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Effects of stage of lactation and season on udder development and milk yield in pasture-fed cows

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ABSTRACT

Effects of stage of lactation and season on mammary development and milk yield were determined in three herds of lactating Friesian cows (n~25 cows/herd) during June and July 1995. The herds in early, mid or late lactation calved in Apr-95, Jan-95 or Oct-94, respectively.

Milk yield, in June, was higher in early and mid than in late lactation (16.1, 15.3 and 11.7 kg/d respectively, $P<0.001$). In July, yield was highest in early lactation and significantly lower with each successive stage of lactation (14.0, 12.5 and 10.4 kg/d, $P<0.02$). Yield decreased from June to July (14.4 to 12.3 kg/day, $P<0.001$) under increasingly severe nutritional/environmental influences. Udder capacity was higher in early and mid lactation than in late (16.1, 16.2 and 14.3 L, $P=0.07$), and decreased 18% from June to July (17.1 to 14.0 L, $P<0.001$). These results suggest that loss of mammary capacity is an important cause of declining milk production due to stage of lactation and season.

Keywords: Mammary gland; development; persistency; bovine; milk.

INTRODUCTION

New Zealand dairy cows are highly synchronised in terms of calving date and stage of lactation, in order to maximise usage of the high pasture growth in spring. Such synchronous lactations produce a highly seasonal variation in milk supply to the dairy factories, the main features being the sharp spring peak and rapid decline post peak. The New Zealand dairy industry has identified this seasonal variation in supply of milk to dairy factories as a major problem (Dunn, 1994; Anon., 1995), and greater persistency of post peak production as an important goal. Because there must be sufficient processing plant capacity to cope with peak milk flow, capacity is under-utilised except at peak. A related problem is that older, less efficient factories must be utilised to cope with peak milk flow, leading to reduced processing efficiency and diverting milk to less profitable product streams. Furthermore, greater consistency of milk supply and composition would help assure product quality and supply of some dairy products that are presently produced on a limited, seasonal basis.

In order to develop strategies for improving post peak lactational persistency, we sought to determine the relative importance of two key factors: mammary development and nutrition. It is well known that the mammary gland begins to regress after peak lactation (Knight and Wilde, 1993), contributing to the characteristic decline in milk yield, even in fully fed cows. In New Zealand however, diminished pasture growth during summer typically limits nutrient intake, creating a "feed gap." Hence, the availability of feed is widely perceived to be the major factor regulating milk supply and lactational persistency. However, in the absence of controlled studies, evaluation of the relative importance of mammary development and nutrition is confounded by seasonal effects (Wilson, 1988; Wilson and Davey, 1982). In particular, peak lactation invariably occurs in spring and late lactation occurs in late summer/autumn. To separate effects of stage of lactation and season, which are related to mammary development and nutrition, respectively, it was necessary to compare herds in different stages of lactation at the same time.

Therefore, our objectives were to determine effects of stage of lactation and nutrition (combined with seasonal environmental influences) on mammary development and milk yield, in New Zealand cows. We hypothesised that stage of lactation would exert a significant effect on milk yield through its effects on mammary development.

MATERIALS AND METHODS

Animals

Three mixed-age Holstein Friesian herds of similar genetic merit (average Payment BI=132), that had calved in late April 1995 (n=28), January 1995 (n=21) or October 1994 (n=24) were studied. All data were collected in June and July of 1995, therefore the herds were in months 2, 5 or 8 of lactation, respectively, at the start of data collection. At a given time these herds experienced similar environmental influences, including pasture quality, rainfall, temperature and photoperiod, but differed by three months in their progress of lactation since calving. The herds were fed according to requirement for milk yield and stage of lactation and to ensure that changes in liveweight and condition score before and during lactation were similar for each herd at each stage of lactation, within the scope of the following rules: at a given time the herds were fed the same percentage of their feed as supplement (grass silage) on a metabolisable energy basis and the dry matter provided by silage did not exceed 30% of the dry matter supplied by pasture.

Treatments

The treatment factors were stage of lactation (stage), and nutrition/environment (season), the latter indicates a combination of seasonal nutritional and environmental influences. Stage of lactation had three levels: early, mid and late; corresponding to the April, January and October calving herds respectively. Season had two levels: June and July of 1995. This latter treatment factor was obviously not able to be regulated outdoors, but an important point is that the three stages of lactation were compared under the same conditions, and only feed quantity was regulated according to stage. Higher rainfall and lower temperature in July (vs. June) created a marked difference in nutritional/environmental conditions. Furthermore, this was a continuation of a trend of increasing environmental/ nutritional stress from the previous months (data not shown). In July it was not possible to maintain body condition score at the intended level using the allowable ration of supplement in any of the herds, and a decline occurred (data not shown).

Measurements

Milk yield (per day) was measured weekly using milk meters, and averaged over a given month. The difference in yield, from June to July, was used as an index of short term persistency under increasing environmental stress, at a given stage of lactation.

Udder capacity was determined, in all of the cows, on 11 June and 17 July (35 day interval), by interrupting milking for 40 hours and measuring bulk milk yield with milk meters. After injection of 10 i.u. of oxytocin (Oxytocin-S, Pharmaco (NZ) Ltd) into the perineal or tail vein, each cow was milked again and residual milk yield was measured. Bulk and residual milk yields were added together to calculate udder capacity (Davis and Hughson, 1988; Mochrie, 1975). Udder capacity was used as an index of mammary secretory cell number (Carruthers *et al.*, 1993).

Udder volume was determined on 29 June and 14 July (16 day interval), in a subset of the cows (n=10/herd), by measuring the physical dimensions of the udder after normal milking. The calculation was based on the assumption that udders approximate a wedge shape (Davis and Bryant, 1985), thus half length was multiplied by height and average width. Udder volume is a measure of the total amount of mammary tissue in the udder, and as such does not distinguish between secretory and non-secretory tissue.

Statistical Analysis

Residual maximum likelihood (REML) was carried out using Genstat® to determine the most parsimonious model for each variate of interest, and to determine the significance of predetermined comparisons.

RESULTS

In June, milk yield was higher in early and mid, than in late lactation (16.1, 15.3 and 11.7 kg/d respectively, P<0.001, Figure 1). In July, yield was highest in early lactation and significantly lower with each increasing stage of lactation (14.0, 12.5 and 10.4 kg/d, P<0.02 for each contrast). The decline in milk yield from June to July, associated with the increasingly severe nutritional/environmental conditions, was less in early than in mid lactation (P<0.05, 2.1 and 2.8 kg/d, 14% and 20%) and lower still in late lactation (P<0.05, 1.4 kg/d, SED=0.35, 12%), thus demonstrating a significant interaction (P<0.001) of stage and season.

Overall, udder capacity (Figure 2) was higher in early and mid lactation, than in late (16.1, 16.2 and 14.3 L, P=0.07). Udder capacity decreased 18% from June to July (17.1 to 14.0 L, P<0.001). No interaction of stage and season was observed.

Udder volume decreased from June to July (8.9 to 8.0, P<0.05), but exhibited no significant differences due to stage or to the interaction of stage and season.

FIGURE 1: Daily milk yield was significantly affected by stage of lactation (P<0.001) and season (P<0.001) and there was a significant interaction between these factors (P<0.001). Data are predicted means and standard errors of the difference for the same treatment factor level of season (SED=0.6, a) and for the same treatment factor level of stage (SED=0.2, b).

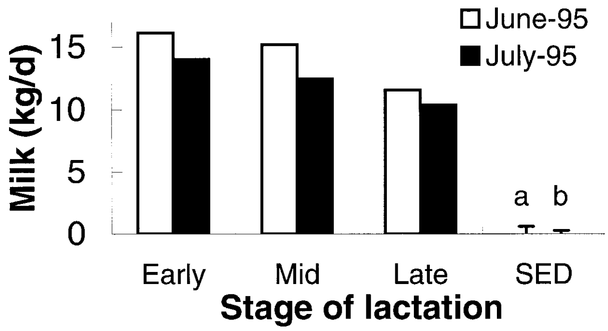
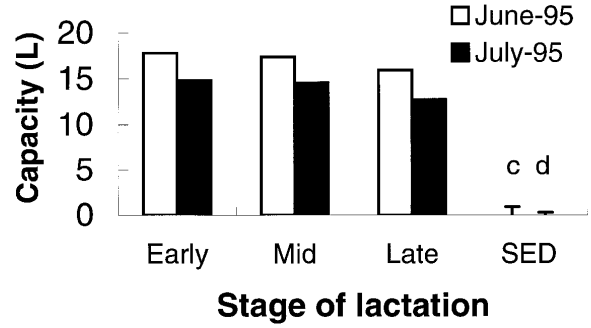


FIGURE 2: Udder capacity was significantly affected by stage of lactation (P=0.07) and decreased with change in season from June to July (P<0.001). No significant stage of lactation by season interaction was observed. Data are predicted means and standard errors of the difference for the main effects of stage (SED=0.9, c) and of season (SED=0.3, d).



DISCUSSION

The average milk yields of the three herds, under similar seasonal conditions, illustrated the marked effect of stage of lactation on milk yield. The relative importance of this stage effect (~30% decrease from early to late lactation) was shown in comparison to the smaller effect of acute seasonal change (~15% decrease from June to July). Differences between early and late, and mid and late lactation were clear and relatively consistent, whereas the difference between early and mid lactation was much smaller, and was significant in July but not June. These results suggest a marked loss of lactational potential between mid (5 months) and late (8 months) lactation. This is consistent with previous reports that the negative effect of pregnancy on lactational persistency became increasingly important after 4 to 5 months of gestation (Auran, 1974). It is unlikely that the lower milk yield of the late lactation herd was associated with seasonal nutritional or environmental factors, because differences existed during June, when body condition was maintained.

In addition to the influence of stage there was a significant effect of season as represented by the decline in milk yield from June to July. This acute effect was due to seasonal nutritional or environmental factors, and was associated with lower body condition score. Such a decline occurred regardless of stage of lactation, but was more pronounced in the early and mid lactation herds than in late lactation, reflecting the higher nutrient requirement for higher milk yield (ARC, 1984). It is not clear why yield diminished more in mid than in early lactation. This effect could relate to greater utilisation of body reserves, but body condition data did not support this explanation.

Effects of stage of lactation and season on udder capacity were similar to those reported for milk yield and, in general, milk yield and udder capacity were highly related. These results are consistent with the hypothesis that the observed negative effects of stage and season on lactational persistency may have been due to loss of mammary capacity. Strong associations between udder capacity and milk yield (Turner, 1955) or lactational persistency (Mochrie, 1975) have been reported previously.

Although changes in milk production and udder capacity were in a similar direction, they differed somewhat in magnitude. The effect of stage was larger for milk production (~30% decrease) than for udder capacity (~10% decrease), whereas the acute effect of season affected milk yield (~15% decrease) less than udder capacity (~20% decrease). Nevertheless, the results were reasonably consistent with the notion that udder capacity is an index of milk production (Davis and Hughson, 1988), as it probably estimates secretory cell number (Carruthers *et al.*, 1993).

The absence of an effect of stage of lactation on udder volume is supported by the finding of Davis and Bryant (1985), that udder volume did not change between 16 and 38 weeks of lactation. In contrast, worsened nutritional/environmental conditions from June to July resulted in an acute decrease in udder volume (~10%) and milk production (~15%) in all of the herds, regardless of stage of lactation. That marked effects of stage of lactation on milk yield and udder capacity occurred without commensurate changes in udder volume indicated the limitations of udder volume as a measure of functional changes in the mammary gland.

In summary, these results demonstrate that regression of the mammary gland, associated with advancing stage of lactation, was highly related to loss of milk yield and lack of persistency. Changes in mammary development due to acute seasonal effects were also related to lower yield, but had a lesser effect than stage.

The main implication of these findings is that manipulation of mammary development is a promising means to improve lactational persistency and steady milk supply to dairy factories. The relative costs of such manipulation, along with feed supplementation and altered management methods, compared to the extra value of shoulder (Dunn, 1994) or winter milk produced, will determine its applicability.

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