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Nutrition at Early Stages of Life Determines the Future Growth and Reproductive Performance of Dairy Calves[1]

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Introduction

Studies suggest that improper nutrition in humans immediately after birth may substantially increase the risk for developing obesity, type 2 diabetes, hypertension, and heart disease during adulthood (Lucas 1991). These events occur because a significant portion of organ development is not complete at birth; it continues for the first few months of life. For a calf, nutrition during the first few months of its life may permanently change the way organs develop and then have long-term consequences. This process is called metabolic imprinting (Lucas 1991). The concept that metabolic imprinting may permanently affect animal development has substantial economic implications for agriculture, and it should be explored if producers want to improve the performance of animals destined for food production. This fact sheet will summarize some of the research conducted in calf nutrition and its impact on the growth and reproductive performance of dairy calves.

Newborn Dairy Calf Nutrition

Dairy calves are born with a naïve adaptive immune system. They have very low concentrations of immunoglobulins and antigen-specific immune cells that aid in recognition and elimination of pathogens. Pathogen-specific immunity of the young calf is acquired from the dam via colostrum. Thus, colostrum intake following birth is crucial to reduce morbidity and death of dairy calves (USDA 2007).

Colostrum production begins 5 weeks before calving. Its composition differs from that of whole milk in that it contains more protein, immunoglobulins (Ig), fat, and vitamins A and E (Davis and Drackley 1998). Proper colostrum management includes provision of colostrum (IgG concentrations above 50 g/L; fewer than 100,000 colony forming units/mL) at 10% of a calf's body weight (as-fed basis) within 6 hours after birth (USDA 2007). This is equivalent to feeding 1 gallon of colostrum per calf. When those guidelines are not followed, calves do not have adequate immune protection and are more susceptible to disease. For instance, dairy calf mortality during the first 56 days following birth is 2% when calves are provided colostrum containing more than 10 g/L of IgG, but it increases to 8% if calves are given colostrum with fewer than 10 g/L of IgG (USDA-NDHEP 1993).

In addition to influencing calf survival and health, colostrum intake during the first hours of a calf's life also impacts its future performance. For instance, calves consuming 3.6 quarts of colostrum at birth had 16% greater milk production during their second lactation compared to dairy calves given 1.8 quarts of colostrum at birth (Faber et al. 2005). The exact mechanisms by which greater colostrum intake enhanced milk production of dairy cows 2 years later are unknown, but they are likely attributed to metabolic modifications induced by colostrum constituents, such as insulin-like growth factor 1, insulin, growth hormone, leptin, and prolactin (Faber et al. 2005;

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Bach 2012). Although the concentration of hormones and growth factors in whole milk is less than in colostrum (Table 1), it is possible that hormones and growth factors present in whole milk but absent in milk replacer have imprinting effects on the metabolism of calves. Milk production increased by 4 to 13% when calves consumed whole milk instead of milk replacer during the first 45 to 60 days of life (Shamay et al. 2005; Moallem et al. 2010).

Conventional and Intensified Nutrition Methods of Dairy Calves

During the first 45 to 60 days following birth, conventional methods of dairy calf feeding provide relatively low amounts of milk or milk replacer (approximately 10% of calf body weight, as-fed; crude protein and fat concentration = 20 to 22% of dry matter) in order to stimulate the early consumption of concentrate, and consequently, ruminal development (Khan et al. 2007). However, industry focus on "accelerated growth" or "intensified nutrition" in dairy calves has increased substantially during the last decade. Intensive nutrition methods utilize milk replacer with greater concentrations of protein and less fat (20 to 30% crude protein and less than 20% fat; dry matter basis) that is fed at approximately 20% of calf body weight as-fed (Brown, Vandehaar, and Daniels 2005; Khan et al. 2007; Tikofsky, Van Amburgh, and Ross 2001), which is similar to the milk consumption of 4-week-old suckling calves (Hafez and Lineweaver 1968).

The intensified nutrition methods increased lean tissue growth and efficiency of body weight gain (Diaz et al. 2001; Tikofsky, Van Amburgh, and Ross 2001; Rius et al. 2012), and enhanced puberty achievement and future milk production (Brown, Vandehaar, and Daniels 2005; Raeth-Knight et al. 2009; Moallem et al. 2010; Soberon and Van Amburgh 2013). For instance, heifers provided with intensive nutrition had a 45% increase in average daily gain from 2 to 42 days of age, and were 29 days younger at puberty compared with heifers given conventional milk replacer (Davis-Rincker et al. 2011). In this study, the conventional diet consisted of a standard milk replacer (22% crude protein and fat) fed at 1.2% of body weight on a dry matter basis, and starter grain (20% crude protein). The intensive diet consisted of a high-protein milk replacer (31% crude protein and 16% fat) fed at 2.1% of body weight on a dry matter basis, and starter grain (24% crude protein). The decreased age at puberty of heifers that received intensive nutrition was observed despite all heifers having a similar body weight as conventionally fed heifers from 12 to 100 weeks of age, which suggests that enhanced nutrition prior to 8 weeks of age had imprinting effects on their reproductive axis and accelerated their puberty achievement.

Enhancing the growth rate of heifers by feeding high-energy diets may decrease age at calving and costs associated with raising replacement. However, a common concern among dairy producers and nutritionists is the accumulation of fat within mammary gland cells due to excessive weight gain. The mammary gland grows at a faster rate than the whole body from 3 to 10 months of age. Consequently, feeding amounts that result in average daily gain above 1.3 to 1.5 lb/day may reduce mammary parenchyma mass, enhance fat accumulation in the mammary gland, and decrease subsequent milk production (Sejrsen et al. 2000). However, enhancing the plane of nutrition of calves prior to 60 days of age decreased age at calving without impairing mammary gland growth and milk production. In fact, intensive calf nutrition from birth to 60 days of age enhanced mammary gland growth and milk production at first lactation. Holstein heifers assigned to receive high levels of protein and energy (30% crude protein and 16% fat; provided at 2.0% of body weight on a dry matter basis) from 7 to 49 days of age had greater total parenchyma tissue mass (indicator of mammary gland growth) compared with heifers provided with milk replacer that contained moderate levels of protein and energy (21% crude protein and fat; fed at 1.1% of body weight on a dry matter basis) (Brown, Vandehaar, and Daniels 2005). In addition, a summary of 9 studies demonstrated that daily milk production during first lactation is increased by 326 lb/day for every 0.25 lb/day increment on preweaning average daily gain (ADG) is enhanced (Gelsinger, Heinrichs, and Jones 2016). In addition, this summary also reported that preweaning ADG seemed to minimally affect milk production when growth rate was below 1.1 lb/day, but had a greater influence as growth rate increased from 1.1 to 2.0 lb/day.

Economics of Accelerated Growth Programs

As discussed above, increasing preweaning growth rate may improve future milk production. However, this increment in milk production may not offset the cost of the increased milk or milk replacer intake necessary to achieve greater calf ADG (Heinrichs and Gelsinger 2017).

The following example assumes that milk price does not change from the time of weaning until first calving. For more details about the economic return of increasing preweaning growth rate, please refer to Heinrichs and Gelsinger (2017). Consider the example of increasing calf ADG from 1.1 to 1.3 lb/day (Gelsinger, Heinrichs, and Jones 2016). An additional ADG increase of 0.2 lb/day required feeding an additional 12.8 lb of a 20:20 milk replacer, 12.3 lb of an accelerated milk replacer (27:17), or 10.4 gallons of milk during a 56-day preweaning period. Assuming a cost of $80 per 50-lb bag of 20:20 and $100 per 50-lb bag of accelerated milk replacer, and milk value of $18/cwt, the cost of increasing preweaning ADG from 1.1 to 1.3 lb/day was $20.45 (if using 20:20 milk replacer), $24.53 (27:17 if using an accelerated milk replacer), or $16.14 (if using saleable milk) per calf (Heinrichs and Gelsinger 2017). The cost significantly decreased to $4.04/calf if using waste milk (valued at $4.50/cwt). However, the expected increase in milk income from these heifers was only $3.09/heifer. Positive returns of increasing preweaning growth rate were achieved if enough waste milk was provided to increase preweaning ADG from 1.1. to 1.5 lb/day or 1.5 to 2.0 lb/day (Table 3).

Achieving the gains mentioned above is far less expensive if using calf starter. Hence, grain feeding is less costly than milk feeding, and the ADG outcomes are the same. Increasing heifer preweaning growth rates, regardless of the feeding strategy, may decrease age at calving and further improve economic return.

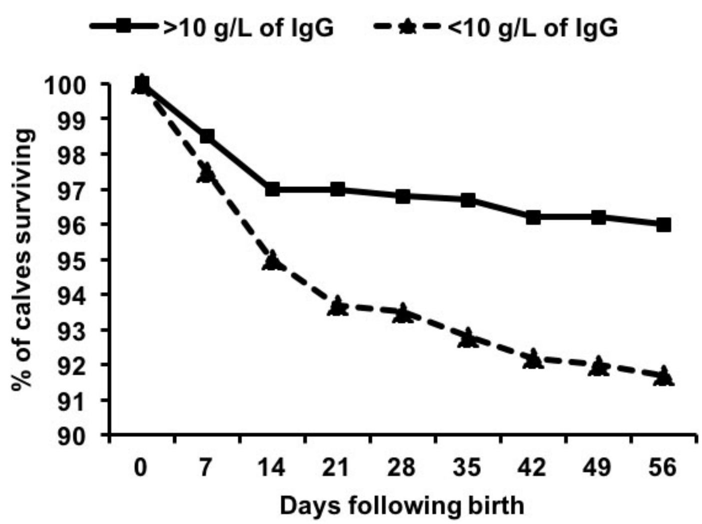

Figure 1. Survival rate of calves provided colostrum with more or less than 10 g/L of immunoglobulin G, IgG.
Credits: USDA-NDHEP (1993)

In summary, nutrition prior to weaning (1 to 45 to 60 days of age) may determine the future performance of dairy calves. Good quality colostrum management is required to maximize health, but it also impacts the growth and reproductive performance of calves. Providing an intensive nutritional method by increasing the amount and nutritional composition of milk replacer and calf starter provided from birth to weaning enhances preweaning growth performance, anticipates puberty achievement, and increases future milk production without impairing mammary gland growth.

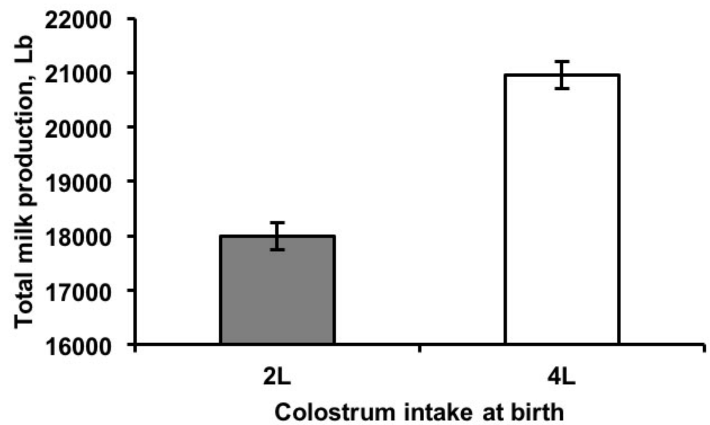

Figure 2. Milk production during second lactation of dairy cows fed 2 or 4 L of colostrum at birth time.
Credits: Faber et al. (2005)

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Table 1. Chemical composition of colostrum, transition milk from second milking, and saleable milk.

		Transition Milk:	
Item	**Colostrum**	**Second Milking**	**Saleable Milk**
Immunoglobulin G, g/L	41	25	0.6
Fat, %	6.7	5.4	3.6
Total protein, %	14.9	8.4	3.2
Lactose, %	2.5	3.9	4.9
Vitamin A, ug/g	4.9	1.8	0.3
Adapted from Foley and Otterby (1978), Davis and Drackley (1998), and Kehoe, Jayarao, and Heinrichs (2007).			

Table 2. Average daily gain (lb/day) and age at puberty (days) of heifers given conventional and intensive nutritional methods from 2 to 42 days of age.

	Nutritional Method	
Item	**Conventional**	**Intensive**
Average daily gain, lb/day	0.97	1.41
Age at puberty, days	271	300
Conventional diet consisted of a standard milk replacer (22% crude protein and fat) fed at 1.2% of body weight on a dry matter basis and starter grain (20% crude protein). Intensive diet consisted of a high-protein milk replacer (31% crude protein and 16% fat) fed at 2.1% of body weight on a dry matter basis and starter grain (24% crude protein). Adapted from Davis-Rincker et al. (2011).		

Table 3. Estimated feed cost and value of additional milk produced in the first lactation if preweaning growth rate was increased by feeding more milk or milk replacer.

	Change in Growth Rate (lb/day)		
Item	**1.1 to 1.3**	**1.1 to 1.5**	**1.5 to 2.0**
Increased feed cost to support greater preweaning growth rate			
Milk replacer ($80/50 lb)	$20.45	$41.92	$45.73
Accelerated milk replacer ($100/50 lb)	$24.53	$50.26	$54.83
Saleable milk ($18/cwt)	$16.14	$33.08	$36.09
Waste milk ($4.50/cwt)	$4.04	$8.27	$9.02
Estimated increase in milk yield (lb/lactation)	17.2	57	147.7
Value of additional milk ($18/cwt)[1]	$3.09	$10.26	$26.58
Additional milk values minus increased feed cost[2]			
Milk replacer ($80/50 lb)	$(17.36)	$(31.66)	$(19.15)
Accelerated milk replacer ($100/50 lb)	$(21.44)	$(40.00)	$(28.25)
Saleable milk ($18/cwt)	$(13.05)	$(22.82)	$(9.51)
Waste milk ($4.50/cwt)	$(0.95)	$1.99	$17.56
[1] Assumes same value for milk that is fed and milk that is sold. [2] Does not include possible benefits from earlier age at first breeding/calving. Adapted from Heinrichs and Gelsinger (2017).			

Table 4. Estimated feed cost and value of additional milk produced in the first lactation if preweaning growth rate was increased by feeding more calf starter.

	Change in Growth Rate (lb/day)		
Item	**1.1 to 1.3**	**1.1 to 1.5**	**1.5 to 2.0**
Total calf starter for greater preweaning ADG (lb/day)	2.63	3.22	4.48
Additional calf starter (lb for 56 days)	30.8	63.8	70.6
Cost of calf starter ($/calf)	$5.56	$11.45	$12.72
Estimated change in milk yield (lb/lactation)	17.2	57	147.7
Value of additional milk ($18/cwt)	$3.09	$10.26	$26.58
Value of additional milk minus cost of calf starter ($/calf)	$(2.47)	$(1.19)	$13.86

[1] Calf starter assumptions: 88% DM, 18% CP, 3.28 Mcal/kg, 57% available nutrients; cost = $0.18/lb.
[2] Assuming all maintenance requirements are met by milk or milk replacer and all growth requirements are met by calf starter.
Adapted from Heinrichs and Gelsinger (2017).