Rearing Calves for Maximum Production and Health

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Introduction

Improving performance and profits of dairy enterprises focuses typically on feeding and managing the lactating herd. However, this approach often results in a less-than-desirable attention to decisions pertaining to calves and heifers. This less-than-desirable attention to calves and heifers is likely to be one the most important reasons behind the astonishing failure rate of the new products of the dairy industry (i.e. heifers after first calving). Several studies report that between 9 and 17% of the heifers that reach first calving do not finish the first lactation (Bach, 2011; Sherwin et al., 2016). This figure is due to many aspects, but basically, it is related to a combination of inadequate nutrition and rearing practices coupled with lack of sufficient on-farm information to properly manage young stock. Contrarily to the situation in lactating cows, where management is based on records of milk yield, milk composition, feed intake, body condition, etc..., the most common situation in heifer rearing is that management is based on "feeling" rather than being based on methodic data collection and record keeping. This article will review several nutritional aspects aimed at improving performance of calves through nutrition and management with special emphasis on potential long-term effects on productivity and health.

Economic Consequences of Calf Rearing

Raising dairy replacements properly may represent important economic savings and lead to a reduced environmental impact of the dairy enterprise.As an example, a dairy herd milking 100 cows, can generate an anual net-profit of ~10,000 $US just by reducing age at first carving (AFC) from 28 to 24 months. Generating the same economic profit through improvements in milk production, with 100 cows, would require to increase average daily milk yield by at least 6-7 kg per cow and day. Both target (decrease AFC or increase milk production) are doable, but the first one is much easier and plausible to attain that the latter; however, in many instances producers and consultants strive to increase a couple of liters milk yield whereas much greater profits could be gathered by decreasing AFC. Nevertheless, not only age is important, it is also crucial to ensure that heifers calve with an adequate body weight (BW). Evidence from the literature (Hoffman and Funk, 1992; Bach and Ahedo, 2008) suggest that age at first calving has little correlation with milk production during the first lactation provided AFC is above 22 months, and BW seems to have a larger effect on milk production than age. Bach and Ahedo (2008) showed that for every 70 kg of BW at calving, an increase of 1,000 kg of milk yield during the first 305 d of the first lactation could be, on average, expected. Therefore, a reasonable target for raising dairy heifers under intensive conditions would be achieving a first calving between 22 and 24 months with a BW about 650 kg, or assuming an 11% loss in BW after parturition, a BW after calving of about 580 kg.

Thus, the question becomes what is the best growth curve to achieve 650 BW at 22 months. Most producers believe that the most expensive rearing period of calves is between birth and weaning (due to high feed costs and labor intensive procedures). This is partly true: the cost of each kilogram of feed (either starter concentrate or milk replacer) is, in many occasions, the greatest among the feeds in a farm. However, this does not directly imply that the return on the investment associated with pre-weaned calves are the greatest. The goal when rearing calves is to achieve 650 kg at 22 months of age, thus, calves need to put about 540 kg (580 kg of final BW minus 40 kg of BW at birth) of true BW (not accounting for the placenta and the baby calf they will carry during the last 9 months). Ironically, and despite that the unit cost of starter feed and milk replacer (MR) are high, every kilogram of BW achieved during the first 2 months of life is less expensive that a kilogram deposited when the heifer is 18 to 20 months of age. The reason for this is that feed efficiency (the proportion of feed that is converted into BW) is greatest (about 60%) during the first 2 months and lowest during the last months of pregnancy (about 7%). Thus, the high efficiency of conversion of MR and starter feeds offsets their high costs, and growing fast during the 2 months is more economically advantageous than postponing the deposition of these kilograms during the last phase of the rearing period (despite unitary feed cost are fairly low at that stage). More important, the most economically efficient growth during the rearing process occurs after weaning, when calves can utilize solid feed (relatively inexpensive at that age) with feed efficiencies around 30% (Bach et al., 2017b).

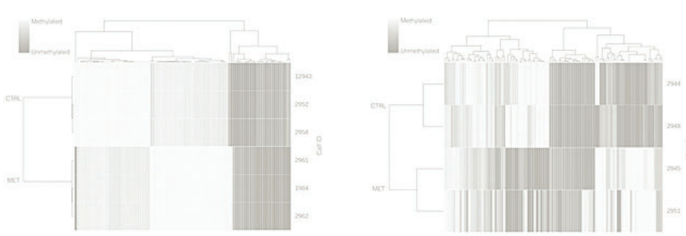
Performance at Adulthood as Affected by Plane of Nutrition Early in Life

Before birth

It is well established that nutrition represents one of the greatest environmental determinants of an individual's health and metabolic activity, and that it is likely that today's cow, with high milk yield but also reproductive and metabolic challenges, is not only a consequence of genetic selection, but also the result of the way her dam was fed and the way she was fed early after birth (Bach, 2012). However, the mechanisms involved in orchestrating the interaction between nutrition and genetic and epigenetic modifications is fairly unknown, and thus the potential long-term effects of nutrition through modifications of gene expression are often overlooked.

Figure 1. Cluster analysis of CpG sites differentially methylated (P < 0.01) in the offspring born to lactating (A) dams or heifers (B) that received a supplementation of methyl donors or a placebo during early pregnancy. Control lactating dams received a placebo, whereas MET dams received weekly administrations of 200 mg of folic acid and 20 mg of vitamin B12. Control heifers received a placebo, whereas MET dams received weekly administrations of 100 mg of folic acid and 10 mg of vitamin B12. (Adapted from Bach et al., 2017a)

A) B)



There is evidence that providing high planes of nutrition in calves results in positive long-term effects on production (Bach, 2012; Soberon et al, 2012; Gelsinger et al., 2016). Furthermore, two prospective studies indicated that growth rate early in life is positively correlated with survivability to second lactation (Bach, 2011; Heinrichs and Heinrichs, 2011). However, whether these changes are due to epigenetic modifications is currently unknown. It is likely that supplementation of methyl donors during pregnancy may have an influence in the regulating epigenetic marks. Some recent evidence (Bach et al., 2017a) shows that supplementation of methyl donors (i.e., vitamin B12 and folic acid) during pregnancy has an effect of the epigenome of the offspring, and the changes in methylation pattern of the offspring differs between daughters born to heifers compared with daughters born to lactating cows (Figure 1). However, we do not yet know whether these changes exert a positive or negative influence in performance at adulthood. Jacometo et al. (2016) reported that supplementing lactating dams with methionine (a methyl-donor) resulted in calves that underwent a faster maturation of gluconeogenesis and fatty acid oxidation in the liver, which would be advantageous for adapting to the metabolic demands of extra-uterine life. On the other hand, the long-term effects associated with greater planes of nutrition could also be mediated by non-epigenetic changes. For instance, feeding a MR rich in linolenic acid (1.5% of the total DM) compared with a regular MR (providing 0.45% of linolenic acid) modified the expression of hepatic genes, including genes predicted to decrease infections and to increase lipid utilization and protein synthesis (Garcia et al., 2016). However, whether these changes were just a result of differences in metabolic pathways or a consequence of epigenetic changes (which would then have a sustained response) was not determined in that study, but it is likely that the observed effects were a result of both, metabolic activity and some changes in the epigenome. Geifer et al. (2017) hypothesized that increased planes of nutrition during the pre-weaning period enhances the responsiveness of the mammary tissue to mammogenic stimulus as they reported an increase in the expression of estrogen receptors in the mammary gland of animals fed increased planes of nutrition compared with traditionally-fed calves.

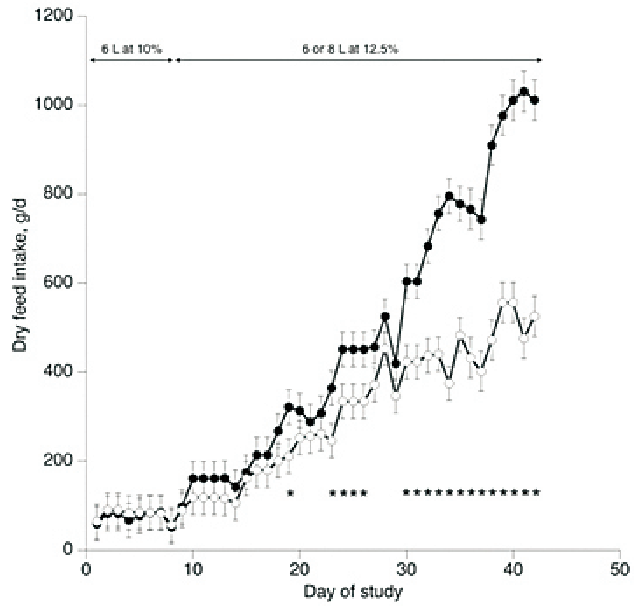
Liquid Feeding

Right after birth, we must ensure that the newborn calf receives an adequate amount of antibodies and nutrients to avoid illness during the early stages of life. Most emphasis in colostrum has been placed on immunity and we have often forgotten that colostrum provides a large amount of nutrients (mainly protein and fat). Calves, only receive colostrum 2 or 3 times and then they are moved to whole milk or MR with a substantial reduction in nutrient supply. To partially compensate for this difference, some producers are increasing the DM of MR by using dilution rates of 15% rather than the traditional 12.5% (similar to the solid contents of milk). However, the relative proportion of nutrients offered in MR still differs quite drastically from that found in whole milk, and there is some controversy about the optimal relative proportion of nutrients in MR. For instance, Hill et al. (2006) concluded optimal concentration of protein and fat in MR should be approximately 26% CP and 17% fat, which was later corroborated by Hill et al.

(2009b) who reported a linear decrease in average daily gain (ADG) as the CP of MR decreased from 27 to 25 and 23% while maintaining fat content fixed at 17%. Daniels et al. (2009) reported no differences in growth rate between 5 and 9 weeks of calves offered 950 g/d of a MR containing either 28% CP and 20% fat of 28% CP and 25% fat although calves offered the 27:28 MR tended to grow more between weeks 5 and 7 than those fed the 28:20 MR. Similarly, Morrison et al. (2009) compared one MR providing 21% CP and 18% with one providing 27% CP and 17% fat and reported no difference in ADG between calves fed either 5 or 10 l/d of each MR, and Hill et al. (2009a) reported no differences between calves fed a MR containing 27% CP and 20% fat or 27% CP and 17% fat. A potential reason for the lack of response to increased fat or protein supply through the MR could be, in part (other reasons could include inadequate amino acid or fatty acid profile, poor digestibility of the ingredients used), changes in solid feed intake, but, Hill et al. (2009a) reported that calves fed a MR containing 27% CP and 31% fat achieved equivalent solid feed intakes than calves consuming a MR containing 27% CP and 17% fat, but surprisingly, calves fed the high-fat MR had a lower ADG compared with those fed the one containing 17% fat. In a former study, Hill et al. (2007) had already reported that adding energy in MR via lactose or CP, but not via fat, improved ADG. However, offering MR with about 27% MR and about 17% fat results in an oversupply of lactose (>45%). Lactose, differently from fat, is vigorously fermented by intestinal bacteria and may represent a risk for diarrhea.

Based on economic arguments and empirical evidence of increased longevity and productivity associated with improved growth rates early in life, the industry is now providing larger amounts nutrients to sustain rapid growth rates (>850 g/d) during the first 2 months by mainly offering larger volumes of milk or MR. An "ideal" feeding program for calves could probably consist on feeding 6 l/d at 15% (900 g/d of solids) along with a highly palatable starter feed and some chopped high-fiber forage (see below). Offering 8 l/d may foster increased growth rates early in life but is likely to compromise intake of starter (Bach et al., 2013b; Figure 2) and if fed twice daily may foster insulin resistance in calves (Bach et al., 2013a). Nevertheless, concerns about incurring in long-lasting detrimental effects due to insulin resistance seem unlikely as Yunta et al. (2015) showed that after 20 d after weaning there were no differences in insulin sensitivity among calves fed 4, 6, o 8 L/d of MR during the first 2 months of life.

Figure 2. Dry feed intake during the first 42 d of the study as affected by the level of milk replacer (MR). Open circles denote 8 L of MR/d and solid circles depict 6 L of MR/d. Asterisks indicate days of study when dry feed consumption differed (P < 0.05) between MR allowances. Adapted from Bach et al. (2013b).



Solid Feeding

Some schools of thought have proposed that the positive effects on future milk production observed when providing high planes of nutrition early life could only be achieved by providing increased amounts of MR (Soberon et al., 2012). However, Bach et al. (2012) and more recently (Gelsinger et al., 2016) have described that nutrients supplied from liquid or solid feeding are equally effective in inducing positive long-term effects in milk production. Thus, fostering solid feed intake should be a pivotal objective for any rearing program mainly because 1) it will help in improving nutrient supply and growth, 2) will contribute to increase milk production in the future, 3) will enhance rumen development, and 4) will facilitate the weaning process. Calves fed high milk allowances tend to struggle during transition onto solid feed, and part of the growth advantage achieved before weaning may be lost due to (1) diminished consumption of nutrients, and (2) reduced digestibility. Early dry feed consumption fosters early rumen microbial development, resulting in a greater rumen metabolic activity (Anderson et al., 1987). Thus, the high level of MR in calves following an enhanced growth feeding program, may delay the start of dry feed consumption, and consequently, it may delay rumen development making it difficult to wean calves and maintain rapid growth rates. This may have important economic consequences (in addition to some potential health issues). Average daily gain right after weaning is the most profitable one during the entire rearing period of a heifer, and in addition, ADG during the late phase of weaning transition (between 160 and 230 d of age) is positively correlated with future milk production (Bach and Ahedo, 2008).

There are several strategies to improve starter feed intake and supporting greater ADG early in life. One strategy consists of including 'palatable' ingredients in the formulation of the starter. Miller-Cushon et al. (2014) evaluated the palatability of several energy and protein ingredients concluded that corn gluten feed and corn gluten meal should be avoided, and wheat, sorghum, corn, soybean meal should be prioritized to increase palatability of starters. Oats, which are commonly included in starters, were found to have low palatability, and thus their inclusion in formulation of starter should not be forced, and if possible it should be avoided. In terms of nutrients, a good starter should contain 18% CP and 3.2 Mcal/kg of metabolizable energy, although starters containing 20% or more CP may have some benefits right after weaning when rearing calves in intensified milk regimes to provide sufficient metabolizable protein and ensure amino acids do not limit growth. In fact, Stamey et al. (2012) reported increased solid feed intake around weaning (with ~300 g difference in DM intake at weaning) when comparing calves fed ~900 g/d of solids from a MR with 28.5% CP and 15% fat and a starter feed containing 25.5% CP compared with one containing 20% CP. However, when offering restricted amounts of milk, feeding starter feeds with >22% CP (DM basis) provides no additional advantage in growth (Akayezu et al., 1994). Thus, it seems that with large milk allowances, calves may benefit from increased CP supply via starter feed. Lastly, it may seem logical to limit starch content to avoid acidosis, but the calf actually needs starch, not only for rumen development (as its fermentation will generate large amounts of volatile fatty acids that stimulate papillae growth), but also to provide energy to sustain growth. Thus, inclusion of low levels of starch in starter feeds is not recommended. In general, feeding starter feeds containing between 30 and 35% starch should be adequate (Bach et al., 2017b).

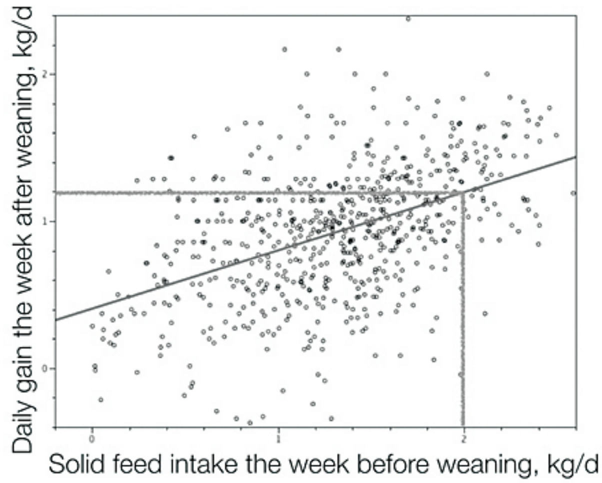
Several studies (Khan et al. 2011; Castells et al., 201; Castells et al., 2013; Montoro et al., 2013) have shown that an effective method to foster solid feed intake of calves, contrary to what it has been traditionally recommended, is to provide ad libitum access to poor quality (nutritionally) chopped straw or chopped grass hay. In the last century, it was believed that feeding a fiber source to young dairy calves was necessary because it improved rumen health and that if no forage was provided to calves, low fiber content of the complete starter should be avoided (Jahn et al., 1970; Thomas and Hinks, 1982). But, later, in the 70's the concept of textured starter was introduced (Warner et al., 1973). It was then assumed that with textured starters no additional feeding of forage was needed. However, several authors (Kincaid, 1980; Thomas and Hinks, 1992; Phillips 2004; Suárez et al., 2007; Castells et al., 2012) have reported either an increase in starter intake or no effect on total feed consumption with the inclusion of dietary forage. Castells et al. (2012) offered an 18% NDF and 19.5% CP pelleted starter in conjunction with different sources of chopped forage to young dairy calves, and reported that feeding chopped grass hay or straw improved total dry feed intake and rate of growth, without impairing nutrient digestibility and gain to feed ratio. In contrast, when the forage was alfalfa hay, these benefits were not observed. Several studies (Hill et al., 2008) have argued that feeding forage (hay and straw) to pre-weaned dairy heifers reduces starter and overall dry matter consumption. It is important to note that, in the studies by Castells et al. (2012, 2013), when calves were fed ad libitum chopped alfalfa hay, forage intake was 14% of total solid feed intake, whereas when calves were offered chopped oats hay, forage consumption did not surpass 4% of total solid feed intake. Nevertheless, some nutrition consultants do not advocate for forage feeding and propose feeding texturized starter feeds, but their success will depend on 1) the scraping ability of the starter feed, and 2) the amount of solid feed consumed by the calf. If calves consume large amounts of starter feed, even a texturized starter feed may fail providing sufficient scraping activity in the rumen. Thus, from a practical point of view and to remove uncertainty, feeding high-fiber (>60 %NDF) chopped forage along with a starter feed is likely to result inadequate growing performance. Lastly, an important consideration regarding feeding chopped forage to calves, is that it needs to be well and consistently chopped at about 2.5 cm in length and despite the fact that it must be high in fiber (>60%NDF) it must be of high quality (i.e., free of molds, mycotoxins and other impurities).

Weaning Calves

With the introduction of enhanced feeding programs, which consist of feeding large volumes of milk or even providing milk ad libitum, calves depend less on starter feed intake to meet their nutrient needs, and solid feed intake generally represents about <60% of total feed intake the week preceding weaning. In other words, with some enhanced feeding programs, calves are weaned with solid feed intakes around 500 g/d (Terré et al., 2007), which makes it impossible for the calf to maintain adequate ADG during the first weeks of transition. This growth slump has 3 main consequences: 1) potential reduction of milking performance at adulthood; 2) increased risk for disease, especially bovine respiratory disease (**BRD**); and 3) economic loss. Heinrichs and Heinrichs (2011) reported that milk yield during first lactation was positively correlated with the amount of solid feed consumed by calves at weaning (among other factors), and Ollivett et al. (2012) reported that fecal scores improved faster among calves challenged with Cryptosporidium parvum and receiving a high plane of nutrition compared with calves on a low plane of nutrition. Lastly, given that feed efficiency and growth potential are high and feed cost is relatively low during the transition, this represents the most profitable period to foster BW accretion and development. The aim should be achieving an ADG in the week following weaning greater >1.2 kg/d, and thus calves should not be weaned until they are consuming at least 2.0 kg/d of starter feed (Figure 3).

Lastly, an important aspect of weaning calves is the way they are socialized. Dairy calves have traditionally been reared individually, with the main purpose of stemming the spread of disease, a growing body of literature suggests several benefits of social housing in which two or more calves are housed together. Social housing allows for normal social development of the calf, and calves reared in groups respond to novel social situations with less fear and reactivity (de Paula Vieira et al., 2012). Social housing has been shown to encourage a greater solid feed meal frequency and intake before and during weaning (Bach et al., 2010; de Paula Vieira et al., 2010), may support greater ADG and reduce stress (de Paula Vieira et al., 2010) through weaning, and might reduce the severity of BRD (Bach et al., 2010). Similarly, grouping calves either at weaning time or during preweaning (Bach et al., 2010), when milk offer is reduced, can result in increased feed intakes and performance. Similarly, social housing at 1 week of age has been reported (Costa et al., 2015) to support greater intake and growth compared with calves grouped at 6 weeks of age; other studies also report similar results when providing social contact to calves before 3 weeks of age when feeding relatively large amounts (~1.0 kg/d) of milk (Jensen et al., 2015).

Figure 3. Relationship between solid feed intake the week preceding weaning and average daily gain the week after weaning (Adapted from Bach et al., 2017b).



Summary

Rearing costs represent a large investment for dairy producers. Implementing adequate rearing programs not only should result in optimal rearing cost but it should also ensure maximum return on the investment through improved productivity and longevity.

There exists substantial evidence that generous growth during the first 2 months of life results in improved milk performance at adulthood, and ironically, calves that grow faster early in life are commonly less expensive at first calving than those that grow more slowly.

This rapid growth can be achieved by providing about ~1 kg of milk powder per day along with a highly palatable pelleted starter feed fed next to free access to a chopped (~2.5 cm) high-fiber (>60% NDF) grass hay or straw.

Fostering growth right after weaning is highly desirable to lower rearing costs. For this reason, the weaning program must avoid the common growth slump that occurs when feeding generous amounts of milk. Thus, calves should no be weaned until they consume at least 2 kg/d of starter feed. Also, calves benefit from being weaned in groups rather than in individual hutches, and this should be moved into group housing as early as possible (ideally around 21 d at the latest).

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