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Interpretive summary: Extended lactation and reproduction. Butler

Extended lactations in seasonal-calving pasture-based systems could be a useful strategy to circumvent the costs of culling and replacing non-pregnant cows. The performance of cows that had failed to conceive during the preceding breeding season was measured in a 24 mo calving interval system, and effects on farm profitability were modeled. Profitability in 24 mo calving interval systems was lower than systems with a 12 mo calving interval, regardless of cow milk production potential. The farm profit was increased when high producing cows that had failed to become pregnant were maintained in a 24 mo calving interval system instead of culling and replacing.

EXTENDED LACTATION AND REPRODUCTIVE LOSS

Extended lactations in a seasonal-calving pastoral system of production to modulate the effects of reproductive failure.

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ABSTRACT

This study was conducted to determine whether extending the calving interval (**CI**) to 24 mo would be an alternative to culling and replacing cows that had failed to become pregnant. Forty six non-pregnant lactating cows were assembled in Nov 2004 and assigned to receive either 3 kg (low) or 6 kg (high) of concentrate supplement and a basal diet of grass silage and maize silage over the winter period (13 wk). Cows returned to pasture in late March, and received 1 kg concentrate/d until dry-off (milk yield <5 kg/d). Cumulative milk production was calculated from calving to the end of Nov 2004 (12 mo CI), and from the start of Dec 2004 until dry off in 2005 (extended lactation part of 24 mo CI). High winter feeding resulted in greater milk production over the winter confinement (20.0 ± 0.3 vs. 17.8 ± 0.3 kg/d), and had a carryover effect during the remainder of the 24 mo CI period (5,177 vs. 4,686 kg; SEM = 173 kg). At the end of the study, cows were ranked on cumulative milk solids, and separated into 3 groups (R1, R2, and R3). During the 24 mo CI, milk yields were 7,287, 6,267 and 5,273 kg (SEM = 308 kg) in Year 1, and 5,738, 4,836, and 4,266 (SEM = 241 kg) in Year 2 for R1, R2, and R3, respectively. Eighty five percent of the cows became pregnant during the breeding season of yr 2, with a conception rate to first service of 52%. An economic analysis of different Ranks with a 12 mo CI, a 24 mo CI, and an annualized herd effect, which compared an efficient spring calving system with a system that had 30% recycled cows in R1 and 10% recycled cows in R3 was carried out. Farm profit was reduced by 60% and 65% at a milk price of 22.3 c/L with the corresponding values of 17% and 30% for a milk price of 30 c/L, respectively, when R1 and R3 systems were compared with an efficient spring milk (12 mo CI) production system. Within a spring system where 30% and 10% of R1 and R3

animals are subjected to extended lactations, the profit difference was substantially reduced compared to an efficient spring system, The results indicated that lactations with a 24 mo CI may be a viable alternative to culling non-pregnant cows, and economically more suited to higher producing cows.

Keywords: extended lactation, pasture, milk production, profitability

INTRODUCTION

The use of AI in conjunction with intensive genetic selection programs resulted in marked improvements in the productive efficiency of dairy cows (Bauman et al., 1985). Genetic improvement for milk production increased, particularly from the 1970's onwards, and this improvement continued in a linear fashion (Foote, 1996). Increased milk production was associated with a decline in reproductive performance, and the underlying basis of the compromised fertility remains inadequately understood. Higher milk production is achieved by higher DMI and preferential partitioning of nutrients to the mammary gland at the expense of body reserves. High producing cows mobilize body condition in early lactation, and continue further into lactation before beginning to repartition nutrients to body reserves. While this is associated with improved feed efficiency, it is antagonistic to the biological signals necessary for a successful pregnancy (Berry et al., 2003, Buckley et al., 2003). It is clear that the continuing trend of increasing genetic potential for milk production is associated with a progressive reduction in reproductive performance.

Efficient seasonal grass based systems of milk production require compact calving coinciding with return to pasture (Dillon et al., 1995), necessitating excellent reproductive performance in a breeding season of similar duration to the desired calving period. The fertility and survival of pasture-based dairy cows in Ireland declined during the interval from 1990 to 2001 (Evans et al., 2006), consistent with other reports of declining fertility from the UK (Royal et al., 2000), the Netherlands (van Knegsel et al., 2005), and the USA (Butler, 2003). Declining reproductive performance had a negative impact on the profitability of all systems of milk production (Esslemont et al., 2001), but the necessity of a compact calving period for successful seasonal grass-based milk production resulted in unacceptably high culling rates due to reduced fertility, eroding the advantage of lower costs of production.

A 305-d lactation is generally recognized as the optimum lactation length, allowing a 12 mo CI, with 10 mo of high milk production and a 2 mo dry period. Yet, modern high producing cows continue to have high milk production at 305 d, the time of typical dry off. Recently, there has been interest in Australia and NZ in examining the potential role of extended lactations with a 24 mo CI on pasture-based systems of production (Auldist et al., 2007, Kolver et al., 2007). A study was undertaken at Moorepark Research Centre to address the following questions: i) can cows lactate for 22 mo and calve every 2 yr; ii) is there a milk production response to greater concentrate supplementation during the winter period of indoor feeding; iii) what is the milk potential of cows in the extended lactation compared to the first 305 d; iv) would cows have good reproductive performance in the second year of lactation; and v) would it be profitable?

MATERIALS AND METHODS

Study animals

Forty-six spring-calving cows that had failed to become pregnant during the preceding breeding season (average 2.8 services/cow; range = 1 to 6) were assembled from 3 Moorepark herds in November 2004 (average 264 DIM; range 197 to 313). In Ireland, it is typical for non-pregnant spring-calving cows to be dried off and culled at this time of the year, but for the purposes of this study lactation was continued through the confinement winter feeding period and the following grazing season. Cows were milked twice daily, and milk yield was recorded at each milking during the entire lactation. Milk composition (fat, protein, and lactose) was determined once weekly. Body condition score was recorded every 2 wk. Cows were dried off when daily milk yield was <5 kg or at 2 mo before calving, whichever occurred first. For all cows, the (mean ± SEM) proportion of Holstein genetics was 81 ± 2.4%, parity was 2.9 ± 0.3, predicted difference for milk production was +225 ± 31 kg, overall Economic Breeding Index (**EBI**) value was €42 ± 4.8, and the mean EBI subindex value for milk solids production was €37.5 ± 2.1.

Winter feeding treatment

Cows were paired on the basis of parity, DIM, previous milk production, and BCS. They were then randomly assigned to receive either low (**LOW**; 3 kg/d per cow) or high (**HIGH**; 6 kg/d per cow) amounts of concentrate supplementation over a 13 wk winter feeding period commencing in December 2004. A basal diet of 50% grass silage and 50% maize silage (DM basis) was offered ad libitum to both treatments. Cows were returned to pasture on March 31, and from then until the end of lactation all cows were offered 1 kg/d of concentrate. The CP and NE_L of the concentrate fed were 186 ± 71 g/kg and 1.0 UFL/kg, respectively.

Ranking based on cumulative milk production

Large variation in milk yield between cows was observed throughout lactation. When all cows had finished milking, cumulative milk solids production (**CMSP**) from calving to dry-off was calculated for each cow, and cows were ranked on the basis of CMSP. The cows were then separated into 3 ranks: **R1** = 15 highest CMSP; **R2** = 15 intermediate CMSP; and **R3** = 16 lowest CMSP. The mean predicted difference for milk production was 225 ± 31, 242 ± 38, and 125 ± 31 kg for R1, R2, and R3, respectively. The number of cows in the LOW and HIGH winter feeding treatments was 6 and 9, 7 and 8, and 10 and 6, for R1, R2 and R3, respectively.

Lactation persistency

A measure of lactation persistency was calculated for all cows during the 12 mo CI period and during the extended lactation portion of the 24 mo CI period. During the 12 mo CI period, persistency was calculated by subtracting weekly milk yield at the end of the 12 mo period from weekly milk yield at peak, and dividing by the number of weeks between peak yield and the end of the 12 mo period. All cows had a characteristic "second peak" during the confined winter feeding period. During the extended portion of the 24 mo CI period, persistency was calculated by subtracting weekly milk yield at the end of the extended lactation period (i.e. at time of dry-off, ~20 mo) from weekly milk yield at the second peak, and dividing by the number of weeks between the second peak yield and the end of the extended lactation period.

Reproductive measures

The second breeding season began on April 18 and finished on July 18, 2005. Tail paint was used as an estrus detection aid (applied 2 to 3 times weekly), and all cows were inseminated based on visual detection of standing estrus and/or removal of tail paint. Cows were 405 DIM (range 336 to 452) on the AI start date. Transrectal ultrasonography of the reproductive tract was carried out prior to the start of the breeding season to assess the ovarian and uterine status. The only abnormality observed was that 4 cows had cystic ovarian disorder (2 from LOW concentrate and 2 from HIGH concentrate winter feeding treatments; 3 from R1 and 1 from R3 CMSP ranks). Cows with cystic ovarian disorder were treated with the following program: GnRH and Controlled Intravaginal Drug Releasing (CIDR) device inserted (d 0), $PGF_{2\alpha}$ (d 9), CIDR removal (d 10), and AI at standing heat or fixed time AI 48 h after CIDR removal. The GnRH injections were 5 mL Receptal (20 μg Buserelin; Intervet Ireland, Dublin, Ireland), the $PGF_2\alpha$ injections were 2 mL Estrumate (500 μg Cloprostenol Sodium; BP (Vet) Coopers, Berkhamsted, England) and the CIDR contained 1.94 g progesterone (InterAg, Hamilton, NZ). The timing of the program facilitated breeding on the first day of the breeding season. Pregnancy diagnosis was carried out using transrectal ultrasonography at 30 to 36 and 60 to 66 d post AI (Aloka 900, 7.5-MHz transrectal transducer; Tokyo, Japan).

Data Handling and Statistical Analysis

All data analyses were carried out using SAS (SAS Institute Inc., Cary, NC). The daily measurements of milk yield were collapsed into weekly means, and mean daily yields of milk fat, protein, and lactose were calculated for each week. For the analysis of the effect of the winter feeding treatment on milk production, HIGH or LOW winter feeding was compared using repeated measures and the MIXED procedure from the beginning until the end of the period of differential feeding (13 wk). The model contained treatment, week, and the interaction of treatment and week as fixed effects, and block as a random effect. Week was used in the repeated statement, and an autoregressive covariance structure was used. Cumulative milk production from the beginning of the feeding treatments until dry off was calculated for each cow, and the effect of winter concentrate feeding was analyzed using PROC MIXED with treatment as a fixed effect and lactation length, parity and previous milk production from calving until initiation of winter feeding treatment used as adjustment variables. Block was included as a random effect. The milk production and BCS of the different Ranks was compared using PROC MIXED with Rank as a fixed effect, and the data adjusted for winter feeding treatment and parity. The effects of winter feeding treatment and Rank on lactation length were compared using survival analysis (PROC LIFETEST). Differences in lactation persistency were compared using PROC MIXED. The model for winter feeding treatment contained the fixed effects winter feeding treatment and parity, and block was included as a random variable. The model for milk production rank contained the fixed effect Rank, parity and winter feeding treatment.

Pearson correlation coefficients (PROC CORR) were used to evaluate the relationship between animal factors (parity 1, 2, or >2; proportion of Holstein genetics; Predicted Transmitting Ability (**PTA)** for milk yield; and EBI value for milk solids production) and various descriptors of the lactation curve profile (milk yield and milk solids yield from calving until 305 DIM, milk yield and milk solids yield from 305 DIM until dry off, milk yield at 305 DIM, lactation length, peak milk yield, week of peak milk yield, and persistency [100 d cumulative milk yield as a proportion of 305 d cumulative milk yield]). Multiple linear regression (PROC REG) and the stepwise variable selection procedures were used to generate a model containing independent variables that were most effective at predicting cumulative milk yield and cumulative milk solids yield based on data available at 305 DIM. The significance level for entry (**sle**) and the significance level to stay (**sls**) in the model were both set at 0.05.

Economic Analysis

The Moorepark Dairy Systems Model (**MDSM;** Shalloo et al., 2004), which is a stochastic budgetary simulation model, was used to simulate the economic effect of a number of strategies involving extending the lactation of dairy cows. The model integrated animal inventory and value, milk production, feed requirement, land and labor utilization, and economic analysis. Biological data recorded in the 2 yr were included in the model to determine the effect on profitability of a 12 mo or a 24 mo CI.

Land area was treated as an opportunity cost with additional land rented when required and leased out when not required for on-farm feeding of animals. Variable costs (fertilizer, agricultural machinery contractor charges (silage, slurry), medical and veterinary costs, AI, silage harvesting, and pasture reseeding), fixed costs (machinery maintenance and running costs, farm maintenance, car, telephone, electricity, and insurance) and prices (calf, milk, and cow) were based on 2008 prices (Teagasc, 2008). The quantity of feeds consumed (grass, grass silage, and concentrate) was determined by the MDSM to meet the NE_M, NE_L, and NE_G (Jarrige, 1989). The key herd default measures used in the model farm are in Table 1. Milk output from the farm was maximized with a limitation on land of 40 Ha, and therefore, a further increase in milk production would require the purchase of additional feed.

Replacement heifer costs were estimated at €1,550 (all costs including capital, land, and labor). All male and 55% of female calves were sold at 1 mo of age. The proportion of cows removed from the herd in each Rank accounted for cows that failed to become pregnant by the end of the breeding season as well as voluntary culling and cow mortality. Based on the different cow BW at the end of a 305 d lactation or an extended 660 d lactation, it was assumed that cull cow values were €400 and €750, respectively.

Due to the impending removal of EU milk quotas and the current uncertain future for milk price, 2 economic scenarios were investigated. In scenario 1 it was assumed that land was fixed at 40 Ha with the only means of increasing milk output from the farm being through increased purchased feed input at a low milk price of 22.3 c/L. In scenario 2 it was assumed that land was fixed at 40 Ha with the only means of increasing milk output from the farm being through increased purchased feed input, but the analysis was carried out at a milk price of 30.0 c/L. The milk prices computed were based on 33 g/kg protein content and 36 g/kg fat content with a price ratio of 2:1 for protein:fat.

The analysis compared R1 (highest CMSP), R3 (lowest CMSP) and an efficient grass-based spring calving system with 12 mo CI. For R1 and R3 animals it was assumed that there was an initial 10 mo lactation followed by an extended lactation period of an additional 12 mo. Genetic merit for milk yield and phenotypic milk yield were greater for R1 cows compared to R3 cows. It was assumed that a herd of R1 cows would have lower reproductive performance compared to a herd of R3 cows. The R1 group of cows was assumed to have a 40% replacement rate if forced into a 12 mo CI, whereas the R3 group was assumed to have a lower replacement rate of 17% (Kennedy et al., 2003; Buckley et al., 2003; McCarthy et al., 2007). All data in relation to the efficient spring (**ES**) calving system originated from a Holstein Friesian genotype with a NZ origin with a stocking rate of 2.47 cows/Ha with 350 kg of purchased supplement based on data from McCarthy et al., (2007). These data were based on a 5 yr study carried out between 2000 and 2005 where 3 genotypes were compared across 3 grass-based feed systems. When analyzing the data for R1 and R3 animals in a 2 yr lactation, it was assumed that there would be a culling rate of 12% in the first 305 d period followed by an additional culling rate of 20% during or at the end of the 24 mo period for both groups of animals. The culling rate of 12% during the first 305 d was included to account for losses during lactation and cows that would be deemed unsuitable for a 24 mo lactation (SCC, lameness, and age). The 20% culling rate at the end of the 24 mo lactation period was based on a proportion of cows failing to establish pregnancy, in addition to some voluntary culling for the same reasons outlined above.

The analysis compared the 3 groups of animals individually, first in a system with a 12 mo CI, and subsequently in a system where the annualized herd effects were captured when the lactation length was extended to 24 mo. In this scenario it was possible to achieve a direct comparison of milk production systems where animals were in a system with a 12 mo CI versus a system where extended lactation was employed to maintain non-pregnant animals in the herd. In order to compare R1, R3 and an ES group in a 12 mo CI with systems that had 24 mo lactations it was assumed that 30% of R1 and 10% of R3 animals would have to be recycled to maintain the system. Therefore R1, R3 and the ES system with 12 mo CI were compared to R1 and R3 animals in a system where 30% and 10% of the animals had a 24 mo CI, respectively.

RESULTS

Reproductive performance during the normal and extended lactation periods

During the breeding season of the 12 mo lactation period (**Yr 1**), the interval (± SEM) from calving to first AI was 66.8 ± 4.6 d (range 13 to 165 d). The number of services per cow was 2.8 ± 0.2 (range 1 to 6 services/cow). Forty cows had at least 2 AI, and the return interval after first AI was 33.8 ± 2.2 d (range 16 to 82 d). The proportion of cows that returned to estrus during the 18 to 24 d interval after AI was 30.0%, and the proportion of repeat AI occurring after d 24 was 67.5%. There were no differences between the different milk production ranks for any of the variables outlined above in Yr 1. During the breeding season of the 24 mo lactation period (**Yr 2**), the interval from calving to first AI was 415 ± 5.5 d (range 337 to 491). The AI submission rate in the first 3 wk of the breeding season was 87%, the pregnancy rate to first service was 52%, the 6-wk pregnancy rate was 65%, and during the 13-wk breeding season, 85% of the cows became pregnant. The number of services per cows was 1.82 ± 0.17 (range 1 to 7), and the number of services per cow that conceived was 1.51 ± 0.11 (range 1 to 3). There were no differences between the different winter feeding treatments or the different milk production ranks for any of the reproduction variables outlined above in Yr 2.

Effect of winter feeding on milk production.

The level of concentrate supplementation during the confinement winter feeding period had a significant effect ($P < 0.001$) on milk production (19.9 ± 0.6 vs. 17.6 ± 0.6 kg/d for HIGH vs. LOW, respectively; Figure 1 and Figure 2), resulting in a total milk production response of 209 kg of milk during the 13 wk period of confinement concentrate supplementation (0.77 kg milk/d per additional kg of concentrate supplement). Cumulative milk production from the beginning of the confinement feeding period until the end of lactation was increased by 462 kg (5,355 ± 217 vs. 4,912 ± 223 kg; $P = 0.04$). This increase in cumulative milk production equated to 1.69 kg milk per additional kg of concentrate supplement, indicating a carryover effect of 0.92 kg milk/kg additional concentrate from the end of the HIGH level of winter feeding until dry off. The effect of winter feeding treatment on milk production and lactation length is in Table 2 and Table 3, respectively. Winter feeding level did not affect lactation length (DIM = 593 ± 12 vs. 593 ± 10 days for HIGH and LOW, respectively; $P > 0.5$). There was no difference in lactation persistency in the period prior to the winter feeding treatment, but cows on the HIGH winter feeding treatment had a greater ($P < 0.01$) weekly decline in milk yield during the extended lactation period (Table 2).

Milk production based on Rank

The milk production of the 3 Ranks are in Table 4 and Figure 3. The adjustment variable winter feeding level was not significant ($P > 0.5$), but parity tended to be significant ($P = 0.08$). The effect of milk production rank on lactation length is in Table 3 and Table 4. An effect of Rank on lactation length was observed ($P < 0.01$), with R3 having a shorter lactation length (558 ± 13 d) compared to either R1 (615 ± 10 d) or R2 (609 ± 13 d). The weekly decline in milk yield did not differ between the milk production ranks during the 12 mo or 24 mo lactation periods.

Body Condition Score

Body condition score data up to and including the normal time of dry-off were recorded before the animals commenced the extended 24 mo lactation study. The BCS results during the 2 yr lactation are in Table 5. The winter feeding treatment did not affect BCS. The final BCS recorded at the end of feeding treatment for LOW and HIGH feeding levels were 3.36 ± 0.08 vs. 3.38 ± 0.08, respectively ($P = 0.9$). Across all cows, BCS declined during early lactation and during the breeding period of Yr 1, and remained relatively flat until the normal time of dry off after 10 months of lactation. Thereafter, BCS increased steadily until actual dry-off in Yr 2. This resulted in a 0.45 unit increase in BCS between the mating start date (**MSD**) in Yr 1 and MSD in Yr 2 (2.88 ± 0.08 vs. 3.33 ± 0.08; $P < 0.001$). The BCS at mating end date (**MED**) was 0.8 units greater in Yr 2 compared to Yr 1 (2.68 ± 0.08 vs. 3.47 ± 0.08; $P < 0.001$). Cows lost 0.2 units of BCS during the breeding period of Yr 1, but gained 0.15 units of BCS during the breeding period of Yr 2. There was a significant effect of milk production rank on BCS during Yr 1, with R3 cows having a higher BCS compared to R1 and R2 cows at MED and time of normal dry-off, respectively (Table 5). There were no differences in BCS between the milk production ranks during the extended period of the 24 mo lactation in Yr 2.

Correlation and multiple regression analysis

The correlation between cumulative milk output (volume and solids) and components of the lactation curve and animal factors are in Table 6. The independent variables that were significantly correlated with cumulative milk yield were, with the exception of lactation persistency, also correlated with cumulative milk solids yield. The multiple regression models for predicting cumulative milk yield and cumulative milk solids yield over the combined normal and extended lactations are in Table 7. The independent variables selected for cumulative milk yield were cumulative 305 d milk yield, PTA for milk yield, and mean weekly milk yield at 305 DIM. The independent variables selected for cumulative milk solids yield were cumulative 305 d milk solids yield, mean weekly milk yield at 305 DIM, and the categorical variable parity.

Economic analysis

Individual years. Table 8 shows the key herd output parameters from the model for an ES calving herd, R1 and R3 herds in a system with a 12 mo CI, and a system where R1 and R3 herds had a 24 mo CI. In the 12 mo CI systems, the highest profit was achieved with the ES system irrespective of milk price (€29,731 compared to €11,875 and €10,385 for ES, R1 and R3 at a milk price of 22.3 c/L, respectively; the corresponding figures at a milk price of 30.0 c/L were €71,094, €49,460 and €58,696, respectively). Milk price had an effect on all profitability indicators across the 3 systems. The increased farm profit for the ES system over both R1 and R3 was associated with lower concentrate supplementation (316, 857 and 537 kg DM/cow for the 3 groups respectively; higher milk fat and protein percentages (4.38 and 3.65% for ES; 4.13 and 3.49% for R1; 4.16 and 3.47% for R3); lower replacement costs (€22,834, €49,797 and €23,692 for the 3 groups, respectively) resulting in lower total costs (€148,106, €184,627 and €158,992 for the 3 groups, respectively).

When R1 and R3 were compared in a 24 mo CI system, there was a difference in the profit in the first 305 d period when compared to the standard ES system. This result arose due to a much reduced replacement cost, with the replacement rate being reduced from 40% to 12% for R1 animals and the replacement rate dropping from 17% to 12% for R3 animals in the first 12 mo period. For both R1 and R3 animals, there was a financial loss in the extended lactation period at the low milk price (-€11,880 and -€47,739, respectively), whereas at the higher milk price R3 animals made a loss in the extended lactation period of the 24 mo CI system (-€14,829), but R1 animals made a profit of €28,578. The reduction in profitability associated with the extended lactation period of the 24 mo CI system for both R1 and R3 animals was due to higher costs of production with reduced milk sales.

Annualized herd affect. Table 9 shows the key herd annualized output parameters from the model for R1, R3, and an ES system with 12 mo CI, R1 animals where 30% of the animals had extended lactations and 24 mo CI and a herd with R3 animals that contained 10% of the animals with extended lactations and 24 mo CI. At a milk price of 22.3 c/L the ES system had the best financial performance with a total farm profit of €29,731 compared to €11,875, €10,385, €22,870 and -€2,528 for R1 cows with a 12 mo CI, R3 cows with a 12 mo CI, R1 in a system with 30% of cows having a 24 mo CI, and R3 in a system with 10% of cows having a 24 mo CI, respectively. The corresponding figures for a milk price of 30.0 c/L were €71,094, €58,696, €49,460, €67,782 and €34,697, respectively. The ES system had the lowest costs of milk production and was more profitable than the alternative systems at a low milk price. The farm profit was 30.0% greater than the next most profitable system – R1 with 30% of the cows having 24 mo CI. At the higher milk price of 30 c/L the difference in profitability was much lower (4.9%). Rank 1 animals became more profitable through extending the lactation of a proportion of the herd when compared to culling and replacing 40% of the herd. The profitability of R3 animals was reduced by having a proportion of the animals with 24 mo lactations.

DISCUSSION

Milk production

Average milk yield during the entire lactation period supported previous reports of extended lactations in pasture-based systems (Auldist et al., 2007, Kolver et al., 2007). A large effect of genetic potential for milk production on milk yield was observed, not just in the 12 mo CI period, but also in the extended lactation period of the 24 mo CI. Similarly, Kolver et al. 2007 reported that North American Holsteins had greater total milk production than NZ Holsteins, reflecting the emphasis placed on milk yield potential in the North American selection indices compared to the NZ selection index. Those authors reported greater responses to additional concentrate supplementation in North American Holsteins compared to NZ Holsteins, in agreement with previous reports with 12 mo CI (Horan et al., 2005).

An interesting feature of 24 mo CI systems was the effect on milk solids composition. As seen in Figures 1 and 3, milk protein and milk fat concentration both increased, whereas milk lactose concentration declined in tandem with decreasing milk volume. Kolver et al. 2007 reported a trend for increasing protein concentration during extended lactation, but did not observe an effect on milk fat concentration. Auldist et al., 2007 reported an increase in milk protein concentration from mo 10 to mo 13 of lactation, but observed no further significant increases in milk protein concentration thereafter. The effects of higher concentrations of protein and fat, and in particular the improved ratio of protein to fat, would have a favorable impact on milk price. Lactose is the primary osmotic regulator of milk volume, and it was expected that lactose concentration would decline as lactation progressed. Milk lactose concentrations are used as a proxy for suitability of milk for processing in Ireland; a bonus is paid and a penalty is inflicted for milk lactose concentrations above and below certain thresholds (~4.35 and ~4.2%, respectively). In the later stages of lactation, milk lactose concentrations were in the range where no penalty was being inflicted. The milk production data from the current study indicated that only a small proportion of cows were capable of completing 22-mo lactations on a low input pasture-based system, but almost 50% of cows were capable of lactating for 20 mo. The most profitable pasture-based systems achieve over 6,000 kg milk volume, 500 kg milk solids (fat + protein), with good reproductive performance in a short breeding period that facilitates calving and return to pasture in early spring, thus synchronizing the supply of and demand for feed (McCarthy et al., 2007). In the current study, R1 cows (i.e., the highest yielding cows) were capable of producing the equivalent milk volume and milk solids of two lactations with 12 mo CI in an extended lactation with a 24 mo CI. This result indicates that modern high genetic merit cows are capable of lactating for considerably longer than the 240 to 300 d lactations observed in seasonal-calving pasture based systems. Thus, extended lactations could represent a viable alternative to culling and replacing high-producing cows that fail to become pregnant during a short breeding period.

Fertility

Declining fertility has resulted in extended lactations in confinement TMR-based year-round calving systems for many years. Year-round calving systems confer greater flexibility than seasonal-based systems when fertility is sub-optimal. The majority of dairy cows in Ireland (>90%) are in spring-calving seasonal systems of production, and the diet is primarily grazed grass with limited use of alternative feeds. At the end of a typical 10 mo lactation when producers are faced with a large proportion of cows that failed to become pregnant during the preceding breeding period, the choices available are: cull the non-pregnant cows and replace with heifers or purchased cows; or continue milking the non-pregnant cows for an additional 12 mo extended lactation period, and rebreed the cow during the spring to result in a 24 mo CI.

Extended lactation was proposed as a strategy to avoid high culling rates due to infertility in seasonally calving herds and cows in confinement systems (Borman et al., 2004, Knight, 2001). In traditional seasonal-calving systems, cows are inseminated at or near the time of peak milk yield, generally coinciding with nadir BCS. Body condition and BCS loss influence reproductive performance (Berry et al., 2003, Buckley et al., 2003). Cows with high genetic potential for milk production are genetically programmed to preferentially partition nutrients to the mammary gland for longer periods into lactation at the expense of body reserves, and are typically below target BCS during the breeding period. As a result, they have reduced conception rates and an overall reduction in fertility performance (Buckley et al., 2003, Evans et al., 2006). In the current study, none of the cows successfully established and maintained a pregnancy during the Year 1 breeding period (average 2.8 inseminations per cow). In the second breeding period in Year 2, conception rates to first service averaged 52%, and though the number of animals was small, there was no indication that reproductive performance was affected by winter feeding treatment or milk production rank. This indicated that reasonable fertility performance could be achieved with these cows, but that a longer interval between parturition and breeding was required. This broadly supports Kolver et al. (2007), who reported improved reproductive performance for both NZ and North American strains of Holstein-Friesian cow during the breeding period of an extended lactation compared with the breeding period of a 12 mo CI.

Financial

Milk production systems are composed of complex interactions between a series of individual biological and mechanical components. One system may be optimal in one environment but not in another, for a range of economic, policy, environmental or biological reasons. This results in huge variation in the optimum systems of milk production throughout the world. In most countries the optimum systems are developed around maximizing output per cow, but optimum systems in NZ and Ireland revolve around maximizing the utilization of grass in the diet and minimizing costs of production (Dillon et al., 2005). The additional costs or increased profit associated with systems of milk production that contain extended lactations will be dependent on a number of factors, including the system of milk production on the farm, the milk price and milk pricing regime operated, additional labor costs and the overall fertility of the herd.

Within grass based systems of milk production the effect of extending lactations beyond 305 d distorts the synchrony between supply of feed in the form of pasture and the requirement for feed to produce milk, which will ultimately lead to increased costs of production (Borman et al., 2004). In systems where the relative costs of grazed grass, conserved feed, and concentrate are not different, the increased costs will not be substantially increased with 24 mo CI systems. This study has shown that high-producing R1-type cows were most suited to extended lactations systems, supporting work from NZ (Kolver et al., 2007). The results of the current study indicate that cows suited to 24 mo CI systems were capable of achieving peak milk yields of ~40 kg/d, cumulative milk yields during the initial 10 mo lactation period of ~7,200 kg, maintaining milk yields of >20 kg/d at 305 DIM, and having a PTA for milk yield of +225 kg. Cows with lower production potential were not profitable in 24 mo lactation systems, and should instead be culled.

Methods of milk payment that are aimed at distorting the seasonal nature of milk production can alter the competitiveness of one system over another. Specific schemes aimed at increasing the production of milk out of season in seasonal systems of milk production are largely developed on a contract basis to produce milk for specific fresh products that require a supply of milk all year round. This study has shown that at higher milk prices the competitiveness of extending the lactation increases. Price volatility is expected in Irish milk production systems as a result of the relaxation of the market management regimes within the EU Common Agricultural Policy; as a consequence, optimum systems will have to be able sustain low milk prices for considerable periods of time.

Infertility and the associated costs affect the profitability of milk production systems right across the world. An economic analysis by Evans et al. (2005) across 14 commercial dairy herds in Ireland from 1990 to 2003 showed that their overall profitability per liter of milk produced did not improve over the period due to declines in reproductive performance, even though milk yield per cow increased. The current study indicated that in seasonal calving systems where herd fertility is low, 24 mo CI systems for cows not pregnant could be a good short term method of reducing the costs associated with infertility. Yet, the results indicated that 24 mo CI systems will be substantially less profitable than systems with a 12 mo CI, and that this is the optimum system to strive to achieve.

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Table 1: Assumptions used in the model farm to study extended lactations in a seasonal-calving pastoral system.

	Yr 1	Extended Yr 2
Farm size (ha)	40	40
Reference fat (g/kg)	36	36
Gross milk price (Low) (c/kg)	22.3	22.3
Gross milk price (High) (c/kg)	30.0	30.0
Price ratio protein to fat	2.00	2.00
Replacement heifer price (€)	1550	1550
Reference cull cow price (€)	400	750
Reference male calf price (€)	108	-
Labor cost per unit (€)	22,800	22,800
Labor requirements per cow/year (h)	42	35
Concentrate costs (€/tonne)	250	250
Opportunity cost of land (€/ha)	375	375

Table 2. Effect of winter feeding treatment[1] on milk production in extended lactations in a seasonal-calving pastoral system

	LOW	HIGH	SEM	*P*
Calving to end Nov 2004				
Cumulative milk yield (kg)	6332	6176	260	0.7
Cumulative milk fat (kg)	256	250	10	0.7
Cumulative milk protein (kg)	217	211	9.8	0.6
Milk yield decline from 1st peak (kg/wk)	4.48	4.67	0.21	0.4
Protein to fat ratio	0.855	0.853	0.010	0.8
Number DIM	266	261	7.3	0.6
Start Dec 2004 to dry off				
Cumulative milk yield (kg)	4686	5177	173	0.05
Cumulative milk fat (kg)	200	230	8.6	0.02
Cumulative milk protein (kg)	181	201	6.1	0.03
Milk yield decline from 2nd peak (kg/wk)	2.47	2.92	0.12	0.009
Protein to fat ratio	0.940	0.913	0.017	0.04
Number DIM	327	332	7.3	0.6
Proportion of 1st period produced in 2nd period				
Milk yield	0.74	0.84	0.05	0.18
Milk fat	0.78	0.92	0.06	0.11
Milk protein	0.83	0.95	0.06	0.16

[1] LOW = low winter feeding treatment; HIGH = high winter feeding treatment;

Table 3. The number (%) of cows achieving lactations of increasing duration in extended lactations in a seasonal-calving pastoral system

		Lactation length (d)				
		420	480	540	600	660
Winter feeding treatment[1]						
LOW	n = 23	23 (100)	23 (100)	20 (87.0)	11 (47.8)	3 (13.0)
HIGH	n = 23	23 (100)	22 (95.7)	20 (87.0)	10 (43.5)	4 (17.4)
Milk production rank[2]						
R1	n = 15	15 (100)	15 (100)	15 (100)	10 (66.7)	2 (13.3)
R2	n = 15	15 (100)	15 (100)	14 (93.3)	7 (46.7)	4 (26.7)
R3	n = 16	16 (100)	15 (93.8)	11 (68.8)	3 (18.8)	1 (6.3)

[1] LOW = low winter feeding treatment; HIGH = high winter feeding treatment;

[2] R1 = 15 highest CMSP; R2 = 15 intermediate CMSP; and R3 = 16 lowest CMSP.

Table 4. Effect of milk production rank on milk production in extended lactations in a seasonal-calving pastoral system

	R1[1]	R2	R3	SEM	*P*
Calving to end Nov 2004					
Milk yield (kg)	7287[a]	6267[b]	5273[c]	308	0.001
Milk fat (kg)	296[a]	253[b]	212[c]	11.1	0.001
Milk protein (kg)	253[a]	213[b]	179[c]	11.2	0.001
Milk yield decline from 1st peak (kg/wk)	4.28	4.84	4.80	0.26	0.3
Protein to fat ratio	0.824[a]	0.870[b]	0.863[b]	0.014	0.045
Number DIM	266[ab]	276[a]	250[b]	8.7	0.11
Dec 2004 to dry off					
Milk yield (kg)	5738[a]	4836[b]	4266[b]	241	0.001
Milk fat (kg)	254[a]	206[b]	186[b]	10.5	0.001
Milk protein (kg)	222[a]	187[b]	164[b]	8.0	0.001
Milk yield decline from 2nd peak (kg/wk)	2.57	2.79	2.80	0.16	0.6
Protein to fat ratio	0.829[a]	0.963[b]	0.971[b]	0.023	0.001
Number DIM	349[a]	333[a]	308[b]	8.0	0.002
Proportion of 1st period produced in 2nd period					
Milk yield	0.79	0.77	0.81	0.07	0.8
Milk fat	0.86	0.81	0.88	0.07	0.7
Milk protein	0.88	0.88	0.92	0.08	0.9

[abc] Within row means not sharing a common superscript differ at least $P < 0.05$.

[1] R1 = 15 highest CMSP; R2 = 15 intermediate CMSP; and R3 = 16 lowest CMSP.

Table 5. Effect of winter feeding treatment and milk production rank on BCS in extended lactations in a seasonal-calving pastoral system

	Winter Feeding Treatment[1]		Milk Production Rank[2]			*P*-values	
	LOW	HIGH	R1	R2	R3	Feeding treatment	Rank
Calving	3.20	3.18	3.12	3.22	3.23	0.9	0.70
MSD[3] Year1	2.87	2.89	2.73	2.80	3.09	0.9	0.10
MED[4] Year1	2.71	2.65	2.55[a]	2.65[ab]	2.83[b]	0.9	0.05
Normal 305 d dry-off	2.80	2.72	2.70[ab]	2.65[a]	2.92[b]	0.9	0.06
MSD Year2	**3.30**	**3.36**	**3.23**	**3.25**	**3.50**	**0.9**	**0.30**
MED Year2	**3.51**	**3.45**	**3.30**	**3.43**	**3.69**	**0.9**	**0.18**
Actual dry-off	**3.66**	**3.57**	**3.40**	**3.68**	**3.75**	**0.9**	**0.14**

[1] LOW = low winter feeding treatment; HIGH = high winter feeding treatment;
[2] R1 = 15 highest CMSP; R2 = 15 intermediate CMSP; and R3 = 16 lowest CMSP.
[3] MSD = Mating start data.
[4] MED = mating end date.
Values in normal type font were recorded in Year 1 prior to the initiation of the extended lactation study. Values in bold type font were recorded in Year 2 during the period of extended lactation;. Pooled SEM for effect of winter feeding treatment was 0.10; Pooled SEM for effect of milk production rank was 0.12

Table 6. Correlation between descriptors of the lactation curve and animal factors with cumulative milk yield and cumulative milk solids (MS) yield in extended lactations in a seasonal-calving pastoral system

	Cumulative Milk yield		Cumulative MS yield	
	r	*P*-value	r	*P*-value
Lactation curve factors				
Milk yield from calving until 305 DIM	0.79	<0.001	0.71	<0.001
Milk yield from 305 DIM until dry off	0.75	<0.001	0.71	<0.001
Milk yield at 305 DIM	0.67	<0.001	0.62	<0.001
MS yield from calving until 305 DIM	0.68	<0.001	0.72	<0.001
MS yield from 305 DIM until dry off	0.65	<0.001	0.73	<0.001
Peak milk yield	0.67	<0.001	0.61	<0.001
Lactation length	0.46	0.001	0.49	<0.001
100-d milk yield/305-d milk yield	-0.31	0.033	-0.26	0.085
Week of peak milk yield	0.16	0.3	0.12	0.4
Animal Factors				
Parity	0.41	0.005	0.36	0.014
PTA[1] for milk production	0.62	<0.001	0.41	0.007
EBI[2] for milk solids production	0.33	0.032	0.41	0.008
Proportion of Holstein genetics	-0.12	0.5	-0.20	0.2

[1]PTA = predicted transmitting ability

[2]EBI = Economic Breeding Index

Table 7. Multiple regression models for cumulative milk yield and cumulative milk solids yield in extended lactations in a seasonal-calving pastoral system

	Cumulative milk yield			Cumulative milk solids yield		
	Parameter estimate	SE	*P*-value	Parameter estimate	SE	*P*-value
Intercept	2,580	931	0.0083	97.3	91.7	0.29
Cum_305D_MY	0.78	0.15	<0.001			
PTA_Milk	3.47	1.27	0.0093			
MY_305D	127	47	0.0104	11.24	3.70	0.004
Cum_305D_MS				1.21	0.22	<0.001
Parity (Par2)				-98.6	41.3	0.022
(Par3)				-121.9	45.0	0.010
R^2		0.74			0.66	

Cum_305D_MY = cumulative 305 d milk yield
PTA_Milk = predicted transmitting ability for milk yield
MY_305D = mean weekly milk yield at 305 DIM
Cum_305D_MS = cumulative 305 d milk solids yield

Table 8. The effect of 24 mo calving interval systems on overall profitability for each individual year in a seasonal-calving pastoral system

	12 mo calving interval			24 mo calving interval			
	R1[1]	R3[1]	Efficient Spring[1]	R1		R3	
	305 day	305 day	305 day	305 day	Extension	305 day	Extension
Grass kg DM/ Cow	3,921	3,333	3,645	3,921	3,106	3,332	2,551
Grass Silage kg DM/cow	1,358	1,123	1,169	1,358	1,715	1,117	1,459
Concentrate kg DM/cow	857	537	316	857	563	535	567
Cows calving (n)	80.3	92.7	86.7	80.3	98.3	92.7	118.5
Stocking rate(LU[2]/ha)	2.22	2.61	2.44	2.22	2.31	2.63	2.77
Milk produced (kg)	605,858	510,655	512,112	605,858	460,475	510,655	378,902
Milk sales (kg)	591,090	493,604	496,167	591,090	460,475	493,604	378,902
Fat sales (kg)	24,403	20,558	21,748	24,403	20,496	20,558	16,595
Protein sales (kg)	20,628	17,128	18,129	20,628	18,078	17,128	14,731
Labour costs (€)	33,008	38,517	36,013	33,008	33,968	38,622	40,868
Feed costs /kg milk (c)	7.7	8.3	7.1	7.7	9.5	8.3	12.4
Total costs (€)	184,627	158,992	148,106	149,920	159,506	150,328	168,264
Milk Price at 22.3 c/L							
Milk returns (€)	153,057	127,760	136,863	153,054	135,197	127,760	109,623
Margin per cow (€)	148	112	343	470	-121	182	-403
Margin per kg milk (c)	1.96	2.03	5.81	6.23	-2.58	3.30	-12.60
Total profit/farm (€)	11,875	10,385	29,731	37,763	-11,880	16,848	-47,739
Milk Price at 30 c/L							
Milk returns (€)	199,577	166,598	177,963	199,577	175,338	166,598	142,256
Margin per cow (€)	731	534	820	1,053	291	603	-125
Margin per kg milk (c)	9.69	9.69	13.88	13.96	6.21	10.95	-3.91
Total profit/farm (€)	58,696	49,460	71,094	84,584	28,578	55,923	-14,829

[1] **R1 =** 15 highest CMSP; **R3** = 16 lowest CMSP; data for efficient spring system are taken from McCarthy *et al*. (2007)

[2] **LU = Livestock Unit**

Table 9. The annualized herd effect on overall profitability with 30% recycling for R1 and 10% recycling for R3 in extended lactations in a seasonal-calving pastoral system

	12 mo calving interval			24 mo calving interval	
	R1[1]	R3[1]	Efficient Spring[1]	R1	R3
	305 d	305 d	305 d	30% Recycling	10% Recycling
Stocking rate(LU[2]/ha)	2.22	2.61	2.44	2.28	2.67
Milk produced (kg)	605,858	510,655	512,112	562,243	471,129
Milk sales (kg)	591,090	493,604	496,167	551,906	459,193
Fat sales (kg)	24,403	20,558	21,748	23,231	19,369
Protein sales (kg)	20,628	17,128	18,129	19,863	16,409
Labour costs (€)	33,008	38,517	36,013	33,589	39,296
Feed costs /kg milk (c)	7.7	8.3	7.7	8.2	9.5
Total costs (€)	184,627	158,992	148,106	152,796	155,709
Milk Price at 22.3 c/L					
Milk returns (€)	153,057	127,760	136,863	147,697	122,319
Margin per cow (€)	148	112	343	293	-6.5
Margin per kg milk (c)	1.96	2.03	5.81	3.59	-1.47
Total profit/farm (€)	11,875	10,385	29,731	22,870	-2,528
Milk Price at 30 c/L					
Milk returns (€)	199,577	166,598	177,963	192,305	159,295
Margin per cow (€)	731	534	820	824	385
Margin per kg milk (c)	9.69	9.69	13.88	11.6	6.49
Total profit/farm (€)	58,696	49,460	71,094	67,782	34,697

[1] **R1 =** 15 highest CMSP; **R3** = 16 lowest CMSP; data for efficient spring system are taken from McCarthy *et al*. (2007)

[2] **LU = Livestock Unit**

Figure 1. Milk production and component profiles during the 22-mo extended lactation of cows offered low (3 kg) or high (6 kg) levels of concentrate supplement during the winter confinement housing period. The approximate times of the first breeding season (BS 1), the winter feeding treatment (WF) and the second breeding season (BS 2) are indicated by the solid bars.

Figure 2. The effect of winter feeding treatment on daily milk yield in extended lactations in a seasonal-calving pastoral system. Significant effects of treatment ($P < 0.001$) and week ($P < 0.001$) were observed, but not for the interaction between treatment and week ($P = 0.1$). The pooled SEM was 0.63 kg/day.

Figure 3. Milk production and component profiles during the 22-mo extended lactation of cows separated into 3 ranks based on cumulative milk solids production (CMSP) during the entire lactation period in a seasonal-calving pastoral system. The approximate times of the first breeding season (BS 1), the winter feeding treatment (WF) and the second breeding season (BS 2) are indicated by the solid bars. **R1** = 15 highest CMSP; **R2** = 15 intermediate CMSP; and **R3** = 16 lowest CMSP.

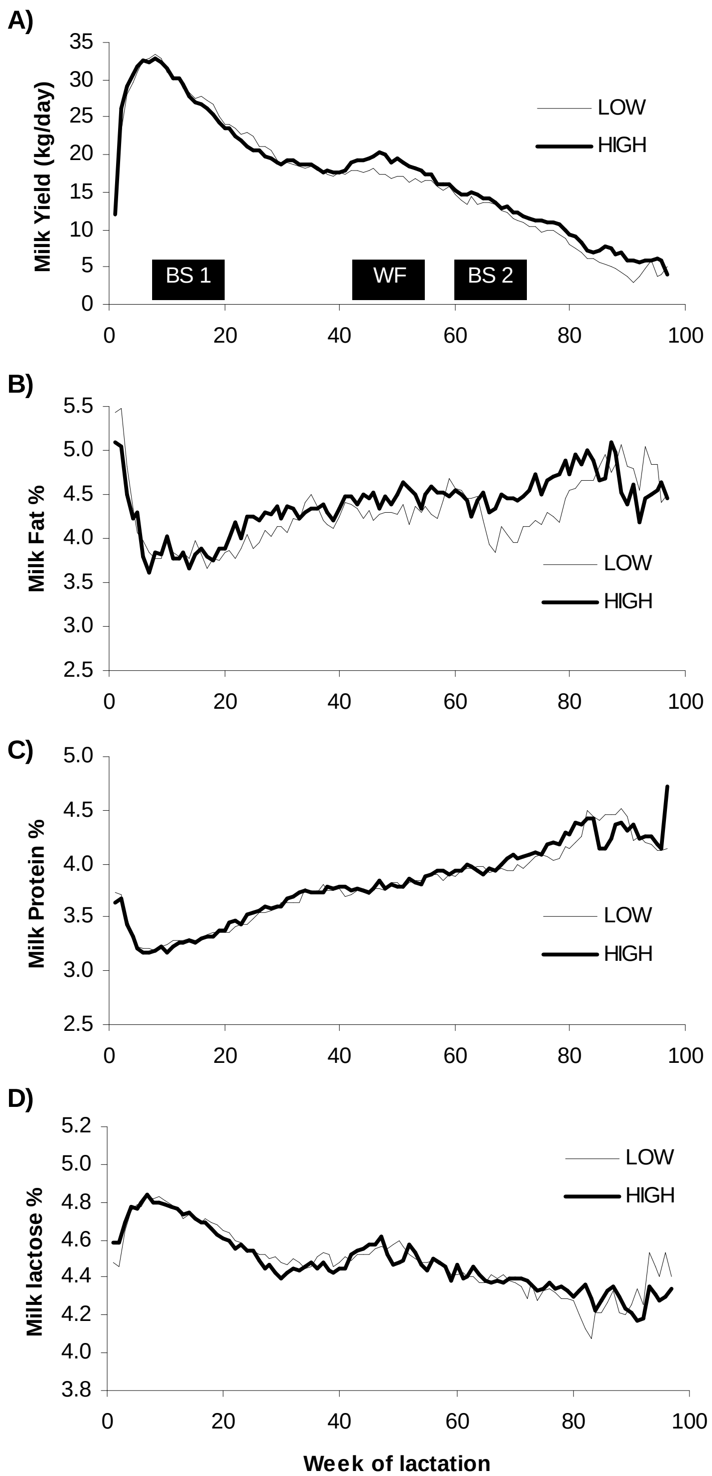

Figure 1 - Butler

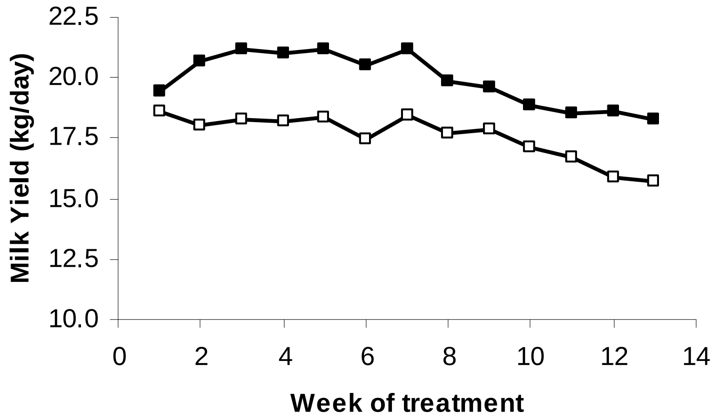

Figure 2 - Butler

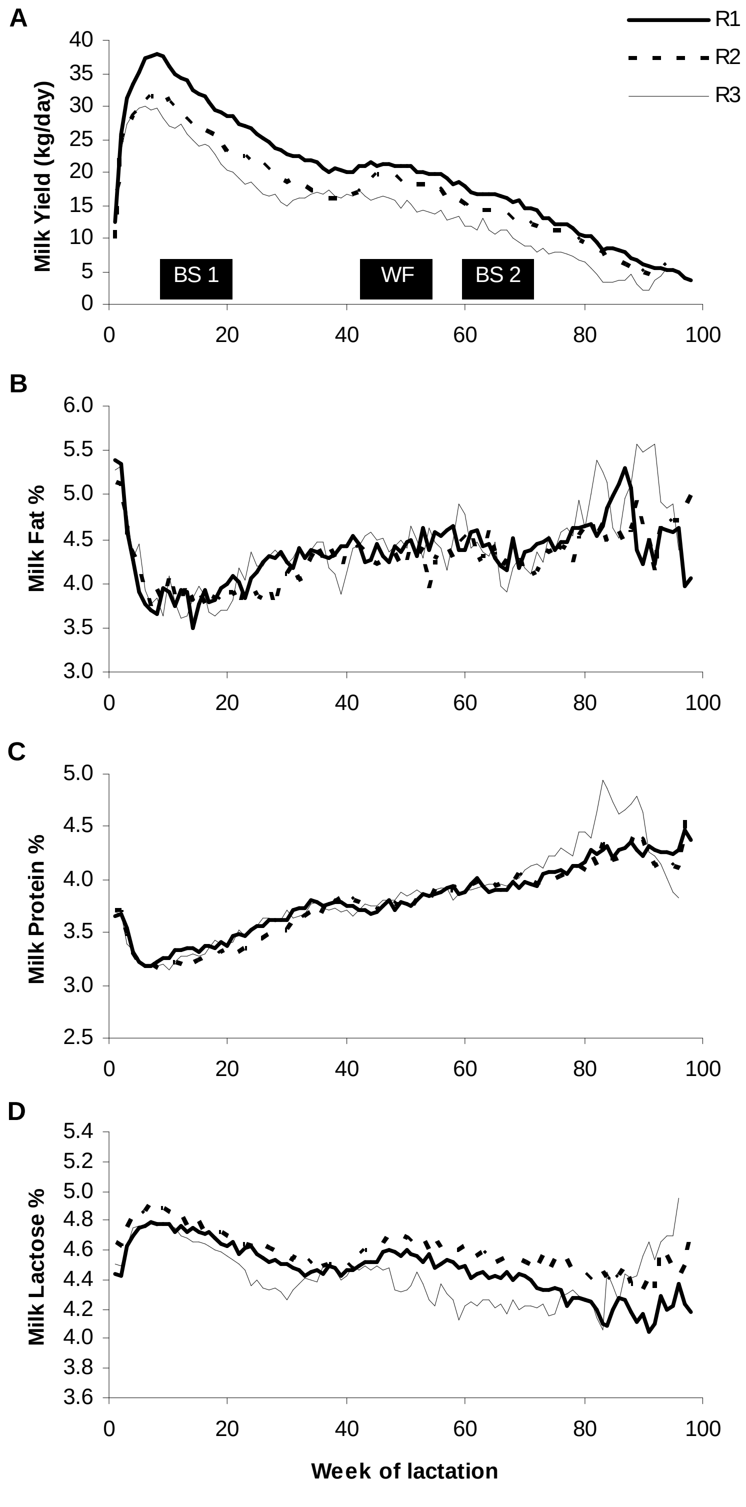

Figure 3 – Butler.