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On Pre-Weaning Calf Weight Gain Differences: Opportunities to Improve Herd Productivity, Health and Longevity

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Abbreviations: ADG: Average Daily Weight Gain; BW: Body Weight at Weaning; CCK: Cholecystokinin; IGF: Insulin-Like Growth Factors

ABSTRACT

In this review article, we mainly aimed to explore and discuss possible causes of different and variable pre-weaning growth rates of dairy calves worldwide. The average daily weight gain (ADG) and body weight at weaning (BW) are two important management indicators, reflecting the degree of success in calf rearing systems pre-weaning. Presuming that increased pre-weaning ADG would be associated with later performance of calves as dairy cows, greater growth rates would be desirable. However, accomplishing this goal is not as easy as it sounds in practice. Although the importance of maximal ADG in the pre-weaning period has been emphasized in the literature; according to the NAHMS report (2014), only 33.3% of the U.S. milk-fed calves (n=1410) had an excellent ADG (i.e., > 0.82 kg/d), and the rest had either fair (35.4%; 0.62-0.82 kg/d) or poor (31.4%; < 0.64 kg/d) ADG. Similar reports seem to be evident worldwide. These results suggest that > half of the calves evaluated had fair or poor growth rates, thus fueling this school of thought that achieving optimal growth rates and development in newborn calves would need improved understanding of a variety of management related factors. Assuming similar calf genotype, differences in ADG among calves may be attributed to variable management conditions in which calves are raised. Milk and starter feeding strategies, disease incidence, environmental stressors, and varying welfare are amongst the main factors influencing growth performance of pre-weaned calves. Nonetheless, concerning growth performance of calves under commercial circumstances, the maturation of newborn calf's digestive tract and early-life energy use and partitioning appear to be overlooked. While the newborn digestive tract requires a minimum of two weeks to adapt to extra-uterine life and nutrition, it sounds logical to suggest that the biology of this time period (i.e., the first two or three weeks) is different from that of the rest of the pre-weaning period. As a result, we propose that the pre-weaning period be divided into two distinct phases with their own management and nutritional demands. As such, it can be hypothesized that the variation of ADG among calves on different farms may, at least partly, be explained by calf performance and health during the early weeks of life which can affect later performance of calves as dairy heifers and mature cows.

Introduction

Traditionally, dairy calves are fed milk at about 8-10% of birth body weight to increase starter feed intake and achieve early and timely weaning. This practice may reduce rearing costs but can also reduce average daily weight gain (ADG) as a result of decreased nutrient intake [1]. The growth performance and health status of dairy heifers in early stages of life have attracted much attention

over the past two decades. Greater weaning weights have been observed in calves on ad libitum milk feeding regimens [2]. Such a greater pre-weaning weight gain might relate to later performance of dairy heifers [3]. Accordingly, some nutritional concepts such as enhanced or intensified milk feeding programs have been developed [4]. Under such systems, milk is fed at approximately 20% of body weight to resemble the time when calves are raised with their mothers. Recent works also support this idea that increased milk intake to gain more weight in the pre-weaning period might be translated into greater milk yield in the subsequent lactation [5]. Given the potential benefits of greater ADG in early-life; however, it seems that considerable variations exist in ADG among farms in the U.S. (the NAHMS report, 2014) and likely worldwide. Some questions come to the mind. Are the producers aware of the possible positive effects of increased pre-weaning ADG on herds' productivity and longevity? To what extent are the scientific reports applicable to commercial circumstances? Addressing these questions may help the dairy industry establish sustainable heifer raising systems globally.

In an interview with dairy farmers and their advisors, it turned out that farmers did not receive adequate instructions for optimal feeding of young calves. This would suggest, and reflect in, under-nutrition and reduced ADG in early calf life [6]. According to this interview, most of the farmers in the UK used traditional milk feeding programs despite the fact that intensified milk feeding programs have been emphasized. In addition, calf growth performance in the literature is commonly expressed in a single time period [7], while weight gain in the later pre-weaning phases (from 3-4 weeks of age up to weaning) is totally greater than that in the early pre-weaning period (the first three weeks of life). In studies investigating the pre-weaning period as two separate phases including

1. The first three weeks and
2. The rest, the results have shown large differences in ADG of calves under different milk feeding strategies (intensified vs. conventional) in early life [8,9].

It seems that plan of nutrition during the critical first three weeks of life is a key factor determining the later performance of dairy calves. During early postnatal period, adaptation to the extra-uterine life occurs through alterations in nutrient assimilation and metabolism as well as thermogenesis which can all be affected by the plan of nutrition [10]. The early three weeks of life would represent a period during which calves are sensitive to many infectious diseases affecting growth performance adversely. It can be hypothesized that combinations of factors including calf physiological status, nutrition, welfare and behavior are involved in the neonatal growth efficiency. Consequently, performance and health of calves during the early weeks of age are key factors that justify the ADG differences, and thus, future performance of dairy herds. The objective of this review article was, therefore, to explore and discuss possible practical causes of different and variable pre-weaning growth rates of dairy calves worldwide. In addition, opportunities for improving dairy herds' productivity, health, and longevity were pointed out.

Extra-Uterine Life and Gut Adaptation in the Neonate Calf

During gestation, energy and protein requirements of the growing fetus are met by the dam which must be replaced by external nutrition post-birth. To utilize new feeds (i.e., milk, milk replacer, and starter feed) efficiently, neonates suffer tremendous metabolic alterations to be able to adapt to the extra-uterine life [11]. Understanding the gut maturation and nutrient assimilation can help producers manage young calves effectively during the early critical weeks of life. The digestive function of neonates is rapidly initiated after birth and suffers remarkable changes during the first 48 hours of the extra-uterine life [12]. For instance, concentrations of gastrin and cholecystokinin (CCK) increase markedly during the late gestation and immediately after birth, respectively, playing a key role in the timely regulation of the gut development. Secretion and activity of pancreatic enzymes and diversity of enzymes involved in hydrolysis of milk nutrients such as lactose are increased as calves age, being affected by diet type and properties [13]. Alongside these changes, immature enterocytes are replaced by adult cells during the first 5-7 d of the postnatal period, resulting in the intestinal barrier closure [12]. As the gastrointestinal tract maturation in neonatal calves is mainly related to age and diet properties, inferior diet characteristics can predispose calves to digestive disorders during the adaptation period [13]. With respect to these findings, lower energy and protein digestibilities have been reported for calves fed milk replacer within the first vs. second week of age [14], further indicating that the adequate adaptation period is needed for better utilization of nutrients supplied by milk or milk replacer. Therefore, profound and mechanistic understanding of the calf's digestive adaptation and nutrient assimilation may help improve ADG during the early weeks of life when compared with the rest of the pre-weaning period.

At the first three weeks of life, nutrients existence in the gut lumen is continually sensed by the epithelial cells receptors and assimilated with the help of other organs such as the liver [13]. It seems that colostrum intake stimulates gut development [13]. Colostrum is the first liquid feed calves ingest within the first few hours of birth. Colostrum intake is not only essential for transfer of passive immunity to the neonate but also has a critical role in

the development and maturation of the living gut [15]. Bioactive compounds found in colostrum including insulin-like growth factors (IGF) and hormones accompanied with immune cells are directly involved in calf's gut maturation process, thereby increasing the absorptive capacity of the small intestine [16]. Colostrum roles as a promoting factor in the gut growth and intestinal cell proliferation are well established [17,18]. Increased absorptive capacity of nutrients such as glucose [19] and improving the intestinal morphology may lead to greater ADG in calved fed maternal colostrum instead of transition milk during the first week of life [20]. In addition, development of digestive secretions and also protein digestibility are the main factors limiting calf growth [12]. There is evidence showing that serum IgG concentrations in the first week of life are positively correlated with energy and N digestibilities [14]. Although, in a recent study, such correlation was not observed [17]. Consequently, colostrum management is a very important practice that can affect growth performance of dairy calves in early and later in the productive life. From a practical viewpoint, some variation in ADG of calves between farms and among calves can partly relate to different colostrum management protocols. In this regard, maternal and pooled colostrum as well as colostrum replacer are frequently used by farmers for the first few meals with different amounts and qualities which can lead to inconsistent results regarding ADG. Mixed pooled colostrum might have lower quality than maternal colostrum. The greater concentrations of serum IgG in calves fed maternal colostrum vs. pooled colostrum has been reported recently [21]. Moreover, lower serum IgG and total protein concentrations as well as lower ADG were reported for calves fed colostrum replacer comparing those fed maternal colostrum [17]. As a result, having a colostrum bunk on-farm would ensure empowered calf immune status and effectively developed gastrointestinal tract.

Following colostrum feeding, dairy calves are ordinarily fed whole milk or milk replacers with variable quantity and quality according to farm management protocols. It is believed that milk feeding strategies in early life could influence gut development and intestinal function [22]. Authors have reported profound effects of intensified milk feeding on the jejunum function and immune activity of calves. The villus circumference in mid-jejunum was greater in ad libitum fed calves vs. restricted fed peers. Moreover, there was a tendency for greater villus surface in the distal part of the jejunum and ratio of villus height/crypt in ad libitum fed calves relative to restrict fed counterparts. However, the crypt depth was greater in the restrict-fed calves. Although little is known about the intestinal development of calves raised under different nutritional regimens, it is well understood that greater dry matter intake in early stages of life would mean greater ADG [23]. Elevated levels of insulin, IGF1 and growth hormone would support anabolic metabolism in calves reared under intensive feeding programs, whereas uncoupled somatotropin axis in limit-fed calves was observed in the first three weeks of life, indicating that greater dry matter intake mainly via milk or milk replacer during the early postnatal period can lead to better energy status of the intensive milk-fed calves [24]. Accordingly, feeding and management of calves in the early three weeks of age may considerably affect performance and health of calves during the rest of the pre-weaning period.

Milk Feeding, Disease Incidence, and Subsequent Performance

Dairy calves are raised under different management conditions according to farm equipment and facilities. Milk and starter feeding, housing, and disease incidence are the major factors influencing growth performance of calves mainly in early stages of life [25]. Pre-weaned calves basically rely on milk or milk replacer to meet their energy and protein requirements. Therefore, the quality and quantity of milk fed, seriously affect calf health and growth performance. Feeding newborn dairy calves is mostly based on two practical methods:

1. Traditional or conventional (also known as restricted milk feeding) and
2. Ad libitum or intensive milk feeding. In the conventional method, calves are fed at about 8-10% of birth body weigh two or three times a day.

In contrast, in the intensive milk feeding method, calves receive twice as much milk at approximately 20% of body weight [26]. The philosophies behind these systems are different. The main reason to feed calves conventionally is to be economical. Based on this concept, milk allowance is restricted to motivate calves to consume low-cost solid feeds. This method causes greater starter feed intake and rumen development, allowing calves to wean in early ages [8]. However, lower energy and protein intake under this milk feeding method can lead to slow growth rates [26]. This scenario is totally different from when the calves are naturally raised by their mothers. It has been demonstrated that calves would consume approximately 12 kg of milk per day in several meals during the second week of life when they are allowed to stay with their dams [27]. Greater DM intake by providing greater volumes of milk results in greater ADG and improved calf welfare [1,28].

Intensive milk feeding programs resemble the natural environment in which calves gain greater weights during the pre-weaning period. In addition to increased ADG; improved behavioral indices, welfare and disease resistance have been noticed for the intensive feeding programs [29,30]. Given such benefits, farmers apparently have only partial desire, if any, to use intensive feeding methods. Instead, the conventional milk feeding method is still used by most farmers worldwide. In our farm experience, the incidence of diarrhea and delayed rumen development are the

two main factors that cause fear in using greater amounts of milk. A traditional belief exists among farmers and labors that diarrhea is rather caused by the provision of greater milk.to young calves. Although a higher incidence of diarrhea has been reported in some studies using intensified milk feeding programs [29,30], others have reported no occurrence of diarrhea in the intensive milk-fed calves [1,23-31]. The difference among studies may be attributed to the different experimental conditions, quality and feeding procedure of milk replacer, as well as fecal scoring systems. It is important to mention that looser feces does not necessarily mean diarrhea and it should not be confused with infectious cases. Looser feces without clinical diarrhea has been recently reported in ad libitum milk replacer-fed calves [32]. Diarrhea has a multifactorial nature, with management and environment being the two significant effectors [33]. As a result, feeding greater amounts of milk especially with increased feeding frequencies does not seem to be the single cause of diarrhea. Despite that, health status and welfare of calves are improved under intensified feeding programs [34].

In human, impaired immune function was reported for individuals who was under-fed [35]. Investigating energy requirements of calves revealed that under thermo-neutral conditions (15-25˚C), restricted milk feeding method meets mainly maintenance energy needs with only limited ADG [36]. The restricted milk feeding would allow only 20-30% of the biological normal growth [37]. Obviously, under stressful environmental conditions such as hot or cold climates, energy needs for maintenance increase to maintain the core body temperature constant, hence, extra energy intake would be greatly needed. Given that it takes at least three weeks for starter intake to be high enough to meet energy requirements, it is expected that calves would suffer from a serious nutritional stress early in life [9]. Depressed growth, health, and welfare reported in the literature lead us to contemplate that older beliefs should be replaced by innovative new concepts. It is now clear that in most farms worldwide, pre-weaned calves are under-fed. As a result, maximal ADG cannot be achieved by conventional milk and non-milk feeding methods. More importantly, later performance and longevity of dairy cows would be closely related to health and growth performance of calves in early life. As such, plan of nutrition is a major factor causing and influencing ADG variations.

Housing System

Newborn dairy calves may be reared in individual or group housing systems. There are several options for calf housing, each with its own advantages and disadvantages. Two main indices that can be influenced by the housing system are calf welfare and growth performance. Greater feed intake and ADG have been reported for group-housed calves; however, if it causes disease outbreak, may not be appealing [38]. Small size (maximum 6 calf/pen) group pens with improved management would be recommendable when producers decide to rear calves in groups. Effective ventilation and draft prevention, and providing hygienic bedding with an appropriate depth are the key factors affecting health and performance of newborn calves in any housing system. Consequently, when the possible causes of lower or variable ADG are explored, housing related factors should be seriously taken into consideration.

Conclusion

The first three weeks of life represent an important phase of the pre-weaning period and overall dairy cow's productive life cycle. Improved ADG during this early period would mean improved weaning weight. From a calf management perspective, it is proposed to divide the pre-weaning period into two separate phases including

1. The early pre-weaning or the first three weeks of life and
2. The later pre-weaning or the rest of the pre-weaning period.

Restricted milk feeding during this critical period is not sufficient enough to meet energy requirements of calves; thus, intensified milk feeding should be used gradually instead of the conventional milk feeding programs. Intensive milk feeding methods do not appear to cause diarrhea in pre-weaning calves. Optimal early life calf health and performance would likely reflect in improved productive heifers and cows' health and longevity.

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