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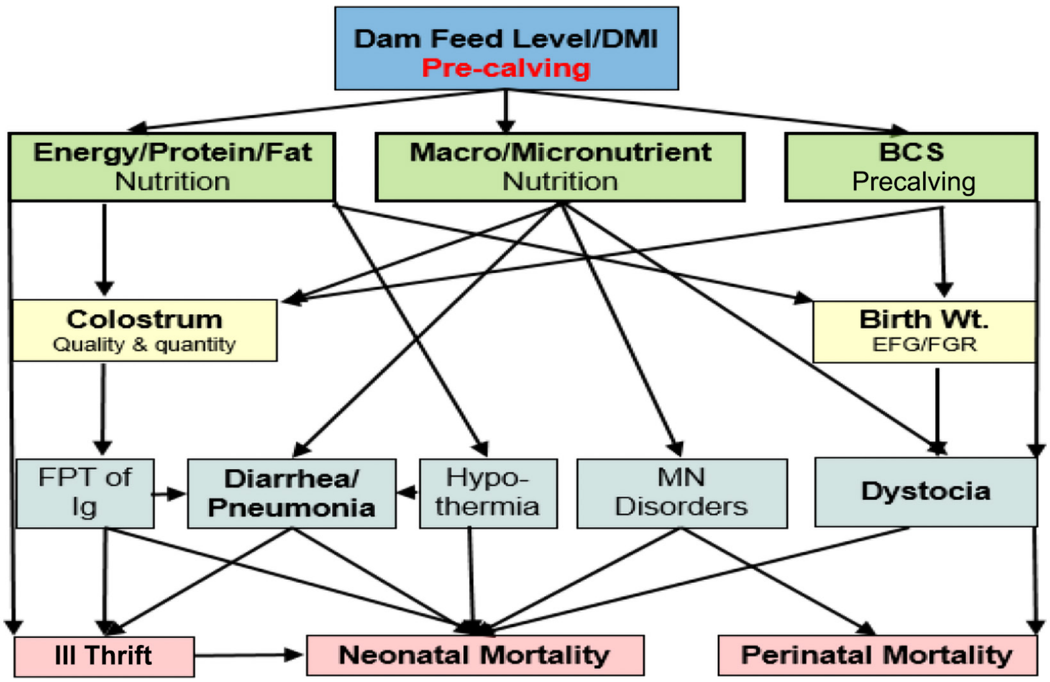
Symposium Review
Health, Behavior, and Well-being

Impacts of dairy cow nutrition precalving on calf health*

J. F. Mee†

Graphical Abstract

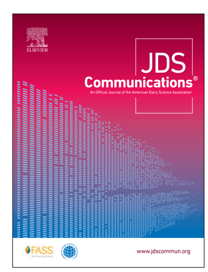


Summary

The transgenerational metabolic-disease complex is shown. DMI = dry matter intake; BCS = body condition score; EFG = excessive fetal growth; FGR = fetal growth restriction; FPT = failure of passive transfer of immunoglobulin (Ig); MN = macro/micronutrient, ill thrift = slower growth rate than expected given feed allocation; birth wt. = birth weight. The arrows imply "associated with" and the text uses key words to highlight components of the complex.

Highlights

- Once dietary energy, protein, and micronutrient requirements are met, prepartum BCS and feeding of the dairy cow have a limited impact on colostrogenesis.
- Maternal nutrition that leads to fetal oversize, bradytocia, dystocia, micronutrient imbalance, or hypothermia increases the risk of perinatal calf mortality.
- Inadequate maternal dietary energy, protein, and micronutrient status can affect young calf immunity and health.



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Impacts of dairy cow nutrition precalving on calf health*

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Abstract: This mini-review focuses on the effects of gestational dairy cow nutrition on calf health as mediated through colostrogenesis and calf immunity, morbidity, and mortality. The nutritional adequacy of the forage and supplementary diet and the metabolic status and body condition score of the dam can affect calf health. The mechanism of action of such impacts include maternal nutritional imbalances or deficiencies causing dyscolostrogenesis, nutritionally mediated calf ill health, and fetal programming impacts on calf health.

The impacts of maternal nutrition on calf health are mediated indirectly through effects on colostrum and fetal programming, and also directly through perinatal vigor, neonatal immunity, and ultimately health. The concept of the nutritional and metabolic status of one generation affecting the health and disease status of the subsequent generation may be described as the trans-/multi-generational metabolic-disease complex (Mee, 2014). Producers may be "blind" to these occult interactions (Mee, 2020).

Only limited data are available on the effects of maternal precalving BCS or BCS change on colostrogenesis. There was no difference in colostrum immunoglobulin (**Ig**) content between dairy cows in high or low BCS precalving in one study (Bland et al., 2007) but in another study dairy cows in higher BCS had higher colostrum Ig content (Smith and Stockdale, 2004), and paradoxically, calves from thin dairy cows (BCS <3 on a 5-point scale) tended to have higher serum Ig values in another study (Immler et al., 2022). Regarding BCS change, Shearer et al. (1992) showed that when dairy cow BCS increased between dry off and calving (compared with remaining stable or decreasing), colostrum Ig content was higher. However, Mann et al. (2016) found that dry dairy cows that gained the most BCS (0.27 units) and BW (90.4 kg) precalving had the lowest colostral Ig content (72.4 g/L), with no effect on colostrum yield (7.0 kg). Conversely, dairy cows that lost BW (>20 kg) during the dry period were 4 times more likely to have colostrum with lower IgG concentrations (Mulder et al., 2018).

Only a limited number of studies are available on the effects of precalving feeding of dairy cows on colostrum quantity and quality; most studies are in beef cows on severe energy or protein restriction, which may not be applicable to dairy cows. In general, the ability to significantly alter colostrum yield or quality by dietary means is limited once the metabolizable energy and protein requirement of the cow are met but not unmet or exceeded (the "Goldilocks principle"). In agreement, Dunn et al. (2017) found no relationship between dry dairy cow nutrition (on grass-silage-based diets) and colostral Ig concentration. However, a possible benefit of a pasture-based diet on colostrum quality was reported by Gulliksen et al. (2008) who found that dairy cows calving during the months following the pasture season had higher quality colostrum (as assessed by single radial immunodiffusion) than cows calving during other seasons.

Recently, Mann et al. (2016) showed that feeding dairy cows a diet that meets their energy and protein requirements during the dry period increased colostrum IgG content compared with cows fed 150% of energy requirements, with no differences in colostrum yield. In contrast, a study in dairy cattle on a grass-silage diet found increased colostrum yield in cows supplemented with concentrates compared with those fed grass-silage alone (Dunn et al., 2017). However, a negative correlation was found between amount of concentrates fed to dairy cows precalving and colostrum IgG content by Gulliksen et al. (2008) attributed to a possible dilution effect with increased colostrum yield. Earlier studies by Smith and Stockdale (2004) found a similar effect with increasing energy intake/plane of nutrition during gestation. Previous studies had shown no effect of altering dietary energy content or restricting DMI during the dry period (Nowak, et al., 2012) on colostrum or dairy calf serum IgG, IgA, or IgM (d 3 and 21).

Numerous dairy cow studies (Santos et al., 2001; Bland et al., 2007; Toghyani and Moharrery, 2015) found no effect of diet CP content on colostrum volume, IgG content, or calf IgG. However, Smith and Stockdale (2004) found that increasing dietary CP content increased colostrum IgG content. But, Van Hese et al. (2021) reported that calves receiving colostrum from high CP-fed dairy cows had significantly lower serum IgG concentrations than those from cow fed a low CP-fed diet, whereas Toghyani and Moharrery (2015) found the opposite. A recent study feeding ruminally protected AA to dairy cows (from 21 d before expected calving date) showed that protected lysine and methionine diets increased colostrum total protein content (Brix units) and calf serum total protein and IgG (0–7 d) and ADG (up to weaning at 60 d; Wang et al., 2021). Feeding mannan oligosaccharide prepartum to dairy cows (for a minimum of 4 wk precalving) has been shown to increase colostrum yield, but not IgG content with no significant effects on calf ADG or health (up to weaning at 8 wk; Westland et al., 2017). However, another study found that supplementing the diet of precalving dairy cows (for 3 wk precalving) with mannan

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oligosaccharides tended to improve calf colostrum-derived rotavirus antibody titers in response to maternal vaccination (Franklin et al., 2005).

Trace mineral supplementation has been shown to alter colostrum quality in dairy cows, but responses may be dependent upon both the individual trace minerals and their formulation. Selenium supplementation of the precalving dairy cow diet has been shown to increase (Pavlata et al., 2004), decrease (Leyan et al., 2004), or have no effect on (Mohrekesh et al., 2019) colostrum Ig. Chromium-methionine supplementation (during the dry period) of pregnant dairy cows did not alter either colostrum quantity or quality (Gultepe et al., 2018). The formulation and dose rate of the mineral supplement may matter. Prenatal parenteral selenium administration to dairy cows has been shown to reduce offspring serum Ig content (Leyan et al., 2004). Dairy cows supplemented with organic trace elements had significantly higher colostrum IgG content compared with cows supplemented with inorganic minerals in most (Kincaid and Socha, 2004; Formigoni et al., 2011; Roshanzamir et al., 2020) but not all studies (Juniper et al., 2019). This suggests a role for trace elements in colostrogenesis, specifically synthesis of IgG.

A recent study has shown that while feeding a low calcium diet precalving did not affect dairy cow colostrum quality, it tended to increase colostrum yield (Rajaeerad et al., 2020). There are conflicting results on the effects of feeding anionic diets to dairy cows precalving on calf acidosis, colostrum Ig absorption, and serum Ig concentration (Quigley and Drewry, 1998). The most recent study by Zimpel et al. (2021) found no effect of maternal DCAD on colostral Ig content or apparent efficiency of absorption of Ig or performance of dairy calves.

Perinatal calf mortality (**PCM**) may be defined as death before, during or within 2 d after calving at full term (>260 d; Mee, 2021). Excessive body condition (>3.5) in pregnant dairy heifers has been shown to be a significant risk factor for bradytocia (prolonged calving; >120 min; Gundelach et al., 2009) and PCM (Vernooy et al., 2007). However, in an older study, Drew (1986) found no difference in dairy heifer BCS at calving between herds with high and low rates of PCM and suggested that calving management factors were more important in the etiology of PCM. Recently, prepartum nonesterified fatty acid (**NEFA**) concentrations (>416 μEq/L) were found in multiparous dairy cows that had stillbirths compared with cows with live calves (Menichetti et al., 2020), which may reflect inadequate energy supply for contractile myo-proteins, leading to dystocia. In contrast, previous work had shown no relationships between prepartum multiple metabolic parameters, including NEFA, and stillbirth in dairy cows (Szenci et al., 2018).

Higher levels of concentrate ration feeding in the last month of pregnancy have been associated with increased risk of stillbirth in dairy cows (Streit and Ernst, 1992; Benjaminsson, 2007) through maternal over-condition and fetal oversize. However, feeding a low level of concentrate (1 kg/cow per d) for 1 mo before the expected calving date compared with no concentrate supplementation reduced the occurrence of stillbirth in dairy cows (Logan et al., 1991). Prepartum maternal dietary energy (Gao et al., 2012) and protein (Micke et al., 2010) supplementation can increase calf birth weight and hence risk of relative fetal oversize. Relative fetal oversize is a significant risk factor for stillbirth (Kausch, 2009). Fetal undersize is also a risk factor for stillbirth (Kausch, 2009), possibly mediated through fetal growth restriction (**FGR**). Thermogenesis (and hence risk of perinatal mortality from hypothermia) of the perinatal beef calf can be reduced by low maternal prepartum dietary fat (1.7%; Lammoglia et al., 1999) and protein content (55% of NRC recommendation; Carstens et al., 1987).

Prepartum maternal dietary micronutrient imbalances (e.g., iodine or selenium deficiencies) are risk factors for PCM (Enjalbert et al., 2006). While lower concentrations of multiple trace elements have been found in aborted and stillborn dairy calves compared with abattoir-retrieved fetuses, the clinical significance of these findings is unclear (Van Saun, 2021). Supplementation with micronutrients can correct micronutrient imbalances and has reduced PCM in some (e.g., Formigoni et al., 2011; organic trace elements, Pontes et al., 2015; vitamin E) but not all dairy cow studies (e.g., Mee et al., 1995; oral micronutrients).

Subclinical hypocalcemia has been shown to be a significant risk factor for both dystocia and PCM in one (Bahrami-Yekdangi et al., 2022) but not in other dairy cow studies (Wilhelm et al., 2017; Szenci et al., 2018). Recent data indicate that if anionic salts are used to induce metabolic acidosis in dairy cows to the point that urine pH is excessively reduced (pH < 6), to improve calcium homeostasis, risk of PCM increases significantly (Melendez et al., 2021). In addition, subclinical hypomagnesemia precalving has been shown to be a significant risk factor for PCM, associated with uterine inertia, in one (Schneider, 2007) though not in another study (Szenci et al., 2018). Studies in dairy cows have shown that peripartum maternal hypocalcemia is associated with increased incidence of neonate enteritis (Hunter, 2015) and respiratory disease (Wilhelm et al., 2017) and that feeding a low DCAD diet to dairy cows can result in increased incidence of diarrhea and treatments in their calves (Rajaeerad et al., 2020). However, results may depend on the degree and duration of the DCAD as no effect on Ig absorption, calf morbidity, or performance was found in some recent dairy cow studies (Collazos et al., 2017; Zimpel et al., 2021).

Surprisingly, there are very few studies on the effects of precalving BCS on neonatal dairy calf health. Recently Karslıoğlu Kara (2020) found that while there was a relationship between BCS at dry off and neonatal dairy calf health (using Wisconsin-Madison calf health scores), there was no association with BCS at calving. Better calf health (higher calf health scores) was associated with cows in optimum BCS (3–3.75 on a 5-point scale); this was attributed to the effects of precalving BCS on colostrum Ig content. Wonfor and Rose (2020) found that transition period change in BCS of dairy cows had no effect on calf serum IgG concentrations or health (using Madison-Wisconsin calf health scores), but calves from cows which had no or small BCS loss (>−0.3 units on a 5-point scale) had higher ADG (0.63 kg/d) between 2 d and 4 wk.

Studies attributed reduced perinate vigor ("weak calf syndrome") to precalving protein and energy restriction (Nakao et al., 2000). More recently, feeding grass silage alone to dairy cows has been associated with increased incidence of enteritis in dairy calves when compared with feeding grass silage and concentrates (Dunn et al., 2017). Additionally, supplementing pregnant dairy cows with ruminally protected AA has been associated with immunometabolic modulatory effects in offspring, suggesting hitherto unknown benefits of protein supplementation of dairy cows for their calves' growth and health (Wang et al., 2021). In contrast, while dairy cows fed mannan oligosaccharide produced more colostrum, this had no effect on calf growth or health in one study (Westland et al., 2017). Immler et al. (2022) showed that higher maternal prepartum NEFA status was associated with higher dairy calf serum IgG concentration between 1 and 9 d. Gao et al. (2012) reported that low maternal energy intake during the last 3 wk precalving reduced both dairy calf birth weight and body size, but also reduced immune system function. Supplementation of pregnant dairy cows with additional fat in the diet (compared with no fat supplementation) has been shown to increase apparent efficiency of absorption of Ig, serum IgG concentrations, and ADG (Garcia et al., 2014).

Late gestational maternal metabolic or oxidative stress (**OS**) has been shown to potentially affect offspring disease susceptibility. Thus, dairy calves born to dams with higher NEFA or OS index had lower BW, higher concentrations of reactive oxygen and nitrogen species, haptoglobin, and TNF-α but lower LPS-induced inflammatory responses, suggesting compromised inflammatory response (Ling et al., 2018). Clinical effects on calf health are yet to be established.

Imbalances of micronutrients in calves are associated with micronutrient-specific disorders (e.g., goiter, nutritional muscular dystrophy). Micronutrient imbalances are also associated with reduced dairy and beef calf immunity and resultant increased incidences of diarrhea, respiratory diseases, and ill thrift (Enjalbert et al., 2006). Both the concentration and the chemical form of the micronutrient and interactions between minerals in the precalving diet can influence its effects on the neonate. In addition to their nutritional properties, some micronutrients are antioxidants that can counteract OS in both the dam and her offspring, though impacts on calf morbidity and mortality have yet to be demonstrated. For example, supplementing pregnant dairy cows with chromium-methionine has been shown to alter the metabolism and immunity of their newborn calves (Gultepe et al., 2018). While supra-nutritional (more than is needed) maternal dietary selenium supplementation increased both absorption efficiency and serum concentrations of IgG in selenium-replete dairy calves in one study (Hall et al., 2014), selenium-enriched yeast supplementation of dairy cows did not alter the Ig content of colostrum or calf serum in another study (Mohrekesh et al., 2019). In a study using selenium biofortified alfalfa in dairy cows, supplementation tended to improve dairy calf antioxidant activity via GSH-Px (Jaaf et al., 2020). Similarly, organic sources of some trace elements fed to dairy cows precalving can increase calf blood antioxidant capacity and Ig concentrations and health parameters (Roshanzamir et al., 2020).

Overall, it may be concluded that there are highly variable impacts of precalving nutrition on colostrum yield, quality, and calf health. The limited number of studies in dairy cows, their generally small size, lack of replication, and conflicting results indicate that further research in this field is required before firm conclusions on specific nutrients and their impact(s) on specific aspects of calf health can be drawn.

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Notes

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