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Invited review: Abomasal emptying in calves and its potential influence on gastrointestinal disease

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ABSTRACT

Creating the ideal nutrition program for calves is a demanding task that has undergone tremendous change in recent years. Products and technologies including novel milk replacers and automated calf feeding systems have been developed to facilitate the ability of dairy producers to feed for higher growth rates before weaning. The creation of new feeding programs and milk replacers has to be looked at carefully, not only from a nutrition point of view but also from the perspective of a potential effect on physiologic digestion and calf health. Abomasal emptying is a critical factor that may link nutrition and disease. The purpose of this article is to review both intrinsic and extrinsic factors that are responsible for abomasal emptying. Predominant extrinsic factors controlling abomasal emptying include meal volume, energy density, and osmolality along with the content and source of protein. This article also reviews experimental methods used to measure abomasal emptying in the calf including those that would be appropriate for use under field conditions. Among these methods, the use of ultrasonography and different absorption tests (D-xylose, acetaminophen) as tools to measure abomasal emptying are discussed. The relationship between abomasal emptying and disease is explored, particularly as it relates to abomasal bloat. Abomasal bloat is a complex syndrome that seems to be increasing in frequency and whose etiology likely at least partially involves slowing of abomasal emptying. Suggestions for minimizing the effect of feeding programs on abomasal emptying are explored as well as needs for future research.
Key words: abomasum, bloat, tympany, milk replacer, osmolality

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INTRODUCTION

Research on nutrition and feeding of the dairy calf has gone through a renaissance in recent years. Conventional programs designed to limit feed calves at approximately 8 to 10% of their BW per day have been popular for decades. These programs were designed to limit the cost spent on milk or milk replacer diets and encourage early solid feed intake so calves could be quickly weaned onto less expensive feeds (Kertz and Loften, 2013). More recently, significant interest has arisen for increasing volumes of liquid feed offered to calves, offering milk more frequently, and increasing the nutrient content (protein, fat, or both) of milk replacers (Khan et al., 2011). Increasing the level of nutrition provided to dairy calves in the first weeks of life has resulted in several benefits such as decreased morbidity and mortality (Godden et al., 2005), faster recovery from disease (Ollivett et al., 2012), decreased age at first calving (Radcliff et al., 2000; Davis Rincker et al., 2011), improved mammary development (Lohakare et al., 2012), and increased milk production as an adult (Soberon et al., 2012; Soberon and Van Amburgh, 2013). Products and technologies including novel milk replacers, automated calf feeding systems, and the acidification of milk have all been introduced largely to assist dairy producers who wish to feed for more preweaning growth.

Some of these improvements in dairy calf feeding have the potential to alter abomasal emptying rates in calves. Abomasal emptying refers to the time span the chymus remains in the abomasum before passing into the intestinal tract, which is a concept similar to gastric emptying in humans. Feeding practices that significantly prolong abomasal emptying could increase rates of gastrointestinal diseases in calves such as abomasal bloat (Glenn Songer and Miskimins, 2005). The condition gastroparesis or delayed gastric emptying is well described in humans and is associated with multiple abnormalities including gastroesophageal reflux, abdominal pain, vomiting, bloating, or poor appetite (Pasricha and Parkman, 2015). Differences between feeding of dairy calves as compared with a beef calf suckling milk from the dam can be seen in milk volume per feeding, frequency of intake, pH, curd formation, content and origin of fat and protein, as well as the electrolytes and osmolality of the milk replacers. The intake of certain milk replacers, which may show substantially different chemical and physical characteristics compared with whole milk, may lead to digestive problems for the calf (Constable et al., 2006; Marshall, 2009). The purpose of this article is to review the factors that influence abomasal emptying and the research methods for determining abomasal emptying. Furthermore, possible relationships between abomasal emptying and gastrointestinal disease in calves will be discussed.

PRIMARY FACTORS CONTROLLING ABOMASAL EMPTYING IN CALVES

Abomasal emptying rate is potentially influenced by several factors (Table 1) such as volume and osmolality of the ingested meal, motility, luminal pressure and abomasal wall contractions, viscosity of ingesta, antroduodenal coordination, and resistance of the pylorus (Thomas et al., 1934; Thomas, 1957; Schulze-Delrieu and Brown, 1985). Even though the forestomachs in ruminants are different from those of monogastric animals from an anatomic point of view, similar mechanisms for gastric emptying have been described (Low, 1990; Cottrell and Stanley, 1992; Malbert and Mathis, 1994). Abomasal emptying occurs if the abomasal body (corpus abomasi) transports ingesta to pyloric antrum (antrum pyloricum), which is then responsible for further transport of the ingesta into the duodenum by coordinated contraction while the pylorus is opened. The beginning of the duodenum incorporates and transports ingesta further down the intestinal tract (Ruckebusch and Pairet, 1984; Malbert and Ruckebusch, 1988, 1991). Motility and emptying of the abomasum are under both neural and humoral control.

Neural Control of Abomasal Motility and Emptying

Extrinsic Innervation. Abomasal motility is predominantly controlled by the ventral branch of the abdominal vagal nerve. Although the dorsal branch primarily innervates the rumen, some parts are also involved in innervation of the abomasum (Habel, 1956). The parasympathetic fibers innervate neurons that increase motility and relax abomasal tone. Therefore, afferent and efferent vagal pathways (vagal reflex) are responsible for accommodation and relaxation of the abomasum while the animal is eating (Jahnberg et al., 1977; Cottrell, 1994; Olson and Holmgreen, 2001). Anatomic position, branching, and anastomosis of the vagal nerve vary significantly from animal to animal, which explains different clinical outcomes from similar damage done to branches of the nerve (Hoflund, 1940; Dietz et al., 1970; Baker, 1979). Vagal nerve damage might result from infectious processes originating from the esophagus, thrombophlebitis of the jugular vein, mediastinitis, or peritonitis. This nerve damage might result in no clinical signs at all, or it could cause a chronic decrease in abomasal emptying, resulting in obstruction of the abomasum (vagal indigestion or Hoflund's syndrome). Changes in the electrical activity of the abomasum were reported after vagotomy (Gregory et al., 1984). The effect of vagotomy on abomasal emptying in calves has been reported by Bell et al. (1977) using radiology to document slower transport of milk containing a contrast agent.

Intrinsic Innervation. Intrinsic innervation is present in the wall of the abomasum. This localization is similar to that of monogastric animals, but ruminants otherwise have substantial differences (Pfannkuche et al., 2002). Cholinergic, muscarinic, and nicotinic parts of the intramural nervous system in the abomasum and small intestine are responsible for generation and control of electrical procedures, called *minute rhythm* (Kuiper and Breukink, 1988; Romański, 2002). Receptors in the wall are able to detect tension and therefore filling of the organ. Increased tension of the wall leads to increased motility of the pyloric antrum, which is affected

Table 1. Factors increasing and decreasing abomasal emptying

Accelerates abomasal emptying	Decreases or slows abomasal emptying
Wheat-, fish-, or soy protein–based milk replacer	Large volume Fed with esophageal intubation or feeder High caloric content High osmolality High intra-abomasal pressure pH lower than 2 or higher than 10 High glucose–containing oral electrolyte solutions