INVITED REVIEW: An evaluation of EFSA opinion on calf welfare from a nutritional and management perspective

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ABSTRACT

In March, 2023, the European Food Safety Authority published a Scientific Opinion on Calf Welfare. This Opinion was prepared in response to a request from the European Commission to provide an independent view on the welfare of calves that reflected the most recent scientific knowledge. Data sources used to develop their recommendations included peer-reviewed studies, expert knowledge, and gray literature. The Opinion considered specific scenarios and welfare consequences of specific management practices, including feeding fiber to calves raised for white veal and amount of cow-calf contact. Their Opinion suggested that calves should be fed specific quantities of forage NDF during the rearing cycle. Regarding separation of calves, the Committee recommended that the calf should remain with the cow for a minimum of 24 h and then be housed with another calf. They further suggested that prolonged cow-calf contact should increasingly be implemented due to benefits to both cow and calf to minimize stress of separation. The objective of this review is to assess the veracity of these recommendations and the scientific data that underpins them. This review will present a literature to support the contention that, from a nutritional and management perspective, these recommendations may impair calf welfare by exposing calves to innutritious rations containing excess fiber and increasing their risk of morbidity and mortality due to poor colostrum intake and exposure to disease-causing pathogens. Alternative recommendations are made that may further the goal of calf welfare in the context of nutrition and housing.

INTRODUCTION

In March of 2023, The European Food Safety Agency (EFSA) published a Scientific Opinion entitled “Welfare of Calves” (EFSA, 2023). A committee of experts developed this document as a guide to governments within the European Union to develop regulations and laws to protect and promote the welfare of young calves. The document will become the basis for recommendations for producers and consumers who wish to ensure that calf welfare is protected during the growing period, whether for white veal, rosé veal, or herd replacement calves.

The mandate from the European Commission to EFSA was to give an independent view on the protection of calves (EFSA, 2023). The request to EFSA was to describe current husbandry systems and practices; relevant welfare consequences and measures to assess these consequences; identify hazards leading to these welfare consequences; and recommendations to prevent, mitigate or correct the welfare consequences. Relevant consequences were not necessarily based on a data-driven risk assessment, but on EFSA’s expert opinion using expert elicitation procedures.

Much of the opinion refers to male calves raised for veal within the EU. In 2018, approximately 4.4 million veal calves were raised in EU-27, with approximately 4 million as white veal and 0.4 million as rosé veal (FEFAC, 2021). While some recommendations were made in the context of veal farming, others did not distinguish among male calves raised for veal, male calves raised for non-veal beef production, or females reared as replacement heifers. Therefore, one or more of these recommendations may be implemented to all calf raising systems, independent of method of management and feeding.

The objective of this review is to review existing literature that may affect interpretation of 2 recommendations published in the EFSA Scientific Opinion: (1) recommendation on fiber intake; and (2) recommendation on separation of calves.

EFSA RECOMMENDATION ON FIBER INTAKE

Introduction

One important recommendation of the EFSA Committee was related to feeding forage to young calves and the welfare aspects of limiting forage. The specific rec-
ommendation (EFSA, 2023) was to provide increasing amounts of forage NDF with advancing age. Calves from 2 wk to 6 mo required 1 kg/d of NDF to show full rumination behavior. The NDF should be provided as long (minimum of 4 to 5 cm in length) forage with a minimum of 40 to 50% NDF. Straw was not recommended as it may increase the risk of abomasal ulcers.

There is an important distinction between fiber required to allow normal rumination behavior and that needed for proper nutrition, health, and rumen development. In the latter case, the role of physically effective fiber and adequacy of fiber in calf diets may be considered from several contexts: for example, effects of NDF on rumen fermentation, intake, and growth. The role of NDF and forage NDF on these parameters has been the subject of considerable research, which may assist interpretation of the EFSA recommendations.

**NDF and Rumen Fermentation**

Before and immediately after weaning, most calves are fed high concentrate diets to provide sufficient fermentable carbohydrate to produce volatile fatty acids which promote development of the absorptive ability of the rumen. Propionate and butyrate are more stimulatory to development of the metabolic activity of the rumen mucosa (Sander et al., 1959). Substrate in the young rumen has a profound effect on its physical and metabolic development (Flatt et al., 1958; Sander et al., 1959; Stobo et al., 1966a) and adaptation of intestinal and hepatic tissues (Baldwin et al., 2004), and peripheral systems (Howarth et al., 1968) to changing fermentative end products. With increasing dry feed intake, concentrations of circulating glucose decline (McCarthy and Kesler, 1956; Quigley et al., 1999a), ketones from rumen metabolism of butyrate to β-hydroxybutyrate increase (Quigley et al., 1992; Greenwood et al., 1997; Quigley et al., 1999a), and acetate increase (McCarthy and Kesler, 1956; Quigley et al., 1999b). The proportion of microbial nitrogen in total intestinal nitrogen increases with increasing rumen development (Leibholz 1975; Quigley et al., 1985), with concomitant changes in digestibility and amino acid profile (Quigley et al., 1985). Forage NDF tends to be fermented to acetate to a greater extent than non-fiber carbohydrate (Stobo et al., 1966b), which effectively slows the rate of rumen development, and, thus, high fiber diets are less conducive to rumen development. Therefore, calves should be fed diets providing more NFC to promote rumen development and prepare the calf for weaning (Kertz, 2023), as is the case for most herd replacement calves.

While NFC is critical to promoting rumen development, a minimum amount of physically effective fiber is important to maintain rumen pH, minimize rumen acidosis and reduce the risk of parakeratosis (Bull et al., 1965; Nocek et al., 1980; Beharka et al., 1998; Khan et al., 2011; Beiranvand et al., 2014). A large body of data supports the idea that including a limited amount of forage in the diet supports rumen pH and reduces the risk of acidosis (Bull et al., 1965; Castells et al., 2012, 2013; Khan et al., 2014; Kim et al., 2016; Suarez-Mena et al., 2016; Ghaffari and Kertz, 2021). The definition of “limited forage” is the subject of some debate in the literature and likely depends on the other components of the ration, particle size, total feed intake, and quantity of liquid feed. Generally, however, recommendations for forage inclusion as a percent of total DMI range from 3 to 5% (Hill et al., 2008; Castells et al., 2013; Kertz, 2023), 10% (Montoro et al., 2013), 15% (Coverdale et al., 2004), to 25% (Nemati et al., 2016).

Since the work of researchers in the 1950s and 1960s (Lengemann and Allen, 1955; Hibbs et al., 1953, 1956; Conrad et al., 1958; Stobo et al., 1966a, b), researchers have increasingly recognized the importance of NFC to rumen development and recommend high NFC diets to promote early rumen development for herd replacement calves (Kertz et al., 2017). Since calves in rosé veal systems are reared in a manner relatively similar to herd replacement calves, emphasis is placed on rumen development as well. However, for calves in white veal systems, little emphasis has been placed on promoting rumen development with high grain diets; however, there is an increasing recognition that calves raised in white veal systems can derive a significant proportion of their nutrient needs via dry feed (Suárez et al., 2006a, b; Berends et al., 2012, 2014), with improvement in calf health (i.e., reduced incidence of abomasal ulcers) and welfare. Therefore, the role of forage NDF to promote rumen development will become more important as feeding programs implement more aggressive dry feed provision.

While these data support a role for forage NDF in the diet of young calves, a significant amount of data suggests that forage NDF, per se, is not necessary to promote rumen development or maintain an acceptable rumen environment. For example, Porter et al. (2007) reported that a textured calf starter with average particle size of 2 cm promoted more rapid rumen development without evidence of rumen parakeratosis compared with pelleted diets with a particle size of 0.9 cm. Ghaffari and Kertz (2021) conducted a systematic review and Bayesian meta-analysis of the effect of starter form and calf intake and growth. They concluded that starter intake was improved when hay was added to finely ground diets or when added to pelleted starters were fed compared with textured starters. This is likely because many textured starters contain sufficient particle size to minimize parakeratosis that may occur when calves are fed finely ground diets (Nocek et al., 1980; Beharka et al., 1998).
The composition of the textured starters affects its ability to support rumen pH (Terré et al., 2015), and ingredients such as whole corn and oats are more effective than other ingredients. Others have shown that forge chopped to geometric mean of > 1.18 mm provides for proper rumen fermentation and initiation of rumination in young calves and increasing particle size above this value had little effect on rumen fermentation or rumen development (Suárez-Mena, 2016). Generally, it is recognized that non-fiber carbohydrates are required for proper rumen development and preparation for weaning in herd replacement and rosé veal systems. Calves fed for white veal production are fed milk replacer throughout the growing period are less reliant on nutrient supply from end products of rumen fermentation. Therefore, the role of forage has traditionally been to minimize digestive abnormalities, allow rumination and expression of normal oral behaviors as indicated in the EU Directive on calf welfare which stipulates that veal calves should be fed 50 to 250 g/d of fibrous feed from 8 to 20 wk of age. More recently, however, modern white veal systems increasingly offer forages and concentrates in amounts greater than those outlined in the EU Directive, thus, rumen fermentation and initiation of rumination (Suárez-Mena, 2016). Generally, it is recognized that non-fiber carbohydrates are required for proper rumen development and preparation for weaning in herd replacement and rosé veal systems. Calves fed for white veal production are fed milk replacer throughout the growing period are less reliant on nutrient supply from end products of rumen fermentation. Therefore, the role of forage has traditionally been to minimize digestive abnormalities, allow rumination and expression of normal oral behaviors as indicated in the EU Directive on calf welfare which stipulates that veal calves should be fed 50 to 250 g/d of fibrous feed from 8 to 20 wk of age. More recently, however, modern white veal systems increasingly offer forages and concentrates in amounts greater than those outlined in the EU Directive, thus, rumen development is increasingly similar to other management systems and increasingly important in white veal systems (Suárez et al., 2006, 2007; Berends et al., 2012).

**NDF and Intake**

The EFSA Committee recommended that calves fed in white veal feeding systems from 2 to 8 weeks of age should be provided with a total of 11 kg of NDF to 8 wk of age, 65 kg of NDF between 9 and 18 wk, and 90 kg between 18 and 25 wk, reaching a total of 166 kg per rearing cycle. The Committee assumed a linear increase in voluntary daily amount of NDF consumption, based on data from Webb et al. (2014) as in Figure 1. However, when calves (whether veal or replacement calves) are fed significant amounts of whole milk or milk replacer, the evolution of dry feed (and NDF) intake is curvilinear regardless of rearing system (Webb et al., 2014; Omidi-Mirzaei et al., 2018; Aragona et al., 2020; Bagheri et al., 2021; Cavallini et al., 2021; Quigley et al., 2021; Downey et al., 2022) and dependent on proportion of metabolizable energy supplied by the liquid diet (NASEM, 2021; Quigley et al., 2021). Larger amounts of ME from liquid feed reduce the need for calves to consume other sources of energy and, thus, initiation of dry feed intake is delayed (Hu et al., 2019). Interpretation and implementation of EFSA recommendations for NDF consumption also depend on the proportion of forage and concentrate consumed when grain and forage are offered separately, as is the case in many calf feeding systems and as recommended by the EFSA.

Calves fed forage and concentrate separately generally consume concentrate in preference to forage in all rearing systems. A convenience sample of 16 published studies and 37 treatments wherein forage and grain were offered separately to herd replacement calves and percent of total DM consumed as forage was calculated is in Table 1. The proportion of dry feed consumed as forage ranged from 4 to 24%. Reported mean forage intake does not reflect variation in forage intake, which is highly variable (Webb et al., 2014; Hill et al., 2019; Aragona et al., 2020) with some individual calves consuming little or no forage. In total, however, all these data suggest that when calves have a choice, they consume a diet mainly of concentrate and not forage, particularly post-weaning.

Herd replacement calves tend to sort ingredients offered separately to select nutrients that meet growth requirements as they age (Bach et al., 2012; Miller-Cushon and DeVries, 2015; Toledo et al., 2020). Toledo et al. (2020) hypothesized that sorting for long particles before weaning may be more common to prevent excessive fermentation in the underdeveloped rumen, especially in diets with high non-fiber carbohydrates. This concept is consistent with data in veal calves from Webb et al. (2014), who reported declining forage preference with advancing age. Preference for long particles in the diet may also decrease with declining milk intake due to increasing energy demand for growth (Engelking et al., 2020). Sorting may occur because ruminants (including preweaned calves) can make dietary choices based on nutritional demands and post-ingestive feedback (Forbes and Kyriazakis, 1995; Mitchell et al., 2020a), whether feed components are offered individually or as a TMR (Miller-Cushon and DeVries, 2011, 2013; Engelking et al., 2020; Toledo et al., 2020). Mitchell et al. (2020a) reported that calves fed long forage at > 10% of the ration sorted for concentrate immediately after feed was offered and then ate grass hay throughout the day, whereas calves fed a TMR with 10% forage immediately selected forage and then consumed concentrate throughout the remainder of the day. The authors also reported that feeding grass hay at > 10% of the ratio reduced growth and intake before 16 wk of age.

To achieve forage NDF intake targets recommended by EFSA for calves in white veal programs, it may be necessary to restrict feeding of liquid and/or concentrate to force calves to consume greater forage, because calves in a white veal system and fed components ad libitum consumed far less NDF voluntarily compared with EFSA recommendations. Total estimated intake of forage NDF to 8 wk of age from veal calf studies by Webb et al., (2013, 2014) were 2 and 3 kg, respectively, which is less than half the EFSA recommendation of 11 kg of forage NDF to 8 wk of age, although total forage intake as a percent of dry feed intake was higher than estimates for
herd replacement calves in Table 1. While reducing concentrate (and perhaps liquid) availability would promote greater NDF intake, this practice raises myriad questions regarding nutrition, calf behavior, and welfare. Further, modeling intakes based on data from Webb et al. (2014) and altering forage to concentrate ratio to ensure forage intakes as recommended by EFSA, estimates of growth based on the NASEM (2021) calf growth model are far lower than recommended for veal calves and would undoubtedly impair behavior and welfare. Thus, based on available data, implementation of EFSA recommendations in white veal feeding systems will be difficult or impossible while maintaining adequate calf growth, behavior, and welfare.

Because of such great variability in voluntary forage intake when calves are offered forage separately, it is recommended that calves are fed a TMR, which has been reported to improve intake and NDF digestibility (Mitchell et al., 2020b) compared with feeding components separately. Significant data on varying combinations of forage and concentrate in herd replacement calves indicate that intake and BW gain are improved when forage and concentrate are fed as at TMR. Optimal forage inclusion depends on the fermentability of the concentrate portion of the ration, particle size of each component, forage chop length, age of calf, and amount of liquid feed consumed. Generally, however, TMR with up to approximately 15% of DM as chopped forage appear optimal, as outlined above for herd replacement calves fed forage and concentrates separately.

Studies have also shown excellent calf growth and meat quality in calves raised in white veal systems when they were fed forage and/or concentrate as TMR well in excess of EU requirements (Cozzi et al., 2002; Prevedel-lo et al., 2012; Berends et al., 2014; Brščić et al., 2014). Berends et al. (2014) reported similar carcass gain in calves fed close to ad libitum amounts of dry feed at the expense of the milk replacer with 2 mixtures of forage and concentrate fed as a TMR at 4 levels of intake. Calves were fed a 20:80 or 50:50 forage to concentrate ratio at amounts of intake targeted to reach 20, 100, 180, and 260 kg total dry feed intake. A follow-up study (Berrends et al., 2015) showed a minimum protein requirement for adequate microbial protein synthesis and subsequent nitrogen retention. Veal calves fed diets of milk replacer and concentrate experience rumen development, but with a higher incidence of rumen parakeratosis (Suarez et al., 2006b). Changing the source of carbohydrate altered total rumen VFA concentrations and rumen development, though differences were generally small (Suarez et al., 2006a). Greater intakes of dry feed at optimal amounts of structural and non-structural carbohydrate will likely reduce rates of ruminal insult, improve intakes, growth, and cost of gain. Further research to optimize composition of the dry feed component of white veal feeding systems is needed.

The effect of increasing NDF intake on gut fill should also be considered within the context of increasing forage and NDF intake in calves raised within any management system. Increasing forage intake above some threshold increases the amount of live BW as digesta, thereby confounding estimates of BW gain (Kertz et al., 2007; Hill et al., 2008, 2009, 2010; Khan et al., 2012; Xiao et al., 2020). Early in life the rumen is relatively small and NDF digestibility is quite low (Hu et al., 2019; Quigley et al., 2019) which limits ruminal outflow and reduces DM intake. Jahn et al. (1970) reported that gut fill as a percentage of BW ranged from approximately 11 to 24% of BW and increased linearly as straw increased from 5 to 60% of ration DM. Jahn et al. (1976) reported gut fill ranged from 9 to 16% of BW and increased linearly as dietary ADF concentration (from corn cobs and grass hay) increased from 11 to 25%. Hill et al. (2008) suggested a correction for gut fill was needed when diets containing greater amounts of NDF. Others have suggested that levels of forage inclusion between 4% (Castells et al., 2013) and 10% (Toledo et al., 2020) are unlikely to contribute meaningfully to gut fill and inclusion of 15% were more likely (Mirzaei et al., 2017). Toledo et al. (2020) suggested that rumen size may increase at different rates, dependent on forage intake. Implementation of EFSA recommendations in white veal systems would likely contribute to increased gut fill, as calves consumed between 30% and 40% of dry feed intake as forage in Webb et al. (2014).

The concept of gut fill and its effects on growth may also be dependent on the type of fermentable carbohydrate in the starter component of the diet. Maktabi et al.
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Table 1. Voluntary intake of forage as a percent of total dry feed intake reported when calves are offered forage for ad libitum consumption

<table>
<thead>
<tr>
<th>Author, Year</th>
<th>Forage type</th>
<th>Particle size, mm</th>
<th>Age of calves, d</th>
<th>Milk1</th>
<th>Wean Age, d</th>
<th>Grain2</th>
<th>DMI3</th>
<th>Pet Forage4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anderson et al., 1982</td>
<td>Alfalfa hay</td>
<td>10</td>
<td>3 to 84</td>
<td>3</td>
<td>90</td>
<td>T</td>
<td>0.7</td>
<td>23.8%</td>
</tr>
<tr>
<td>Khan et al., 2011</td>
<td>Chopped grass hay</td>
<td>12</td>
<td>3 to 70</td>
<td>8</td>
<td>56</td>
<td>T</td>
<td>0.7</td>
<td>22.5%</td>
</tr>
<tr>
<td>Castells et al., 2012</td>
<td>Alfalfa hay</td>
<td>39% &gt; 20</td>
<td>14 to 71</td>
<td>4</td>
<td>57</td>
<td>NR</td>
<td>1.4</td>
<td>13.6%</td>
</tr>
<tr>
<td></td>
<td>Ryegrass</td>
<td>50% &gt; 20</td>
<td>14 to 71</td>
<td>4</td>
<td>57</td>
<td>NR</td>
<td>1.4</td>
<td>13.6%</td>
</tr>
<tr>
<td></td>
<td>Oat hay</td>
<td>28% &gt; 20</td>
<td>14 to 71</td>
<td>4</td>
<td>57</td>
<td>NR</td>
<td>1.4</td>
<td>13.6%</td>
</tr>
<tr>
<td></td>
<td>Barley straw</td>
<td>31% &gt; 20</td>
<td>14 to 71</td>
<td>4</td>
<td>57</td>
<td>NR</td>
<td>1.4</td>
<td>13.6%</td>
</tr>
<tr>
<td></td>
<td>Triticale silage</td>
<td>2% &gt; 20</td>
<td>14 to 71</td>
<td>4</td>
<td>57</td>
<td>NR</td>
<td>1.4</td>
<td>13.6%</td>
</tr>
<tr>
<td></td>
<td>Corn silage</td>
<td>8% &gt; 20</td>
<td>14 to 71</td>
<td>4</td>
<td>57</td>
<td>NR</td>
<td>1.4</td>
<td>13.6%</td>
</tr>
<tr>
<td>Terré et al., 2013</td>
<td>Low NDF CS + oat hay</td>
<td>38% &gt; 20</td>
<td>3 to 64</td>
<td>4</td>
<td>P</td>
<td>1.0</td>
<td>5.0%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>High NDF CS + oat hay</td>
<td>38% &gt; 20</td>
<td>3 to 64</td>
<td>4</td>
<td>P</td>
<td>1.0</td>
<td>5.0%</td>
<td></td>
</tr>
<tr>
<td>Castells et al., 2015</td>
<td>Oat hay</td>
<td>28% &gt; 20</td>
<td>10–51</td>
<td>6</td>
<td>52</td>
<td>G</td>
<td>0.6</td>
<td>6.3%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>52–65</td>
<td>6</td>
<td>52</td>
<td>G</td>
<td>0.6</td>
<td>6.3%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pelleted + straw</td>
<td>50% &gt; 19</td>
<td>7 to 63</td>
<td>4</td>
<td>P</td>
<td>0.7</td>
<td>6.9%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Textured + straw</td>
<td>50% &gt; 19</td>
<td>7 to 63</td>
<td>4</td>
<td>P</td>
<td>0.7</td>
<td>6.9%</td>
<td></td>
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<tr>
<td>Horvath et al., 2017</td>
<td>Milk in bucket</td>
<td>50</td>
<td>14 to 42</td>
<td>6</td>
<td>45</td>
<td>P</td>
<td>0.7</td>
<td>11.7%</td>
</tr>
<tr>
<td>Wu et al., 2017</td>
<td>Alfalfa from 15 d</td>
<td>32% &gt; 19</td>
<td>3 to 56</td>
<td>8</td>
<td>56</td>
<td>T</td>
<td>1.2</td>
<td>20.9%</td>
</tr>
<tr>
<td></td>
<td>Oat hay from 15 d</td>
<td>32% &gt; 19</td>
<td>3 to 56</td>
<td>8</td>
<td>56</td>
<td>T</td>
<td>1.2</td>
<td>20.9%</td>
</tr>
<tr>
<td></td>
<td>Alfalfa from 3 d</td>
<td>32% &gt; 19</td>
<td>3 to 56</td>
<td>8</td>
<td>56</td>
<td>T</td>
<td>1.2</td>
<td>20.9%</td>
</tr>
<tr>
<td></td>
<td>Oat hay from 3 d</td>
<td>32% &gt; 19</td>
<td>3 to 56</td>
<td>8</td>
<td>56</td>
<td>T</td>
<td>1.2</td>
<td>20.9%</td>
</tr>
<tr>
<td>Omidi-Mirzaei 2018b</td>
<td>Alfalfa hay</td>
<td>2 to 4</td>
<td>3 to 70</td>
<td>6</td>
<td>49</td>
<td>T</td>
<td>1.1</td>
<td>7.1%</td>
</tr>
<tr>
<td>Aragona et al., 2020</td>
<td>Wheat straw</td>
<td>50</td>
<td>58 to 114</td>
<td>0</td>
<td>Weaned</td>
<td>T</td>
<td>1.9</td>
<td>16.3%</td>
</tr>
<tr>
<td></td>
<td>High starch textured</td>
<td>50</td>
<td>58 to 114</td>
<td>0</td>
<td>Weaned</td>
<td>T</td>
<td>1.9</td>
<td>16.3%</td>
</tr>
<tr>
<td></td>
<td>Low starch pellet</td>
<td>50</td>
<td>58 to 114</td>
<td>0</td>
<td>Weaned</td>
<td>T</td>
<td>1.9</td>
<td>16.3%</td>
</tr>
<tr>
<td>Bagheri et al., 2020</td>
<td>Wheat straw</td>
<td>1 mm GPS</td>
<td>15–90</td>
<td>7</td>
<td>56</td>
<td>G</td>
<td>1.8</td>
<td>7.8%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4 mm GPS</td>
<td>15–90</td>
<td>7</td>
<td>56</td>
<td>G</td>
<td>1.8</td>
<td>7.8%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7 mm GPS</td>
<td>15–90</td>
<td>7</td>
<td>56</td>
<td>G</td>
<td>1.8</td>
<td>7.8%</td>
</tr>
<tr>
<td>Leao et al., 2020</td>
<td>Grass hay</td>
<td>60% &gt; 19</td>
<td>3 to 72</td>
<td>4</td>
<td>64</td>
<td>P</td>
<td>0.8</td>
<td>4.5%</td>
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<tr>
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<td>60% &gt; 19</td>
<td>3 to 72</td>
<td>4</td>
<td>64</td>
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<td>64</td>
<td>P</td>
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<td>4.5%</td>
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<td>60% &gt; 19</td>
<td>3 to 72</td>
<td>4</td>
<td>64</td>
<td>P</td>
<td>0.8</td>
<td>4.5%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>21–56</td>
<td>4</td>
<td>64</td>
<td>P</td>
<td>0.8</td>
<td>4.5%</td>
<td></td>
</tr>
<tr>
<td>Downey et al., 2022</td>
<td>Grass hay</td>
<td>55% &gt; 19</td>
<td>3 to 64</td>
<td>8.4</td>
<td>60</td>
<td>0.2</td>
<td>20.0%</td>
<td></td>
</tr>
<tr>
<td>Antunez-Tort et al., 2023</td>
<td>Barley straw</td>
<td>70% &gt; 20</td>
<td>3 to 91</td>
<td>6</td>
<td>57</td>
<td>P</td>
<td>1.5</td>
<td>5.8%</td>
</tr>
<tr>
<td></td>
<td>Alfalfa hay</td>
<td>60% &lt; 8</td>
<td>3 to 84</td>
<td>10</td>
<td>57</td>
<td>P</td>
<td>0.8</td>
<td>10.3%</td>
</tr>
<tr>
<td></td>
<td>Oat hay Early</td>
<td>&lt;25</td>
<td>3 to 84</td>
<td>10</td>
<td>57</td>
<td>P</td>
<td>0.8</td>
<td>10.3%</td>
</tr>
<tr>
<td></td>
<td>Oat hay moderate</td>
<td>&lt;25</td>
<td>3 to 84</td>
<td>10</td>
<td>57</td>
<td>P</td>
<td>0.8</td>
<td>10.3%</td>
</tr>
<tr>
<td></td>
<td>Oat hay late</td>
<td>&lt;25</td>
<td>3 to 84</td>
<td>10</td>
<td>57</td>
<td>P</td>
<td>0.8</td>
<td>10.3%</td>
</tr>
</tbody>
</table>

1Maximum volume (L) offered to calves before weaning.
2Grain type: T = textured; P = Pelleted; G = Ground; NR = Not reported.
3Maximum dry feed intake, kg.
4Forage intake as a percent of dry feed intake.

(2016) and Mojahedi et al. (2018) reported lower starter intake in calves fed starters containing cracked corn versus steam-flaked corn and suggested that lower rate and extent of ruminal digestion due to difference in rumen development may be responsible. Similar amounts of alfalfa hay have been shown to increase gut fill compared with oat hay (Castells et al., 2013). On the other hand, Khan et al. (2011) concluded that, at high levels of milk feeding, inclusion of forage in the diet of preweaned replacement calves improved total dry feed intake and rumen development.

Dairy heifers from 4 to 28 mo of age and fed total mixed rations of varying proportions of forage and concentrate (36 to 49% NDF) consumed a consistent amount of forage NDF (1%) as a percentage of BW (Hoffman et al., 2008). The authors suggested that this was the level at which gut fill restricted feed intake, consistent with the feed intake theory of Mertens et al. (1994). Most modern diets for weaned herd replacement and rose veal calves provide sufficient energy and limited NDF so that the threshold for physical fill limit of intake is not reached (e.g., Aragona et al., 2020). However, assuming typical growth rates for white veal calves, NDF intakes recommended by EFSA approach 1% of BW by 16 wk of age (calculations based on intake from Webb et al., 2014), whereas ad libitum forage NDF intake as reported by Webb et al. (2014) was 0% to 0.2% of BW.

Intake of dry feed (both forage and concentrate) will improve when young calves are fed sufficient amounts of physically effective fiber, whether from whole grains such as oats or from chopped forage. Allowing calves to select feed components increases variability of nutrient intake. A dry TMR containing from 5 to 15% forage (or equivalent physically effective NDF from forage) will
optimize intake, minimize variability in nutrient intake, and reduce negative effects of gut fill.

**NDF and Growth**

Another consideration of the EFSA recommendation relates to provision of fiber and its effect on the availability of energy and protein for growth. The role of forage in supporting acceptable rates of BW gain has been the subject of considerable investigation and results are often contradictory. For example, Hill (2008; 2009; 2010) and others (Maktabi et al., 2015; Mitchell and Heinrichs, 2020; Aragona, et al., 2020, 2021) reported reduced intake, digestion, and growth with increasing forage inclusion compared with 100% concentrate diets in herd replacement calves. Many researchers have reported improved calf performance, often reported as a result of improved rumen development, more stable rumen pH, and improved health (Coverdale et al., 2004; Khan et al., 2011; Castells et al., 2012; Beiranvand et al., 2014; Daneshvar et al., 2015; Mirzaei et al., 2016; Nemati et al., 2016) whereas others have reported no significant effect of forage inclusion (EbnAli et al., 2015; Mirzaei et al., 2015; Movahedi et al., 2017). Xiao et al. (2023) evaluated effects of age when forage intake commenced at different ages reported that consuming hay early reduced BW gain and nutrient digestion. Effects may depend on the starter formulation (Mirzaei et al., 2016; Nemati et al., 2016), forage sources (Castells et al., 2012), and free choice versus TMR feeding. Imani et al. (2017) conducted a meta-analysis to estimate the effect of dietary forage on growth and concluded that ADG was improved when diets contained > 10% forage in the ration DM; however, increased BW could be associated with greater gut fill. In their review of the effects of forage feeding on calves, Xiao et al. (2020) concluded that a small amount of forage in the diet was likely to increase feed intake and growth rates in preweaned calves and may promote rumination, eating behavior and reduce feed sorting. Mohammadadeh et al. (2021) reported that calves fed 7% wheat straw spent more time ruminating, had improved fecal scores and greater nutrient digestibility compared with calves fed 7% of their diet as alfalfa hay. Generally, recommendations for herd replacement and rosé veal calves are that feeding up to 10% of dry feed DM as chopped in a dry TMR is optimal for growth. Optima for calves fed in white veal systems are not yet fully defined, but forage inclusion will almost certainly be lower than EFSA recommendations. The effects of NDF on calf growth may be somewhat confounded by feeding system and sex of calf. Herd replacement calves are female and are smaller at birth and grow more slowly than bull calves, which are used in rosé and white veal systems. Holstein bull calves are heavier at birth and grow faster than heifers early in life (Arrayet et al., 2002), therefore, extrapolation of studies conducted exclusively with Holstein bull calves to herd replacement calves should be done with caution.

**NDF and Abomasal Ulcers**

Prevalence of abomasal ulcers in calves fed in white veal feeding systems are common. For example, Wiekema et al. (1987) reported that 67% of veal calves fed only milk for 22 to 24 wk showed evidence of abomasal erosion, ulcers, or scars, suggesting that high milk feeding at least predisposes calves to abomasal ulceration, independent of forage inclusion. Welchman and Baust (1987) found that 87% of loose housed veal calves fed milk ad libitum and access to straw had evidence of abomasal lesions, though growth seemed unrelated to lesion incidence. Definition and methods to effectively evaluate lesion incidence and severity are needed. Van Driessche et al. (2023) evaluated 76 abomasae from veal calf slaughterhouses in Quebec and scored each for presence of abomasal lesions by 4 independent evaluators using different systems to score lesions. The authors reported wide variability in agreement among evaluators and systems, indicating significant variation in our current understanding of the prevalence and severity of abomasal lesions. These authors suggested that a fast, simple, and reliable scoring system is needed to allow for larger studies to investigate the factors associated with abomasal lesions in veal calves.

The EFSA opinion advised against feeding straw to veal calves, citing data of Brščić et al. (2011a, b) and Bus et al. (2019) that suggested that roughage inclusion may contribute to increasing abomasal ulceration, particularly in the pyloric region and coarse roughage such as straw exacerbates the lesions. However, they also recognized abomasal ulcers are multi-factorial and other factors may contribute, including abomasal overloading, insufficient water, stress, and low frequency of large meals (EFSA, 2023). Bus et al. (2019) reviewed the etiology of abomasal damage in veal calves and concluded a multi-factorial etiology to abomasal ulceration including diet, stress, feeding management, and other factors. The authors recommend that feeding smaller milk replacer meals in conjunction with solid feeds containing both concentrate and forage be offered as well. Regarding including straw in diets of veal calves in white veal feeding systems, the authors concluded that straw offered in restricted amounts worsened the incidence of abomasal lesions compared with milk only; feeding straw exacerbated lesions in 4 studies while 5 studies indicated no consistent effect of straw on lesion incidence. Cozzi et al. (2002) reported no difference in incidence of abomasal erosion, ulceration,
or scarring in calves fed 250 g/d of chopped straw versus 250 g/d of barley grain. However, ulceration index, which considers the number and seriousness of damage was greater in calves fed barley, suggesting that particle size may have an important effect on the incidence of ulcers.

Webb et al. (2013) reported that increasing coarse roughage inclusion in the diets of white veal calves increased the prevalence of abomasal ulcers. The authors opined that poor rumen development in calves fed little fermentable carbohydrate and consumption and passage of coarse fiber could exacerbate abomasal damage. Supporting the idea that rumen development may be important to abomasal health, Berends et al. (2012) reported that early rumen development reduced prevalence of abomasal scars compared with calves fed to delayed rumen development. Mattielo et al. (2002) found a higher incidence of ulcers in calves fed straw and posited that straw exerted a mechanically abrasive effect on the mucosa, or caused a partial blockage of the pyloric exit, increasing the risk of other initiators of abomasal ulceration. However, it is important to recognize that calves fed straw in this study were fed 250 g/d of wheat straw containing very little non-fiber carbohydrate, resulting in little rumen development and little reduction in straw mean particle size. It seems possible that a more balanced diet of concentrate and forage such as straw would promote sufficient rumen development to allow for adequate fermentation of forage particles and reduction of particle size to reduce the effect of forage (of any form) on abomasal lesions. Studies evaluating effects of diet on abomasal lesions in calves raised in white veal systems should consider not only amounts and types of forage, but development of a stable rumen capable of processing forage particles before transit to the abomasum.

In addition to its role as a nutrient source, straw is often used as bedding material for young calves and is recommended by EFSA (2023) to provide increased thermal comfort during periods of cold stress and to foster play and foraging behavior. Straw used as bedding may be a source of nutrients, as calves will eat straw bedding (Kertz, 2007), which may influence rumen development and gut fill. Fokkink et al. (2011) concluded that straw intake was measurable and significant, but did not differ among calves fed high or low starch diets, while Bateman et al. (2009) recognized that straw consumption from bedding likely influenced total nutrient intake in calves bedded on straw and was used by calves to manage ruminal pH when finely ground diets were fed. Others (Laarman et al., 2012; Salter et al., 2021) altered experimental conditions to eliminate the risk of bedding consumption on calculation of nutrient intake. In light of the existing research with herd replacement calves housed on straw bedding, it seems likely that inclusion of straw bedding in the environment of veal calves, whether as bedding or as play substrate, are likely to contribute to overall nutrient intake, and should be considered in any recommendation for housing or feeding system.

**Importance of Growth to Calf Welfare**

A high rate of growth in the first weeks of life is paramount for optimal animal performance and financial results later in life. Low growth linked to low CMR intake or poor-quality dry feed is associated with feelings of hunger causing stress and thus leading to poor welfare. Carulla et al. (2023) reviewed the welfare implications of feed management in rearing dairy calves and concluded that liquid and solid feed management have a significant effect on growth and welfare. Correct feed management, including starter feed to support natural growth is critical to calf welfare. For example, a low CMR feeding rate in the first weeks after birth results in lower play behavior (Krachun et al., 2010; Rosenberger et al., 2017), more vocalization and more non-nutritive suckling behavior (Thomas et al., 2001; Jongman et al., 2020). High calf growth rates improve development of the intestinal immune system, and some data suggest better resistance against infectious diseases (Hammon et al., 2020), though not all data support this contention (e.g., Curtis et al., 2023). Finally, while research such as Webb et al. (2014) report that calves prefer long versus chopped hay, incorporation of long forages into feeding systems to optimize consistent nutrient intake and minimize variability is highly problematic. Thus, the EFSA view on rumination behavior without considering growth, play, and suckling behavior, disease, and stress is a questionable approach to calf welfare.

**Summary**

Forage and NDF intakes recommended by EFSA are difficult to justify when the biology and nutrition of the calf are considered. Calves are unlikely to consume the forage recommended, and if they did, their growth would be significantly and irreparably impaired with negative effects on welfare and production. While the concept of providing sufficient forage to ensure normal rumination and ruminating behavior, the amounts of NDF recommended by EFSA are far in excess of that needed for proper rumen development and rumination. Clearly, NDF is critical to rumen health, adequate rate of passage, and expression of normal behaviors. However, within the context of calves fed in white veal systems, more information is needed regarding feeding programs to optimize rumen development to allow satisfactory ruminal fermentation of forage NDF in the rumen while
at the same time provide forage for expression of normal behaviors.

**EFSA RECOMMENDATION ON CALF SEPARATION**

*Introduction*

The EFSA Committee reviewed the effects of separation of calves from cows on calf and cow welfare and referenced studies related to welfare aspects of separation of calves from the dam at varying ages. The Committee’s recommendations were that calves should be kept with the dam for a minimum of 24 h and housed with another calf thereafter. In the future, prolonged cow-calf contact should be increasingly implemented, with a goal of allowing calves contact with the dam throughout the preweaning period. The Committee also concluded that early calf separation prevents calves from experiencing improved calf welfare, vitality, and resistance to disease. The goal of this review is to evaluate existing literature regarding early calf separation within the context of calf health and risk of disease.

The Committee concluded that a great majority of dairy farms separate cows shortly after birth. Early calf separation is the recommendation of the great majority of veterinarians and other dairy professionals around the world. In their review of colostrum feeding, Lopez and Heinrichs (2022) recommended that calves should be fed colostrum with a concentration ≥ 50 mg/mL of IgG within 2 h after birth. Godden (2009) recommended that early separation from the dam reduces risk of exposure to pathogens in the calving environment and facilitates feeding of 10 to 12% of BW as colostrum within a 1 to 2 h timeframe.

Most producers separate calves from cows to facilitate early colostrum feeding and to reduce the risk of transmission of pathogens to the calf from the dam, other cows in the calving area, and the calving environment. A separate location also facilitates the use of supplemental heat in cold climates. When calves are left to nurse the dam, a significant proportion fail to consume sufficient maternal colostrum which increases neonatal morbidity and mortality. Early separation of calves has also been recommended to reduce separation anxiety, which appears to increase with increasing time with the dam (Flower and Weary, 2023).

Although EFSA concluded that calves left with the dam benefit from increased vitality and lower risk of disease, a significant body of data concludes that calves left with the dam have neither higher vitality, growth, nor resilience to gastrointestinal disorders. Calves left to nurse the dam without farmer intervention are more likely to have failure of passive transfer of immunity (FPT), which is consistently associated with greater calf morbidity and mortality. For example, Beam et al. (2009) reported that the overall rate of FPT in calves (n = 1,816) sampled during the 2007 NAHMS study in the United States was 19.2% but was significantly higher in calves left to nurse the dam. On the other hand, early separation of the calf and hand-feeding colostrum appears effective in reducing FPT. Proper training to separate calves and implement intensive colostrum feeding programs have reduced or eliminated FPT on many dairy farms (Williams et al., 2014). This management practice allows administration of sufficient colostrum to ensure successful passive transfer in most calves and has resulted in declining rates of morbidity and mortality.

**Minimize FPT to Minimize Morbidity and Mortality**

The importance of colostrum to the newborn calf has been known since the first report of controlled studies with calves fed or deprived of colostrum by Smith and Little (1922). The relationship between FPT and increasing rates of neonatal morbidity and mortality is well established (e.g., Robison et al., 1988; Donovan et al., 1998; Raboisson et al., 2016, Urie et al., 2018). For example, Robison et al. (1988) reported that calves with FPT had 2 times the mortality rate compared with calves with successful passive transfer (6.8% vs. 3.3%, respectively). Other researchers have made similar observations with individual herds and in multi-farm surveys.

Dissemination of programs to ensure early consumption of an adequate amount of colostrum has resulted in great improvements in rates of passive transfer of immunity and reduced losses due to sickness and death of newborn calves. Rates of FPT are declining as farmers implement early and aggressive colostrum feeding programs. For example, rates of FPT in the United States have declined from 41% in 1991 (USDA, 1993) to 19% in 2007 (Beam et al., 2009) and to 12% in 2014 (Shivley et al., 2018). Renaud et al. (2020) reported the rate of FPT in Ontario dairy farms was 21 to 24% and an improvement over previous studies conducted in Canada following implementation of educational programs for intensive colostrum feeding. Rates of FPT in other countries show great variability and generally reflect the intensity of colostrum management in those parts of the world. Published studies reporting rates of FPT generally ranged from 17% in Turkey (Kara and Ceylan, 2021) to 21 to 24% in Canada (Renaud et al., 2020), 33% in New Zealand (Cuttance et al., 2017), 35% in the Czech Republic (Staněk et al., 2019) and 41% in Italy (Lora et al., 2018). Abuelo et al. (2019) reported that 42% of calves had FPT on Australian dairy farms and the authors attributed at least part of this high rate of FPT to a significant proportion of producers (24%) allowing calves to nurse the dam as their primary method of colostrum acquisition.
tion. Reduced rates of FPT result in greater calf health, lower rates of mortality, and improved calf welfare. Key to these improvements have been monitoring colostrum quality by BRIX refractometry and feeding a sufficient quantity of colostrum to ensure ingestion of 150 to 200 g of IgG by 2 h of age.

Inherent (but not obligatory) to these programs is separation of the calf from the cow. This enables the farmer to proactively provide the requisite amount of colostrum at the appropriate time and minimize the risk of infection with pathogens that may be in the calving environment. A recent example is from Sutter et al. (2023), wherein calvings from 3,434 Holstein cows on one farm in Germany were monitored. Calves were separated at birth and fed 4 L of high-quality colostrum (BRIX > 22%) within 1 h of birth and an additional 2 L of colostrum at 6 to 12 h thereafter. Rate of FPT (serum IgG <10 g of IgG/L) as estimated by BRIX refractometry was 4.8%. Overall rates of mortality and morbidity on the farm for all calves were 3.1% and 32.6%, respectively. Calves with FPT were more likely to have diarrhea (odds ratio \( \text{OR} = 1.57 \)), pneumonia (\( \text{OR} = 2.00 \)), overall morbidity (\( \text{OR} = 1.99 \)) and mortality (\( \text{OR} = 2.47 \)) compared with calves with excellent passive transfer of immunity.

Similarly, Bandlow et al. (2023) recently reported that only 4.9% of Jersey calves had FPT when calves were separated from the dam and fed 4 L of heat treated, pooled colostrum. Educational programs to improve colostrum management and feeding practices, including separating calves from the dam, and feeding high quality colostrum, can reduce rates of FPT (Atkinson et al., 2017).

Of course, separation of the calf from the cow and individually feeding colostrum does not guarantee high rates of successful passive transfer (SPT) of immunity. Variation in colostrum quality, amount of colostrum fed and timing of feeding all affect the calf’s ability to absorb ingested IgG (Godden et al., 2019). This is why colostrum quality should be measured with a BRIX refractometer and many veterinarians recommend administration of 4 L of colostrum to large breed calves by esophageal feeder within 2 h of birth.

**Calves Left with the Dam and Rates of FPT**

When rates of FPT in conventional systems are evaluated, one factor commonly associated with greater rates of FPT is allowing the calf to nurse the dam. For example, Beam et al. (2009) reported that the odds of FPT were 2.4 times higher for calves that were allowed to nurse the dam compared with those that were hand-fed colostrum.

An important consideration of leaving calf with dam is the time required for the calf to stand, find the udder, and begin to nurse. For some calves, the process of nursing may be delayed, particularly if they have experienced a difficult birth. For example, Edwards and Broom (1979) reported that 11% of calves born from heifers and 46% of calves born from multiparous cows did not suckle by 6 h after birth. Bulls are normally larger than heifers and are more likely to experience dystocia. Others have reported varying proportions of failure to suckle by 6 h of age, from 13% (Illmann and Špinka, 1993; \( n = 31 \)), 30% (Edwards, 1982; \( n = 161 \)), and 40% (Rajala and Castren, 1995; \( n = 30 \)). Rates of FPT in calves not nursing by 6 h are dramatically higher than when calves are fed early in life (Edwards et al., 1982, Rajala and Castren, 1995).

Factors affecting time to nurse included udder conformation, alien cows, abnormal maternal behavior, parity, and poor calf vigor. Ventrop and Michanek (1992) also reported the importance of udder conformation on the calf’s ability to consume colostrum when left to nurse the dam and concluded that calves born from cows with malformed udders were less likely to achieve successful passive transfer compared with cows with well-formed udders. Penhale et al. (1973) argued that higher rates of FPT in calves nursing the dam were attributed to inability to suckle rather than a defect in absorptive capacity or colostral quality.

Jenny et al. (1981) reported a linear increase in neonatal mortality with time left with the dam up to 3 d, as well as a linear decline in mortality with volume of colostrum fed. Trotz-Williams et al. (2008) surveyed management on Ontario dairy farms in 2004 and reported that the odds of FPT in calves on farms where > 75% of cows were allowed to remain with their calves for more than 3 h after calving were significantly higher than when dams and calves were separated within 3 h of the birth. They also reported that feeding more colostrum to calves within 6 h of birth was significantly associated with a reduced risk of FPT.

Nocek et al. (1984) reported that allowing the calf to nurse the dam for 12 to 24 h resulted in lower serum IgG at 24 h compared with calves fed 1.8 L of colostrum. Calves that nursed were assisted to ensure that they began nursing within a few hours of birth. There were no differences in administration of veterinary treatments between the 2 treatment groups. Vasseur et al. (2009) reported that ad libitum intake of colostrum from a nipple bottle depended on calf body weight and vigor; calves with low vigor after calving (usually related to calving difficulties) consumed less colostrum voluntarily. On the other hand, vigorous calves were able to consume significant amounts of colostrum. They also reported that more than 40% of calves voluntarily consumed > 4 L of colostrum whereas 22% of calves consumed < 2 L.

Many calves are born on pasture in locations such as Ireland or Australia. A common practice in Australia is to collect calves from the pastures once or twice per day and to feed them 2 to 4 L of colostrum in addition to the
amount consumed from the dam. In a study by Vogels et al. (2013), 38% of calves were reported to have FPT (total serum protein <5.0 g/dl). More frequent (i.e., twice daily) removal of calves from pasture and earlier administration of supplemental colostrum was associated with reduced rates of FPT. A more recent meta-analysis by Van et al. (2023) also reported 38% FPT rate in pasture-born calves in Australasia. The researchers reported a high prevalence of FPT when calves were not fed supplemental colostrum and suggested that more frequent collection of calves and early feeding of colostrum would reduce rates of FPT. Finally, Wesselink et al. (1999) monitored 74 dairy calves left to nurse the dam during the first 24 h of life. They concluded that up to 50% of calves in New Zealand may not consume colostrum from the dam even though they are together for up to 24 h. Calves that will suckle will generally do so by 6 h of age.

Interestingly, Shivley et al. (2018) reported rates of FPT in calves suckling the dam were not different from those of calves fed by hand. However, the authors failed to discuss whether calves left with the dam were fed supplemental colostrum.

Benefits of Nursing the Dam

Several researchers have suggested that the efficiency of IgG absorption is improved when the calf nurses colostrum from the dam (Stott et al., 1979) or nurses in the presence of the dam (Selman, 1971a, b; Selman, 1973). Waltner-Toews et al. (1986) concluded that farms with policies to ensure calves receive sufficient amounts of colostrum after (active suckling without or with supplemental hand-fed colostrum) had lower odds of mortality than farms that allowed the calf to nurse the dam without intervention. A report by Quigley et al. (1995) with Jersey calves suggested that when properly managed to ensure intake of colostrum, calves nursing the dam for 3 d achieved serum IgG concentrations higher than calves that were bottle fed 1.8 L of colostrum in the first 24 h of life. This is likely due to increased colostrum intake of calves nursing compared with the relatively limited amount of colostrum hand-fed.

Beaver et al. (2019) published a systematic review of the effects of early calf separation on many aspects of calf health and welfare, including the acquisition of passive immunity and calf predisposition to disease. The authors’ assessment of the existing literature regarding acquisition of passive immunity was that there was considerable variation in existing literature and the influence of calf separation on SPT was not evidence based. Their recommendation that calves may stay with the dam during the colostral period included the caveat that ensuring adequate colostrum intake was essential even when calves remained with the dam.

Acquisition of passive immunity is complex and multifactorial. However, a significant body of data suggests a significant risk of FPT when calves are left with the cow. A convenience sample of 13 studies wherein calves were left with the dam without intervention to ensure colostrum intake (Table 2) indicates high rates of FPT. These studies suggest that calves left to nurse the dam without intervention to ensure adequate colostrum intake are at greater risk of FPT.

Latency to stand, delays in colostrum intake, and smaller amounts of colostrum consumed by calves left with the dam likely result in greater rates of FPT compared with calves that are separated from the dam and fed large amounts of high-quality colostrum by nipple bottle or esophageal feeder. Thus, equalizing colostrum intake of unseparated calves by “assisted nursing” might be a viable option for reducing rates of FPT.

Timing of Colostrum Ingestion and Risk of Infection

Calves are born agammaglobulinemic due to structure of the placenta (e.g., Godden et al., 2019). Therefore, they have minimal defenses against infectious organisms that may be ingested before colostrum consumption. Delays in colostrum ingestion and exposure of the calf to potential pathogens in the calving pen are major risks of infection of the newborn before colostrum ingestion. This was shown clearly by Logan et al. (1977), who challenged newborn calves with enteropathogenic strain of Escherichia coli before or after colostrum ingestion (approximately 1.4 L of undetermined quality colostrum). All calves challenged before colostrum ingestion exhibited severe diarrhea and 75% of those calves died. On the other hand, none of the calves fed colostrum before infection developed diarrhea and none died. The authors summarized their study by reporting that colostrum must be fed before infection to be prophylactically active. Corley et al. (1977) observed that early consumption of colostrum may prevent transepithelial migration of microorganisms and if invasion occurs, the interaction of immunoglobulins and immune cells may eliminate the invading organisms.

The relationship between time of ingestion of colostrum and exposure to pathogens may also affect our understanding of the role of circulating IgG on calf health. Calves exposed to pathogens before consumption of colostrum are at great risk of disease, but they may consume colostrum following infection but before gut closure. Hungerford et al. (1999) posited that delays in colostral ingestion and exposure to pathogens in the calving environment confounds the relationship between circulating serum IgG after 24 h of age and rates of morbidity and mortality.
The dam and calving environment are significant vectors for transmission of pathogens to the newborn, particularly for pathogens transmitted by the fecal-oral route such as *Mycobacterium avium* ssp. *paratuberculosis* (MAP), *Escherichia coli*, rotavirus, and *Cryptosporidium parvum*. Ingestion of contaminated bedding or manure, particularly before colostrum ingestion is a major risk for neonatal disease. Systems that include immediate calf separation (within 2 h of birth) from the dam and housing them in an environment without feces from adults or other calves have been recommended as a means for reducing the risk of general neonatal infection (Cho and Yoon, 2014), *C. parvum* (Trotz-Williams et al. (2007), and MAP infection (Collins et al., 2010; Nielsen and Toft, 2011; Pithua et al., 2011; Doré et al., 2012; Espejo et al., 2012; Vass-Bognár et al., 2022; Tuberquia-López et al., 2022). Although implementation of this recommendation along with other sanitation and management practices has resulted in reductions in prevalence of MAP infections globally (Sorge et al., 2011; Doré et al., 2012; Donat et al., 2016), the practice of removing the calf from the calving environment shortly after birth remains controversial. Beaver et al. (2019) concluded that separation of calf from dam per se is not necessarily associated with MAP infection; rather, minimizing contamination of the maternal environment – particularly for MAP-positive animals (e.g., separate facilities for MAP-positive cows) may reduce the risk of infection. Early removal of the calf from the maternal environment (presumably with a higher risk of MAP infection) to clean, dry calf housing free of manure from other animals (presumably, with a lower risk of MAP infection) is a plausible way to reduce risk of MAP infection as well as infection with other potential pathogens in the calving environment and should not be ignored in MAP control programs, as suggested by Donat et al. (2016). Conversely, Windsor and Whittington (2010) concluded that there was no difference in risk of MAP infection when calves were separated before 12 vs. before 24 h of age, though they concluded that if exposure occurs at birth, the risk of Johne’s disease is high. That studies reported no direct relationship between MAP seropositivity of animals and the age at which they were removed from the calving pen may be less related to lack of risk but more of the multi-factorial nature of MAP infection and differing definitions of important variables such as time of separation, timing and volume of colostrum consumption, and variation in cleanliness on test farms. For example, Nunney et al. (2023) reported that calves staying longer in a dirty calving area were 3.7 times more likely to test MAP positive compared with calves that were removed sooner. Further, definition of “time with the dam” varies considerably among published research. For example, comparison of results of studies wherein calves were separated within 1 h of birth may be quite different from results of studies separation was defined as removal of the calf at 1 d of age. Wells and Wagner (2000) reported a positive association was between prior diagnosis of MAP infection and early separation of calves (within 1 h), suggesting that farmers with Johne’s disease on their farms were implementing changes in management to reduce the rate of infection and the conclusion that early calf separation was protective against MAP infection in this study was dubious. Another potential confounding factor is consumption of colostrum. Consumption of colostrum has been shown to be protective against infection with some organisms (e.g., *E. coli*), but not others (Nielsen et al., 2008). Results of studies wherein calves were left to nurse the dam without assistance may be quite different from those wherein calves were immediately assisted to nurse to ensure adequate passive transfer of immunity.

Fauber and Litvinsky (2000) concluded that neonates acquire infection with *C. parvum* at birth mainly because of the high number of oocysts shed by the dam at calving. These authors reported a 4-fold increase in fecal oocysts counts in cows for the first 10 d after calving compared with the prepartal period. This contradicts the conclusion of Silverlås et al. (2009) who reported that increasing time with the dam (<5 h to >24 h) was protective against shedding of *C. parvum* oocysts in univariate analyses, but not in multivariate analyses. The authors opined that higher levels of infestation in calf rearing facilities compared with calving areas may have reduced risk of infection when calves remained in the maternity pens. Brainard et al. (2020) also reviewed risk factors associated with *C. parvum* infection and concluded the data regarding this management practice was inconclusive. Besides *C. parvum* and MAP, infection with *E. coli*, rotavirus (Bertoni et al., 2021), and coronavirus are commonly associated with contaminated calving pens and neonatal contact with infectious organisms or oocysts. Perhaps because *C. parvum* is ubiquitous in calf facilities on many farms, removal of the calf from the maternity pen may do little to reduce the risk of infection.

In their literature review regarding calf separation and incidence of disease, Beaver et al. (2019) concluded that early separation from the dam was unrelated to incidence of diarrhea, infection with *C. parvum*, or respiratory disease. Defining management practices and variables in statistical models is challenging, and there is often confounding with one or more variables, as noted above. For example, Garro et al. (2016) was time spent with the dam was protective in their univariate analysis but not in the multivariate analyses. This does not necessarily imply a protective effect of time with the dam, but rather confounding with other model parameters (i.e., calves < 20 d of age and occurrence of diarrhea). Garro et al. (2016) concluded that the observed association with young age
suggested early exposure of neonatal calves to *C. parvum* oocysts in maternity pens or an age-related susceptibility. Stenkamp-Strahm et al. (2017) monitored the shedding of *E. coli* O157 on 3 dairy farms in Colorado. One of 399 samples (0.2%) from preweaned calves (n = 111) were positive for *E. coli* O157. On the other hand, 32% of 111 cows shed *E. coli* O157. The authors attributed the low prevalence in calves to the management practice on all farms of removing the calf from the calving environment within one hour of birth. Formenti et al. (2021) reviewed factors associated with antimicrobial resistance (AMR) of *E. coli* in dairy calves and concluded that resistance could have been acquired directly from dams or through the farm environment. The role of environmental contamination, mainly from the calving pen, as a vehicle for AMR bacteria transfer, or as a source of antimicrobial contamination source deserved further investigation.

The use of specialized facilities for calving (i.e., a calving pen) is important to ensure adequate care of both dam and calf, facilitate feeding of colostrum, and minimize risk of infection. Use of calving pens versus allowing the cow to calve in lactation or dry cow groups such as tie stalls varies with region and size of dairy. Vasseur et al. (2010) reported that less than half of dairy farmers in Quebec utilized a calving pen. Similarly, about 39% of US dairy producers did not have separate facilities for calving (USDA, 2016). When calving facilities are implemented, they may be either individual or group pens. Group calving pens are common in many parts of the world (USDA, 2016; Love et al., 2016; Creutzinger and Proudfoot, 2020). In group calving pens, interactions between calves and alien cows are frequent (Edwards, 1983) and group calving pens also allow the opportunity for alien cows to suckle the calf (Creutzinger and Proudfoot, 2020).

Data regarding advantages of individual versus group calving pens are conflicting. Cows generally seek isolation at calving (Proudfoot et al., 2014), but this may be difficult in group calving pens. Diarrhea (Frank and Kaneene, 1993), respiratory problems (Svensson et al., 2003), pneumonia (Pithua et al., 2009), and the risk of Salmonella infections (Losinger et al., 1995) are reported to be lower when calving occurs in individual calving pens compared with group calving pens. On the other hand, Karle et al. (2019) found no difference between group or individual calving pens in risk of BRD; however, more frequent changing of bedding was associated with reduced risk of infection. Pithua et al. (2009) reported no effect of group or individual calving pens on incidence of calf pneumonia. However, bedding in individual calving pens was changed only monthly, and the authors suggested that potential build-up of contaminated materials therein could have influenced the results of their study.

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<th>Author</th>
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*FPT (failure of passive transfer) was generally defined as serum IgG <10 g/L or serum total protein <5.2 g/dl when measured > 24 h after birth.*

Regardless of whether the calving pen is individual or group, calving pen hygiene is paramount to reducing the risk of neonatal infection (Frank and Kaneene, 1993; Bendali et al., 1999; Klein-Jöbstl et al., 2014). More frequent cleaning of the calving pen was associated with reduced risk of neonatal bovine respiratory disease (BRD) on California dairy farms (Dubrovsky et al., 2019). Unfortunately, the calving area is an often-overlooked part of the dairy farm. For example, Kennedy et al. (2014) reported that 97% of Irish dairy farmers used the calving area for more than one calving, 34% of farmers failed to clean the calving area between calving, and 57% used the calving area to isolate sick cows. Hayer et al. (2021) also reported that German dairy farmers cleaned calving pens infrequently and the most common method of cleaning was removal of soiled bedding, which is similar to results from Austria and Ireland (Klein-Jöbstl et al., 2015; Cummins et al., 2016). Love et al. (2016) reported that 41% of grade A dairies in California changed bedding weekly or less frequently. Increasing frequency of calving pen cleaning was associated with lower risk of transmission of MAP (Johnson-Ihearulumdu and Kaneene, 1998). Klein-Jöbstl et al. (2014) found that, while cleaning the calving pen after each calving significantly reduced the risk of calf diarrhea, but time spent within the calving pen was not significantly associated with risk of calf diarrhea. However, in their study, all calves were fed colostrum within 6 h of birth, suggesting the importance of early colostrum ingestion.

Time for a calf to stand and time to nurse are important considerations in determining risk of infection whether in calving pens or other type of housing. The interval between standing and suckling is particularly important, as this would be the time when the calf is ambulatory and able to investigate its environment, thereby increasing the risk of ingestion of potentially infective agents. Houwing...
et al. (1990) reported that heifer and bull calves required 1.5 and 2.5 h to stand and 1.5 and 2.9 h to begin nursing the dam. Campler et al. (2015) also reported time to stand and time to suckle in Holstein and Jersey calves born to cows housed in freestalls or in a deep straw pack. Times to stand were approximately 0.9 and 2.1 h for Holsteins and Jerseys, respectively, and calves nursed at 1.7 and 2.8 h after birth. Cuttance et al. (2022) reported that only 58% of calves born on pastures in New Zealand suckled before 6 h of age. Individual farm averages ranged from 33% to 84% of calves standing by 6 h, indicating a significant effect of farm on the time required for calves to stand and nurse the dam.

The EFSA recommendation to leave newborn calves with cows is fraught with risk to the newborn, particularly if early intervention to ensure consumption of sufficient high-quality colostrum is not emphasized. Although some literature reviews suggest little negative effect (or indeed, positive effects) of leaving the calf with the cow, a lack of clarity regarding definitions of time of separation, levels of contamination in the calving area, and the influence of colostrum intake makes these reviews difficult to interpret and unsatisfactory guidance for recommendations like those of EFSA. That the cow is a potential vector for transmission of pathogens such as MAP and *C. parvum* via the fecal-oral route is clear. The calving environment will contain various amounts of these pathogens depending on the degree of cleaning and sanitation, number of cows in the pen and length of time each cow remains in the pen before calving. Housing dry cows on pasture should have a lower risk of infection than when compared with active methods to deliver colostrum, such as esophageal or bottle feeding.

Assisted nursing has been successful in reducing the rate of FPT in calves not separated from the dam immediately after birth in other studies (e.g., Logan et al., 1981; Petrie et al., 1984; Franklin et al., 2003; Webb et al., 2022). Conversely, Johnsen et al. (2019) reported that mean serum IgG (average = 16 g/L) was lower when calves were supplemented with colostrum on 20 organic herds in Norway and Sweden. Calves that were routinely fed colostrum in addition to nursing the dam consumed an average of 1.9 L of colostrum at an average of 4 h after birth. However, colostrum IgG was low in this study (39 g/L) and only 23% of samples were > 50 g of IgG/L. Further, only healthy calves were included in the analysis, thereby potentially skewing results. Robbers et al. (2021) distinguished between voluntary suckling and assisted suckling and concluded that assisted sucking can promote SPT, though levels of serum IgG were lower than when compared with active methods to deliver colostrum, such as esophageal or bottle feeding.

The act of separating calf from cow at birth may be unnecessary with the following caveats: (1) cows are housed in individual calving pens with sufficient space, bedding, feed, and water to ensure cow comfort; (2) the calving area is meticulously clean and disinfected before each calving; (3) consumption of colostrum within the first 1 to 2 h of birth by providing them a minimum of 3 L of high quality, clean colostrum. Whether that colostrum is provided by nursing the dam or fed by esophageal

### A Role for “Assisted Nursing”

An important manuscript by Lora et al. (2019) indicates the potential value of “assisted nursing” or providing an additional colostrum meal to calves left to nurse the dam. In this study, 107 cow-calf pairs were assigned to be hand fed colostrum from the dam to the calf (HF), nursed the dam (NF), or left to nurse the dam with an additional feeding of 3 L of colostrum from the dam by nipple bottle (SF) within 6 h of birth. Serum IgG was measured after 24 h. Calves fed HF consumed 1.9 L of colostrum at a mean age of 2.2 h. Calves fed SF consumed 2.0 L of colostrum at a mean age of 1.4 h. Sixty percent of calves in NF treatment had FPT whereas only 11% of calves had FPT when they were supplemented with maternal colostrum (SF group; Figure 2). Assisted nursing also resulted in a greater percentage of calves with serum IgG > 16 g/L, indicating greater SPT. The authors concluded that offering a supplementary colostrum meal within 6 h of birth to calves allowed to nurse their dams for 12 h was an effective practice in maximizing SPT.

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**Figure 2. Distribution of calves within serum IgG in groups hand fed colostrum from the dam (HF), nursing the dam (NF), or nursing the dam and an additional feeding of 3 L of colostrum from the dam by nipple bottle (SF) within 6 h of birth. Means are the percent of calves in each serum IgG category (< 10 g of IgG/L; > 10 and < 16 g/L; and > 16 g/L). Mean serum IgG concentrations (g/L) for groups were different *p < 0.01. Adapted from Lora et al., 2019.*
feeder is unimportant; the critical factor to calf health is ingestion of colostrum—the sooner, the better. However, significant additional research is needed to determine optimal programs to ensure that calves remaining with the dam obtain SPT and the environment is free of potential pathogens.

**Summary**

There are important interactions between cow, calf, and the calving environment that determine the relative risk of morbidity and mortality in newborn calves. Cleanliness of the calving pen and concentration of potential pathogens profoundly affects the calf’s risk of disease. Frequency of cleaning and disinfection, presence of alien cows, and level of infestation with pathogens (e.g., MAP) on the farm will also contribute to risk. The cow must be present and available to provide sufficient high-quality colostrum to the calf within a few hours of birth. Cows producing inferior quality colostrum or insufficient volumes of colostrum predispose calves to FPT. Cows with poor udder conformation or elevated levels of udder contamination further increase risk. Presence of alien cows in group calving pens serves as a reservoir for pathogens and may interrupt the natural event of suckling the dam. Finally, the calf, when left unattended, must stand, find the udder, and ingest sufficient colostrum to ensure SPT. Concomitantly, the calf must avoid contamination in the environment before colostrum ingestion. As documented by Logan et al. (1981), the ramifications of precolostral ingestion of pathogens are usually fatal.

The EFSA recommendation that calves be left with the dam for a minimum of 24 h without intervention to ensure adequate colostral intake and management to minimize risk of exposure is counter-productive to calf welfare. Without a comprehensive plan for administration of sufficient high-quality colostrum (as determined by BRIX refractometry) to ensure successful passive transfer as recommended by Lombard et al. (2020), neonatal morbidity and mortality will be greater than necessary. Further, leaving the calf—exquisitely sensitive to pathogenic challenge before colostrum consumption—in an environment potentially rich with pathogens seems difficult to justify from an animal welfare perspective. The most appropriate method is to separate the calf from the dam to ensure early consumption of high-quality, clean colostrum in volumes sufficient to ensure successful transfer of passive immunity. If the calf is left with the dam, a well-designed program of “assisted nursing” should be considered. Strategies to improve hygiene of the calving area and allow cows to calve individually are required to minimize the risk of transmission of pathogens from cow to calf. More research is needed to define these programs, followed by comprehensive educational programs to properly apply them. Only then will the practice of leaving calf with cow after birth improve animal welfare.

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