Relationships Between Protein and Energy Consumed and Calf Growth and First Lactation Production Performance of Holstein Dairy Cows

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Take-Home Message

- Data from 2,880 Holstein dairy calves were used to determine if early life average daily gain, calf starter intake, and milk replacer intake were related to first-lactation 305-d production.
- Average daily gain at 6 and 8 weeks had positive effects on 305-d first-lactation production.
- Growth data from 4,534 Holstein dairy calves had a positive relationship between energy and protein consumed in early life and calf growth and milk production in first lactation.
- Additional factors other than average daily gain and pre-weaning growth and intake affect first-lactation performance.

Does early life calf nutrition affect milk production of cows?

During the past few years, higher levels of milk or milk replacer have been recommended to achieve greater pre-weaning growth of calves and to and increase milk production of first-lactation cows. Excellent first-lactation production is a key component of dairy farm sustainability. Some studies have indicated that improvements in calf growth are associated with higher first-lactation production, but others have disagreed. Recently, Penn State researchers (Gelsinger et al., 2016) indicated that although pre-weaning average daily gain is positively related to first-lactation milk production, there are more important factors in determining first-lactation performance than pre-weaning calf growth.

We decided to evaluate the relationships between early life growth and first-lactation production of Holstein dairy cows from commercial dairy farms in Minnesota. These calves were enrolled in calf research trials at the University of Minnesota Southern Research and Outreach Center (SROC) in Waseca, MN. Calves were contract raised for three commercial dairy farms which represent over 2,000 dairy cows. Heifer calves were picked-up twice a week at 2 to 5 days of age and taken to the SROC. For our study, data were collected from 2004 to 2012 for 2,880 Holstein animals. The calves were enrolled in 37 different calf research trials at the SROC from 3 to 195 days of age. At the end of the trials, calves were grouped housed and returned to their respective farms or moved to heifer growers at about 6 months of age. Milk replacer fed to calves included varying levels of protein and amounts fed, but in the majority of studies, calves were fed a milk replacer containing 20% fat and 20% protein at 1.25 lb/calf daily. Most calves (93%) were weaned at 6 weeks of age. Average daily gain at 8 weeks for the 2,880 calves was 1.4 lbs/day.

The results show that calf growth had a significant positive effect on 305-day first lactation milk, fat, and protein production. For every 1 pound of average daily gain at 8 weeks of age, milk production increased by 1,276 lbs in first lactation. To put this in perspective, if a farm increased their calf average daily gain from 1.5 to 2.0 lbs/day, first lactation milk production in 305 days would increase by only 648 lbs. The variation in milk production and average daily gain was high, and this suggests additional factors impact first lactation performance (i.e. environment, feed quality, housing, and animal health). Figure 1 shows the relationship between 8-week average daily gain and 305-milk production in first lactation. There was great variation for calf growth and milk production. In the figure, we observe that calves that achieve a 2 lb average daily gain, may have 15,000 or 30,000 pounds of milk in first lactation.

Intake of calf starter had an impact on first-lactation production while milk intake, which varied less, had no effect. Each additional pound of calf starter DM intake at 8 weeks of age resulted in 18.1 lbs of more milk in first lactation. Therefore, calf starter intake may be a better indicator of future milk production than just average daily gain alone. Furthermore, we found that calves born during the fall and winter had greater starter intake and average daily gain at 8 weeks. However, calves born during the summer produced more milk in 305 days during their first lactation than those born during the fall and winter. From this study it may be difficult to be confident in the prediction equations generated for calf growth versus first lactation performance because of the high variation in calf growth and production. Therefore, excellent colostrum and disease management, hygiene, milk replacer quality and consumption, calf starter quality and consumption, water quality and access, and post-weaning nutrition are all necessary to achieve optimal heifer growth and future milk production.

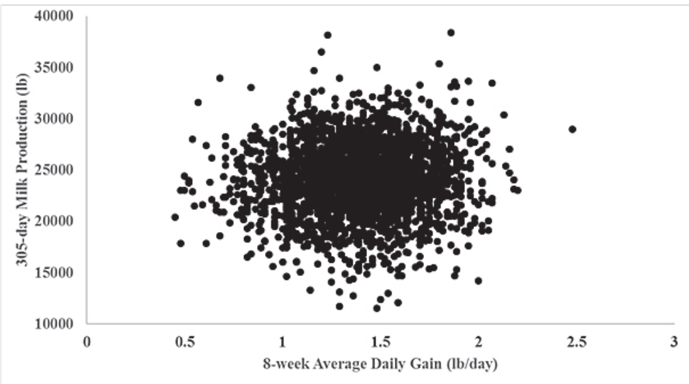

Figure 1. Relationship between 8-week average daily gain and 305-d milk production in first lactation.

Relationships between protein and energy consumed from milk replacer and calf starter and calf growth and first lactation production performance of Holstein dairy cows.

The Dairy NRC (2001) provides nutrient guidelines to maximize calf health and lean tissue growth, and protein requirements to maximize growth. Achieving faster growth and ensuring the health of the calf involves numerous factors including colostrum management, proper hygiene, and feeding management. There are many different calf milk replacer and starter options that are available to be fed to dairy calves, many of which have undergone research by scientists and nutritionists. With so many options, dairy farmers may find themselves overwhelmed by the choice as to what will truly help them achieve greater calf growth and optimize health.

First-lactation milk production has been shown to be positively correlated with pre-weaning average daily gain and weaning weight (Soberon et al., 2012). The authors showed that the higher the nutrient intake pre-weaning, the more nutrient intake the heifer would have post-weaning. They also found that for every lb increase in pre-weaning average daily gain, first-lactation cows produced an additional 1,874 lb of milk in 305 days and 518 lb of milk for every Mcal of ME intake.

More recently, studies have analyzed early life calf growth and it relationship to first lactation production (Chester-Jones et al., 2017; Gelsinger et al., 2016). In a meta-analysis by Gelsinger et al. (2016), they reported that pre-weaned calf nutrition contributed to a positive effect on 305-d milk and component production. The authors reported that growth rate had little effect on first lactation between 0.66 and 1.1 lb/day for average daily gain, but the effects increased as growth rate increased from 0.66 lb/day to 1.98 lb/day for average daily gain.

Based on previous research that determined the relationship between average daily gain and first-lactation production in Holstein cows in Chester-Jones et al. (2017), the objective of the study was to determine relationships between protein and energy consumed from milk replacer and starter and growth and first-lactation performance of Holstein dairy heifer calves. Our findings can be useful information to dairy farmers and nutritionists when they are planning their calf feeding regimen and can assist in outlining objectives a specific dairy farm has for calf growth and average daily gain.

Data were collected from calves born from 2004 to 2014 for 4,534 Holstein heifer calves. Calves came from 3 commercial dairy farms which all together represent over 2,000 dairy cows in Minnesota. Between 2 to 5 days of age, heifer calves were picked up twice weekly and taken to the University of Minnesota Southern Research and Outreach Center in Waseca, Minnesota. Calves were then assigned to 45 different calf nursery studies at SROC over the 11-year period.

Of the 45 calf studies in the current data set, the majority of calves (85%) were fed a milk replacer of all milk protein that contained 20% CP and 20% fat. Fifteen percent of the calves were fed 20% protein and 20% fat milk replacer where alternative animal and vegetable proteins partially replaced milk protein. The alternative protein milk replacer contained either soy, wheat, plasma, or a mixture of both wheat and plasma sources at varying percentages of the total milk replacer protein. Ninety percent of these trials utilized a milk replacer feeding rate of 1.25 lb/calf daily. Ten percent of the studies did not feed a conventional 20:20 milk replacer or feed at a 1.25 lb/calf daily feeding rate and fed an accelerated feeding rate regimen. These studies included milk replacer containing protein and fat levels of 24:20 up to and 28:20 fed from1.25 to over 2 lb solids/day. The majority of calves were weaned at 6 weeks. Data collected on calves included daily milk replacer intake, starter intake, growth (body weights and hip height), calf health, and feed efficiency. Body weights were taken every 2 weeks until day 56.

Protein and ME consumed were calculated for each individual calf for 6 and 8 weeks. These weeks were chosen because weaning took place at 6 weeks and the end of the nursery period was at 8 weeks. Protein consumed was calculated from the protein content of the milk replacer and calf starter. The basic 18% crude protein texturized calf starter was the same across years. Starter ME average of 3.28 Mcal was used from the NRC (2001) because energy was the same for starter across all the studies. The NRC (2001) equations were used to calculate ME;

1) ME of milk replacer (Mcal) = [0.057 × crude protein (%) + 0.092 × Fat (%) + 0.0395 × Lactose (%)] × 0.9312, and
2) ME (Mcal) = 0.1 $BW^{0.75}$ + (0.84 $BW^{0.355}$ x $BWG^{1.2}$), where BW is body weight and BWG is BW gain.

First-lactation milk, fat, and protein production records for 3,627 cows of the original 4,534 calves were acquired from Dairy Records Management Systems (Raleigh, NC), and merged with body growth and protein and ME intake data from milk replacer and starter. The production data set included an additional 747 cows compared to a previous study with the same calves that analyzed the relationship between body weight and average daily gain and first-lactation milk production (Chester-Jones et al., 2017).

Table 1 has dry matter intake and average daily gain from milk replacer and starter, ME intake, protein intake, and first-lactation production of the 3 individual farms and across all the farms. All calves were managed the same at SROC, and therefore, similarities existed for growth rates and production from calves from different farms (Table 1).

Table 1. Holstein calf milk replacer, starter intake, body weight, average daily gain, and first-lactation production for all 3 Minnesota herds. All values are in pounds and ME is Mcal.

	Farm A (n =1,787)	Farm B (n =1,659)	Farm C (n =1,088)	All farms (n =4,534)
	Mean	Mean	Mean	Mean
8-week Milk replacer intake	48.5	48.9	48.5	48.7
8-week Starter intake	98.8	103.0	103.8	101.4
8-week Milk replacer protein intake	10.4	10.6	10.6	10.6
8-week Starter protein intake	20.3	21.2	21.4	20.9
8-week Combined protein intake	30.6	31.7	31.9	31.3
8-week Milk replacer ME intake	102.4	103.2	102.3	102.7
8-week Starter ME intake	146.8	153.3	154.4	151.0
8-week Combined ME intake	249.2	256.4	256.7	253.6
8-week average daily gain	1.4	1.5	1.5	1.43
305-day milk	22,948	25,051	24,599	24,132
305-day fat	818	972	886	891
305-day protein	708	787	732	743

Early life protein and ME consumption and growth

For milk replacer protein consumed, slight if any differences existed between average daily gain classes. The majority of the calves in this study did not consume more than 1.25 lb of milk replacer per day, and therefore, variation in milk replacer protein consumed was not expected. There were no differences for milk replacer protein consumed for calves that had average daily gain from 0.51 to 0.75 lb/day compared to calves that had average daily gain greater than 1.76 lb/day. Calves that had greater average daily gain in 8 weeks consumed more protein from calf starter compared to calves from the other average daily gain classes.

Table 2. Average daily gain class at 8 week for milk replacer and starter protein (lb) and ME (Mcal).

	0.50 to 0.75	0.76 to 1.0	1.01 to 1.25	1.26 to 1.5	1.51 to 1.75	> 1.75
	----------(lb/day)----------					
	Mean	Mean	Mean	Mean	Mean	Mean
Milk replacer protein	11.0[a]	10.4[bc]	10.4[c]	10.4[bc]	10.4[b]	10.8[a]
Starter protein	6.8[f]	11.5[e]	16.1[d]	20.1[c]	23.8[b]	28.7[a]
Combined protein	18.1[f]	22.0[e]	26.5[d]	30.4[c]	34.4[b]	39.7[a]
Milk replacer ME	108.2[a]	102.5[c]	101.6[c]	101.9[c]	102.2[c]	105.1[b]
Starter ME	49.5[f]	83.5[e]	117.1[d]	144.7[c]	172.6[b]	206.6[a]
Combined ME	158.9[f]	186.6[e]	219.0[d]	246.8[c]	275.2[b]	312.3[a]
[abcdefg] Means within the same row with different superscripts are different ($P < 0.05$)						

For milk replacer ME consumption, calves that had an average daily gain from 0.50 to 0.75 lb/day consumed more ME than calves in the greater average daily gain classes. There were only 58 calves in the lowest average daily gain class and the small number of calves and the higher standard deviation of those calves may have caused the differences reported between average daily gain classes. There were no differences from milk replacer ME consumed from average daily gain classes that ranged 0.76 to 1.0 lb/day. For starter ME consumption, calves that had the greatest average daily gain (> 1.75 lb/day) consumed the most (206.6 Mcal) starter ME compared to calves that had lower average daily gain. Similarly to combined protein, calves that consumed more combined ME from milk replacer and starter had greater average daily gain at 8 weeks of age. Generally, a calf that consumes more feed from starter has more protein and ME intake, so the relationship between dry matter intake and nutrient intake is highly correlated. Dairy farmers may achieve a younger age of puberty and first calving in heifers by manipulating pre-weaning diets and the amount of energy and protein consumed, without the risk of over conditioned calves and heifers (Gabler and Heinrichs, 2003; Lammers and Heinrichs, 2000; Brown et al., 2005).

Birth season and early life protein and ME consumption and growth

Calves born during the fall (28.7 lb) and winter (29.5 lb) consumed more combined protein than calves born during the spring (27.8 lb) and summer (28.0 lb). The calves born during the winter had the greatest consumption of protein intake compared with all other calves which was supported by a higher protein to ME ratio. The increase in combined protein intake was attributable to increased starter intake during the fall and winter season. For ME intake, calves born during the winter had greater ME intake compared to calves born during the spring, summer, and fall. The combined ME intake follows that of starter protein intake, and calves born during the fall and winter consumed more ME than calves born during the spring and summer. Increased consumption of protein and ME is observed in calves during the fall and winter to maintain or increase growth in cold weather (Kuehn et al., 1994), which was found in the current study. Calves may require more energy for maintenance in harsher environments.

Early life protein consumption and first lactation performance

Calf milk replacer protein, starter protein, and combined protein intake at 6 and 8 weeks and the effect on first-lactation 305-d milk, fat, and protein production are in Table 3. Milk replacer protein consumption at 6 and 8 weeks did not have an effect on

305-d milk, fat, and protein production during first lactation. Six- and eight-week starter protein had a positive relationship with first lactation 305-d fat and protein production. Each additional lb of calf starter protein intake at 8 week resulted in 2.89 lb and 2.91 lb more 305-d fat and protein production, respectively. Starter protein intake had a tendency to affect 305-d milk production in first lactation. However, 6 and 8 week combined protein intake had a positive relationship with 305-d milk, fat, and protein production in first lactation. For every 1 lb increase in combined protein intake at 8 week of life, milk production increased by 57.4 lb, fat increased by 3.04 lb, and protein increase by 2.93 lb in 305-d in first lactation (Table 3).

Perhaps, a combination of high protein in milk replacer and calf starter contributes to increased production in 305-d compared to milk replacer or calf starter protein alone. Differences observed between 6 and 8 weeks may be due to management practices after weaning or adjustment for calves after weaning at 6 weeks. Gelsinger et al. (2016) reported that management on the farm may have a greater influence on first-lactation production than nutrition and growth prior to weaning. Although, the combined protein intake of calves through the first 8 week of life had an effect on first lactation production, considerable variation exists in the relationship between combined protein intake at 8 weeks of age and 305-d milk production.

Table 3. Regression coefficients for calf milk replacer protein, starter protein, and combined protein intake at 6 week and 8 week for the effect on first-lactation 305-d milk, fat, and protein production (n=3,627).

Variable	Week	Milk replacer protein Estimate	Starter protein Estimate	Combined protein Estimate
305-d milk	6	85.6	69.5	86.4
305-d fat	6	2.8	4.4	4.5
305-d protein	6	1.6	4.3	4.1
Variable	Week			
305-d milk	8	76.3	50.5	57.4
305-d fat	8	3.1	2.9	3.0
305-d protein	8	3.3	2.9	2.9

Table 4. Regression coefficients for calf milk replacer ME, starter ME, and combined ME intake (Mcal) at 6 week and 8 week for the effect on first-lactation 305-d milk, fat, and protein production (n=3,627).

Variable	Week	Milk replacer ME (Mcal) Estimate	Starter ME (Mcal) Estimate	Combined ME (Mcal) Estimate
305-d milk	6	4.31	1.99	2.95
305-d fat	6	0.15	0.12	0.14
305-d protein	6	0.11	0.12	0.14
Variable	Week			
305-d milk	8	3.63	1.43	1.80
305-d fat	8	0.15	0.08	0.09
305-d protein	8	0.09	0.08	0.09

Early life ME consumption and first lactation performance

The milk replacer ME intake did not have an effect on 305-d milk, fat, or protein production; however, the starter ME intake had a positive effect on 305-d fat and protein production. Six and 8 week combined ME intake had a positive relationship with 305-d milk, fat, and protein production in first lactation. For every 1 lb increase in combined ME intake at 8 week of life, milk production increased by 3.96 lb, fat increased by 0.20 lb, and protein increase by 0.20 lb in 305-day in first lactation (Table 4).

Birth season and early life protein and ME consumption and first lactation performance

The effects of birth season on 8-week milk replacer and starter protein and ME intake are in Table 5. Calves born during the fall and winter consumed more combined protein than calves born during the spring and summer at 8 weeks of age. Differences were not observed between calves born during the fall and winter for combined protein or ME intake at 8 weeks of age.

The ME and protein consumed from milk replacer and starter and its effects on first-lactation production indicate that both milk replacer and starter are important components in the pre-weaned calf diet. Both combined protein and combined ME are meaningful when it comes to increasing 305-d milk and component production. Birth season plays a role in how much protein and ME is consumed by calves, suggesting that supplementing calf diets with more energy and protein may be beneficial for the calf during colder weather to maintain energy requirements. When planning a feeding program for dairy calves, the current study suggests that both milk replacer and starter have an effect on the calf through first-lactation production. Further investigation is needed to compare current NRC (2001) requirements to what calves are consuming and how it correlates to average daily gain and calf growth.

Table 5. Effect of birth season on 8 week milk replacer (MR) and starter protein (lb) and ME (Mcal) and first-lactation 305-d milk production (n=3,627)

Variable	Spring	Summer	Fall	Winter
8 week MR protein intake	10.4^{ab}	10.4^{a}	10.1^{b}	10.4^{a}
8 week Starter protein intake	19.8^{b}	20.1^{b}	22.5^{a}	22.5^{a}
8 week Combined protein intake	30.4^{b}	30.6^{b}	32.6^{a}	32.8^{a}
8 week MR ME intake (Mcal)	101.8^{a}	101.5^{a}	100.2^{b}	102.9^{a}
8 week Starter ME intake (Mcal)	143.6^{b}	144.9^{b}	162.9^{a}	162.8^{a}
8 week Combined ME intake (Mcal)	245.9^{b}	246.8^{b}	262.9^{a}	265.8^{a}
305-d milk (lb)	$24,116^{ab}$	$24,343^{a}$	$24,134^{ab}$	$23,878^{b}$
305-d fat (lb)	886^{bc}	900^{ab}	907^{a}	874^{c}
305-d protein (lb)	736^{bc}	746^{a}	746^{ab}	731^{c}

^{abc}Means within the same row with different superscripts are different ($P < 0.05$)

Conclusions

Calves fed a 20:20 milk replacer at a rate of 1.25 lb/day had higher intake of both milk replacer and starter protein and higher intake of both milk replacer and starter ME during the first 8 weeks of life had higher average daily gain. A combination of both early life milk replacer and starter protein and ME intake positively affected 305-d first-lactation performance. However, variance was high in all the estimates suggesting additional factors may affect growth to 8 week of age.

intake				
8 week MR ME intake (Mcal)	101.8[a]	101.5[a]	100.2[b]	102.9[a]
8 week Starter ME intake (Mcal)	143.6[b]	144.9[b]	162.9[a]	162.8[a]
8 week Combined ME intake (Mcal)	245.9[b]	246.8[b]	262.9[a]	265.8[a]
305-d milk (lb)	24,116[ab]	24,343[a]	24,134[ab]	23,878[b]
305-d fat (lb)	886[bc]	900[ab]	907[a]	874[c]
305-d protein (lb)	736[bc]	746[a]	746[ab]	731[c]

[abc] Means within the same row with different superscripts are different ($P < 0.05$)

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