



J. Dairy Sci. 99:1–9  
<http://dx.doi.org/10.3168/jds.2014-9043>  
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## Invited review: Carryover effects of early lactation feeding on total lactation performance in dairy cows

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### ABSTRACT

In comparison with the intensive research on the direct effects of energy supply on dairy cow lactation performance, little attention has been paid to the effect of early lactation feeding on subsequent production. The present paper reviews 9 studies carried out with the aim of quantifying the immediate and subsequent responses in milk production and body weight to early lactation feeding. Most results showed that a more generous feeding in early lactation caused a positive carryover effect on subsequent production, whereas an inadequate level of feed in early lactation has been shown to reduce subsequent milk yield. The carryover periods ranged from 3 to 12 wk and the difference in milk yield between cows in the carryover periods ranged between 1.5 and 4.5 kg of milk/cow per day. When calculated as a percentage of the immediate effect, the carryover effect ranged from 22 to 63%. In 2 of the 9 papers reviewed, the authors found no carryover effect, probably due to the long post-treatment periods in these studies. This is supported by the other studies in which the carryover effect was only significant in a limited period after end of treatment. The magnitude of the carryover effect seems to be determined by several factors including duration of the treatment and post-treatment feeding level. The most important factor though appears to be the magnitude of over- or underfeeding (i.e., a strong relationship between the treatment period feeding level and the subsequent response in production).

**Key words:** dairy cow, feeding level, milk yield, carryover effect

### INTRODUCTION

Traditionally recommendations for feeding dairy cows in early lactation have been based on standard need of energy and protein for maintenance, growth,

and milk production. The optimal feeding on the farm level seen from an economic point of view should, however, be estimated with respect to feed and milk prices. As prices may vary considerably over time (FAO, 2012), it could be argued that the feeding level of the dairy cows should be adjusted according to price changes during the lactation. Economic optimization within herds requires an accurate prediction of the marginal production responses to changes in nutrient supply. The evidence on immediate effects of feeding on production has been variously reviewed (e.g., Wiktorsson, 1971; Coulon and Rémond, 1991; Broster et al., 1993). However, research indicates that changes in feeding level during the lactation not only have an immediate effect on production, but that level of nutrition during the first few weeks of lactation can have a major effect on subsequent lactation performance. As early as 1950 (cited in Broster and Broster, 1984), attention was drawn to the possibility that previous feeding could affect current production. Since then, numerous studies have investigated the carryover effect of energy and protein level on milk production and BW changes.

In a review, Sejrsen and Purup (1997) described the effect of prepubertal feeding on milk yield potential in dairy heifers. Also, the effect of feeding level during the dry period on subsequent lactation performance has been demonstrated in different studies (Holter et al., 1990; Holcomb et al., 2001). Other studies have focused on the carryover effects of feeding in one lactation on production and body condition in the subsequent lactation, as reviewed by Broster et al. (1993).

In a comprehensive review, Broster and Broster (1984) studied the effects of feeding level on production in dairy cows in literature through about 30 yr. The conclusions of the review were that underfeeding in the first part of the lactation results in a carryover effect in the range of 35 to 50% of the immediate effect in the first part of the postunderfeeding period and up to 15% of the total lactation production. The immediate milk response from increased feeding level ranged from 1.87 to 3.44 kg of milk/d and the mean carryover response ranged from 0.67 to 1.30 kg of milk/d, with the highest

Received October 30, 2014.

Accepted December 6, 2015.

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responses found when previous feeding levels were the lowest. These results showed that the production gains of high feeding levels were smaller than the production losses of underfeeding due to the law of diminishing returns (Broster and Broster, 1984). The results for live weight changes showed a carryover effect of the opposite trend to that shown by milk yield. This means that, by imposing a low feeding level to cows in early lactation, they prioritize more nutrients toward live weight gain in later lactation (Broster and Broster, 1984). Since these studies were conducted, notable changes have occurred in dairy management and cow genetics. Several recent studies on the subject have been published. The present paper gathers this newer knowledge to quantify the carryover effects of early lactation feeding on total lactation performance. All selected studies practiced group feeding of cows in contrast to older studies where restricted amounts or forage was allocated individually to the animals (neck-tied cows). The cows in the selected studies were pasture fed, paddocks fed, or indoor fed, and to gain a sufficient number of studies no separate analysis was made for these 3 systems of forage feeding. Studies with individually restricted forage feeding, however, were rejected for the purpose of this review.

## MATERIALS AND METHODS

The first selection criterion for articles was year of publication, and it was decided only to use articles written from 1980 and later. Feeding, pasture, animal management, and cow genetics have changed over years; therefore, the results obtained in older studies might not be relevant in modern dairy production. Another criterion was the study design, which should include a change in energy feeding level during one lactation. Several studies investigated the carryover effect of feeding in one lactation on production in subsequent lactations, but these studies were not relevant in the present article. The production parameters required in the articles included, at minimum, milk production and feeding level during the treatment period and during the carryover period together with the length of the treatment period and the carryover period. After this selection, 9 papers fulfilled the criteria and were included in present review. Eight out of the 9 papers were from pasture-based systems. Most studies used Holstein-Friesian cows, but other breeds are also represented.

The immediate effect of feeding level is the difference in production between groups of cows on different feeding levels during the treatment period. The carryover effect on milk yield was calculated as the difference in production between 2 groups of cows on the same feeding level that were previously fed different levels

of energy. The length of the carryover period differed markedly between articles. Thus, the difference in production was divided by the number of days in the carryover period (i.e., the carryover effect is presented as production response per day).

## RESULTS

Kennedy et al. (2007) studied the influence of daily pasture allowance and supplementation level during 11 wk for 66 Holstein-Friesian dairy cows in early lactation on animal performance throughout lactation. Treatments were imposed when cows were, on average, 2 to 11 wk in milk and consisted of 3 pasture allowance levels (13, 16, and 19 kg of DM/cow, >4 cm) and 2 concentrate supplementation levels (0 and 4 kg of DM/cow per day). Concentrate supplementation increased production of milk (4.1 kg/cow per day) and SCM (2.8 kg/cow per day). In addition, supplemented animals gained 0.23 kg/cow per day ( $P < 0.01$ ) more than unsupplemented cows. The authors found a significant ( $P < 0.001$ ) carryover effect of concentrate supplementation on milk (+2.6 kg/cow per day), SCM (+2.3 kg/cow per day), milk fat (+91.1 g/d), and protein (+71.9 g/d) yields during a subsequent 4-wk period following the treatment period. On the other hand, no carryover effect of pasture level was noted in the treatment period on any milk production variables. Neither did Kennedy et al. (2007) find any effect of initial concentrate supplementation on BW 4 wk after the treatment period. The cumulative concentrate input for supplemented animals was 382 kg of DM/cow. The total lactation milk yield of cows offered concentrate in the treatment period was increased (+432 kg/cow per year;  $P < 0.01$ ) compared with cows that received no concentrate throughout the year (5,168 kg/cow per year). The mean milk production response during the treatment period was 1.1 kg of milk/kg of concentrate DM offered and over the total lactation the response was 1.13 kg of milk/kg of concentrate DM.

In a similar study (McEvoy et al., 2008), the effects of concentrate and pasture allowance level were studied to estimate the optimal concentrate level for dairy cows in early lactation and to investigate the carryover effects of the treatments in early lactation on milk output and BW. The experiment included 72 Holstein-Friesian assigned to 1 of 6 grazing treatments for a treatment period of 11 wk. Treatments consisted of 2 pasture allowance levels (13 or 17 kg of herbage DM/cow per day, >4 cm) and 3 levels of concentrate (0, 3, or 6 kg of DM/cow per day). Increased herbage intake significantly increased milk (1.85 kg/cow per day), SCM, and BW during the treatment period. During this time, a linear response in milk and SCM yield to concentrate

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