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Variation in yields of milk and milk solids in Holstein cows induced to calve prematurely

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ABSTRACT

Milk production was compared between multiparous Holstein cows that were induced to calve and herdmates that calved spontaneously at approximately the same time in 88 dairy herds from Victoria and Tasmania. Yield averages for each herd were calculated for induced and spontaneously calving cows for milk volume, milkfat and protein during the first 120 days of lactation and for 305 days. Associations between induced and spontaneously calving groups for 305-day yields were described using linear equations. Slopes ranged from 0.82 (for milk yield) to 0.87 (for protein yield) and R^2 values ranged from 0.84 to 0.88 ($p<0.001$). The average reduction in milk yield over the 88 herds was 366 litres (7%). The estimated milk yield reduction for induced groups in herds where spontaneously calving contemporaries averaged only 3500 litres per 305 days was 40 litres (1.1%) compared to an average estimated reduction of 915 litres (11%) in herds averaging 8500 litres. Similar proportional reductions were calculated for 305-day yields of milkfat and protein. Collectively these results show that yield reductions following induced premature parturition are substantially higher in absolute as well as proportional terms in herds with higher milk yields.

Keywords: induced parturition; Holstein; milk yield.

INTRODUCTION

Herds utilising seasonal calving, pasture-based dairy systems in Australia and New Zealand commonly use pharmacological induction of premature parturition as a reproductive management tool (MacDiarmid, 1983; Macmillan, 2002). Declining fertility associated with increased yield has been accommodated either by utilising treatments for anoestrus or by strategic use of induction to advance the calving date in late conceiving cows (Macmillan, 2002). A common method of induction currently employed in Australia involves injecting long-acting dexamethasone followed by a prostaglandin injection 9 to 10 days later if calving has not occurred (Malmo & Brightling, 1982; Malmo, 1991; Murray *et al.*, 1981). Variations of this protocol are also used with subsequent dexamethasone injections utilised at 10 day intervals if substantial udder development has not occurred and lactation commenced within 10-20 days (Morton & Butler, 1995a). Induction has both direct and indirect effects on milk production (Morton and Butler, 1995b) and reproductive performance (Morton and Butler, 1995c). Indirect effects occur due to the alteration of the calving date. Induced cows calve an average of 40 days earlier in Australian herds (Morton & Butler, 1995b) and 39 days earlier in New Zealand herds (Stevens *et al.*, 2000), potentially lengthening the overall lactation by these intervals. This increase in lactation length decreases the overall effects of induction on production (Macmillan, 2002; Malmo, 1991; Welch *et al.*, 1979). The earlier induced calving date also increases the interval from calving to the first day of the artificial breeding (AB) program and consequently substantially enhances subsequent reproductive performance (Morton, 2004). This indirect effect outweighs any direct reductions in reproductive performance due to induction. Direct reductions because of lower first service conception rate following late induction (induction occurring in the last 10-14 days of gestation) of 4.6% (Beardsley *et al.*, 1974) and 13% (Davis & Macmillan, 2001) and early induction (induction from 6 months to 8.5 months of gestation) of 5% (Hayes *et al.*, 1998) have been reported. Direct effects on submission rates appear minimal. Induced cows appear as likely to be cycling prior to the onset of the mating period as spontaneously calved cows calving on the same date (DRDC., 2000; Macmillan, 2002; Thomas, 1975) and submission rates at 3 weeks are unaltered (Davis & Macmillan, 2001) or even increased (Morton, 2004) by induction.

Induced calving can also enhance survivability of cows in the herd due to the associated earlier calving date. Survivability is influenced more by an earlier calving date than the occurrence of calving induction, with a delay in calving date increasing the culling rate by 23% when calving occurred between weeks 4 and 13 of the calving period compared to within the first 3 weeks (Stevens et al., 2000). There was an

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increase in culling risk of only 2.8% due to induction itself (Stevens et al., 2000).

Induced calving, however, also has some negative consequences. Low calf survival rates following early gestation calving induction have raised animal welfare concerns. Following early induction, the incidence risk of mortality at birth and within the first week of life has been reported to be 72% with higher mortality risk where induction is implemented earlier in gestation (Morton & Butler, 1995a). The risk of calf mortality born following spontaneous calving in the same study was 7%.

Reductions in milk production as a direct effect of premature parturition have also been reported. Estimates range from no reduction, particularly if induction occurred close to term (Davis & Macmillan, 2001; Peters & Poole, 1992; Thomas, 1975) to reductions only in early lactation (Beardsley et al., 1974) or over the entire lactation (Hayes et al., 1998; Malmo, 1991; Morton & Butler, 1995b), with the extent of loss being influenced by stage of gestation (Hayes et al., 1998; Macmillan, 2002; Stevens et al., 2000) or being independent of stage of gestation (Morton & Butler, 1995b). Estimates of the proportional reductions in milk yield have ranged from 4% to 9%. In a paired study involving 40 herds and 1312 induced cows, Hayes et al, (1998) reported daily reductions of 2.5 litres/day/cow in early lactation and smaller reductions of 1.2 litres/day/cow over the whole lactation. In this study the difference reduced with each subsequent herd test until by 8 months following calving no significant difference existed. The milkfat reduction over the entire lactation was 0.07 kg/day and the protein reduction was 0.03 kg/day.

We hypothesised that any milk production reduction associated with induced premature parturition would be influenced by the herd's level of production, with greater reductions in higher producing herds. The objective of this study was to estimate effects of early induction on production in herds with various 305-day milk yields. This information is essential when determining the cost effectiveness of the procedure as a reproductive tool in individual herds.

MATERIALS AND METHODS

A retrospective cohort study was conducted using records selected from the extensive InCalf database established in 1997-1998 with data from 168 Australian dairy herds (Morton 2004). All herds (n=91) that induced parturition in more than 5% of cows in the study year were selected. These herds all had a single seasonally concentrated period of calving in the study year. They were located in one of the three dairying regions of Victoria or in the North West corner of Tasmania (Morton, 2004).

In a seasonal calving system, herd calving period commences on a specified date (the planned start of calving date or PSC). As the average length of gestation is 282 days, the herd mating period must commence 282 days before this date. Where the herd PSC is unchanged from one year to the next, the first day of insemination is 83 days after PSC (Macmillan, 2002; Morton, 2004). Thus, the date of each herd's PSC was assumed to be 83 days prior to the first day of inseminating.

All multiparous Holstein cows that calved in these herds in the study year and that had 120-day milk production estimates (n=11,199) were initially selected. By the end of the sixth week following each herd's PSC, 85% (7688/9006) of spontaneous and 51% (1116/2193) of induced calvings had occurred. Thus, 1318 (15%) of the spontaneous calvings occurred after the sixth week compared to 1077 (49%) of the induced calvings. Given that only 9% of induced calvings occurred between the planned start of calving and the end of the first three weeks, calvings for the current study were restricted to those occurring in the following 9 weeks (the 9 weeks prior to the start of AB).

During this 9-week period, 5710 multiparous Holstein cows calved in the 91 selected herds, of which 1899 were induced to calve (87% of the 2193 all induced calvings in the 91 herds) and 3811 calved spontaneously (42% of the 9006 spontaneous calvings in the 91 herds). Three herds with less than 3 induced and 3 spontaneously calving cows calved in the 9 weeks prior to breeding were then excluded, leaving 88 herds for analyses. Two of these 88 herds had 3 induced cows and 72% of herds had 10 or more induced cows calve in this period. In total, 5573 multiparous Holstein cows were retained for analyses. Of these cows, 1806 were induced and 3767 calved spontaneously.

The selected dataset included cumulative 120-day and 305-day production estimates for each cow, calculated from test day production records for milk yield, milkfat yield and protein yield (Morton, 2004). Of the 5573 cows, 305-day milk production estimates were available for 97.1% (3659/3767) of spontaneously calving cows and 97.9% (1768/1806) of induced cows.

Cumulative yields of milk, milkfat and protein were estimated for each cow as the areas under the respective assumed lactation curves. Constant daily production was assumed from calving to the first test day. After this date, daily production was estimated by interpolation between test day estimates. Dry-off date was taken as date of culling, death or removal from the herd to suckle calves, or, where none of these events occurred, last test day plus 14 days. Production on dry off date was estimated by extrapolation from last test day using the lactation curve slope from the second last to last test day. Where yield was higher on the last test day than the second last test day, constant daily production was assumed from last test day to dry-off date. Yield to 305 days was estimated as the area under the assumed lactation curve to 305 days or, where the lactation duration was less than 305 days, to dry-off date.

The unit for statistical analyses was the average of the induced cows and the average of the spontaneous cows within each herd. Linear regression of the herd averages of the induced cows (response variable on the y axis) and the spontaneously calving herdmates (predictor variable on the x axis) were undertaken for 120-day and 305-day milk, milkfat and protein yields. For each linear regression, the R^2, slope (and standard error) and intercept (and standard error) were calculated using Stata software (StataCorp 2005). The null hypothesis of both the slope being equal to one and the intercept being equal to zero simultaneously was tested using the test command of Stata.

The 95% confidence intervals of the calculated production difference between induced and spontaneously calving groups were calculated at varying spontaneously calving herd averages using Stata software (StataCorp 2005). The values of the spontaneously calving herd average for which the 95% confidence interval included zero as the upper bound were also calculated as these values represent the point at which the effects of induction begin to have a statistically significant effect on production.

RESULTS

Induced and spontaneously calving groups had similar average ages with the spontaneous calving groups averaging 5.6 years (standard deviation or SD 0.7) and induced groups averaging 5.4 years (SD 0.9). The average lactation length for spontaneously calving groups was 10 days longer than induced calving groups; the average for spontaneous calving groups was 267 days (SD 22) and the average for induced groups was 257 days (SD 25). The average calving date for spontaneously calving groups was 11 days earlier than induced calving groups; the average for spontaneous calving groups was August 27th and the average for induced groups was September 7th.

There were significantly linear and positive associations ($p<0.001$ $R^2=0.78$ to 0.88) between the average yield statistics for the spontaneously calving cows in each herd and the equivalent figures for the induced cows in the same herd (Table 1). Figure 1 shows the linear regression for 305-day milk volume.

FIGURE 1: Linear regression of induced calving cows 305-day herd average milk (L) versus spontaneous calving cows 305-day herd average milk (L) (n=88).

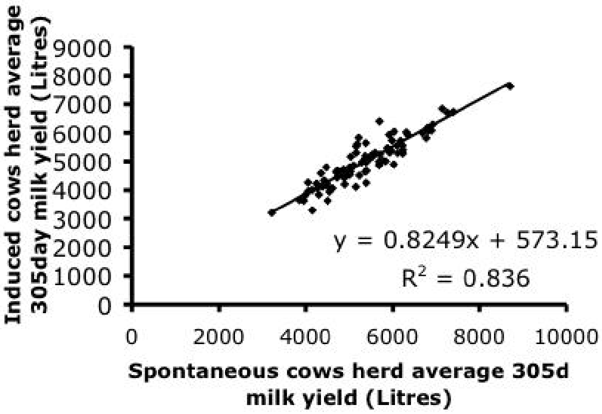

TABLE 1: Linear regression equations with standard error (SE) and R^2 values for 120-day and 305-day parameters, where y=induced cows herd average and x= spontaneous cows herd average (n=88).

	Equations 120-day
Milk volume	y=0.8663(±0.050)x+248.74(±156.79) $R^2=0.78$
Milkfat yield	y=0.8624(±0.048)x+11.488(±5.68) $R^2=0.79$
Protein yield	y=0.9054(±0.041)x+4.9362(±4.00) $R^2=0.85$
	Equations 305-day
Milk volume	y=0.8249(±0.039)x+573.15(±214.62) $R^2=0.84$
Milkfat yield	y=0.8421(±0.038)x+20.841(±8.33) $R^2=0.85$
Protein yield	y=0.8666(±0.035)x+12.546(±6.16) $R^2=0.88$

Table 1 shows the linear regression equations for 120-day and 305-day production with the standard errors of the slope and intercept estimates, and the R^2 values. All six equations rejected the null hypothesis of simultaneously having the slope equal to one and the intercept equal to zero ($p<0.001$). The higher producing herds experienced greater reductions associated

TABLE 2: Calculation of the effect of induction based on the linear regression equations at three nominated spontaneous herd average levels of production over a 120-day lactation. Calculated difference: diff (95% confidence interval). The spontaneous averages are the average of the herd averages.

Production level		Spontaneous calving	Induced calving	Diff	% Loss
Milk volume (L)	Low	2200	2155	-45 (-146,55)	2
	Average	3108	2941	-167 (-211,-122)	5
	High	4000	3714	-286 (-385,-187)	7
Milkfat (Kg)	Low	80	80.5	0.5 (-3.4, 4.3)	0
	Average	117	112.4	-4.6 (-6.2,-3.1)	4
	High	140	132.2	-7.8 (-10.4,-5.1)	6
Protein (Kg)	Low	70	68.3	-1.7 (-4.2,0.8)	2
	Average	98	93.7	-4.3 (-5.5,-3.2)	4
	High	120	113.6	-6.4 (-8.6,-4.3)	5

TABLE 3: Calculation of the effect of induction based on the linear regression equations at three nominated spontaneous herd average levels of production over a 305-day lactation. Calculated difference: diff (95% confidence interval). The spontaneous averages are the average of the herd averages.

Production level		Spontaneous calving	Induced calving	Diff	% Loss
Milk volume (L)	Low	3500	3460	-40 (-203,124)	1
	Average	5366	5000	-366 (-439,-293)	7
	High	8500	7585	-915 (-1171,-659)	11
Milkfat (Kg)	Low	150	147.1	-2.8 (-8.5, 2.8)	2
	Average	215	201.9	-13.1 (-15.8,-10.4)	6
	High	330	298.7	-31.3 (-40.5,-22.1)	9
Protein (Kg)	Low	105	103.5	-1.5 (-6.6,3.7)	1
	Average	172	161.6	-10.4 (-12.5,-8.3)	6
	High	280	255.2	-24.8 (-32.6,-17.0)	9

with induction both absolutely and proportionately, example herd average differences calculated from the equations in Table 1 are shown in Tables 2 and 3 at nominated spontaneous calving herd average values.

The 305-day milk volume at which the induced and spontaneous calving herd averages were equal (the point where the line of identity crosses the trendline of the regression) was only 3272 litres. This was just above the lowest herd average of 3212 litres. The respective values for milkfat and protein over 305 days were 132kg and 94kg. At a spontaneous calving herd average of 4010 litres over 305 days, the upper limit of the 95% confidence interval was zero, indicating that above this production level, the effect of induction on milk volume was statistically significant ($p<0.05$). The equivalent point for milkfat and protein was 162kg and 124kg respectively over 305 days.

At higher production levels for spontaneously calving cows, the effects of induction on production were greater. For the selected low herd production values of spontaneously calving cows, estimated reductions in 120-day and 305-day yields were similar (45 litres and 40 litres respectively). In contrast, at the average of herd averages production values of spontaneously calving cows of 3108 litres for 120-day yield and 5366 litres for 305-day yield, reductions were larger and appeared to occur throughout lactation with estimated reductions for 120-day yields of 167 litres, which was 46% of the estimated reduction for 305 days of 366 litres. For high selected herd production of spontaneously calving cows (Table 3), estimated reductions were substantial (915 litres, 31kg milkfat and 25kg protein). This increasing estimated reduction with higher herd average yield was evident both as a percentage and as an absolute value at calculated test values at both 120 days and 305 days (Tables 2 and 3). At this high production level, the estimated reduction in 120-day yield was 286 litres or only 31% of the 915 litre reduction in 305-day yield.

DISCUSSION

The estimated effects of induction were confounded by differences in calving date. As the induced groups calved, on average, 11 days later than spontaneously calving groups, their average lactation length was shorter by about the same amount and this will have resulted in overestimation of the direct reductions in 305-day yield due to induction, particularly in high producing herds. However this bias was probably modest as the overestimation was likely to have been the equivalent of 10-11 days at late lactation daily yields.

At higher herd production levels, the associated effects of induction on production were greater. The higher estimated reductions in yield due to induction amongst average and high herd average production are of particular relevance to industry if per cow milk yields continue to increase over time as expected reductions in milk production following induction would increase. At current New Zealand prices, the direct reduction in milk yield associated with the use of induction would be equivalent to less than $20NZD per cow in low-producing herds but about $256NZD per cow in high-producing herds. The indirect benefits of earlier calving and associated 39-40 day increase in lactation length of induced cows (Morton & Butler, 1995b; Stevens *et al.*, 2000) would be expected to exceed this direct reduction in low-producing herds but would only offset the direct reductions associated with induction treatment in high-producing herds. Thus, in high-producing herds, the indirect reproductive benefits of induced calving due to earlier calving constitute the major advantage of induction. In conclusion, the direct effect of induction on production varied between herds and was dependent on the herd's level of production with herd average productions above 4010 litres showing statistically significant production losses. This should be considered when estimating the economic costs and benefits of induced calving.

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