
To optimize first lactation and lifetime milk yield, growth benchmarks were established to help nutritionists meet the appropriate growth objectives of breeding weight and age at an economically viable time and to achieve the optimum body size and composition at first calving (NRC, 2001). However, there are still concerns that mammary development is impaired when BW gain exceeds a certain threshold and this impairment negatively affects milk yield. The objective of this review will be to integrate concepts of body growth and composition, mammary development and milk yield to provide a systems based perspective on first lactation milk differences that have been associated with mammary development. The seminal work by Sejrsen et al. (1982; 1983) describing the effect of high energy intake on mammary development and the relationship with circulating growth hormone linked the relationship between pre-pubertal growth, mammary development and future milk yield. The primary outcome of Sejrsen et al. was to provide an intuitive mechanism to explain why rapid growth during the pre-pubertal phase resulted in reduced milk yield. The observation of reduced mammary development could be repeated in almost every experiment (Pritchard et al., 1972; Petitclerc et al., 1984; Mäntysaari et al., 1995; Capuco et al., 1995; Meyer et al., 2006). These repeatable observations lead to the conclusion that high energy intake and increased ADG reduced mammary development through altered hormone status or some signaling processes. However, Meyer et al. (2006) were the first to recognize that mammary development was not reduced by high energy intake, and instead a function of the time to reach puberty and the associated signals to change from allometric mammary growth. The mammary gland, like all reproductive organs, grows in proportion to the size of the body and not in proportion to nutrient intake during the post-weaning, pre-pubertal phase. First lactation milk yield, mammary development and body composition will be further discussed in the context of mechanisms and opportunities.

Key Words: heifer, mammary development, milk yield


Under conventional milk feeding systems, calves are provided restricted amounts of milk or milk replacer and weaned after a few weeks of age. With increasing awareness that early nutrient intake may increase milk yield in first lactation, high milk replacer schemes in early life are currently intensively researched. In the veal industry, high milk replacer schemes for calves are common practice, but in Europe, the intake of concentrates in this sector is strongly increasing, at the expense of milk replacer. Combining knowledge on nutrient metabolism of these areas provides valuable insights for future development of targeted feeding schemes for young calves. Protein efficiency in calves drops dramatically in early life, particularly related to metabolic inefficiencies. Typically for calves and unlike in monogastric species, protein and energy simultaneously limit protein retention. With the possible exception of the first weeks of life, amino acid imbalance is rarely a cause of protein inefficiency. Fats and lactose are well digested, but digestion of starch appears limited. After absorption, fats are oxidized or stored as body fat, but lactose is predominantly oxidized. Recently, it was revealed that calves do possess the enzyme systems for de novo lipogenesis from glucose, but use it only at very high lactose intakes. Consequently, the increase in fat deposition following an increase in feed intake is almost exclusively from dietary fat. Insulin sensitivity rapidly drops in the first 6 weeks of life to levels that are invariably low. This decrease seems independent of diet, as it occurs in milk fed as well as in weaned calves. Meal responses of glucose and insulin largely reflect portal glucose appearance rather than insulin sensitivity. Nonetheless, available glucose is virtually completely oxidized. Apparently, despite the low insulin sensitivity, glucose transport into cells is almost complete. In veal calves of 4-6 months of age, the efficiency of utilization of lactose, fat and protein for growth was found to be independent of the level of intake of solid feeds, suggesting that feeding scheme’s for milk replacers and solid feeds for calves may be developed independently.

Key Words: macronutrient, metabolism, calf


Estimates of energy content of dry feeds used by the National Research Council (NRC, 2001) are based on equations to estimate truly digestible non-fiber carbohydrate (NFC), CP, fatty acids and NDF from composition of feed. Total digestible nutrients, digestible and metabolizable energy (ME) are then calculated from these fractions with appropriate corrections and adjustments. Although this approach is efficient for adult animals, errors may occur when calculating ME in calf starters (CS). Digestion of nutrients, but particularly starch and NDF, is low in young calves consuming little CS and with negligible rumen development. Apparent total-tract digestion (TTD) of ADF and NFC in calves fed > 0.8 kg/d MR are < 50% of estimates in calves fed < 0.8 kg/d until 12–13 wk (6–7 wk post-weaning). Although CS intake increases rapidly post-weaning, inability to digest CS nutrients may partially explain post-weaning depressions in BW gain in the first few weeks post-weaning when calves are fed > 0.8 kg/d MR. Further, nutrient content of CS may influence TTD of nutrients. Calves fed a 41% starch, texturized CS had lower ADF and NDF digestion at 8 wk (1 wk post-weaning) compared with calves fed a 10% starch, pelleted CS, which may be due to low ruminal pH and depression of fiber digestion. We calculated ME in CS fed to Holstein bull calves from 0 to 16 wk using TTD data from 3 published studies. Calves were fed varying amounts of MR, and water and CS were available ad libitum. The TTD of NFC, NFC and total DM in CS increased with increasing NFC intake from CS in a logarithmic fashion. Calculated ME in CS in calves fed > 0.8 kg/d MR (lower CS intake) were lower than calves fed less MR (greater CS intake) at similar ages. Natural logarithm of NFC intake from CS accounted for 70% of variation in calculated ME in CS. Calculated ME in CS was < 75% of NRC estimated ME when calves consumed 0.2 kg/d of NFC and 98% of NRC estimated ME when calves consumed 1 kg/d of NFC. Ability of the calf to extract energy from CS changes with age and rumen development and depends on intake of NFC from CS. Feeding management that delays NFC intake may reduce ME in CS. Equations using NFC intake may provide greater accuracy in estimating ME in CS.

Key Words: calves, energy, digestion
Growing and developing dairy heifers from birth to weaning. A. J. Heinrichs*, The Pennsylvania State University, University Park, PA.

We have made dramatic changes in the nutrition and management of dairy heifers over the past 20 years. Significant basic nutrition research and applied management studies have moved our knowledge of the dairy heifer forward. Increasingly, the industry has become more progressive in adopting management practices based on the physiology and nutrient needs of the heifer. The US has experienced consistent progress toward optimizing heifer growth rates and reducing age at first calving. Part of this change has to be a result of economic analyses showing that age at first calving drives the overall cost of the heifer enterprise. Studies using data from the early 1990s demonstrated the economic advantage of calving at 23 to 24 mo, yet the industry lagged far behind at that time. Recent industry trends show a marked reduction in age at first calving, from 28 mo in 1980 to 25.5 mo in 2004 and a sustained decline since then. Research into growth rates and standards for body size and stature have been instrumental in developing rearing programs that provide heifers with adequate nutrients to support growth and improve milk production in first lactation. Free stall and bedded pack housing along with use of higher quality forage in total mixed rations and limit feeding systems have improved the feed efficiency of heifers to allow improved growth rates and breeding at younger ages. Transitioning the weaned heifer to this feed efficient system remains a problem on many farms. There remains opportunity for research to more fully understand management and feed efficiency of heifers as they continue to mature at younger ages. Currently, calving at 22 to 23 mo appears to best balance the cost of growing heifers with their lifetime production and income potential. 

Key Words: dairy heifer, growth rates, age at first calving