Myth: "What doesn't kill you makes you stronger": Early life performance and future implications

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Abstract

The effects of pre- and post-weaning performance and environment on production and longevity of cows later in life has become the focus of intense research in recent years. Here, we will present examples of the positive effects of accelerated early growth during weaning, post-weaning, and adulthood. Most importantly, we describe how producers can achieve elevated performance in their calves to see these benefits in the long-term, while also discussing potential risks in this investment.

Key words: dairy, calves, feeding, environment

Résumé

L'effet de la performance avant et après le sevrage et de l'environnement sur la production et la longévité éventuelle des vaches a été l'objet de recherche intensive ces dernières années. Ici, nous allons présenter des exemples d'effets positifs d'une croissance initiale plus rapide durant le sevrage, après le sevrage et pendant la vie adulte. Plus important encore, nous décrivons comment les producteurs peuvent augmenter la performance de leurs veaux pour réaliser ces bénéfices à long terme tout en discutant des risques potentiels de ce type d'investissement.

Introduction

The last decade of research on dairy cattle health and welfare has mainly focused on the adult dairy cow or replacement animals, yet very few articles have tried to link how pre- and post-weaning conditions for the calf can impact the future dairy cow. We know that management and housing conditions can impact the health and welfare of adult cows, so it follows that the quality of rearing conditions for dairy replacement animals may also impact growth, health, welfare, and even future productivity. There is a growing discussion of the sensitive or critical period of development just after birth, and how the rearing environment can profoundly impact the life of the animal, including how the animal behaves in a social environment, ability to cope with novelty and stressors, and cognitive ability allowing for flexibility in a changing environment. These effects are found in many mammal species, but also in cattle (reviewed in Costa et al[5] and in a complementary report in this issue of the AABP *Proceedings*). The central topic of this article focuses on how we can provide our replacement animals with accelerated growth and a healthy start in life that will translate to benefits as adults. Herein, we will present examples of how early life calf nutrition impacts performance, especially solid feed intake and average daily gain, and how producers can successfully raise calves on high milk allowances. Next we explore how accelerated growth by feeding more milk during the pre-weaning period can positively affect future production, reproduction, and health. Finally, we discuss the opportunities and risks of investing in early-life nutrition that is necessary for accelerated growth in replacement animals.

First Things First – Feeding More Milk for Accelerated Growth

The discussion about long-term effects related with the pre- and post-weaning period is relevant because the industry standard has typically fed a restricted diet to calves in their early life, primarily in fluid allowance (milk replacer, whole or waste milk). Limiting milk intake was thought to encourage calves to consume grain earlier in life, and thus could be weaned at a younger age with an accelerated rumen development. This feeding strategy for calves was also a more economical choice for the farmer, since a pound of milk solids or milk powder was a lot more expensive than a pound of grain. This milk-feeding strategy is still prevalent today, where calves are fed a restricted milk allowance of approximately 10% of their body weight (typically 4 to 6 L of milk/d) in the USA, Canada, Brazil, and Europe, among others (e.g. Vasseur et al;[33] Hötzel et al;[15] Staněk et al[29]). In the US a recent survey indicated that 53% of farms provided dairy heifer calves with just 4 to 5 L/d.[32]

Feeding calves a restricted milk allowance has some challenges. A major pitfall of this type of feeding regime is that, as expected, calves fed a restricted diet grow more slowly before weaning compared with calves fed more milk (e.g. Appleby et al;[1] Diaz et al;[9] Kiezebrink et al;[23] see review by Khan et al[21]). For many decades, one of the success measures of a pre-weaning calf program is that calves should double their weight by the time of weaning. This means that a 77 lb (35 kg) newborn Holstein calf should gain at least 1.32 lb (600 g) of body weight per day to achieve 154 lb (70 kg) around weaning at 60 d of age. On many farms, this target is not normally achieved when calves are fed restricted milk allowances, or 10% of body weight: weight gains will gener-

ally average around 0.66 to 0.99 lb (300 to 450 g) per day. These gains are much lower than what is possible; research now consistently shows that providing higher amounts of milk can improve pre-weaning weight gains to around 1.76 to 2.2 lb (800 g to 1 kg) per day (e.g. Sweeney et al;[30] Rosenberger et al[27]).

A second issue with feeding lower milk rations to calves is that they are much more likely to experience prolonged hunger, resulting in a serious welfare problem. For calves fed using automated feeding systems, a high number of unrewarded visits to the milk feeder (ie. a visit with no milk delivery because the calf is not permitted to drink) has been associated with a high motivation to obtain milk,[10] and is now used as a measure of hunger level in milk-fed calves.[11] Calves fed low milk rations (in this case approximately 10% of the calf's birth weight or between 4 to 5 L of milk per day) show increased behavioral signs of hunger, including a higher number of vocalizations at 5 weeks of age[31] and many unrewarded visits to the milk feeder as early as 1 to 2 weeks of age, and up to 3 to 9 weeks of age.[11,19]

Consequently, in the last decade there has been a surge of interest in feeding higher planes of nutrition to dairy calves, with special interest in both the short- and long-term benefits. These higher planes of nutrition programs are often called "Enhanced Growth", "Accelerated", "Intensive" or "Full Potential" milk-feeding programs. This practice is often coupled with modern weaning techniques and milk feeding plans, thus allowing for the provision of high milk allowances while also ensuring familiarity with solid feeds before weaning. This prior experience with solid feed is fundamental to a smooth transition from milk onto solid feeds. In the next sections we first address the issue of how much milk should be fed in a high plane of nutrition program, and second, how calves on these milk-feeding programs should be weaned. For an in-depth discussion on this topic, see the review by Khan et al.[21]

How much milk is considered a high allowance?

A common question from farmers is how much milk should be fed to be considered 'high enough'. Many studies to date have compared restricted levels of milk (4 or 5 L/d) to a specific 'high' level of milk, such as 8 L/d,[20] or to *ad-libitum* milk.[17] In each of these studies, results have consistently shown that greater weight gain can be achieved by feeding higher milk allowances compared to restricted allowances. However, it was only recently that our study from the University of British Columbia set out to specifically determine what the optimal milk allowance is that will maximize body weight gain without reducing grain intake. Rosenberger et al[27] assigned 56 dairy calves at 7 days of age to either 6, 8, 10, or 12 L of milk daily from automated feeders until 41 days of age, after which milk was offered at 50% of initial allowance until 50 days of age. Calves were then weaned by gradually reducing the allowance by 20% per day until weaning was complete at 55 days of age. All calves were provided free-choice access to grain, hay, and water from 7 d of age. As expected, calves achieved higher average daily gain (ADG) with increasing milk allowance over both pre- and post-weaning periods (7 d to 70 d): calves allowed 10 L/d gained 1.83 lb (830 g) per day and calves allowed 12 L/d gained 1.94 lb (880 g) per day compared to an ADG of 1.67 lb (760 g) per day for calves allowed either 6 or 8 L/d. Most importantly, during the pre-weaning period we found that calves fed 12 L/d grew 1.94 lb (880 g) per day while calves fed 6 L/d grew just 1.3 lb (580 g) per day, a significant difference of 0.66 lb (300 g) in ADG. Although calves on the lowest milk allowance consumed more grain before and during weaning, all calves consumed similar amounts of grain after weaning. Behavior at the feeder also differed depending on milk allowance. Calves receiving 12 L/d had the fewest rewarded visits to the feeder (i.e. when milk was available), likely due to the large meal allotments when they did visit the feeder. However, calves receiving 6 or 8 L/d had the most unrewarded visits per day, suggesting that these calves were experiencing more hunger than calves receiving more milk. This research suggests that milk allowances of at least 10 L/d result in pre-weaning weight gain advantages that persist after weaning, despite lower grain intakes pre-weaning.

How to wean when feeding high milk allowances?

Another major question from farmers feeding high milk allowances to calves is how to wean these calves without losing the weight advantages achieved before weaning. This is certainly a valid question, given that feeding high milk allowances is known to reduce early intake of solid feed. For example, several studies have reported higher solid feed intakes in calves fed less milk, leading to improved weight gains around weaning (e.g. Huuskonen and Khalili;[16] Bach et al[2]), and in some cases this may allow calves fed less milk to reach similar or greater body weights as those of calves fed more milk during or after weaning. Thus to maintain the early weight gain advantage in high milk allowance calves, weaning must be strategic. Successful weaning relies upon calves being already familiar with solid feeds at least 1 month before weaning begins to ensure a smooth transition from milk to solid feed, such that higher milk rations do not provoke added stress and growth check at weaning. If this transition is not done properly, weaning can be an extremely stressful time for dairy calves.

To ease the transition to a solid diet, several techniques can be used to increase starter intakes before weaning for calves fed more milk. First, abrupt weaning should never be an option. For example, Sweeney et al found that calves fed 12 L/d and weaned abruptly lost their body weight advantage after weaning, compared to calves fed restricted milk.[30] Abrupt weaning of calves fed high volumes of milk also increases signs of hunger associated with low energy intakes.[24] Gradual weaning methods that reduce milk slowly over a period of at least 2 weeks before the final weaning date or include step-down techniques (reducing 30% or more of the milk allowance over a period of 3 to 5 days) work best. Additionally, as

a general rule it is always best to try to increase the number of steps when reducing from high milk allowances, since an abrupt reduction of milk even by 50 percent can depress growth during a step-down procedure.

An additional benefit of these gradual weaning techniques is that they decrease the feeling of hunger experienced by calves, which reduces fruitless visits to the milk feeder and cross-sucking. This in turn decreases the stress associated with weaning and increases the overall welfare of the weaning calf. For example, gradual weaning methods (including step-down techniques[20]) and social housing[5,6,19] can increase solid feed intake before weaning and thus help maintain body weight during and after weaning. While these techniques effectively support the weaning transition, it is crucial to ensure that calves are eating at least 3.3 lb (1.5 kg), ideally 4.4 lb (2 kg), of grain daily before weaning is completed. Many studies have reported close to 1.98 lb (900 g) of ADG during the pre- and post-weaning periods in combination with high milk allowances and gradual weaning (e.g. Rosenberger et al[27]). The use of these techniques, combined with milk allowances greater than 20% of body weight, allow for improved weight gain and calf welfare in comparison to the standard 10% of body weight.[21]

In conclusion, higher milk allowances affect solid feed intake, body weight gain, and behavior before, during and after weaning in dairy calves. Producers can achieve these benefits by feeding higher milk allowances, but must have an appropriate weaning strategy, such as gradual or step-down techniques that reduce milk over at least 14 days. Will improved calf performance during pre- and post-weaning translate to benefits later in life? This is a hot topic that we discuss in the next section.

Long-Term Effects of Increased Performance in Early Life

There are many ways to measure calf raising input such as feeding rate, nutrient intake or simply ADG, and each of these factors has been investigated for its influence on future milk production in adult cows. Before we discuss the associated research on this topic, we remind readers to review the literature with a critical eye to determine if claims about long-term effects come from an appropriate population of calves. To put this in perspective, let's take an example of 2 calves: 1 is fed the traditional restricted milk allowance of 10% of body weight and 1 is fed a so-called 'enhanced' milk allowance of 12 to 15% of body weight. A difference of 0.33 lb (150 g) of weight gain per day is found between the 2 calves. While this weight gain sounds promising, in reality the restricted-fed calf grew just 0.66 lb/d (300 g/d) and the 'enhanced-fed' calf grew just 0.99 lb/d (450 g/d). In this example, the end result is a comparison between 2 poorly raised calves, but 1 calf is less poorly raised than the other. As discussed earlier, when calves are offered more milk, ADG can far exceed 1.1 lb/d (500 g/d). For example, a calf fed *ad libitum* milk allowance will drink on average 10.5 L of whole milk and can gain 1.76 to 2.2 lb (800 g to 1 kg) of body weight per day (e.g. Appleby et al;[1] Jasper and Weary[17]). In a recent meta-analysis, Gelsinger et al found that when pre-weaning ADG was between 0.66 and 1.1 lb/d (300 and 500 g/d) there was minimal effect on future lactation performance, but increasing effects were found when ADG increased from 1.1 lb and 1.98 lb (500 to 900 g/d).[12] For this reason, we encourage critical interpretation of the long-term effects of early life performance, keeping in mind that calves on a true successful milk allowance feeding regime (as described earlier) should be achieving at least 1.32 lb (600 g/d) of ADG .

One of the most famous reports on the effects of pre-weaning growth of heifers on first-lactation milk yield was by Soberon et al.[28] Using a large sample of heifers (n = 792), the authors investigated the relationship between a number of factors such as pre-weaning ADG, energy intake from milk replacer, and other growth outcomes and management variables with lactation performance. Interestingly, pre-weaning ADG had the highest correlation with first-lactation milk production, explaining about 25% of the variation in first-lactation milk yield. For every 0.22 lb (100 g) increase in pre-weaning ADG, heifers produced about 242 lb (110 kg) more milk during their first lactation. Other studies have since found similar results (eg. Van De Stroet et al).[34] Futhermore, a well-known longitudinal calf growth study that began in 1991 and followed calves from birth through multiple lactations found that dry matter intake (DMI) at weaning positively affected first-lactation milk production: every 2.2 lb (1 kg) increase in DMI translated to an additional 638 lb (290 kg) of milk yield in first lactation.[14]

Typically, milk yield is a primary focus in long-term studies but several studies have examined other short- and long-term effects of increased milk allowances. One of these effects of increased performance in early life is earlier age of puberty, and consequently reduced breeding age (e.g. Bar-Peled et al;[4] Raeth-Knight et al[26]). Interestingly, a recent study found that Holstein bull calves presented the same effects, where calves fed a high-nutrition diet reached puberty earlier and had larger testicles than those fed a low-nutrition diet, providing clear evidence that nutritional modulation during early life can have effects on reproductive development in Holstein cattle.[7]

Another positive outcome of feeding high milk allowances is improved health and immune capacity during and after the milk feeding period. For example, 1 interesting study reported that calves fed a higher plane of nutrition had improved immune responses to an oral *Cryptosporidium parvum* challenge.[25] Another series of studies indicated that an enhanced plane of nutrition influenced the immune responses of calves with effects extending into the immediate post-weaning period.[3,13] Furthermore, Heinrichs and Heinrichs reported that calves with fewer illness bouts (coughing and diarrhea) in the first 4 months of life had increased first-lactation milk production.[14]

While not all meta-analyses or reviews have agreed with these findings (e.g. Raeth-Knight et al;[26] Davis Rinker et al;[8] Kiezebrink et al[23]), we can certainly conclude that a wealth of information so far suggests that early-life experiences, especially nutrition, weight gain and health, can influence long-term performance of dairy cattle. If the evidence points to enhanced early-life nutrition as a potential to improve future milk yields, should we be changing our calf feeding practices? This discussion follows.

Does the Investment in an Enhanced Milk Feeding Program Pay Off?

If calves are fed more milk and gain more weight, can they actually produce more milk that would pay off the initial investment in milk-feeding? This is a very complex question and deserves a lot more discussion and interest from the research community. With the information we have today, we can at best make an educated gamble.

To try to answer this question, let's try a simple calculation based on the estimations of long-term milk returns in Soberon et al[28] and the average daily gains reported in 6 and 12 L-fed calves in Rosenberger et al.[27] In the Soberon et al study,[28] 2 separate herds showed that pre-weaning ADG was correlated with first-lactation milk yield: 1 kg of average daily gain translated to 850 kg more milk in the Cornell University herd, and 1113 kg more milk in the commercial herd. Using the more conservative estimate of 850 kg, this is equivalent to 85 kg more milk in first lactation when average daily gain during pre-weaning is 100 g/d. In our study (Rosenberger et al, 2017) we found that calves fed 12 L of milk grew 880 g/d while calves fed 6 L of milk grew 580 g/d during the pre-weaning period, amounting to a difference of 300 g/d total weight gained by feeding the higher milk allowance. This additional weight gain would then translate to 255 L of future milk yield, following the estimation from Soberon et al (2012).

Now let's imagine that we give this additional 255 L of milk yield back to the calf fed the more restricted milk allowance of 6 L/d. Dividing this 255 L of milk into 45 days of milk feeding would allow for an additional 5.7 L of milk to be allotted to this calf per day. This calf could now instead be fed close to 12 L of milk per day; if the prediction is correct, feeding higher milk allowances should come close to paying itself back just from the additional milk produced in the first lactation. In addition, there is potential for further returns from subsequent lactations or other secondary effects that an enhanced milk-feeding program can bring. Of course this is a very simple calculation that does not account for the increased costs in feeding management or labor, among other costs. While it is can certainly be daunting for a producer to invest the extra milk in young calves and wait years for the returns, the research to date suggests that feeding more milk should be a winning game for both calves and producers in the end.

Conclusions

We have reviewed the literature describing how pre- and post-weaning performance can produce positive benefits for production of cows later in life. Conventional feeding practices that limit milk intake (such as 4 or 5 L of milk per day, or 0.6 kg of solids) compromise the growth of calves, but also leave calves feeling hungry. While feeding higher milk rations can negatively affect solid feed intake before weaning, significant weight gain advantages over restricted-fed calves can be achieved as long as weaning is strategic. We recommend using gradual and step-down weaning techniques that reduce milk consumption at least 2-3 weeks before weaning ends to encourage early grain intake. Feeding higher milk allowances has been shown to have long-term effects such as increased first-lactation milk yield, improved health and even early-onset puberty. With these lines of evidence, we predict that producers who invest in an enhanced milk feeding program for their calves will see benefits in the short-term, such as increased weight gains, and are likely to see long-term benefits too, especially milk yield, and earlier age at first breeding and improved health, resulting in a positive feedback cycle for the animals, producer and consequently the dairy industry.

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