79409
†Department of Animal Science, and
‡Department of Population Medicine and Diagnostic Sciences, Cornell University, Ithaca, NY 14853

- Ca was associated with the risk of metritis at 2, 3, and 4 DIM
- Ca concentration was associated with the risk of metritis or displaced abomasum diagnosis (or both) for 2nd parity animals at 2 DIM), and at 4 DIM for 3rd and greater lactations
- ↓ Ca concentration was associated with ↑ milk production at 1 DIM in primiparous and multiparous cows
- ↓ milk production when assessed at 4 DIM in multiparous cows
- Assessments of SCH at the individual cow level must take into account the DIM of Ca concentration measurement and parity of the cow, as the epidemiology of the disorder was demonstrated to be highly dependent on these variables

Why is it important?

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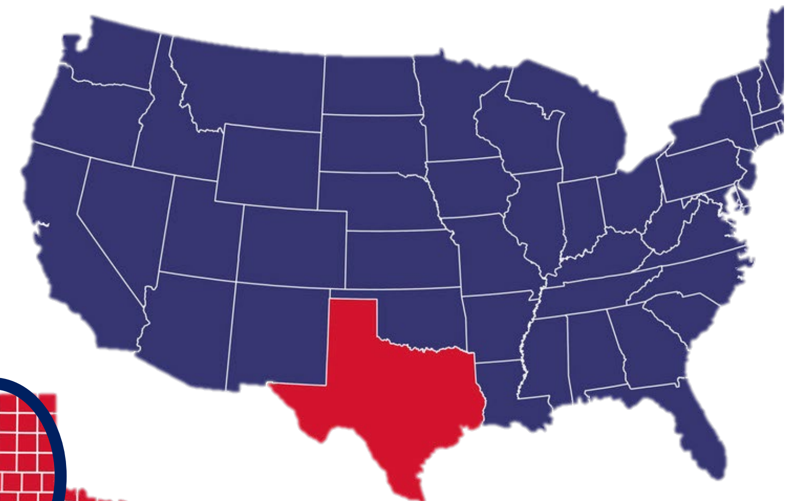
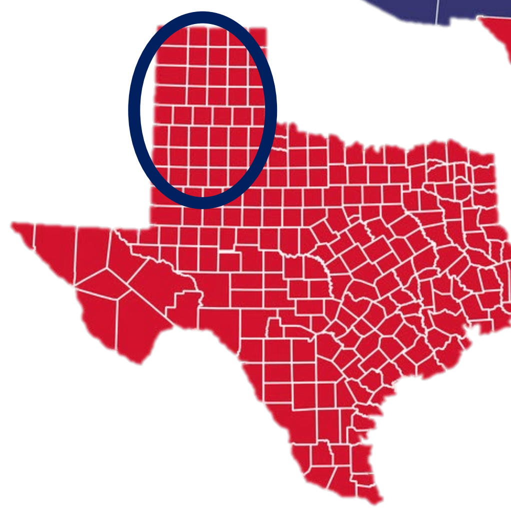
- Jersey vs. Holstein
  - Calcium demands (Cerbulis and Farrell, 1976)
    - greater milk total ash content
  - Calcium absorption
    - Vitamin D receptors (Goff et al., 1995)
  - Negative energy balance (Friggens et al., 2007; Olson et al., 2010)
    - ↑ energy demands
    - ↓ Glucose
    - ↑ Lipolysis
  - Energetic metabolism
    - FFA
    - BHB

Why is it important?

- Differences between breeds can influence the ability of extrapolating results and disorder classification performed in one breed to the other

- West TX is the 2nd largest region in concentration of Jersey cattle in the U.S
  - 64,251 cows (American Jersey Cattle Association, 2017)





Study #1

- **Objetive**
  - Evaluate the associations of plasma total Ca measured at 1 through 3 DIM and FFA, BHB, and glucose measured at 3 DIM with:

    - the risk of multiparous Jersey cows being diagnosed with early-lactation diseases and culling

    - milk production in the first 9 wk of lactation

    - the risk of pregnancy in the first 150 DIM

Cut points for SCH and appropriate DIM for SCH testing to better assess this metabolic disorder in Jerseys would benefit technicians in the field

Material and Methods

- Prospective Cohort Study
  - July – April/2018
  - West Texas
  - 380 purebred Jersey cows
  - Data was extracted from the farm's DC305

Material and Methods

Data collection regarding monthly milk yield, fertility and culling

Days pospartum

0 1 2 3 4 7 10 180

tCa tCa tCa
FFA
BHB
Glu

Metritis diagnosis

Purebred
No oral Ca
No twin
DCC < 260
2 Lact
≥ Lact

- **Calving** season (**warm**: cows calving from July 19 to September 22, 2018; **cool**: calving from September 23 to December 9, 2018)
- **Calving problem**: Cows that suffered from dystocia, stillbirth or both

Material and Methods: Statistics

- Data modeling were developed in SAS (version 9.4)
  - Multivariable Poisson regression models were built to evaluate the association of the analytes with the risks of early lactation disease and culling
  - Linear mixed models were used to evaluate the association of the analytes with milk production
  - Cox Proportional hazards modeling were built to assess the risk of pregnancy
  - ROC curves were performed using MedCalc (version 9.5.2.0)
    - Metabolites were dichotomized if the AUC was significantly different than 0.5
    - Dichotomizations were based on thresholds that maximized the Sn and Sp for classification purposes

Descriptive Statistics

Disorder	n (%)
Stillbirth	14 (3.7)
Dystocia	11 (2.9)
Retained placenta	3 (0.8)
Left displaced abomasum	1 (0.3)
Metritis	100 (26.3)
Mastitis	46 (12.1)
Culling (sold/died)	36 (9.5)

Descriptive Statistics

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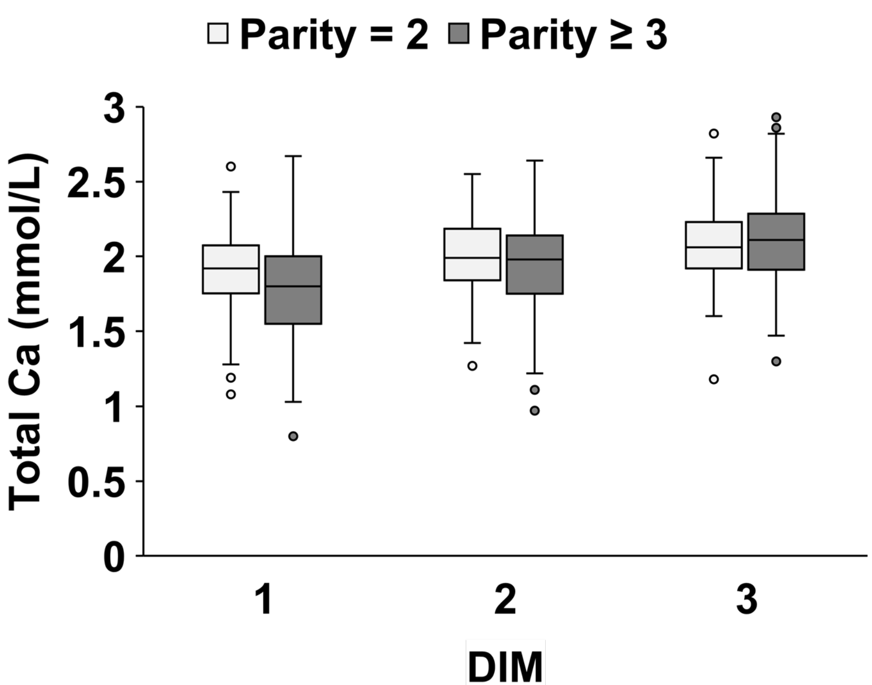
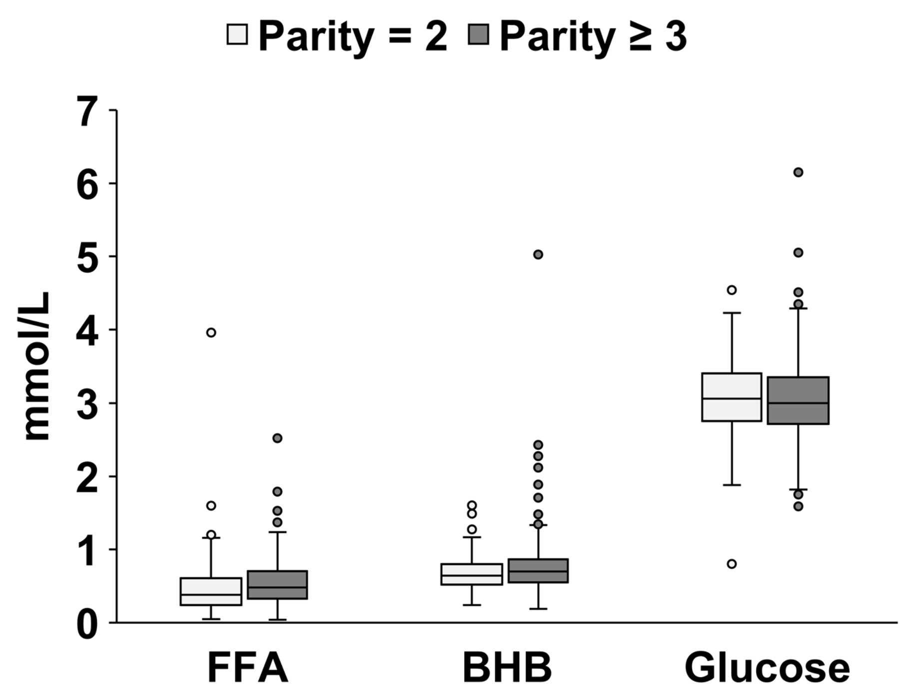
	DIM		
Plasma total Ca concentration	1	2	3
1 DIM in 2nd parity cows (n = 147)			
r	1.00	0.65	0.08
P-value	-	<0.01	0.32
1 DIM in ≥3 parity cows (n = 233)			
r	1.00	0.52	0.06
P-value	-	<0.01	0.39

Descriptive Statistics





Risk of metritis

Variable	Relative risk	95% CI	P-value
Parity			
2	–	–	–
≥3	–	–	0.26
Calving season			
Cool	–	–	–
Warm	0.58	0.39 - 0.86	<0.01
Calving-related problem(s)	2.32	1.26 - 4.25	<0.01
Retained placenta	7.29	2.39 - 22.24	<0.01
FFA ≥0.43 mmol/L at 3 DIM	1.78	1.20 - 2.66	<0.01

Risk of metritis

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Variable	Relative risk	95% CI	P-value
Intercept	–	–	<0.01
Parity			
2	–	–	–
≥3	–	–	0.26
Calving season			
Cool	–	–	–
Warm	0.58	0.39 - 0.86	<0.01
Calving-related problem(s)	2.32	1.26 - 4.25	<0.01
Retained placenta	7.29	2.39 - 22.24	<0.01
FFA ≥0.43 mmol/L at 3 DIM	1.78	1.20 - 2.66	<0.01

- ↓ blood Ca concentrations impair innate immunity (Kimura et al., 2006; Martinez et al., 2014)
- Parity dependency and temporality of Ca association (Neves et al., 2017)
- No correlation of Ca at 1 and 3 DIM was evidenced for our dataset
- Holstein vs. Jersey
- Consequence other than a risk factor for the disease
- ↑ FFA can adversely affect oxidative burst and the phagocytic capacity of PMNL (Scalia et al., 2006)

Risk of culling

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Variable	Relative risk	95% CI	P-value
Parity			
2	–	–	–
3	4.36	2.02 - 9.43	<0.01
Body condition score			
1	–	–	–
2	0.41	0.23 - 0.74	<0.01
3	0.30	0.12 - 0.72	<0.01
Glucose at 3 DIM	1.75	1.16 - 2.64	<0.01
BHB at 3 DIM	1.63	1.0 - 2.64	0.08
FFA at 3 DIM	2.18	1.03 - 4.60	0.05
Total Ca at 3 DIM ≤1.99 mmol/L	2.93	1.74 - 4.94	<0.01

Risk of culling

- **Literature is inconsistent**
  - **↓ [Ca] associated with culling in the first 2 weeks postpartum (Seifi et al., 2011; Roberts et al., 2012).**
  - **[Ca] concentration <2.00 mmol/L had increased risk of being culled in the first 60 DIM (Venjakob et al. 2018)**
  - **↓ [Ca] within 12 h after parturition tendendof increased tCa concentration and the risk of culling within 60 DIM (Neves et al., 2018)**

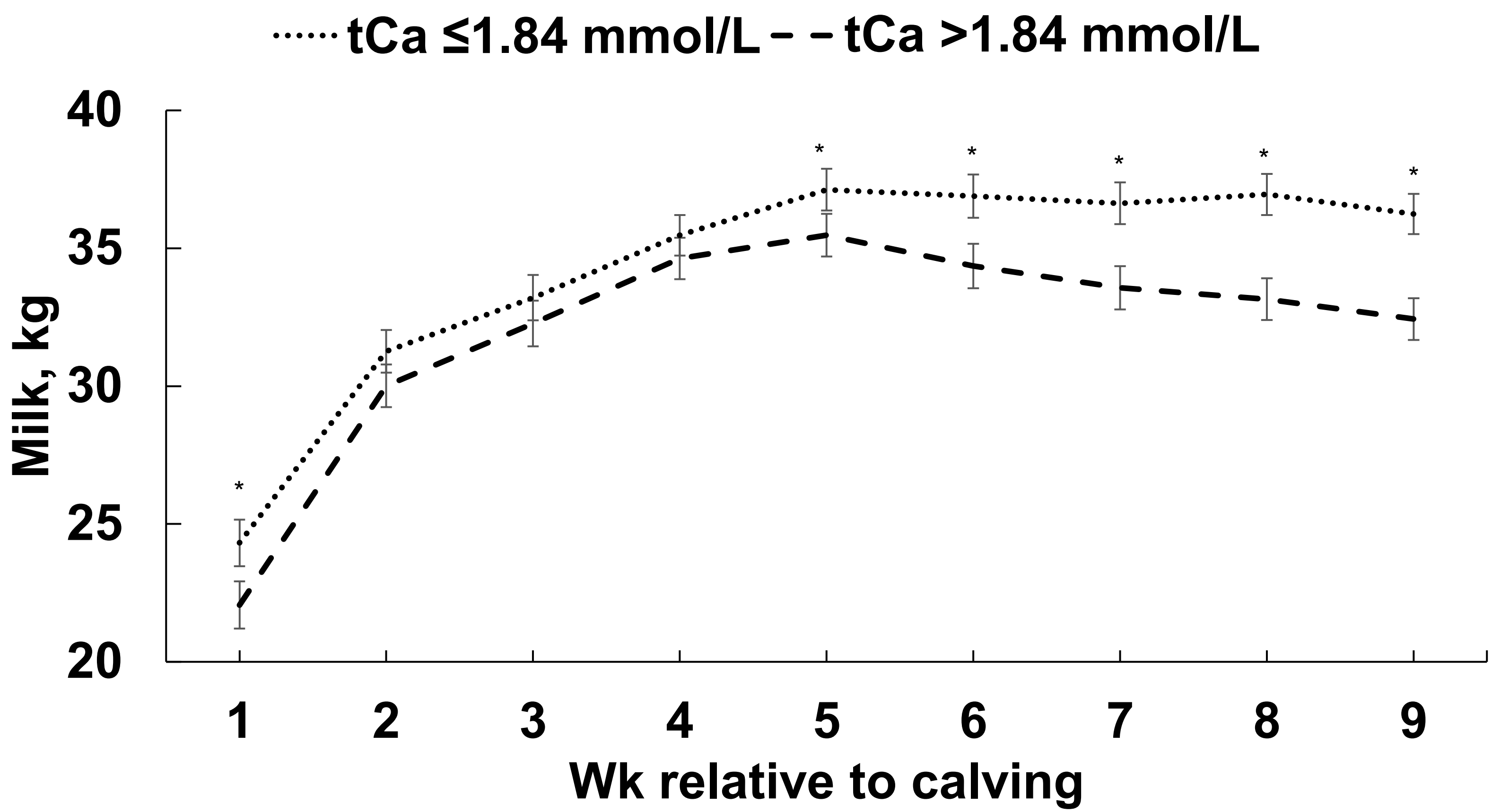
  - **Lipolysis before parturition is a known risk factor for metritis (Chapinal et al., 2011; Giuliodori et al., 2013)**
    - **↑ metritic cows are more likely to be culled (Wittrock et al., 2011)**
    - **↑ FFA associated with metritis and culling**

Variable	Relative risk	95% CI	P-value
Parity			
2	[illegible]	[illegible]	[illegible]
3	4.36	2.02 - 9.43	<0.01
Body condition score			
1	[illegible]	[illegible]	[illegible]
2	0.41	0.23 - 0.74	<0.01
3	0.30	0.12 - 0.72	<0.01
Glucose at 3 DIM	1.75	1.16 - 2.64	<0.01
BHB at 3 DIM	1.63	1.0 - 2.64	0.08
FFA at 3 DIM	2.18	1.03 - 4.60	0.05
Total Ca at 3 DIM ≤1.99 mmol/L	2.93	1.74 - 4.94	<0.01

Milk Yield

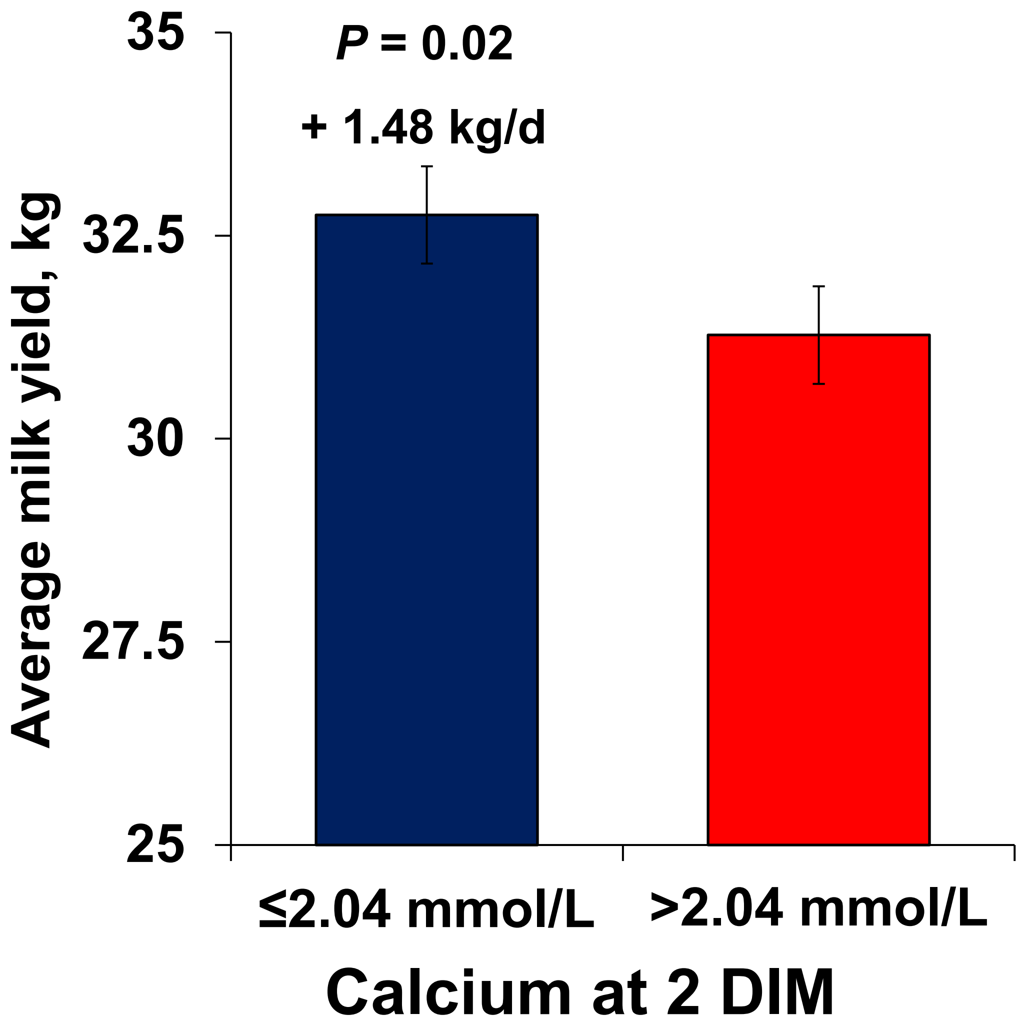
	1 DIM			2 DIM		
Variable	Estimate	SE	P-value	Estimate	SE	P-value
Parity						
2	Ref	-	-	Ref	-	-
3	-0.10	0.64	0.88	0.19	0.64	0.76
BCS Score						
1	Ref	-	-	Ref	-	-
2	2.79	0.89	<0.01	2.81	0.91	<0.01
3	4.49	1.15	<0.01	4.32	1.17	<0.01
Calving season						
Cool	Ref	-	-	Ref	-	-
Warm	1.22	0.63	0.05	1.23	0.66	0.06
Gestation length (d)	0.19	0.06	<0.01	0.20	0.06	<0.01
Metritis	-0.45	0.69	0.51	-0.52	0.70	0.46
Mastitis	-3.24	0.92	<0.01	-3.18	0.93	<0.01
Dichotomized total Ca variable	-	-	<0.01	1.48	0.66	0.02
Weekly test*Dichotomized total Ca variable	-	-	0.02	-	-	0.35

Milk Yield



tCa ≤1.84 mmol/L
tCa >1.84 mmol/L
40
35
30
25
20
Milk, kg
*
*
*
*
*
*
1
2
3
4
5
6
7
8
9
Wk relative to calving

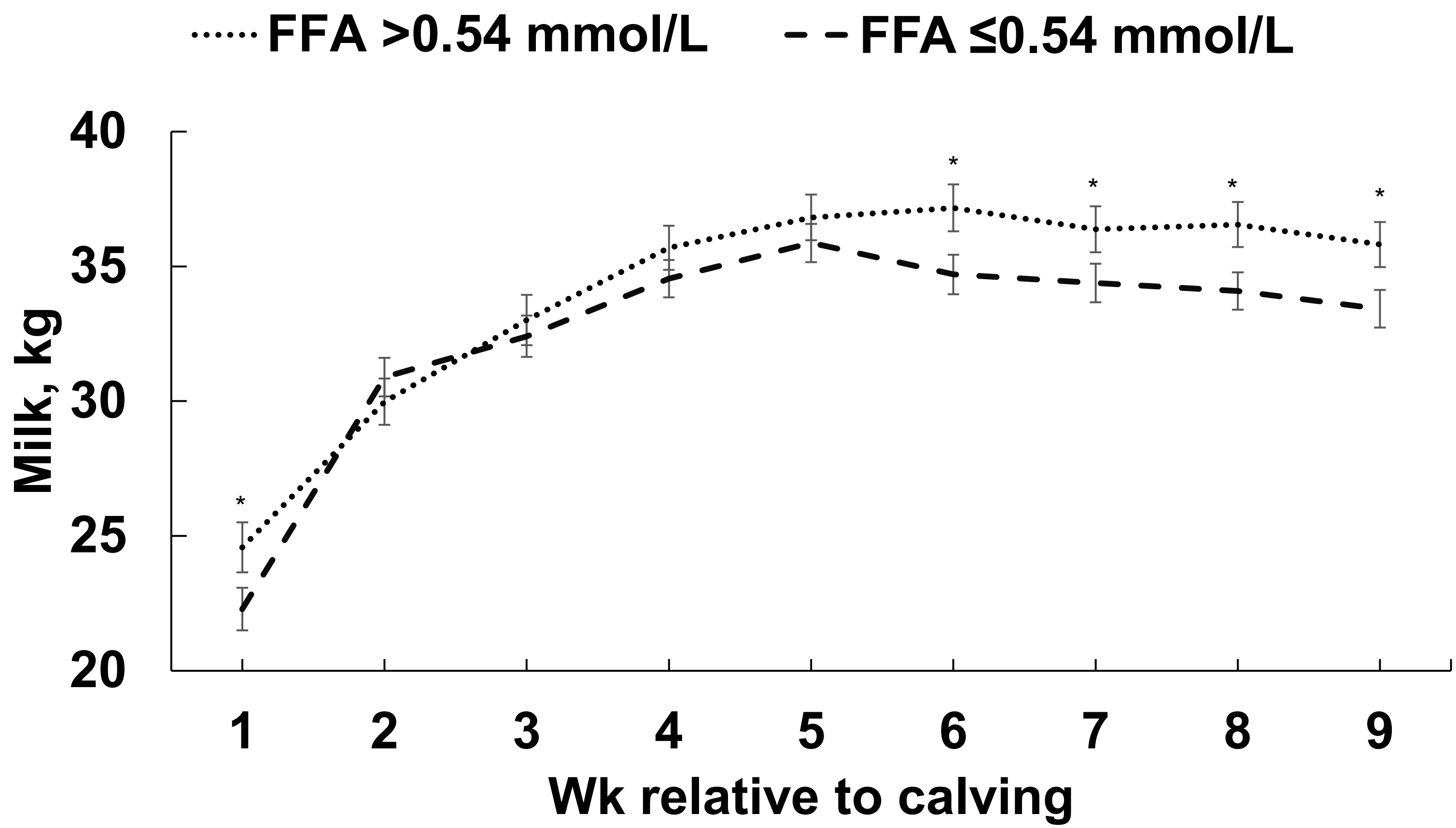
Milk Yield


P = 0.02
+ 1.48 kg/d
35
32.5
30
27.5
25
Average milk yield, kg
≤2.04 mmol/L
>2.04 mmol/L
Calcium at 2 DIM

Milk Yield

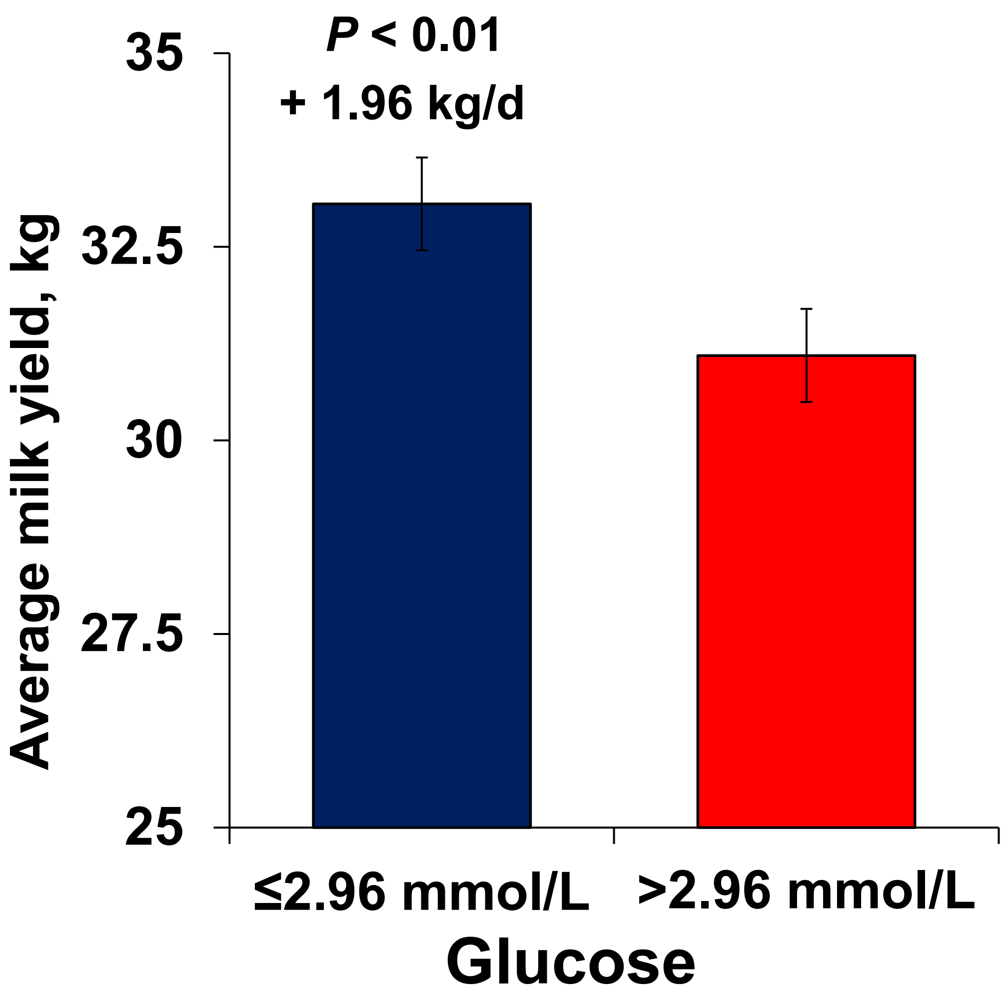
Variable	Estimate	SE	P-value
Parity			
2	Ref		
≥3	-0.24	0.63	0.70
BCS Score			
1	Ref		
2	2.38	0.90	<0.01
3	3.44	1.17	<0.01
Season			
Cool	Ref		
Warm	1.30	0.62	0.04
Gestation length (d)	0.19	0.06	<0.01
Metritis	-0.41	0.69	0.55
Mastitis	-3.12	0.92	<0.01
FFA ≥0.37 mmol/L			<0.01
Weekly milk test*FFA ≥0.37 mmol/L			0.01
Glucose ≤2.96 mmol/L	1.96	0.61	<0.01

Milk Yield



FFA >0.54 mmol/L
FFA ≤0.54 mmol/L
40
35
30
25
20
Milk, kg
*
*
*
*
*
1
2
3
4
5
6
7
8
9
Wk relative to calving

Milk Yield



P < 0.01
+ 1.96 kg/d
35
32.5
30
27.5
25
Average milk yield, kg
≤2.96 mmol/L
>2.96 mmol/L
Glucose

Milk Yield

Association of immediate postpartum plasma calcium concentration with early-lactation clinical diseases, culling, reproduction, and milk production in Holstein cows

R. C. Neves,* B. M. Leno,† M. D. Curler,‡ M. J. Thomas,‡ T. R. Overton,† and J. A. A. McArt*[1]
*Department of Population Medicine and Diagnostic Sciences, College of Veterinary Medicine, and
†Department of Animal Science, Cornell University, Ithaca, NY 14853
‡Dairy Health and Management Services LLC, Lowville, NY 13367

Association of postpartum hypocalcemia with early-lactation milk yield, reproductive performance, and culling in dairy cows

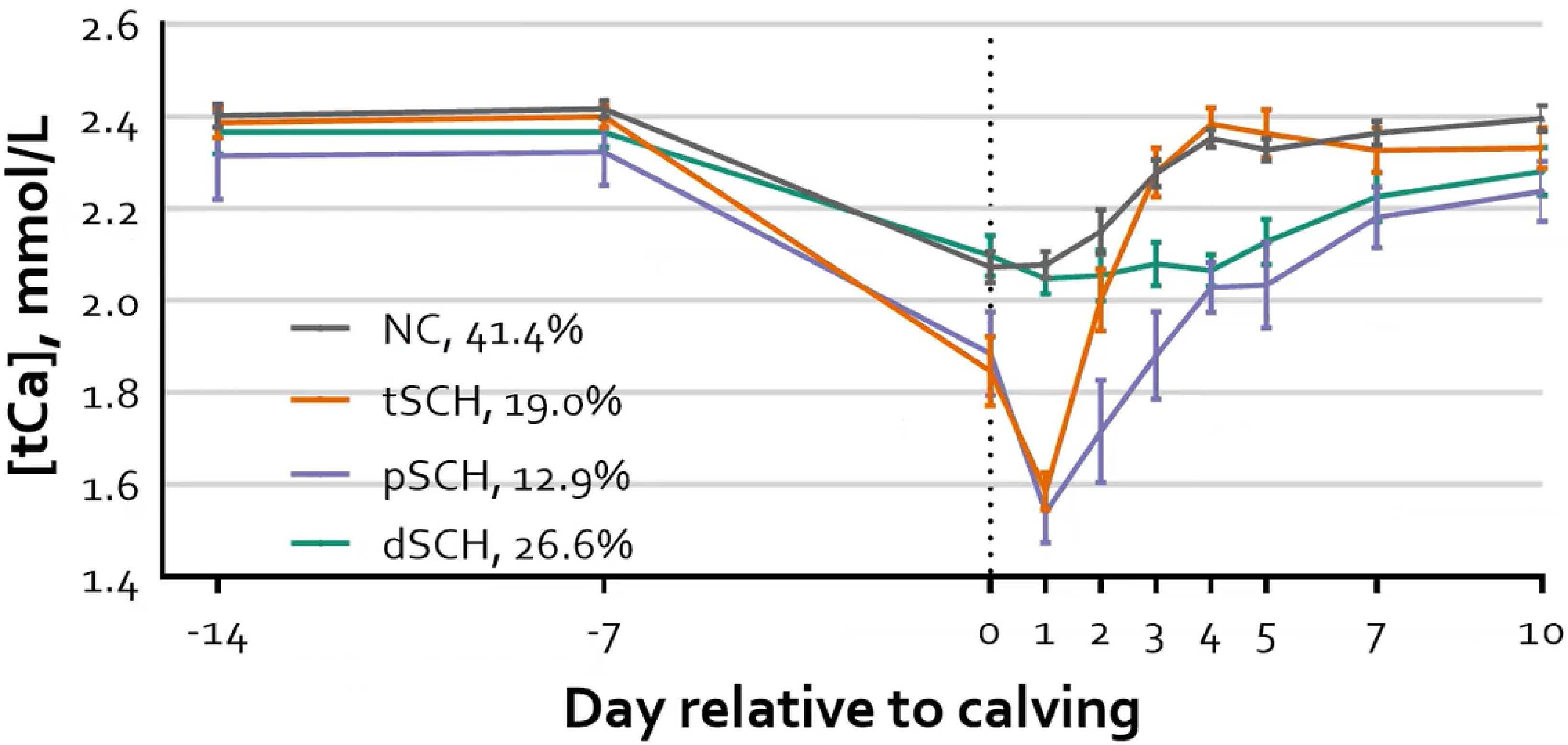
P. L. Venjakob,*† L. Pieper,‡ W. Heuwieser,*[1] and S. Borchardt*
*Clinic for Animal Reproduction, Faculty of Veterinary Medicine, Freie Universität Berlin, 14163 Berlin, Germany
†Veterinary practice G. Thiele, 15837 Baruth/Mark, Germany
‡Institute for Veterinary Epidemiology and Biostatistics, Faculty of Veterinary Medicine, Freie Universität Berlin, 14163 Berlin, Germany

J. Dairy Sci. 104:11983–11994
https://doi.org/10.3168/jds.2020-19527

Association of low serum calcium concentration after calving with productive and reproductive performance in multiparous Jersey cows

Ainhoa Valldecabres[1,2] and Noelia Silva-del-Río[1,2]*
[1]Veterinary Medicine Teaching and Research Center, Tulare, CA 93274
[2]Department of Population Health and Reproduction, School of Veterinary Medicine, University of California, Davis 95616

Discussion



McArt and Neves., 2020

Conclusions

- Multiparous Jersey cows with lower [Ca] in the first 2 DIM and reduced glucose at 3 DIM were more likely to have increased milk production across the first 9 wk of lactation

- Cows with increased concentration of FFA at 3 DIM had an overall higher milk production; however, they were also more likely to develop metritis within 10 DIM

- Reproduction was not affected by time to cure in this dataset

- More studies evaluating the association of Ca and energy balance markers during the transition period with lactation performance while including a greater number of herds are needed to best characterize subclinical hypocalcemia and hyperketonemia in Jersey cows

Study #2

animals

MDPI

Article

A Randomized Clinical Trial Evaluating the Effect of an Oral Calcium Bolus Supplementation Strategy in Postpartum Jersey Cows on Mastitis, Culling, Milk Production, and Reproductive Performance

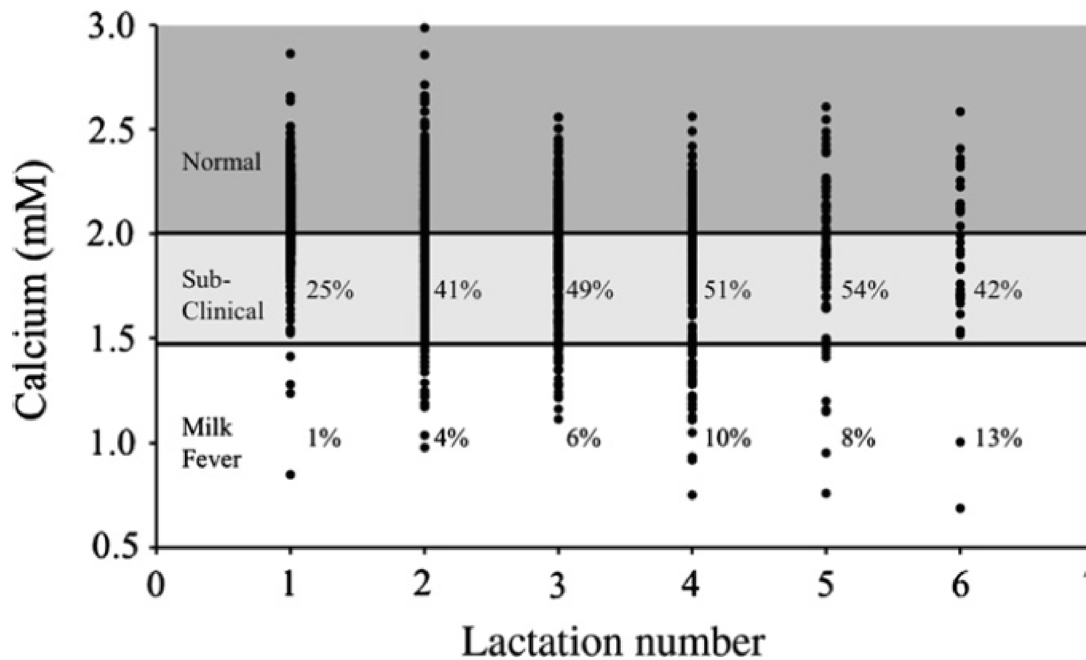
Paulo R. Menta [1], Leticia Fernandes [1], Diego Poit [1], Maria Luiza Celestino [1], Vinicius S. Machado [1] and Rafael C. Neves [2,*]

Introduction

- Cows develop clinical and subclinical hypocalcemia
  - Sequestration of Ca into mammary gland

- Jersey cows are more susceptible
  - Greater [Ca] in colostrum
  - Fewer vitamin D_3 receptor expression in the intestine

- Older cows are more susceptible
  - Greater colostrum production
  - Smaller number of vitamin D_3 binding sites in the intestine



Reinhardt et al. (2011).

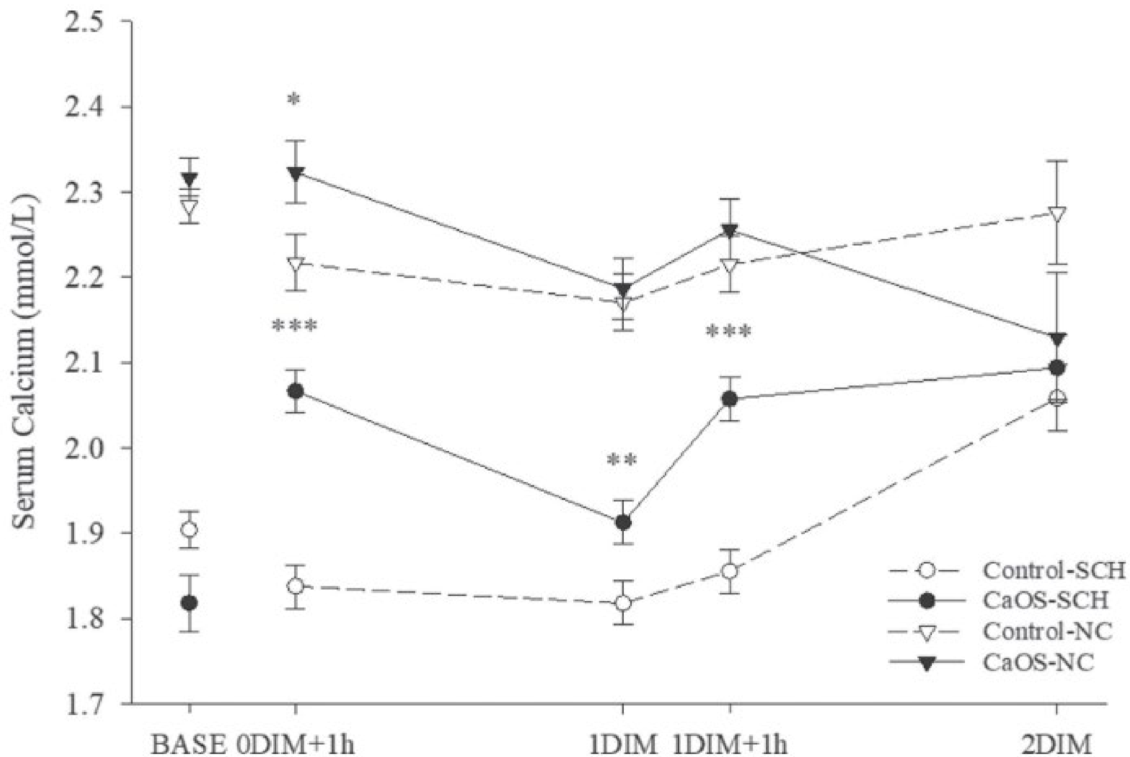
Introduction

- Acidogenic diets have not been demonstrated to be as effective for SCH prevention as for CH (Reinhardt et al., 2011)

- Strategies to mitigate the potential effects of SCH via postpartum oral Ca supplementation are still widely adopted

- In the U.S. for instance, 80% of the large farms used some combination of injectable, drench, or oral Ca as a preventative strategy to postpartum diseases (USDA, 2014)

Introduction



- Benefits are incosistent
- High milk producers
- Lame cows
- Parity
- Data limited for Jersey cows

Oetzel and Miller, (2012); Valldecabres et al., (2018); Valldecabres and Silva-del-Rio, (2020)

Introduction

VS

Objective

- **Objective**
  - Determine the effect of an oral Ca supplementation strategy applied to multiparous Jersey cows on:
    - health outcomes
    - reproductive performance
    - milk production

- **Hypothesis**
  - Postpartum oral Ca supplementation would:
    - decrease the odds of clinical diseases
    - improve milk production
    - reproductive performance

Material and Methods

- Randomized clinical trial – CTRL and TRT
  - July/2018 – April/2019
  - West Texas
  - 852 purebred Jersey cows
  - Data was extracted from the farm's DC305
    - Milk yield
    - DIM at pregnancy
    - Culling
    - Mastitis incidence
  - **TRT:** two doses of a commercial oral Ca bolus (Bovikalc®, Boehringer Ingelheim Vetmedica, Inc., St. Joseph, MO, USA)
    - calcium chloride and calcium sulfate (43 g of Ca per bolus);
  - **CTRL**: No oral Ca supplementation

Material and Methods

Data collection regarding health events monthly milk yield, fertility and culling

Days pospartum

0 1 2 3 4 7 10 180

TRT

Metritis diagnosis

1st bolus: within 1h after calving

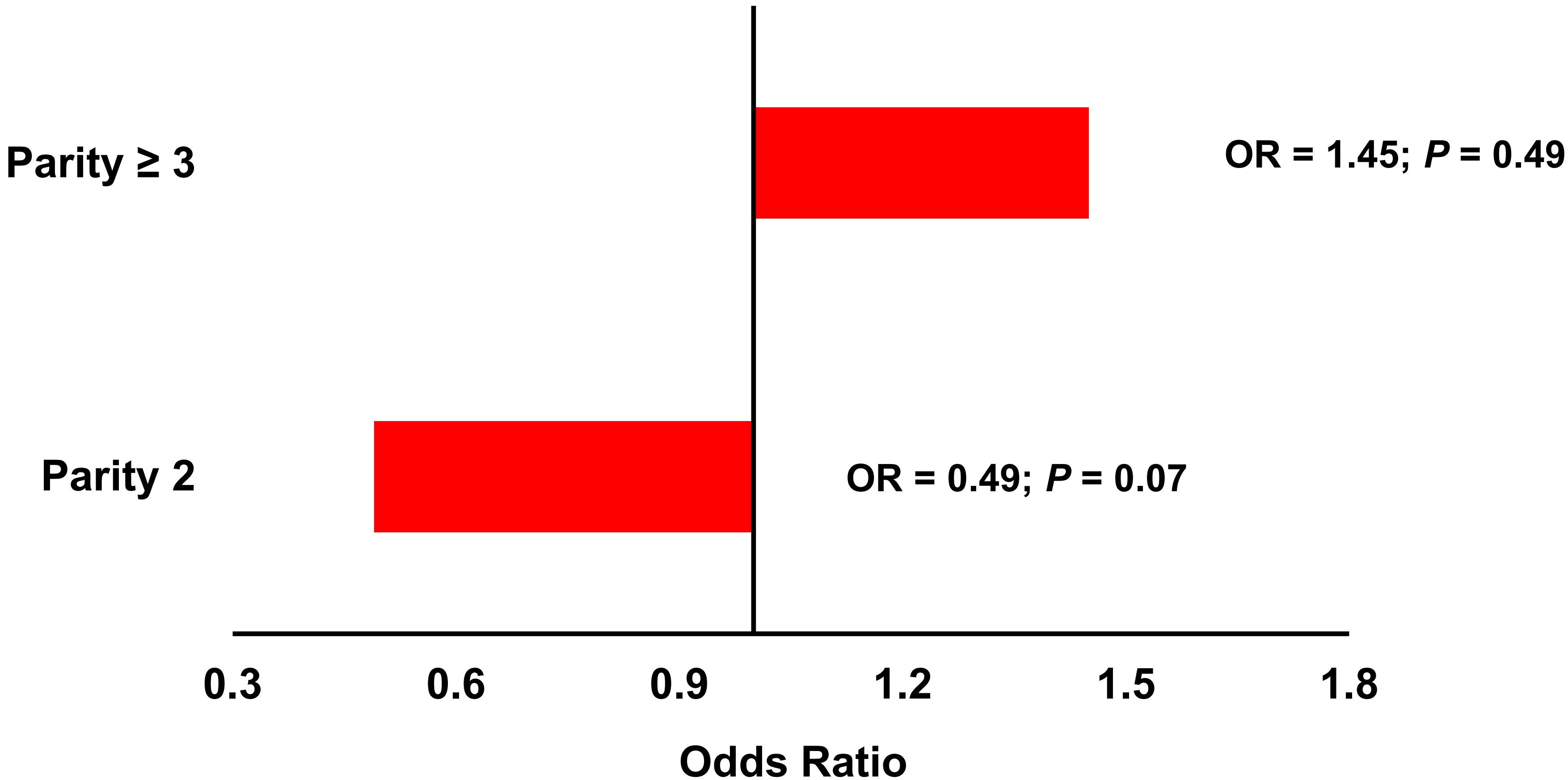
2nd boluses: occurred around 21 h after calving

Purebred
No oral Ca
No twin
DCC < 260
2 Lact
≥ Lact

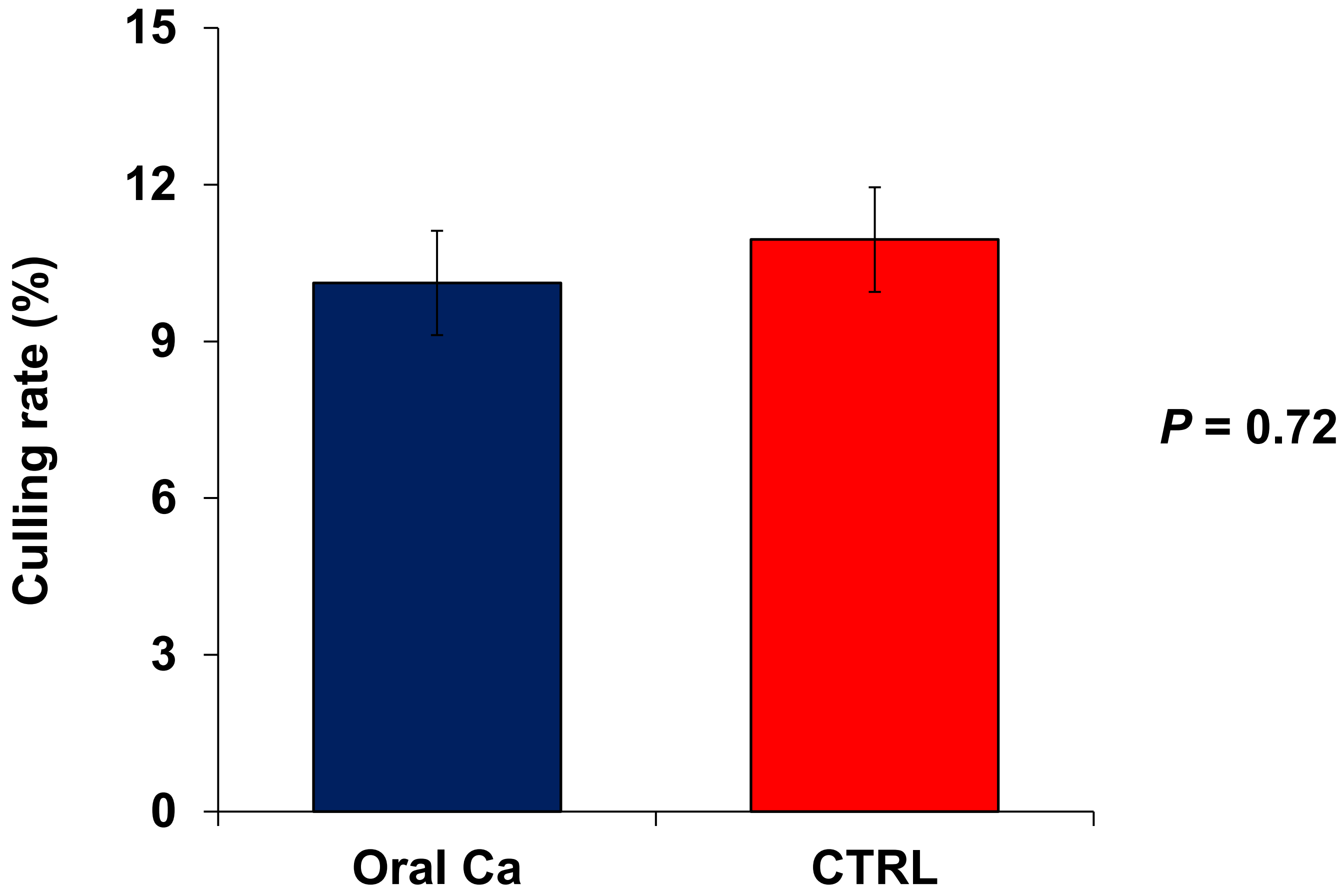
Mastitis within 60 DIM

Variable	Estimate	SE	P-value
Postpartum Ca supplementation			
Control	Ref	–	–
Treatment	-0.72	0.39	0.06
Parity			
2	Ref	–	–
≥3	-0.15	0.30	0.62
Calving problem			
No	Ref	–	–
Yes	-1.36	0.73	0.06
Parity × Treatment	1.08	0.47	0.02

Mastitis within 60 DIM



Culling within 60 DIM



Reproductive Performance

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Variable	Estimate	SE	P-value	HR
Postpartum Ca supplementation				
Control	Ref	–	–	
Treatment	0.04	0.10	0.67	1.04
Parity				
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≥3	-0.01	0.10	0.91	0.99
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No	Ref	–	–	
Yes	-0.37	0.26	0.16	0.69

Milk yield

Variable	Estimate	SE	P-value
Postpartum Ca supplementation			
Control	Ref	–	–
Treatment	0.24	0.69	0.73
Parity			
2	Ref	–	–
≥3	0.50	0.41	0.22
Test number	–	–	<0.01
Calving season			
Warm	Ref	–	–
Cool	-0.97	0.40	0.02
Gestation length (d)	0.15	0.04	<0.01
Body condition score			
Thin	Ref	–	–
Normal	0.76	0.72	0.29
Over-conditioned	1.64	0.99	0.10

Conclusions

- Prophylactic postpartum Ca supplementation to multiparous Jersey cows had no effects on:
  - culling
  - milk yield
  - Reproduction

- Second parity cows that were supplemented with oral Ca boluses tended to have reduced odds of mastitis compared to non-supplemented cows

- Our data do not support blanket oral Ca supplementation in Jersey cows as the effects were minimal to none; however, targeted oral Ca supplementation for subpopulations of cows and at different times relative to parturition remain to be investigated

Acknowledgment

This work was funded by the Texas Animal Nutrition Council via the 2018 competitive grant funding

paulo.menta@ttu.edu

Feeding and Management of Beef on Dairy Calves for Optimal Performance

Current concepts in calf and heifer feeding and the NASEM requirements

James K. Drackley

University of Illinois Urbana-Champaign

drackley@illinois.edu

While data are beginning to accumulate about the growth and nutritional needs of beef-on-dairy calves, at present we know very little specific information about their nutritional requirements. We can use the NASEM 2021 calf chapter to provide background on which to assess predicted performance and factors affecting growth.

Beef feeders report differences of growth between beef-on-dairy calves and either straight-bred beef calves or Holstein calves, and a greater occurrence of liver abscesses. We do not know whether these are effects of genetics or the generally different management between beef calves and dairy calves. Male dairy calves are often colostrum deprived and are often transported in the first few days of life, in contrast to beef calves. Dairy calves are fed limited amounts of milk or milk replacer, whereas beef calves feed to appetite. Dairy calves are weaned at 4 to 8 wk, whereas even “early weaned” beef calves receive milk for at least 80 days. Dairy calves are weaned on to a high-energy starter feed, while beef calves generally consume grass and have a longer time for rumen development before weaning.

The NASEM 2021 calf chapter is an extensive revision over the NRC 2001. Requirements are based on empty body weight calculations, which removes the influence of varying amounts of gut fill. New equations were developed to predict starter intake, both in temperate conditions and in hot climates. The energy requirements have been extensively revised, using data from Holstein and Jersey calves that were slaughtered to determine body composition and the composition of empty body gain. Feed energy values are calculated differently. A new metabolizable protein system was adopted. Mineral requirements (or adequate intakes) are calculated using a factorial approach where possible. Requirements for vitamins D and E have been increased. The text discussion of various nutritional and management topics is vastly expanded.

Although data from beef-on-dairy calves are not available currently, there is every reason to expect that the new NASEM 2021 model will do a reasonable job of predicting growth and body composition of such calves up to 220 – 250 lb body weight. As published data accumulate, there will be an opportunity to more rigorously evaluate the NASEM model for beef-on-dairy calves.

Calf Nutrition Program for Long-Term Health

Michael A. Ballou, Ph.D.
Professor and Chair
Department of Veterinary Sciences
Texas Tech University, Lubbock, TX, USA
Michael.Ballou@ttu.edu
(806) 543-5653

Topics to be covered

- Why do pre-weaned calves get sick?
  - Development of gastrointestinal immunity
- Why do post-weaned calves get sick?
  - Development of active immunity
- Nutrition and immunity of calves
  - Reduce interaction of potential pathogens with calf
  - Stimulate gastrointestinal immunity
  - Stimulate adaptive immune development

Why do so many calves get sick?

- Risk of mortality greatly decreases after the first few weeks of life
- What changed in the calf during this period?

Gastrointestinal Maturation

- Some components of the GI immune system develop after birth
- Catch-22 Situation
  - Passive absorption of macromolecules but increases risk for translocation of microorganisms
- Ideal situation
  - Absorb adequate antibodies
  - No absorption of microorganisms
  - Rapid maturation of the GI tract

Gastrointestinal Maturation

- Many components to the GI immune system
  - Physical barrier
  - Chemical barrier
  - Immunological barrier
  - Microbial barrier

Strategies to improve immunity

- What role can nutrition play in reducing enteric disease?

Strategies to improve immunity

- Putative nutrition supplements added to milk replacer and/or calf starter
  - Post-day 1 colostrum
  - Bovine serum/plasma proteins
  - Yeast cell walls
    - *Whole cell wall extract*
    - *MOS and β-glucan fractions*
  - Live yeast
  - Yeast cultures
  - Direct fed microbials
  - Butyric acid
  - Hyper immunized egg proteins
  - Adsorbents

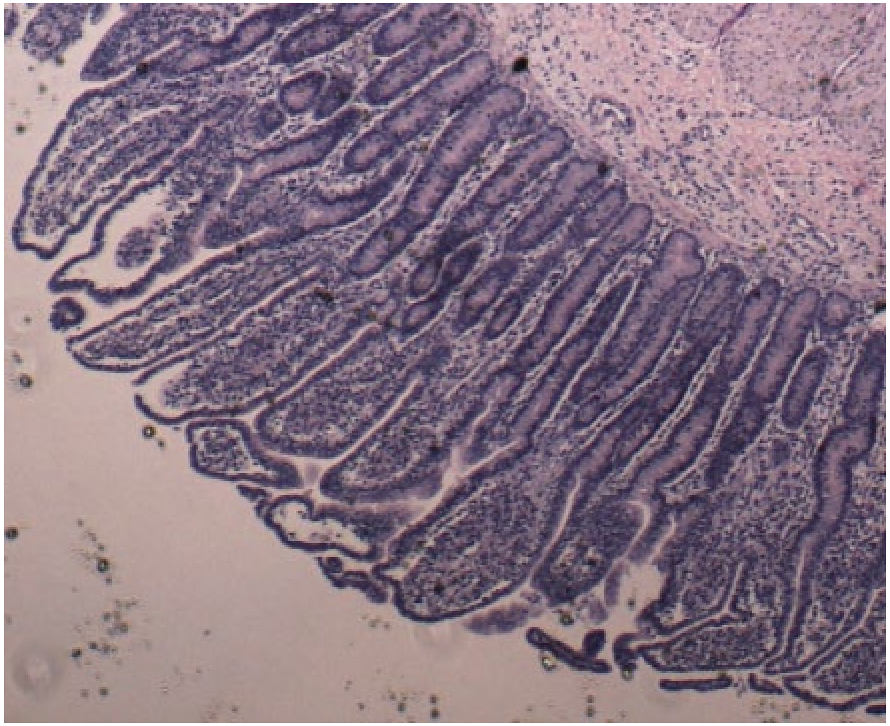
Strategies to improve immunity

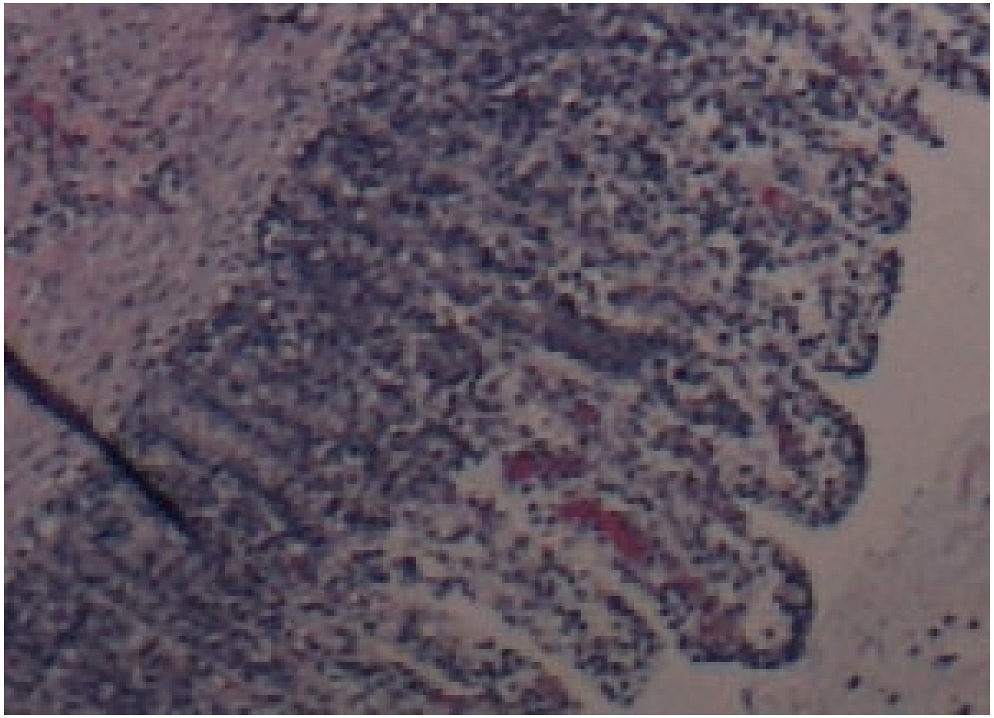
General Mechanisms of Action

- Competitive inhibition
- Binding/Adsorption
- Antimicrobial factors
  - Low pH, Bacteriocins, Organic Acids
- Stimulate other mucosal immune defenses
  - Epithelial growth, mucin production, host defense peptides, secretory IgA, T regs
- Alter systemic immune defenses

Colostrum

- Colostrum – Non-Immunoglobulin





Post-Day 1 Colostrum

supplementation (control group; n = 100), received 454 g of a commercial milk replacer (28% CP, 20% crude fat; Land O'Lakes Milk Replacer, Shoreview, MN), mixed according to label directions to a final volume of 3 L, twice daily until weaning (d 56). Calves fed milk replacer supplemented with colostrum replacer powder (treatment group; n = 102), received 150 g of dried bovine colostrum powder containing 32 g of IgG (>40% CP, >20% crude fat; Calf's Choice Total Hi-Cal, The Saskatoon Colostrum Co. Ltd., Saskatchewan, Canada) added to 304 g of Land O'Lakes Milk Replacer powder and then mixed according to label directions to a final volume of 3 L, twice daily for the first 14 d of life. Fol-

- 64 g of IgG per day
- Low Mortality - 2/202 calves died
- $0.20 - $0.30 / g IgG

Chamorro et al., 2017

Post-Day 1 Colostrum

Post Day 1 Colostrum

Table 1. Descriptive statistics of serum IgG, BW, and ADG by group (CS vs. MR)[1]

Variable, unit	Treatment	n	Mean	Median	SD[2]	Minimum	Maximum
Mean BW (d 0), kg	CS	102	40.6	40.4	4.8	27.7	51.3
	MR	100	39.2	39.7	4.8	20.4	50.3
Mean BW (d 14), kg	CS	101	45.1	44.9	3.8	34.9	54.4
	MR	98	44.4	44.9	4.4	31.1	52.6
Mean BW (d 56), kg	CS	101	80.3	79.4	8.4	50.8	101.2
	MR	97	79.6	80.3	9.1	51.7	99.8
IgG (d 0), g/L	CS	102	25.2	24.8	9.4	8.6	52.7
	MR	100	24.5	25.3	9.3	10.1	50.2
ADG	CS	100	0.7	0.7	0.1	0.1	1.1
(Birth to weaning), kg	MR	98	0.7	0.7	0.4	0.2	1.2

[1]CS = dried bovine colostrum powder + milk replacer; MR = milk replacer.

Table 2. Descriptive statistics of antibiotic treatment by group (CS vs. MR)[1]

Item		CS	MR	Total
Antibiotic treatment (ATB) by treatment group	ATB Yes	19	70	89
	ATB No	83	30	113
	Total	102	100	202
Number of antibiotic treatments (ATB n) by treatment group	ATB n	n (%)	n (%)	Total
	0	83 (81.4)	32 (32.0)	115
	1	13 (12.8)	38 (38.0)	51
	2	4 (3.9)	13 (13.0)	17
	3	2 (1.9)	12 (12.0)	14
	4	0 (0.0)	3 (3.0)	3
	5	0 (0.0)	2 (2.0)	2
	Total	102 (100)	100 (100)	202

[1]CS = dried bovine colostrum powder + milk replacer; MR = milk replacer.

Chamorro et al., 2017

Post-Day 1 Colostrum

gain of preweaned calves. Ninety 1-d-old calves on each of 3 commercial calf ranches were randomly allocated to 1 of 3 groups. Treatment-group calves received 10 g of supplemental immunoglobulin G (IgG) in the form of 70 g of colostrum powder in the milk replacer twice daily for 14 d. The placebo-group calves received a nutritionally equivalent supplement lacking IgG in the milk replacer twice daily for 14 d. Control calves received milk replacer without supplements twice daily. Calves were housed in individual hutches and were

- 10 g of IgG per day
- \$0.20 - \$0.30 / g IgG

Berge et al., 2009

Post-Day 1 Colostrum

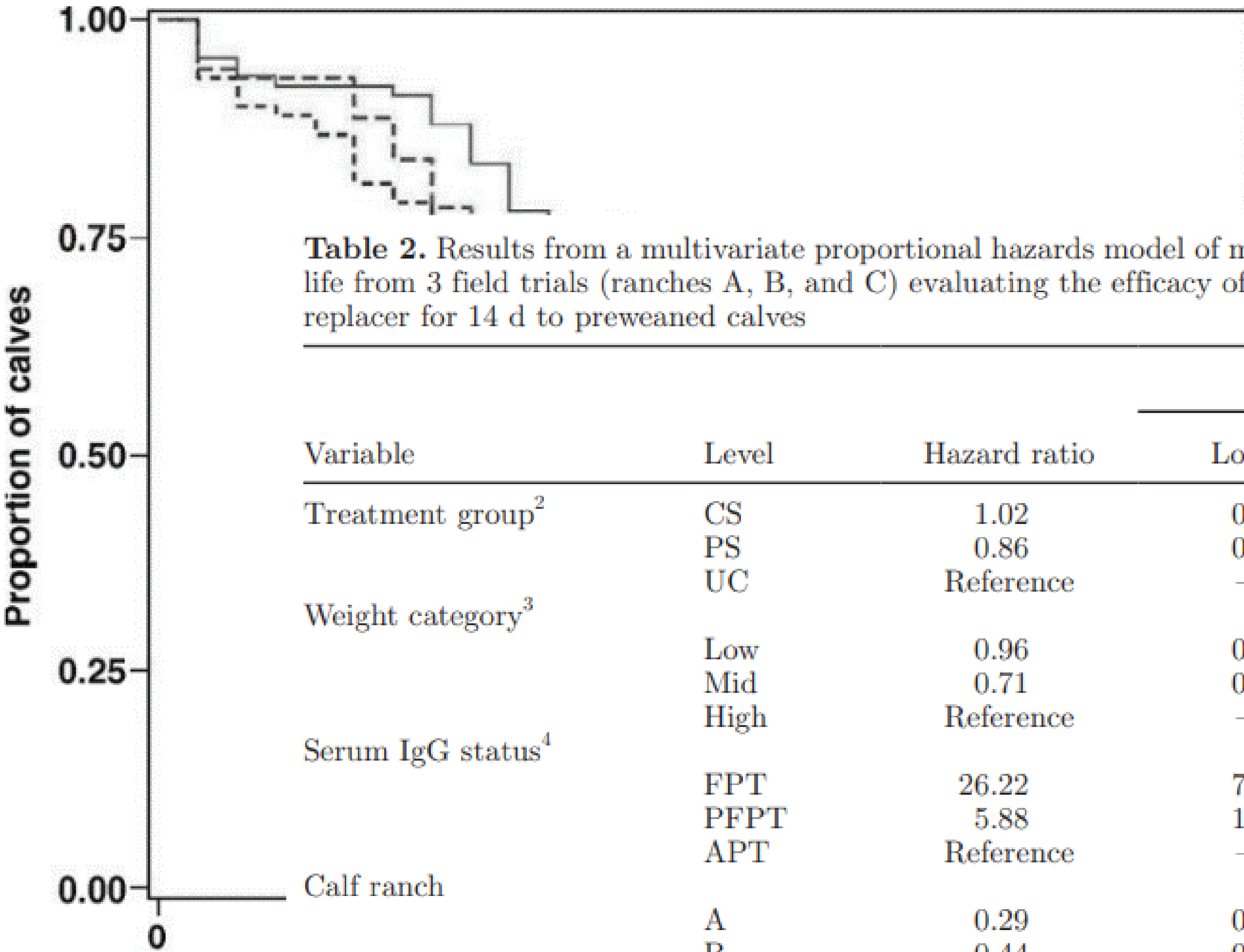


Table 2. Results from a multivariate proportional hazards model of mortality in calves during the first 28 d of life from 3 field trials (ranches A, B, and C) evaluating the efficacy of feeding a colostrum supplement in milk replacer for 14 d to preweaned calves

			90% CI[1]		
Variable	Level	Hazard ratio	Lower	Upper	Wald's *P*-value
Treatment group[2]	CS	1.02	0.52	1.98	0.96
	PS	0.86	0.44	1.69	0.72
	UC	Reference	—	—	—
Weight category[3]					
	Low	0.96	0.44	2.07	0.93
	Mid	0.71	0.33	1.52	0.46
	High	Reference	—	—	—
Serum IgG status[4]					
	FPT	26.22	7.60	90.38	<0.01
	PFPT	5.88	1.68	20.52	0.02
	APT	Reference	—	—	—
Calf ranch					
	A	0.29	0.14	0.60	<0.01
	B	0.44	0.21	0.95	0.08
	C	Reference	—	—	—

Berge et al., 2009

Post-Day 1 Colostrum

J. Dairy Sci. 103:12104–12108
https://doi.org/10.3168/jds.2020-18361

Short communication: Effects of transition milk and milk replacer supplemented with colostrum replacer on growth and health of dairy calves

B. Van Soest,[1] F. Cullens,[2] M. J. VandeHaar,[1] and M. Weber Nielsen[1]*
[1]Department of Animal Science, Michigan State University, East Lansing 48824
[2]Michigan State Extension, East Lansing 48824

Table 1. Chemical composition of milk replacer, transition milk, and a 1:1 mix of milk replacer and colostrum replacer fed to calves from 2 to 4 d of age, nutrient intake, and predicted ADG

	Diet[1]		
Variable	MR	TM	MCR
Fat (% on DM basis)	10.3	25.9	14.6
Protein (% on DM basis)	27.8	41.8	38.6
IgG (g/kg of DM)	0	10	98
ME (Mcal/kg of DM)	4.03	5.40	4.47
DMI[2] (g/d)	770	862	864
CP intake[2] (g/d)	214	360	332
ME intake[2] (Mcal/d)	3.10	4.65	3.86
Expected ADG[2] (kg/d)	0.59	1.02	0.78

Post-Day 1 Colostrum

Table 2. Biomarkers of inflammation and health scores (scores averaged by calf for the first 21 d of age)

Variable	Diet[1] MR	Diet[1] TM	Diet[1] MCR	SEM	*P*-value MR vs. TM and MCR[2]	*P*-value TM vs. MCR[3]
Eye[4]	0.60	0.31	0.30	0.16	0.13	0.9
Feces[4]	6.8	7.8	7.2	0.83	0.4	0.6
Ear[4]	2.4	2.3	2.6	0.42	0.9	0.6
Haptoglobin[5] (μg/mL)	7.5	4.6	3.6	1.40	0.05	0.6
LBP[6] (μg/mL)	5.8	5.5	5.3	0.45	0.4	0.7

[1]Diets contained milk replacer (MR), pooled and pasteurized transition milk (TM), or milk replacer supplemented at a ratio of 1:1 with colostrum replacement powder (MCR).

[2]Contrast of MR and treatments TM and MCR.

[3]Contrast of TM and MCR.

[4]Daily health scores averaged by calf for the first 21 d.

[5]Haptoglobin samples from d 14 and 21.

[6]LBP = LPS binding protein samples from d 14 and 21.

Table 3. Initial BW, weaning weight, and gain for calves fed experimental diets

Variable	Diet[1] MR	Diet[1] TM	Diet[1] MCR	SEM	*P*-value MR vs. TM and MCR[2]	*P*-value TM vs. MCR[3]
Birth weight (kg)	36.8 ± 3.7	37.6 ± 5.3	38.7 ± 4.0	0.75	0.13	0.24
Weaning weight (kg)	68.1 ± 6.8	71.8 ± 5.3	73.0 ± 6.6	1.01	<0.01	0.7
Weight gain (kg)	31.3 ± 5.8	34.2 ± 6.0	34.3 ± 6.2	0.98	0.02	0.9
Preweaning ADG (kg/d)	0.562 ± 0.10	0.616 ± 0.14	0.620 ± 0.11	0.017	0.01	0.9

Post-Day 1 Colostrum

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https://doi.org/10.3168/jds.2021-21723

Transition milk stimulates intestinal development of neonatal Holstein calves

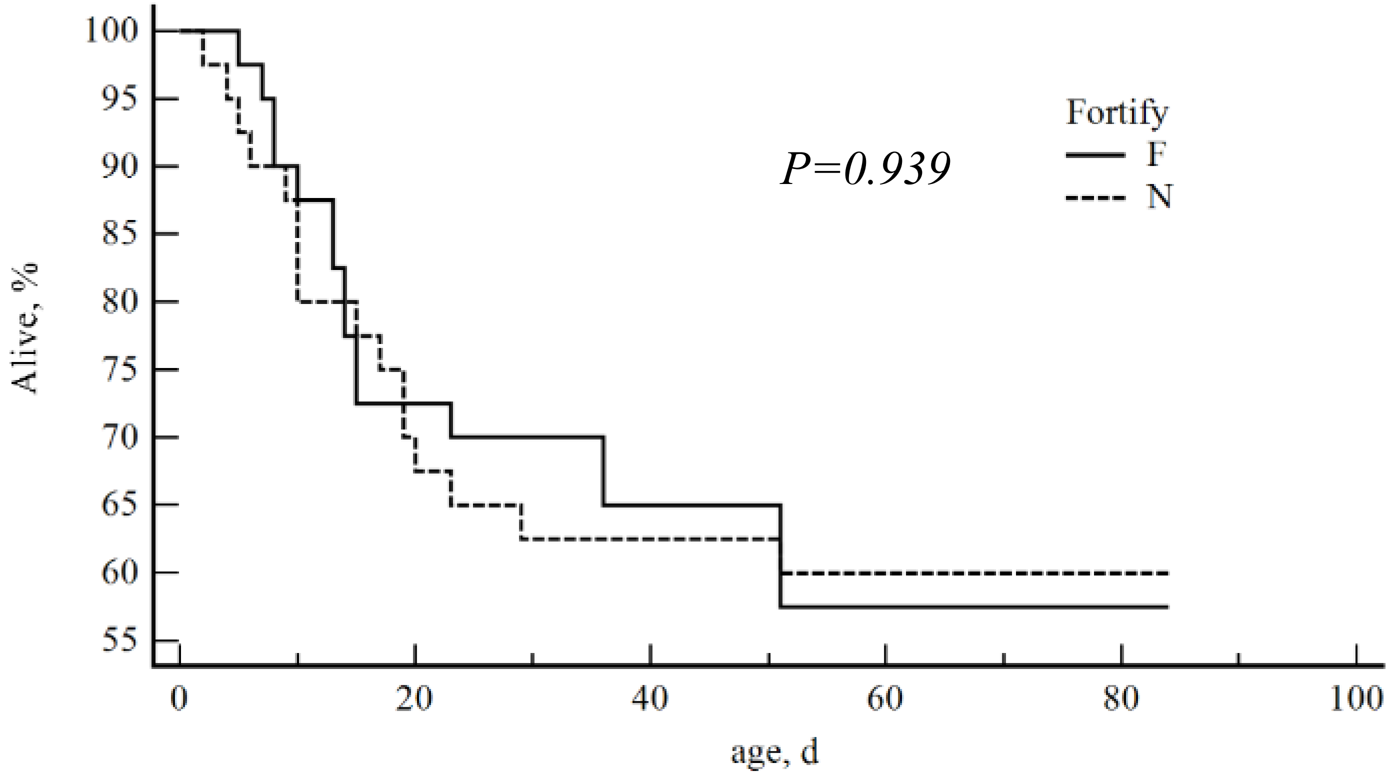
B. Van Soest,[1] M. Weber Nielsen,[1] A. J. Moeser,[2] A. Abuelo,[2] and M. J. VandeHaar[1]*
[1]Department of Animal Science, Michigan State University, East Lansing 48824
[2]Department of Large Animal Clinical Sciences, Michigan State University, East Lansing 48824

Table 3. Small intestine morphology (mean ± SE)

	~20g/L IgG Treatment[1]		
Item	TM	MR	*P*-value
Villus length (mm)			
Duodenum	0.824 ± 0.060	0.504 ± 0.058	0.003
Proximal jejunum	1.190 ± 0.048	0.609 ± 0.047	<0.001
Mid jejunum	1.004 ± 0.059	0.568 ± 0.058	<0.001
Ileum	0.812 ± 0.045	0.536 ± 0.044	0.001

Plasma

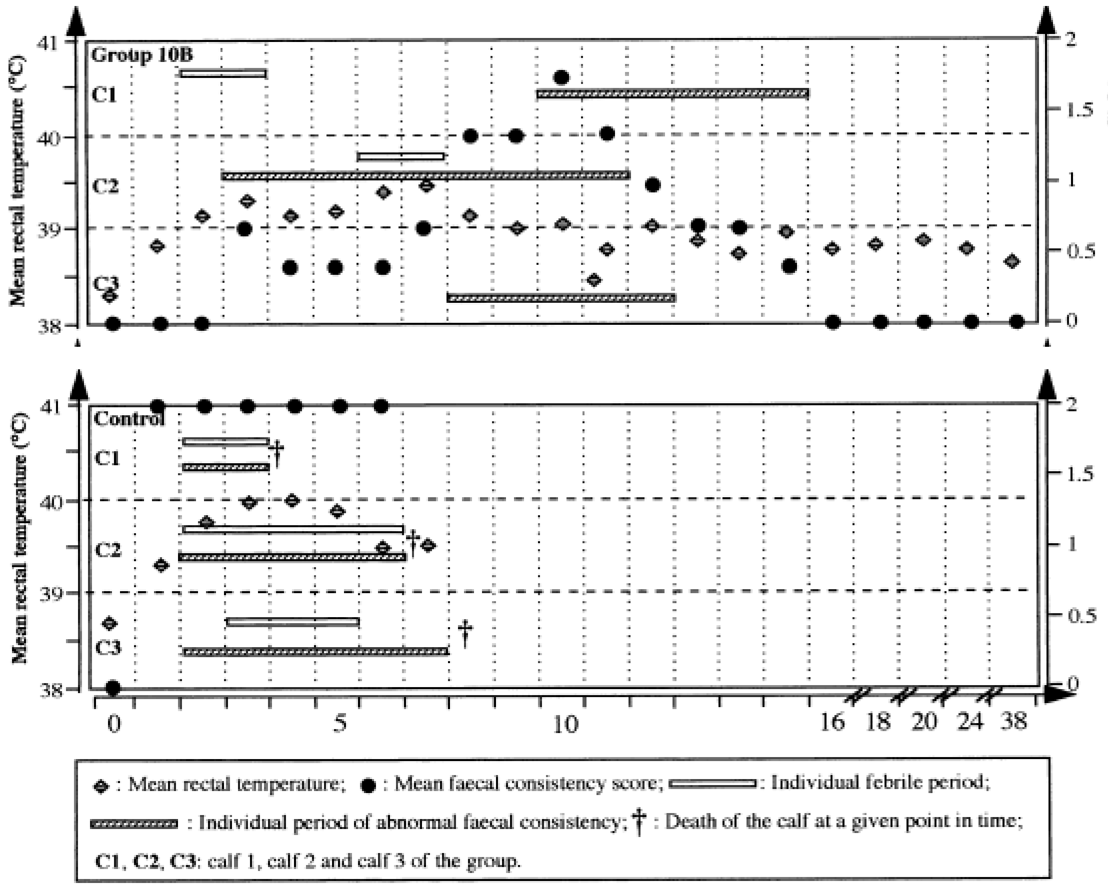
- Spray Dried Plasma
  - Fed a plasma-based colostrum supplement
    - *454 in total volume of 2L first feeding in calf ranch*



Langenkamp & Ballou (ongoing)

Plasma

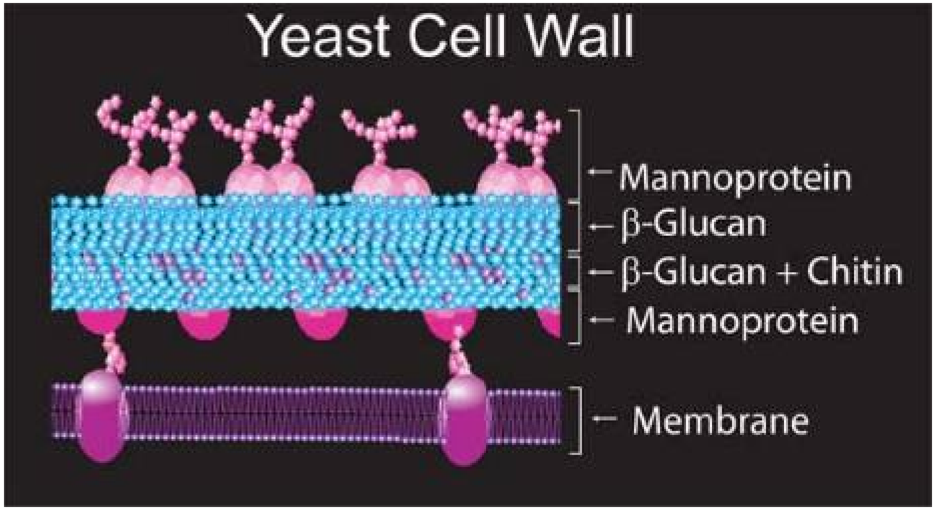
- Spray Dried Plasma
  - Approximately 22.2% IgG



Nollet et al. (1999)

Yeast cell wall fractions

- **Yeast cell wall (MOS)**
  - **Whole yeast cell wall** – insoluble cell wall is extracted from a culture of yeast.
    - ***Polysaccharides (30 -60%)*** *– β-Glucan and Mannan Polymers. Yeast cell wall contains typically between 5 to 30% of each.*
    - ***Proteins (30%)*** *– Most of the protein is linked to the Mannan Polymers*



Yeast cell wall fractions

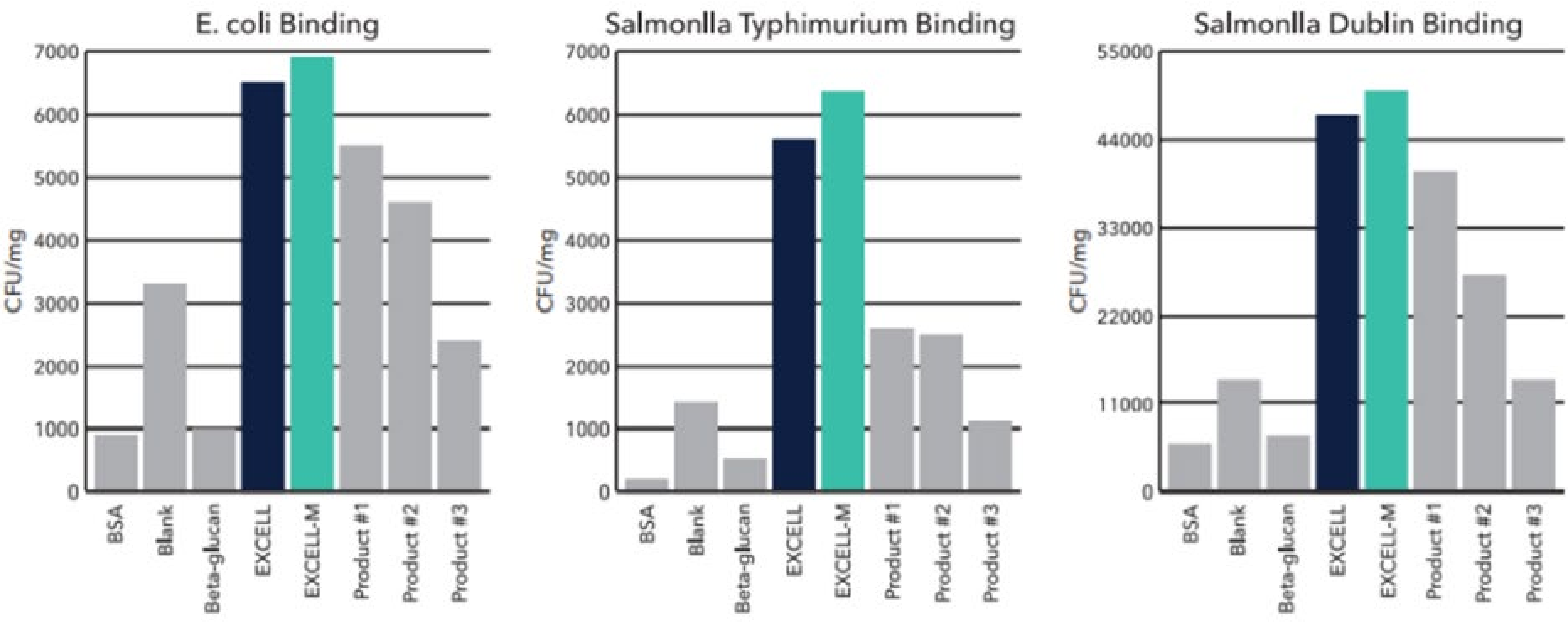


Figure 1. A comparison of the binding efficacy of an enteropathogenic *E. coli, Salmonella Typhimurium,* and *Salmonella Dublin* by CEREVIDA® EXCELL and EXCELL-M when compared against 3 leading commercial products.

Yeast cell wall fractions

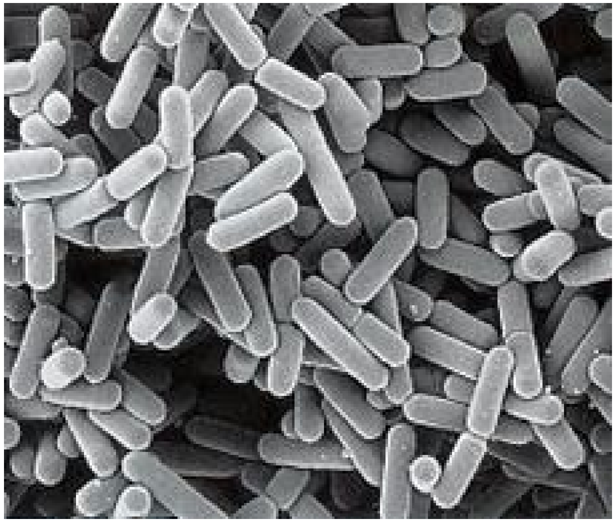
Table 1. Performance of high-risk Holstein calves supplemented with either CEREVIDA® EXCELL - M or PROVIDA® Calf probiotics (n=20 calves per treatment).

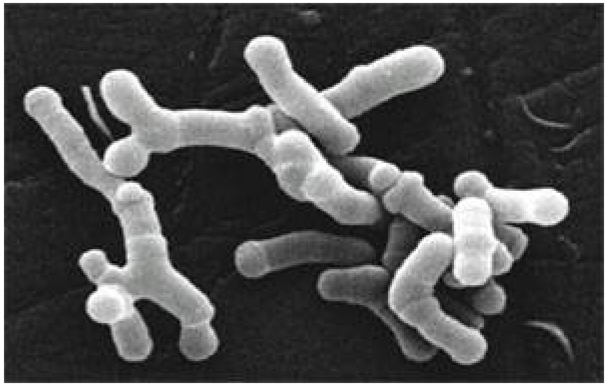
Variable	Control	CEREVIDA EXCELL-M	PROVIDA Calf	SEM	Trt
Initial BW, lbs	91.7	91.7	91.7	2.5	…
Weaned body weight, lbs	146.5	151.5	155.3	7.99	0.664
Preweaned starter intake, lbs	30.7	38.3	40.7	8.9	0.413
age 1 to 28 days, lbs	2.2[a]	3.9[b]	3.0[ab]	0.6028	0.016
age 29 to 56 days, lbs	27.1	34.6	36.1	8.2	0.32
Preweaned ADG, lbs/d	0.97[a]	1.06[ab]	1.12[b]	0.073	0.081

Means with different superscripts differ $P \leq 0.05$.

Direct fed microbials

- Direct fed microbials
  - Probiotics – are live microorganisms that are thought to be beneficial to the host organism
    - *Include lactobacillus sp, bifidobacterium sp, saccharomyces sp, enterococcus, bacillus sp*





Direct fed microbials

J. Dairy Sci. 103:7351–7363
https://doi.org/10.3168/jds.2019-17480

Supplementing neonatal Jersey calves with a blend of probiotic bacteria improves the pathophysiological response to an oral *Salmonella enterica* serotype Typhimurium challenge

Y. Liang,[1,2]* R. E. Hudson,[2] and M. A. Ballou[1,2]
[1]MB Nutritional Sciences LLC, Lubbock, TX 79403
[2]Department of Veterinary Science, Texas Tech University, Lubbock 79409

Direct fed microbials

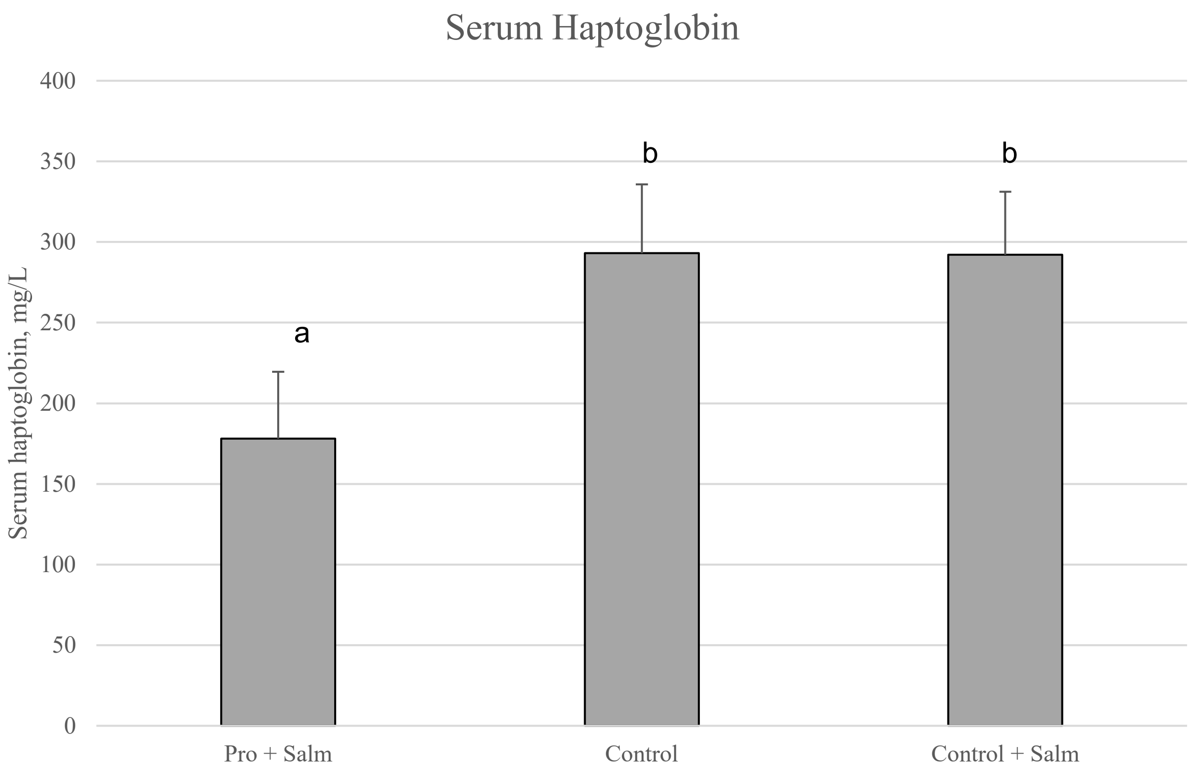
Materials and Methods

- Challenged with log-growth *Salmonella enterica* in morning milk replacer
- BW collected on d 0, 7, 14, and 21
- Blood collected on d 0, 7, 10, 14, and 21
- Histology d 21
  - *Duodenum and Ileum*

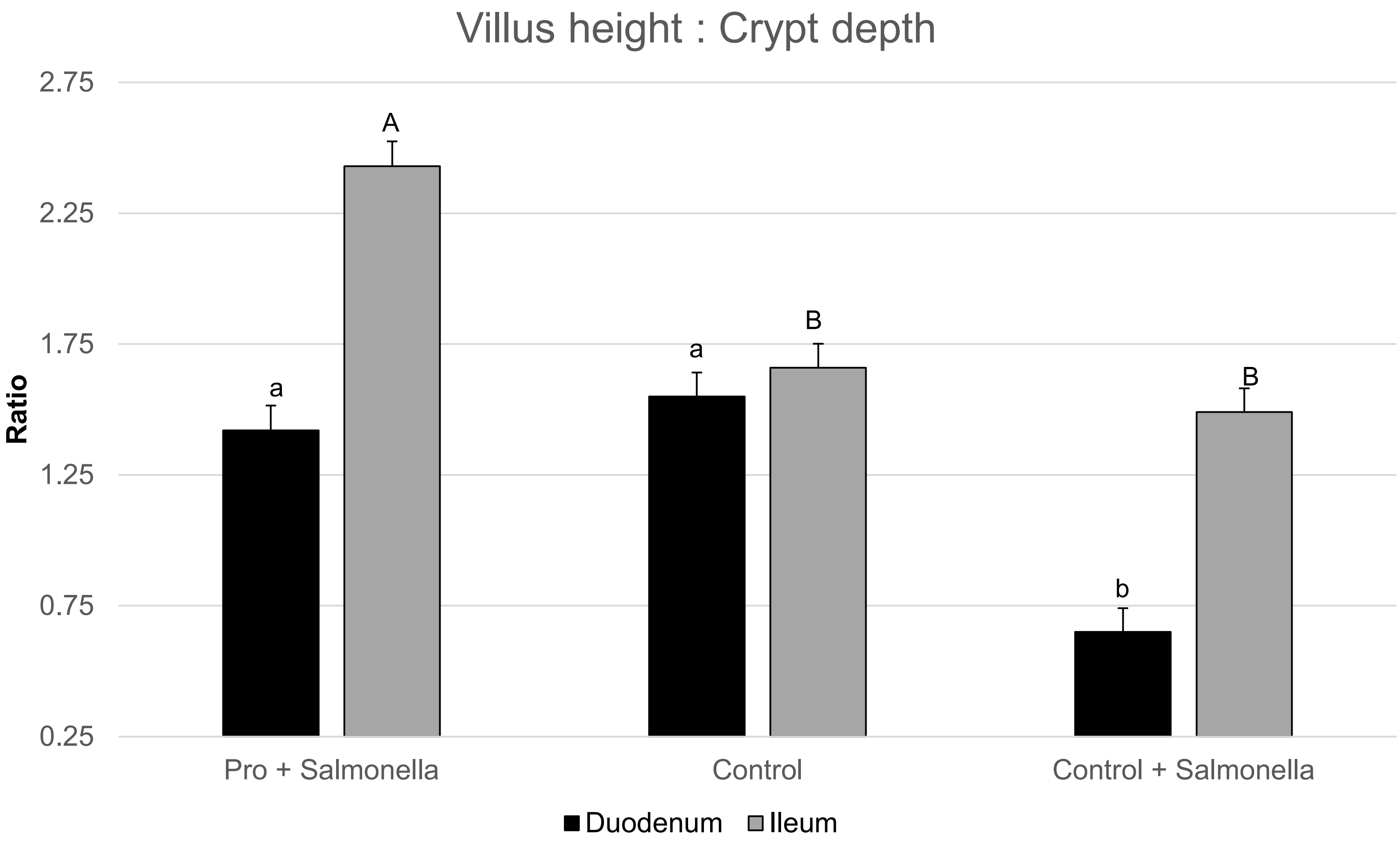
Direct fed microbials

Results

- Probiotic supplemented calves had reduced systemic inflammation throughout the entire study period



Direct fed microbials

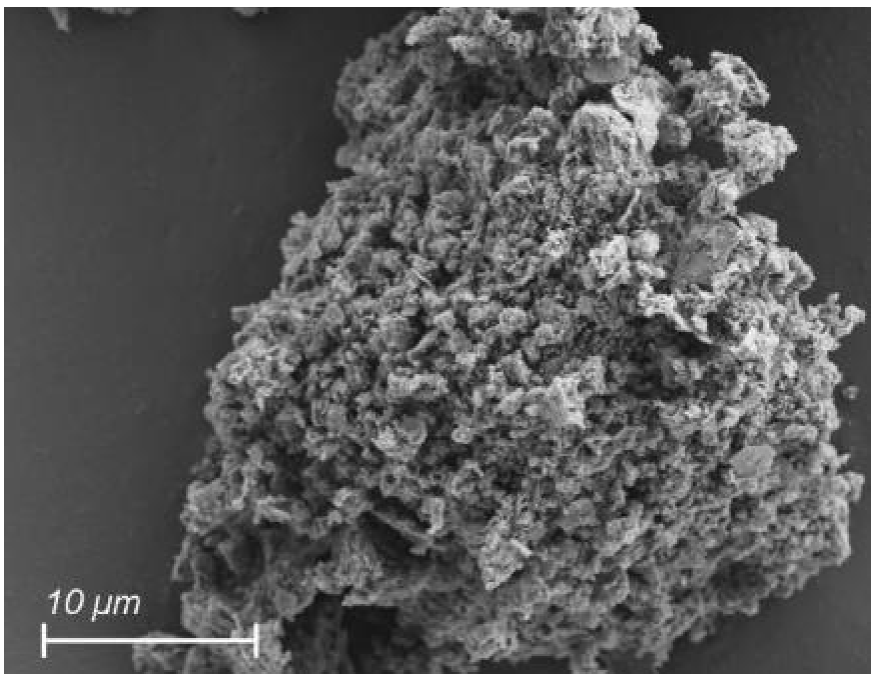


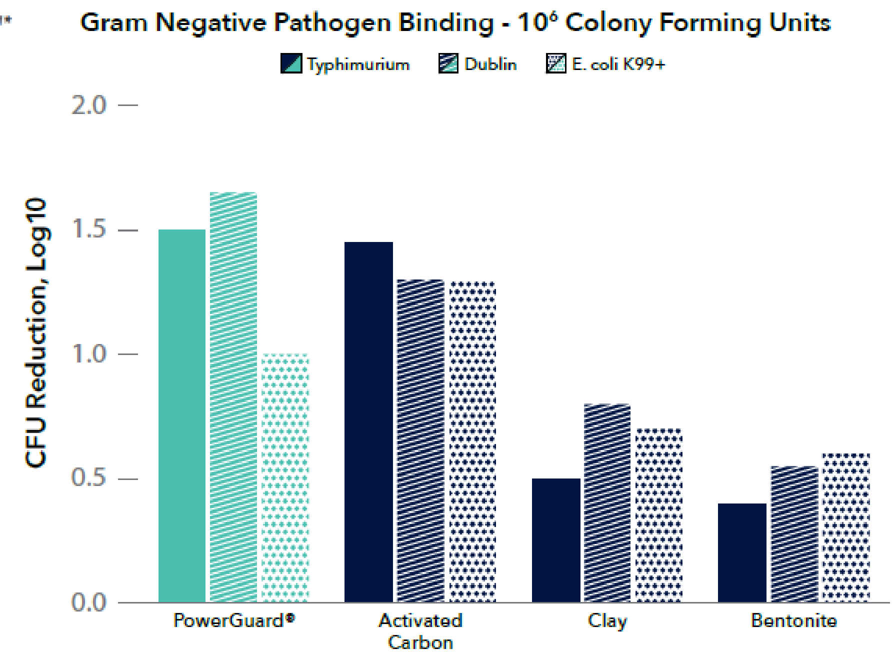
Adsorbents

A Dose-Response Investigation of a Micronized Porous Ceramic Particle to Improve the Health and Performance of Post-weaned Pigs Infected With *Salmonella enterica* Serotype Typhimurium

frontiers | Frontiers in Animal Science

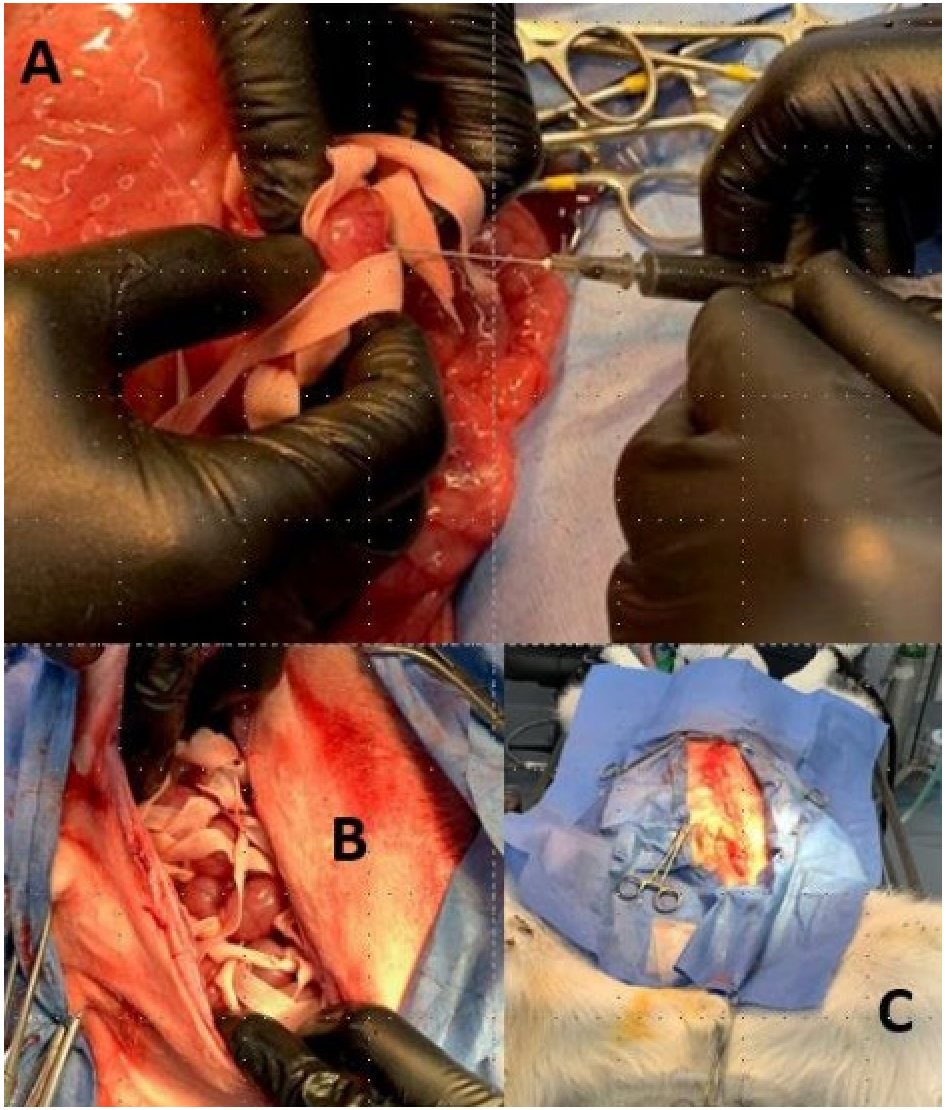
Emily M. Davis[1], Kayla P. Wallace[2], Michael J. Cruz Penn[2], Amy L. Petry[3], Rand Broadway[4], Nicole C. Burdick Sanchez[4], Jeffery A. Carroll[4] and Michael A. Ballou[1]*

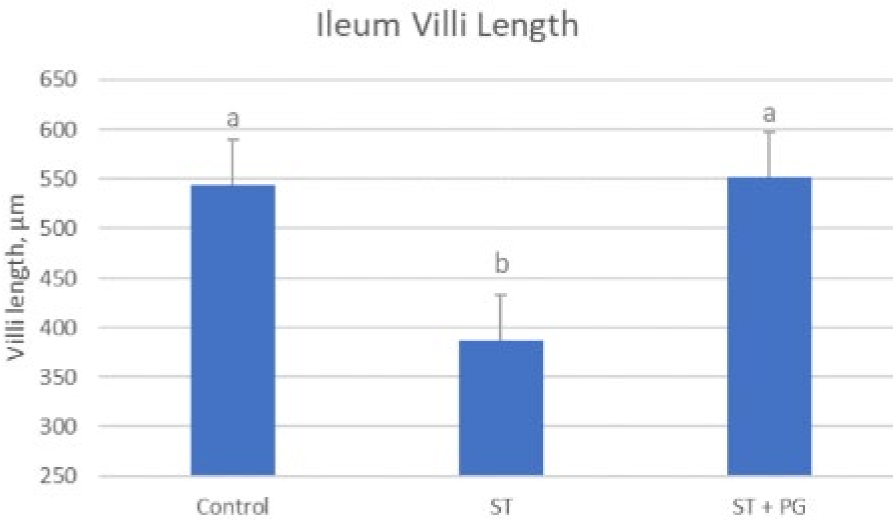


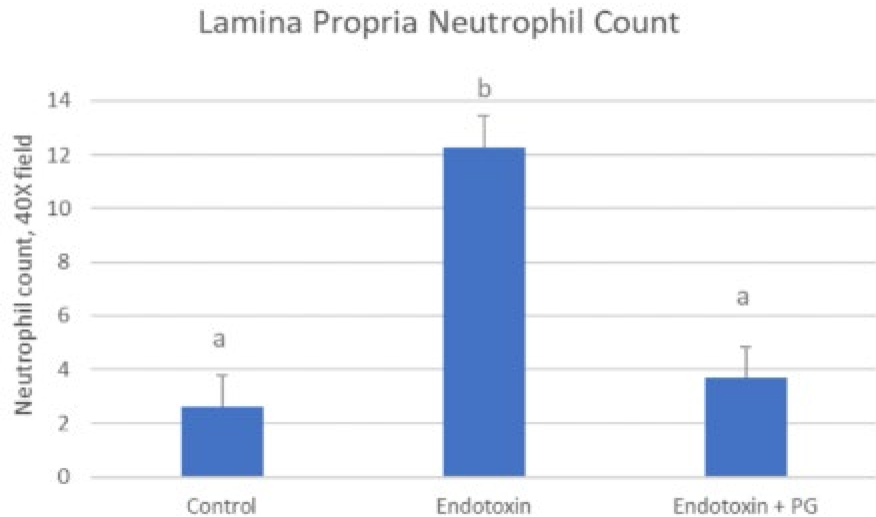


PowerGuard is able to bind pathogenic gram negative bacteria, such as *E. coli* and *Salmonella enterica* sp. better than commercial clay absorbents.

Adsorbents







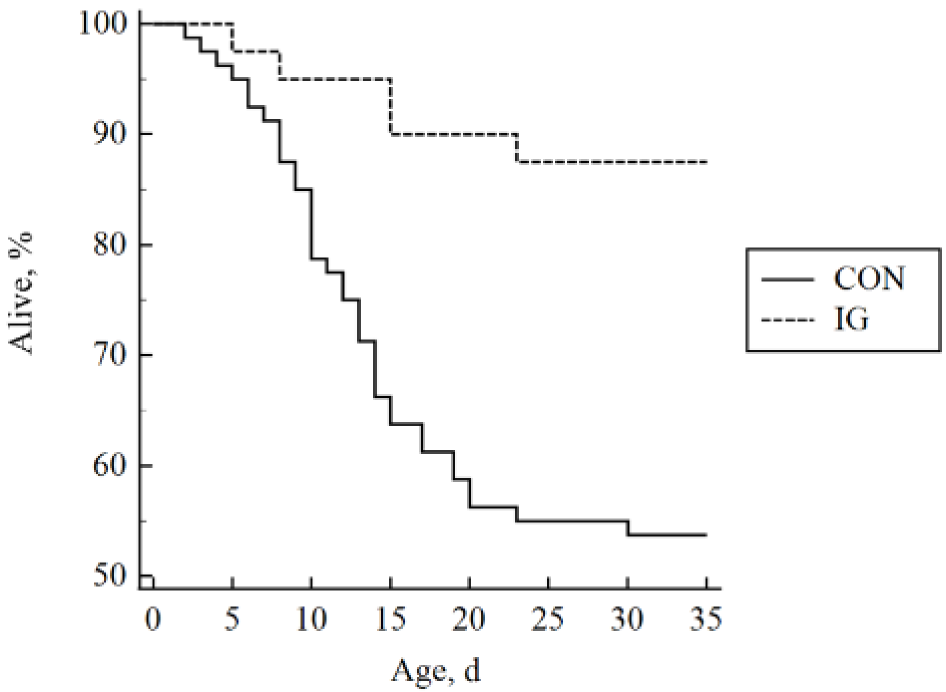
Davis et al. (ongoing)

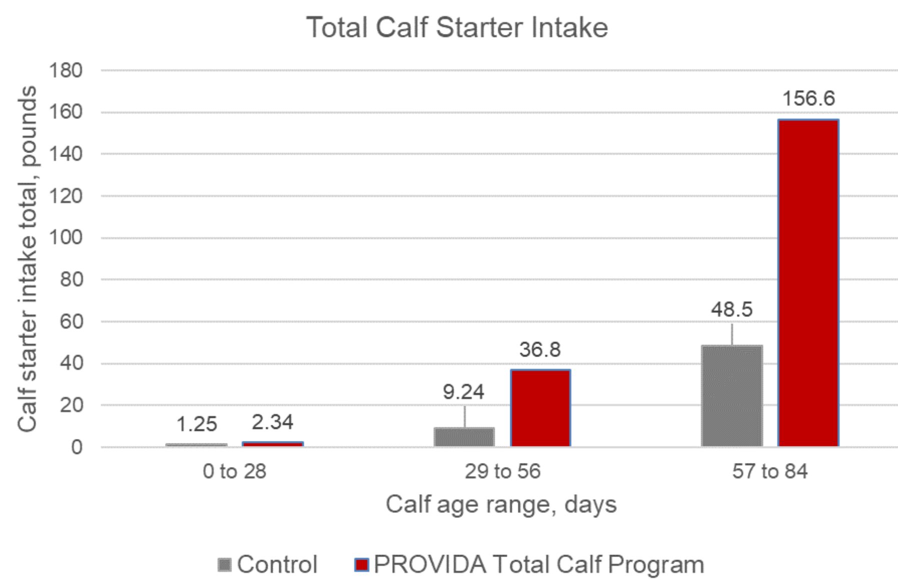
Take Home Messages / Discussion Points

- Many holes in G.I. immune system and undergoing rapid maturation
- Many interactions among host, pathogens, and environment
- Nutrition attractive approach
- Primary strategies to improve enteric immunity
  - Reduce interaction of potential pathogen with calf
  - Improve G.I. immune system maturation

Combination Treatment

- Control calves fed 22-20 Component, Non-Med
  - Skim, 7-60 (or Liquid Fat), 99% Lactose
- IG supplemented with 45 g/calf/day
  - 21 days then 6 g/calf/day PROVIDA VTM
- IG = Plasma, PowerGuard, EXCELL-M, Whey, DFM, VTM, Lys/Met
- n=60/treatment; ~75% FPT





Langenkamp and Ballou, ongoing

Respiratory Disease

J. Dairy Sci. 102:9082–9096
https://doi.org/10.3168/jds.2018-15997

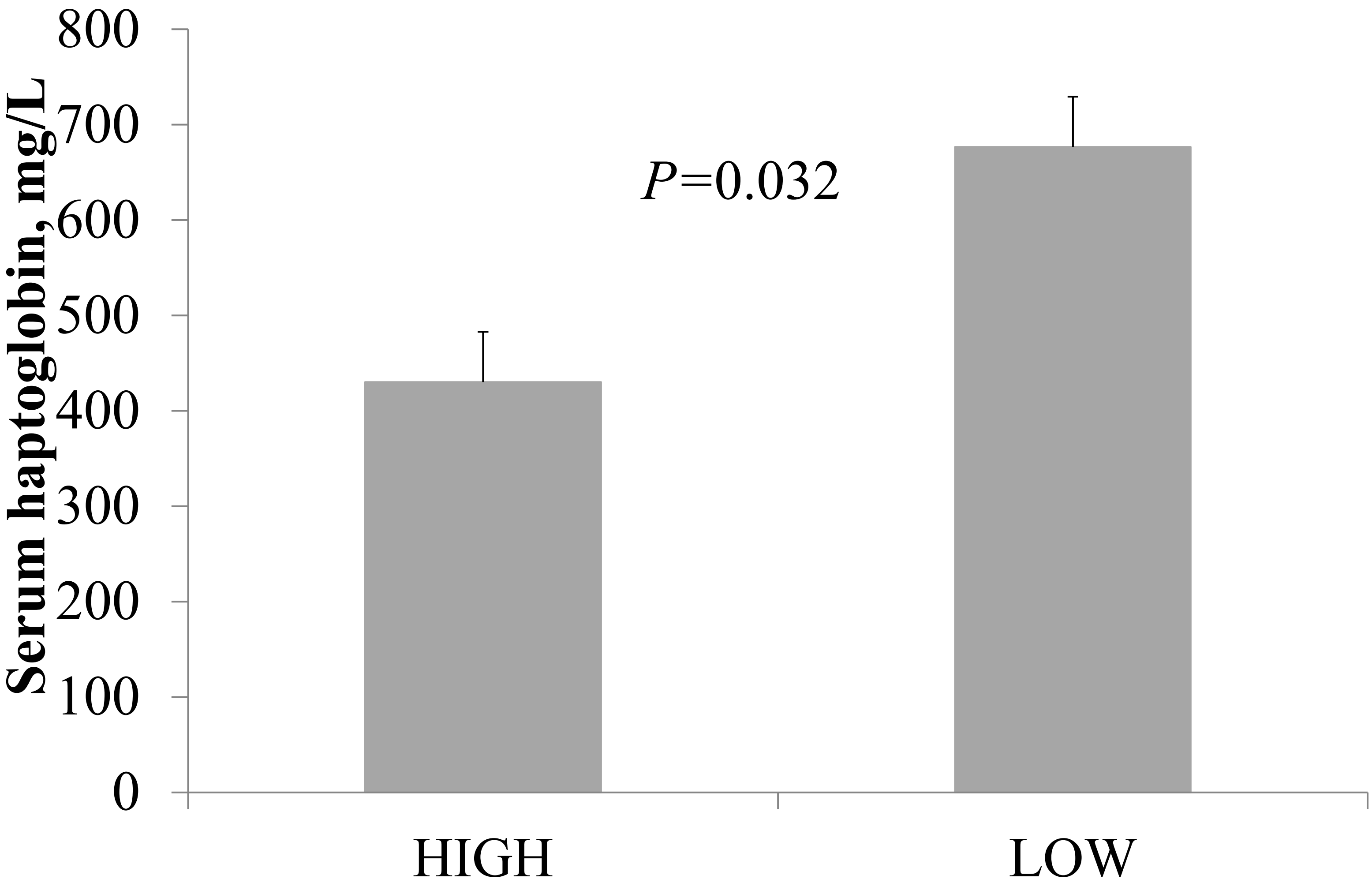
Pre-weaning plane of nutrition and *Mannheimia haemolytica* dose influence inflammatory responses to a bovine herpesvirus-1 and *Mannheimia haemolytica* challenge in post-weaning Holstein calves

K. P. Sharon,[1,2] Y. Liang,[1] N. C. Burdick Sanchez,[2] J. A. Carroll,[2] P. R. Broadway,[2] E. M. Davis,[1] and M. A. Ballou[1]*
[1]Texas Tech University, Department of Animal and Food Sciences, Lubbock 79409
[2]USDA-Agricultural Research Service, Livestock Issues Research Unit, Lubbock, TX 79403

Quantity of milk solids

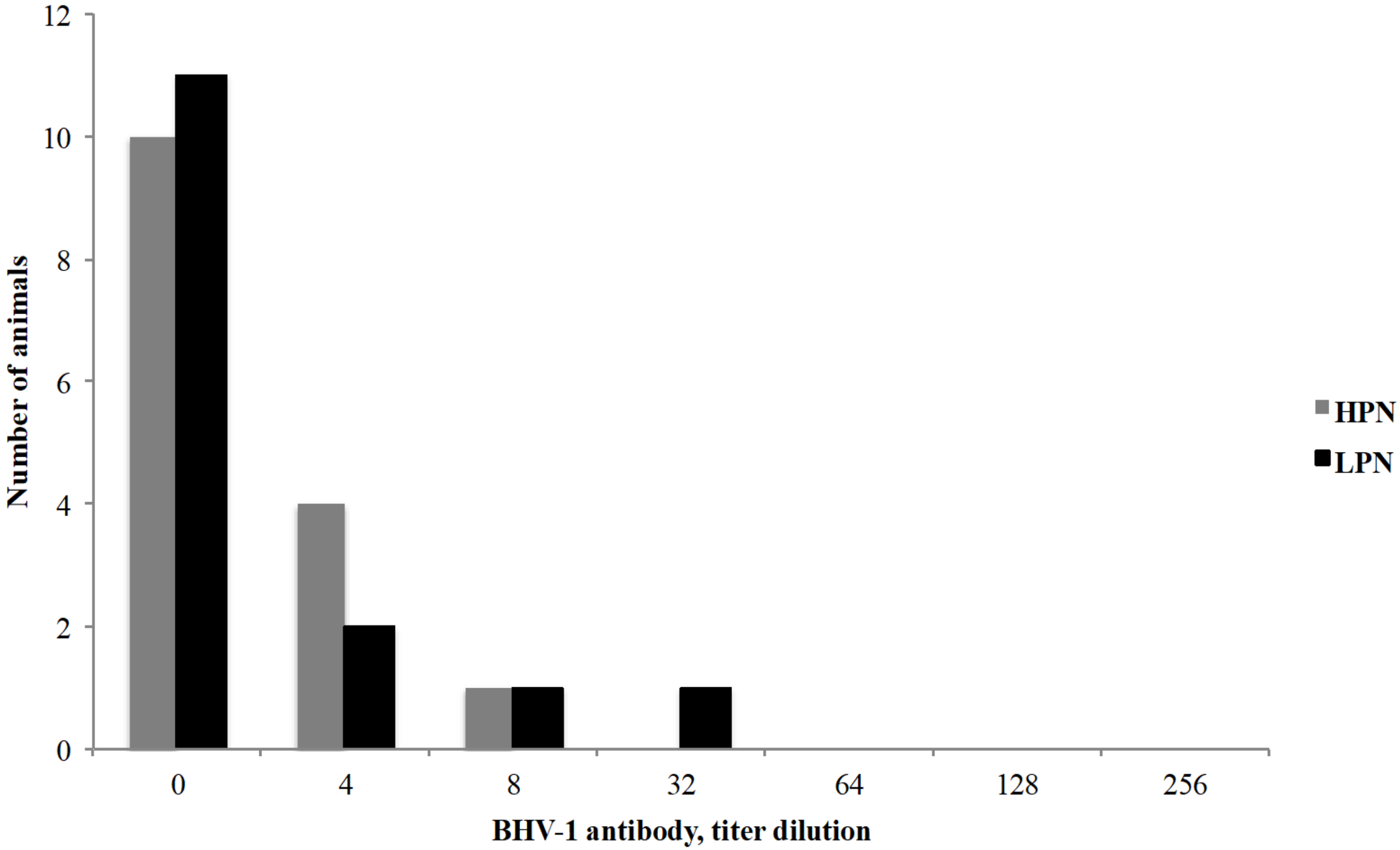
- 30 Holstein bull calves fed either **LOW** or **HIGH** and weaned at 54 d of age
- Challenged with 10^8 PFU/nostril with bovine herpesvirus-1 at 81 d of age
- Challenged with 10^6,10^7, or 10^8 CFU *Mannheimia haemolytica* at 84 d
  - Observation period through 94 d
  - 4/15 Low calves died consistent with respiratory disease
    - *1, 2, and 1 challenged with 10^6, 10^7 & 10^8, respectively*
  - 0/15 High calves died

Quantity of milk solids



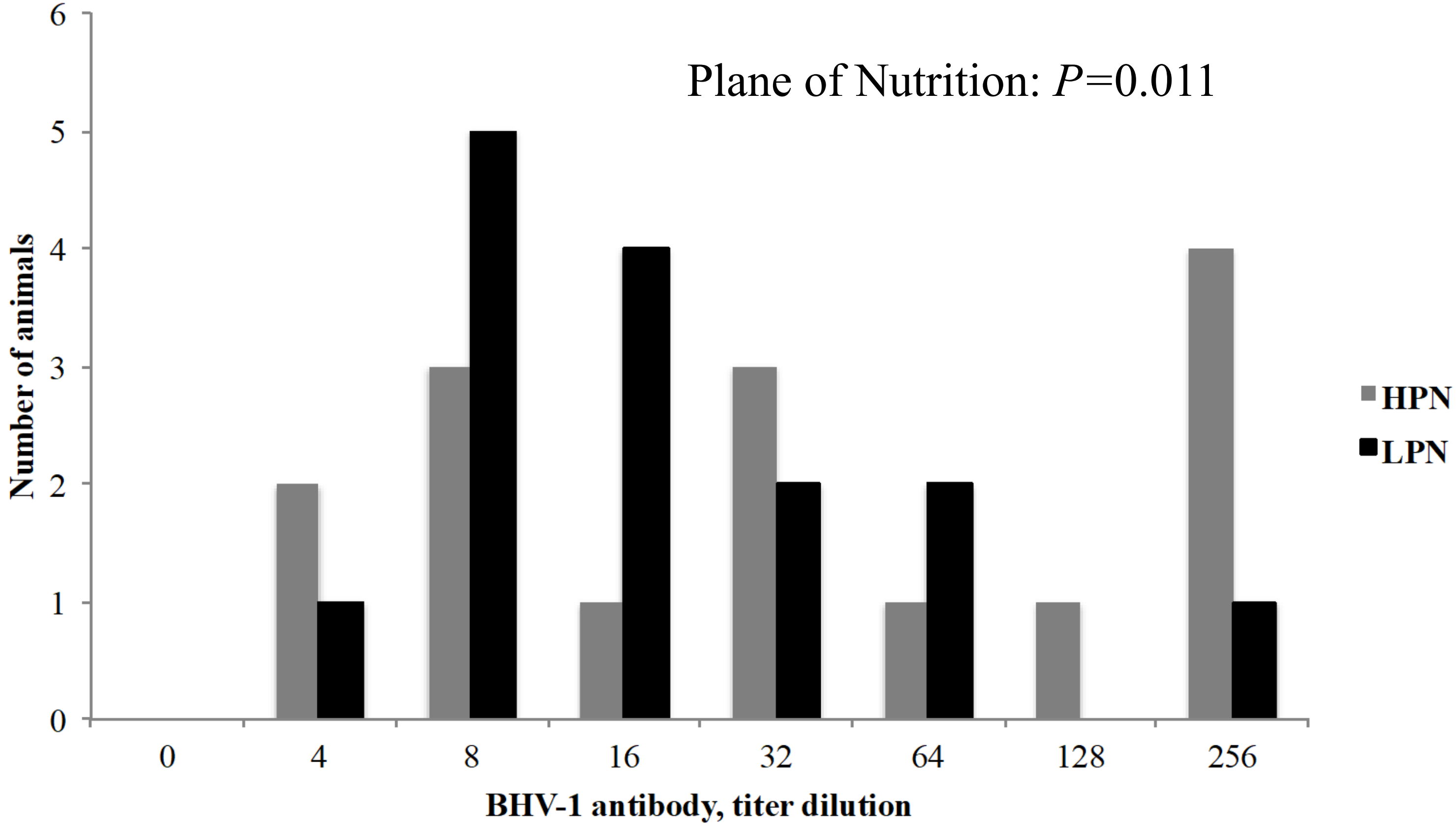
Quantity of milk solids

- BHV-1 Titers: Prior to Challenge



Quantity of milk solids

- BHV-1 Titers: 13 days Post-Challenge



Quantity of milk solids

- **TAKE HOME**
- Data indicate that post-weaned health was improved among calves that were previously fed a higher plane of milk replacer
- Was it due to an improved vaccination response during the pre-weaned period?
- Data indicate that early life performance can influence response to respiratory challenge.