The Other Side of the Transition: Effects on Colostrum and Calf

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Over the last 25 yr, extensive research has been conducted on the biology, nutrition, and management of dairy cows during the transition from gestation to lactation. The focus of this research has been to minimize the occurrence of health problems around parturition and to maximize subsequent milk production. Very little attention has been paid to potential effects of different nutritional programs on quantity or quality of colostrum produced at calving, or on the viability or subsequent performance of calves born to cows fed differently during late gestation. This lack of research is unfortunate because dairy producers often report situations where cows calve with too little colostrum to feed to their calves. Likewise, producers may claim that feeding too much energy during the close-up period produces larger calves. What is the scientific evidence that these phenomena actually occur?

The objective of this paper is to outline the potential issues and to briefly summarize what is known about the topics. Because of the paucity of data, the paper will be more speculative than review and will attempt to point to where research effort is needed.

Colostrum Volume and Quality

Colostrum is formed by synthesis of components within the mammary gland and by transfer of preformed immunoglobulins (primarily IgG) and other proteins into the secretions with the gland. The IgG1 immunoglobulins are transported into mammary cells from the blood, against a concentration gradient, by specific transporter proteins (Larson et al., 1980). Other classes of antibodies, including IgG2, do not seem to be concentrated in the mammary cells (Larson et al., 1980). In addition to the high concentration of maternal antibodies, colostrum contains a rich supply of nutrients for the calf (Foley and Otterby, 1978), as well as a host of growth factors and hormones (Blum and Baumrucker, 2008).

The concentration of immunoglobulins in colostrum (i.e., colostrum quality) is highly variable among cows, even within the same herd. Likewise, the volume of colostrum produced also is highly variable. The total mass of immunoglobulins accumulated within the mammary gland during late gestation and around calving is independent of colostrum volume, but even this measure is widely variable among cows (Baumrucker et al., 2010). The timing of secretory cell activation and the interval between calving and removal (milking) of colostrum affect dilution of the colostral immunoglobulins and thus both colostrum volume and quality; however, mass transfer of IgG1 into colostrum does not appear to be related to mammary gland size (Baumrucker et al., 2010).

There is little evidence that nutrition plays a large role in either the volume of colostrum synthesized or in colostrum quality in cattle (Halliday et al., 1978). In contrast, Banchero et al. (2006)

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found that colostrum accumulation to parturition was lower in ewes that were underfed energy [70% of metabolizable energy (**ME**) requirements] compared with adequately fed ewes (110% of ME required), although after parturition the difference narrowed. While inadequate supply of metabolizable protein is often suspected or implicated in low colostrum production, there do not appear to be any scientific studies that demonstrate such an effect.

In a recent study, neither colostrum volume nor IgG concentration were affected by feeding to requirements versus overfeeding (Richards et al., 2009). These results were confirmed in a subsequent study (Table 1; Vasquez et al., 2001, unpublished).

In the author's experience, most reports of low colostrum volume occur during late summer through fall. Such "outbreaks" usually are not specifically related to any particular dietary regime. This suggests that photoperiod or residual effects of heat stress might be related to low colostrum production. However, cows housed under different lighting regimes during the dry period did not differ in either amount or quality of colostrum produced (Morin et al., 2010). Heat stress effects on colostrum formation are not well documented.

In summary, there is little evidence to indicate that under- or overfeeding in the range likely to be found in the industry has an repeatable effect on colostrum volume or quality. Likewise, photoperiod does not appear to have a strong influence. Thus, causes and frequency of low colostrum volume remain undefined.

Effects of Prepartum nutrition on Calf Size and Viability

A common perception among producers is the higher rates of feeding during the dry period will result in heavier and larger calves at birth. However, research does not, in general, support such a relationship. Research on effects of maternal protein or energy restriction has been more abundant in beef cattle than in dairy cows. In general, this work provides little evidence that underfeeding or either energy or protein will affect calf birth weight (Davis and Drackley, 1998. Over the last 15 years, we have conducted a number of studies in which intakes of energy were varied greatly between slight undernutrition and substantial excess. These studies, representing over 360 calvings, have found little relationship between maternal plane of nutrition and calf birth weight (Table 2).

There is considerably stronger evidence, however, that physiological function may be altered by differences in maternal nutrient supply during late gestation. For example, underfeeding of either energy (Ridder et al., 1991) or protein (Carstens et al., 1987) during late gestation in beef cattle resulted in calves that were less able to generate heat to maintain body temperature after birth. These effects occurred despite no significant difference in birth weight. It should be noted, however, that the degree of restriction was quite severe; energy supply varied from 70 to 40% of requirements (Ridder et al., 1991) and protein supply was only 65% of requirements (Carstens et al., 1987). Such extremes should be rarely encountered in dairy production. We have begun to investigate effects of dry period plane of nutrition on the neonatal calves (Osorio et al., 2010), but effects are so far inconclusive.

Dystocia (difficult calving) is well-known to increase calf mortality (Peeler et al., 1994) and to negatively affect the viability of the young calf. Vermorel et al. (1989) found that calves born after difficult labor had lower body temperatures, were less able to regulate body temperature, and had lower IgG concentration in blood after consumption of the same amount of the same pooled colostrum compared with calves born in normal births. Cows that are overconditioned at calving are more likely to have difficult births, largely due to excessive fat deposits around the birth canal (Meijering, 1984).

We have recently shown that overfeeding, even during an 8-wk period such as the dry period, results in substantial internal fat deposition in Holstein cows, including around the reproductive tract (Nikkhah et al., 2008).

Effects of Prepartum Nutrition on Long-Term Metabolism and Production of Calves

One of the most exciting current areas of research is to understand the long-term and later-life consequences of different maternal nutrient and environmental conditions during gestation on the offspring. This is an area of intense activity in human biomedical research and has begun to increase in dairy cattle research as well. The concept of "metabolic programming" or "imprinting" (Patel and Srinivasan, 2002) has been discussed for some time. For example, the "pup in a cup" model, in which neonatal rat pups were artificially reared with different milk compositions, showed that pups raised on a low-fat, high-carbohydrate milk had higher body weight **(BW)**, higher insulin, lower glucose tolerance, increased lipogenic capacity in liver and adipose, and lower glycogen synthase activity in muscle as adults. Perhaps more remarkable is that pups born to *these* rats had the same characteristics as adults, despite the fact that they never received the high-carbohydrate milk. This indicates that the nutrition-induced characteristics in the first generation were somehow transmitted to their offspring. Such findings, of course, have important current implications in the worsening problem of human obesity and insulin resistance.

More recently, the explosion of the field of "epigenetics" has established mechanisms for such imprinting or metabolic programming effects. Epigenetic effects are mediated by alterations of chromatin that silence or enhance expression of genes by changing accessibility to the cellular transcription machinery (Szyf et al., 2007). The alterations are carried out by specific enzymes that add or remove methyl groups or acetyl groups from specific regions of the deoxyribonucleic acid **(DNA)** and chromatin proteins. These changes are dynamic and potentially reversible, and so may represent opportunities for intervention or manipulation.

There are a number of examples of these phenomena in ruminant animals, although few yet in dairy cows. Maternal feed restriction (50% of requirements) between 110 days and term in ewes did not affect lamb birth weight or average daily gain to 1 year of age but markedly disturbed insulin secretion and response in the lambs (Gardner et al., 2005). Maternal restriction (50% of requirements) from day 30 to 70 of gestation in ewes did not affect lamb birth weight but decreased final BW at 24 wk (Daniel et al., 2007). In beef heifers, protein supplementation (50% of requirements) during late gestation did not affect calf birth weight but increased pre-breeding BW and increased conception rate (Martin et al., 2007). In an experiment that demonstrated the potential impact of differences in methylation around conception, Sinclair et al. (2007) restricted dietary supply of sulfur and cobalt before and around mating. This decreased the availability of methionine, vitamin B12, and folate, which are involved in methyl group metabolism. The methylation status of DNA was decreased in the restricted ewes, but this did not affect pregnancy rate or lamb birth weight. However, the female lambs in adulthood were heavier and fatter, had altered immune responses to antigenic challenges, were insulin-resistant, and had elevated blood pressure (Sinclair et al., 2007). It is not difficult to think of potential situations, then, where differences in nutrient supply to cows might affect the viability, health, production, or reproduction of their calves as they grow into adult cows. How much of the change in characteristics of our dairy cows over time might be attributable to these non-genetic effects of environment?

Conclusions

Differences in nutrient supply during the dry period and transition period are neither likely to have important effects on colostrum supply or quality, nor on calf birth weight. While effects of nutrient supply can be demonstrated in research, the severity of the deficiencies is generally much larger than encountered in practice. Dystocia, which may be increased by fattening or overfeeding, does negatively impact calves. An exciting future area of investigation involves trying to elucidate long-term consequences of nutrition and environment at critical times around conception and during gestation on the calf as she grows into a mature cow.

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Table 1. Colostrum production and quality in Holstein cows fed a single-group controlled-energy, high-fiber diet (CEHF) or a two-group far-off plus close-up (CU) diet during the dry period (Vasquez et al., 2011, unpublished).

	Diet		
Variable	CEHF	CU	SE
First milking colostrum, kg (lb)	5.51 (12.1)	6.12 (13.5)	0.52 (1.1)
Colostral IgG, g/L	76.1	63.1	7.2
Total IgG secreted in first colostrum, g	390	373	43

Table 2. Effect of maternal dry period nutrition programs varying in net energy (NE_L) supply on birth weight of calves.

Study and dry period treatments[1,2]	NE_L, % of NRC requirement[1]	Calf birth BW (lb)	*P*
Grum et al., 1996			
Control	108	97.0	> 0.50
High fat	103	91.7	
High grain	140	93.5	
Douglas et al., 2006			
Ad libitum, moderate grain	157	96.6	0.94
Ad libitum, moderate fat	161	95.9	
Restricted, moderate grain	81	93.7	
Restricted, moderate fat	81	95.3	
Dann et al., 2005			
Ad libitum intake	142	94.2	0.28
Restricted intake	85	98.1	
Dann et al., 2006			
CEHF/Ad lib CU	93/147	96.8	> 0.61
CEHF/Restricted CU	93/80	93.5	
Ad lib FO/Ad lib CU	160/135	92.2	
Ad lib FO/Restricted CU	160/72	92.8	
Restricted FO/ Ad lib CU	77/126	92.4	
Restricted FO/Restricted CU	77/83	90.9	
Richards et al., 2009			
Ad libitum, moderate grain	149/129	88.2	0.57
CEHF	93/93	92.8	
CEHF/Ad libitum moderate grain	84/119	90.0	
Janovick and Drackley, 2010			
CEHF	97	94.8	0.50
Ad libitum, moderate grain	137	98.8	
Restricted, moderate grain	78	101.4	
Vasquez et al., 2011 (unpublished)			
CEHF	97	93.9	0.09
CEHF/CU	96/142	99.2	

[1] Where different treatments were applied during far-off and close-up periods, they are separated by a "/".

[2] CEHF = controlled-energy, high-fiber; CU = close-up; and FO - far-off period.