A physiological basis of genetic improvement in milk production of Friesian and Jersey cows

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ABSTRACT

Udder volume (post-milking) was determined in high and low breeding index (HBI; LBI) Jersey and Friesian cows.

The difference in milk production of HBI and LBI Jersey herds (2 to 4 ℓ /d) was entirely attributable to difference in udder volume. This difference was generated during late pregnancy. Udder volume declined during lactation; 35 to 40% of udder volume at calving being lost by 20 weeks of lactation.

There was no difference in udder volume between HBI and LBI Friesian cows measured at peak and in late lactation. Differences in production between these herds were due to increased udder productivity in the HBI animals (HBI, 2.0 ℓ /ℓ tissue/d; LBI 1.8 ℓ /ℓ tissue/d). Udder productivity in Friesians was 25% greater than in Jersey cows at peak and in late lactation.

Milk yield and udder volume were significantly correlated ($P<0.05$) in Friesian and Jersey cows at all stages of lactation.

Genetic selection of Friesian and Jersey cows has resulted in more productive animals in both breeds but through differing physiological mechanisms.

Keywords Milk yield; udder volume; udder productivity; Jersey; Friesian; lactation; breeding index.

INTRODUCTION

Milk production is a function of the number of secretory cells in the udder and their productivity. Secretory cell productivity is influenced by nutrient supply (Davis and Collier, 1985) and milk accumulation (Peaker, 1980).

In sheep (Davis *et al.*, 1980) and goats (Linzell, 1966) secretory cell numbers have been assessed during pregnancy and lactation by measurement of post-milking udder volume. Udder volume reached a maximum in these species around parturition and declined thereafter. The decline in milk production of goats was associated with decline in cell numbers and a decrease in cell productivity (Knight and Peaker, 1984).

Similar data on udder size and productivity in cattle have been lacking. A previous study (Davis *et al.*, 1983) demonstrated that the advantage (20%) in peak milk production of Jersey cows of high genetic merit (>120 breeding index units) compared with unimproved Jersey cows (*ca.* 100 breeding index units) was largely associated with an increased post-milking udder volume. Such a difference may have arisen through an enhancement of udder development or a difference in the rate of udder regression (cell loss) during lactation.

This study examines the pattern of udder development in Jersey cows of known high (HBI) or low (LBI) breeding index through late pregnancy and lactation. Further, measurements of udder volume have now been made on HBI and LBI Friesian cows.

MATERIALS AND METHODS

Animals

Jersey cows were grazed at No. 5 Dairy, Ruakura in 8 herds (4 HBI and 4 LBI) of 15 cows/herd. Stocking rate varied within BI (Bryant, 1985). Measurements were made on 24 HBI (9 heifers) and 17 LBI animals (3 heifers) at 5 weeks and 10 days before calving, 10 days after calving and at approximately 6-week intervals during lactation. Additional data were obtained on 1 HBI cow which contracted mastitis and 7 LBI cows which had lactations <180 days and high residual milk volumes (see Results).

Measurements were made on Friesian cows in HBI/LBI comparison herds (Davey *et al.*, 1983) at Massey University (17 animals of each BI) at peak (12 to 14 weeks) and in declining (30 to 32 weeks) lactation. Additional data were obtained from 3 HBI and 4 LBI animals which were discarded from the trial because of unusually low udder productivity. In

most cases this was attributed to mastitis or assumed high residual milk volumes.

Milk Yield and Udder Volume Measurements

Milk yield was determined in Jerseys as the average of 5 consecutive days preceding the day of udder volume measurement. Friesian milk yields were determined over 2 consecutive days preceding udder volume measurement.

The technique and validation of udder volume measurement was as described by Davis *et al.* (1983). Briefly, udder volume was determined as half the product of udder height, length and width measurements following milking and removal of residual milk by intravenous injection of 5 i.u. of oxytocin.

In Jerseys, measurements were made in duplicate following morning milking. In Friesians, duplicate measurements were made at both morning and afternoon milkings. Residual milk was not removed in the Friesian cows but, on average, the effect of this was unlikely to be significant. In Jerseys, high residual milk volumes were associated with low udder productivity. Similar data from Friesian cows with low udder productivity were excluded (see above).

Statistical Analysis

As the Jersey cows were grazed at differing stocking rates, Jersey udder volume and milk yield data were adjusted by regression to a common stocking rate of 3.7/ha and average post-calving live weights of 380 and 340 kg for HBI and LBI cows repectively. These weights were representative of the BI group averages (Bryant and Trigg, 1981; Davis *et al.*, 1983).

RESULTS

The Pattern of Mammary Development in Jersey Cows

In both HBI and LBI Jerseys, udder volume increased 2 to 3 fold in the last 5 weeks of pregnancy, reaching maxima around calving of 15 ℓ and 11 ℓ respectively for HBI and LBI groups (Fig. 1). Udder volume was greater ($P < 0.01$) in HBI than LBI cows on all occasions it was measured, the difference being greatest around calving (4.8 ℓ before, 3.6 ℓ after) then narrowing to 1.4 ℓ by the end of lactation.

The decline in udder volume over the first 18 to 20 weeks of lactation, amounted to almost 40% of initial volume. For the remainder of lactation the rate of regression in udder volume was reduced.

In the LBI "exclusion group" characterised by high residual milk volumes and short lactations, udder development was initially normal but subsequent regression was accelerated such that mean udder volume was less than 5 ℓ by 18 weeks of lactation (Fig. 1).

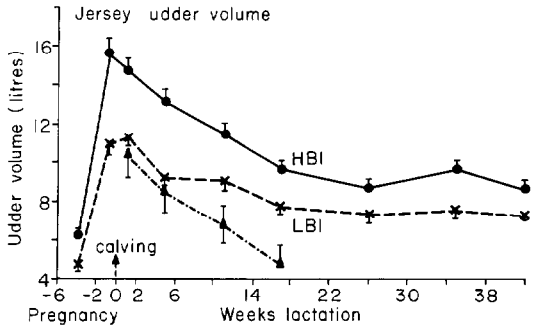

FIG. 1 Udder volume (post-milking) in high (n = 24) and low (n = 17) breeding index Jersey cows (HBI; LBI) during late pregnancy and lactation. Numbers were reduced at 42 weeks to 19 HBI and 12 LBI animals. 'LBI exclusion group' shows increased rate of udder regression (▲—·—·—·—▲).

Milk Yield (Jersey)

Milk production reached peaks of 17.8 and 13.8 ℓ /d respectively for HBI and LBI cows by week 11 of lactation (Fig. 2). The difference in milk yield between BI herds was significant ($P<0.05$) on all except the last measurement occasion (when the number of observations was reduced) but narrowed to 2.1 ℓ /d towards the end of lactation. Milk yield of the LBI "exclusion group" declined rapidly from an initial yield of 9.5 ℓ /d to be significantly ($P<0.001$) less than their LBI herdmates by 18 weeks of lactation at 4.9 ℓ /d (Fig. 2).

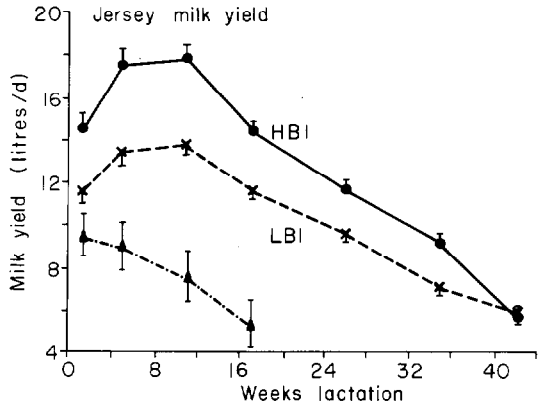

FIG. 2 Lactation curves for Jersey cows of high (n = 24) and low (n = 17) breeding index (HBI; LBI). 'LBI exclusion group' characterised by short lactations and high residual milk volumes is shown (▲—·—·—·—▲).

Udder Productivity (Jersey)

Udder productivity increased from 1.0 ℓ milk/ℓ tissue/d after calving to a maximum around 1.6 ℓ /ℓ tissue/d at 11 weeks of lactation in

both HBI and LBI cows (Fig. 3), thereafter declining to less than 1.0 ℓ /ℓ tissue/d by the end of lactation. There were no significant differences in udder productivity between the HBI and LBI groups.

Udder productivity in the LBI "exclusion group" was significantly impaired as was the productivity of one HBI cow which suffered severe mastitis around peak lactation (Fig. 3).

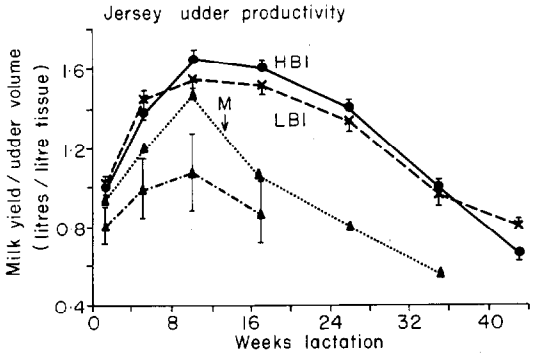

FIG. 3 Udder productivity in high (n = 24) and low (n = 17) breeding index Jersey cows (HBI; LBI). Udder productivity was significantly reduced in the 'LBI exclusion group' (▲—·—·—·—▲) and apparently impaired in a single HBI cow (▲·····▲) which contracted mastitis at peak lactation (M).

Udder Volume, Milk Yield and Udder Productivity (Friesian)

Relevant data for Friesian cows at peak and in late lactation are given in Table 1. HBI Friesians were lighter after calving than LBI Friesians but this difference was not statistically significant.

Milk production of HBI Friesians was greater (12 to 15%) than that of LBI Friesians but this was statistically significant ($P<0.05$) only in late lactation. However, the increased milk yield and small advantage in fat test in favour of HBI cows led to 17% and 25% greater fat yield at peak ($P<0.01$) and in late ($P<0.001$) lactation respectively.

In contrast to Jerseys there was no difference in udder volume between BI groups at either stage of lactation. However, udder productivity was significantly ($P<0.05$) greater in HBI cows at both stages of lactation; this level of productivity (Table 1) being about 25% greater than that found in Jersey cows.

Correlation of Milk Yield and Udder Volume

There were significant correlations between milk yield and udder volume in both breeds and both BI groups at both stages of lactation (Table 2). The single exception was the LBI Jersey group where the relationship did not quite achieve statistical significance ($P<0.10$) in late lactation. There were significant ($P<0.05$) differences in slope between BI groups within breeds and between breeds.

Udder volume was correlated ($P<0.05$) with post-calving live weight in HBI and LBI Jerseys and HBI Friesians at both stages of lactation. There was no correlation of udder volume with live weight in LBI Friesians.

TABLE 1 Production characteristics of HBI (n = 17) and LBI (n = 17) Friesian cows. Post-calving live weight did not differ significantly at 462 (HBI) and 481 kg. Indicated significance levels apply to differences between BI groups at each stage of lactation.

Breeding index Stage of lactation	HBI Peak	LBI Peak	HBI Late	LBI Late
Milk yield (ℓ /d)	21.0	18.8	14.8	12.9
Udder volume (ℓ)	10.6	10.5	8.3	8.3
Milk yield/udder volume (ℓ /ℓ tissue/d)	2.01	1.82*	1.81	1.58*
Fat yield (g/d)	960	819*	714	567*
Fat test (%)	4.56	4.44	4.87	4.46

TABLE 2 Regressions of milk yield on udder volume in HBI and LBI Jersey and Friesian cows at 2 stages of lactation.

Herd	Stage of lactation	Slope (± SE)	Intercept (± SE)	r^2	RSD
HBI Jersey	Peak	0.91 ± 0.14	7.1 ± 1.5	0.66	1.9
	Late	0.65 ± 0.15	2.7 ± 1.3	0.46	1.6
LBI Jersey	Peak	0.55 ± 0.26	9.0 ± 2.5	0.23	2.0
	Late	0.50 ± 0.24	3.3 ± 1.9	0.22	1.6
HBI Friesian	Peak	1.21 ± 0.26	8.1 ± 2.8	0.59	2.4
	Late	1.17 ± 0.24	5.1 ± 2.1	0.61	1.6
LBI Friesian	Peak	1.13 ± 0.32	7.0 ± 3.4	0.45	2.5
	Late	0.73 ± 0.32	6.8 ± 2.7	0.26	2.1

DISCUSSION

Jersey *v* Friesian

Genetic selection of Friesian and Jersey cows in New Zealand has resulted in improved milk and milkfat yield. Recent comparisons within Jerseys and Friesians have indicated the value of breeding index as a measure of producing ability (Bryant and Trigg, 1981; Davey *et al.*, 1983).

The present study shows that genetic selection has acted to increase production through mechanisms which differ in Jersey and Friesian cows. In HBI Jerseys udder size and live weight are increased while in HBI Friesians udder productivity is increased relative to that of LBI cows. Udder productivity was lower in Jersey than Friesian HBI (1.6 *v* 2.0 ℓ /ℓ tissue/day) but this difference may

reflect environment/management differences. In a previous trial udder productivity of HBI Jerseys was 1.8 ℓ /ℓ tissue/day (Davis *et al.*, 1983).

Udder productivity may be useful in diagnosis of factors limiting producing ability whether these are related to inadequate milk removal or nutrition. Exemplifying the former were the LBI "exclusion group" whose high residual milk levels were probably limiting to udder capacity and productivity and accelerated the rate of udder regression. Nutritional effects on udder productivity have not been examined directly, but the rise in productivity to peak lactation (Fig. 3) is correlated with increasing feed intake during this period.

Udder Growth and Regression

The difference in udder size between HBI and LBI Jersey cows was generated during late pregnancy and was apparent at least 5 weeks before calving. Udder growth ceased at calving, regression being relatively rapid for the first 18 to 20 weeks of lactation. Only part of the difference in udder volume between Jersey BI groups was attributable to live-weight difference (Davis *et al.*, 1983).

Factors which affect udder growth and regression are largely unknown, although inadequate nutrition and/or milk removal (Fig. 2) are likely to accelerate regression.

Udder development is under hormonal control (Forsyth, 1983) but the hormones responsible for the quantitative control of udder growth remain undefined. The success of lactation induction by treatment with exogenous steroids (Davis *et al.*, 1981) indicates that a placenta is not essential for some udder growth to occur except perhaps to provide a mammogenic stimulus via oestrogens.

Udder volume is an indicator of potential milk production. Milk yield was significantly correlated with udder volume in HBI and LBI cows in early and late lactation. While there was no response of Friesian udder volume to genetic selection there was a significant correlation of milk yield with udder volume in HBI and LBI herds at both stages of lactation.

Udder Productivity

Increased udder productivity in HBI Friesians may reflect an influence of galactopoietic hormones or may be a genetic influence on key enzyme activities in the udder. Certainly the increased cell activity will necessitate an increased supply of nutrients/unit of tissue, probably mediated by a relative increase in udder blood flow (see Davis and Collier, 1985).

Both Jersey and Friesian data indicate that udder productivity declines with advancing lactation. Part of this apparent decline may be due to a loss of cells which is masked by intramammary growth of adipose tissue. However, in goats real reductions in cell productivity in declining lactation have been reported (Knight and Peaker, 1984). The causal factors of such a decline have not been elucidated.

Functional capacity of the udder and empty udder volume are closely correlated in goats (Peaker, 1980) and cows (Davis and Hughson, unpublished data). Changes in udder productivity whether brought about genetically or via exogenous hormone treatment (see Davis and Bass, 1984) will likely increase the rate of udder filling such that cows with high udder productivity will be more sensitive to the adverse effects of extended milking intervals and, conversely, more responsive to increased milking frequency.

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