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## Production and physiological indicators to select cows suitable for extended lactations

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### ABSTRACT

Individual cows vary in their ability to maintain milk production for an extended lactation. Identifying production and physiological markers to indicate cows suitable for extended lactations would allow dairy farmers to make early decisions to withhold mating of individual cows or to continue milking specific non-pregnant cows through the winter months. Fifty-six genetically divergent overseas and New Zealand Holstein Friesians were allocated to three pasture-based dietary treatments (0, 3 and 6 kg concentrate DM/cow/d) and mating was withheld to target a 670-d lactation. Within each treatment there was little correlation between animal evaluation index values and milksolids (MS) production during the extended lactation period (>296 days in milk; DIM). There was a positive correlation between MS yield from the initial normal season (<296 DIM) and extended lactation MS production; and a negative correlation between body condition score (BCS) at theoretical dry off date (~296 DIM) and extended lactation MS yield. Plasma hormone and metabolite data from wk 1-10 postpartum demonstrated a positive association between non-esterified fatty acid levels and extended lactation MS production, whereas glucose, insulin, and insulin like growth factor-1 were negatively associated with extended lactation MS production. Overall, data indicate that the animal evaluation index is not a good indicator of animals suitable for extended lactation, however normal season milk production, early lactation plasma hormone and metabolite and late lactation BCS data may be useful to identify animals that will undergo a successful extended lactation.

**Keywords:** extended lactation; genotype; supplements.

### INTRODUCTION

Traditionally, pasture-based dairy cows have been managed to calve every 12 months resulting in lactations of approximately 250-300 d (Borman *et al.*, 2004; Kolver *et al.*, 2005; LIC, 2006). In the past twenty years, incorporation of overseas (OS; predominantly North American Holstein Friesian; HF) genetics into NZ dairy herds has increased, resulting in metabolic and physiological changes that increase the genetic potential for milk production but conversely have a negative impact on reproductive performance (Lucy *et al.*, 2001; Harris, 2005; Kolver *et al.*, 2005). Milking cows continuously for ~670 d (with a 24-month calving interval) has been proposed as a management strategy to improve reproductive parameters while maintaining high milk yield from superior dairy cows (Borman *et al.*, 2004; Kolver *et al.*, 2006b; Auldist *et al.*, 2007).

Two primary strategies can be used to achieve an extended lactation. A decision can be made in early lactation to establish a 24-month calving interval which replaces the typical 12-month breeding programme. Mating is delayed from ~80 days in milk (DIM) until ~450 DIM to allow lactation to be extended. An alternative strategy is to target non-pregnant dairy cows in late lactation. Traditionally, these cows would be culled and

replaced, resulting in reduced revenue due to shorter lactation length, decreased production lifespan, and increased replacement costs (Butler *et al.*, 2006). An opportunity exists to continue milking these cows through the winter months and initiate mating at ~450 DIM, resulting in a 24-month calving interval and an extended lactation for each cow.

Dairy cows managed under a pasture-based system are able to sustain an extended lactation with some genotype and diet combinations showing little loss of annualised milk production (Butler *et al.*, 2006; Kolver *et al.*, 2006b; Auldist *et al.*, 2007). However, a wide range exists in the individual cow's ability to maintain milk production for an extended period (Kolver *et al.*, 2006b). For the decision to be made to delay mating or to continue milking non-pregnant cows after their theoretical culling date, production or physiological markers are needed to identify those cows that will undergo a successful extended lactation. Thus the primary aim of the present study was to use data from Kolver *et al.* (2006b) to investigate production and physiological markers that may be able to identify in advance, those individual cows suitable for extended lactations.

## MATERIALS AND METHODS

The experimental design, cow selection, feeding and management practices, breeding programme and production measurements from the present study have been described previously (Kolver *et al.*, 2006b).

Briefly, 56 OS and NZ HF grazed pasture as one herd and were individually offered 0, 3 or 6 kg DM/cow/d of a pelleted concentrate supplement from June 2003 to May 2005. Milk yield was recorded daily and milk composition determined weekly. Liveweight (LWT) was recorded weekly and body condition score (BCS) measured fortnightly.

Blood samples (~10 mL) were collected weekly for the first 10 wks postpartum immediately following the AM milking. Samples were kept on ice until centrifuged at 1120 x g for 10 minutes. Plasma was harvested and frozen at -20°C for subsequent analyses of insulin, growth hormone (GH), insulin like growth factor-1 (IGF-1), leptin, glucose, non-esterified fatty acids (NEFA),  $\beta$ -hydroxybutyrate (BOH), ammonia, calcium, and urea as previously described (Roche *et al.*, 2005; Kolver *et al.*, 2006a).

Lactation length for the “normal” 12-month calving interval was calculated from time of calving to a theoretical dry-off date based on BCS, time from calving, and daily milk production (Macdonald *et al.*, 2005). Final dry off date following the extended lactation was also based on decisions outlined in Macdonald *et al.* (2005) with a final dry-off date imposed 52 d before the planned start of calving (~670 DIM). Drying off decisions for the rest of lactation were based on milk production (<4 kg milk/d for two wk; <5 kg milk/d for two wk during the last two months of lactation).

Animal evaluation index outputs were calculated according to the LIC Animal Evaluation Unit Report.

## STATISTICAL ANALYSIS

Within treatment (genotype x diet) correlations were calculated between extended lactation milksolids (MS) production (kg/cow) and various milk production, plasma hormone and metabolite, BCS and animal evaluation index values using Genstat 8.1 and P values, slope and  $r^2$  have been reported. In addition, treatment means and within treatment standard deviations for the variables used for correlation analysis have been presented. A “normal” lactation was defined as the period from calving to the theoretical dry off date ( $296 \pm 24$  DIM). Extended lactation was defined as the period from this theoretical dry off date until actual dry off date ( $604 \pm 59$  DIM). Significant effects for correlation analyses were declared at  $P < 0.05$ .

## RESULTS

Production, LWT, BCS and reproductive data have been previously reported (Kolver *et al.*, 2006b). Correlation analyses from the present study demonstrate that within each treatment group (genotype x diet), there was a positive association ( $P < 0.05$ ) between total milk, MS (kg/cow) and peak MS yield (kg/cow/d) from the “normal” lactation (first 296 DIM) and MS production during the extended lactation (>296 DIM; Table 1). Daily milk and MS production measured at the theoretical dry off date (~296 DIM) were positively associated ( $P < 0.01$ ) with MS production during the extended lactation (Table 1). Body condition score at theoretical dry off date was negatively associated ( $P < 0.01$ ) with extended lactation MS production (Table 1).

**Table 1:** Within treatment correlations between milksolids (MS) production (kg/cow) during the extended lactation period (>296 DIM) and production parameters during the “normal” season (NS) and at theoretical dry off date (DO) for New Zealand (NZ) and overseas (OS) Holstein-Friesians grazing pasture and fed 0, 3 or 6 kg concentrate DM/cow/d.

| Variable                              | Treatment means |        |        |        |        |        | sd <sup>1</sup> | Within treatment correlations |        |                |
|---------------------------------------|-----------------|--------|--------|--------|--------|--------|-----------------|-------------------------------|--------|----------------|
|                                       | NZ0             | NZ3    | NZ6    | OS0    | OS3    | OS6    |                 | P                             | Slope  | r <sup>2</sup> |
| NS milk yield (kg/cow) <sup>2</sup>   | 5936.1          | 6911.6 | 6996.2 | 6397.7 | 7481.2 | 8738.2 | 1020.4          | <0.01                         | 0.07   | 0.18           |
| NS MS yield (kg/cow) <sup>2</sup>     | 488.9           | 551.2  | 529.9  | 494.2  | 556.0  | 624.7  | 73.6            | <0.01                         | 0.65   | 0.19           |
| NS peak MS yield                      | 2.2             | 2.4    | 2.4    | 2.3    | 2.6    | 2.6    | 0.4             | 0.05                          | 87.78  | 0.18           |
| DO milk yield (kg/cow/d) <sup>3</sup> | 13.4            | 18.5   | 15.5   | 17.2   | 21.4   | 23.3   | 4.6             | <0.01                         | 25.90  | 0.32           |
| DO MS yield (kg/cow/d) <sup>3</sup>   | 1.3             | 1.7    | 1.4    | 1.5    | 1.8    | 2.0    | 0.4             | <0.01                         | 320.71 | 0.48           |
| DO body condition score <sup>3</sup>  | 5.1             | 5.2    | 6.4    | 4.3    | 4.0    | 5.1    | 1.1             | <0.01                         | -94.05 | 0.39           |

<sup>1</sup>Within treatment standard deviations for production variables used in correlation analyses.

<sup>2</sup>Based on data for the “normal” season (NS; <296 DIM).

<sup>3</sup>Based on data at theoretical dry off date (DO; ~296 DIM).

**Table 2:** Within treatment correlations between milksolids (MS) production (kg/cow) during the extended lactation period (>296 DIM) and animal evaluation outputs for New Zealand (NZ) and overseas (OS) Holstein-Friesians grazing pasture and fed 0, 3 or 6 kg concentrate DM/cow/d.

| Variable                  | Treatment means |       |       |        |        |        | sd <sup>1</sup> | Within treatment correlations |       |                |
|---------------------------|-----------------|-------|-------|--------|--------|--------|-----------------|-------------------------------|-------|----------------|
|                           | NZ0             | NZ3   | NZ6   | OS0    | OS3    | OS6    |                 | P                             | Slope | r <sup>2</sup> |
| Breeding Worth            | 121.2           | 117.7 | 121.0 | 113.0  | 122.0  | 106.0  | 22.7            | NS                            | 0.00  | 0.01           |
| Fat breeding value (BV)   | 31.7            | 28.8  | 28.4  | 33.6   | 35.2   | 34.9   | 4.7             | NS                            | 1.02  | 0.01           |
| Protein BV                | 29.1            | 30.7  | 29.2  | 40.4   | 42.4   | 39.0   | 4.6             | NS                            | 2.08  | 0.00           |
| Milk yield BV             | 797.6           | 881.2 | 822.8 | 1296.3 | 1332.4 | 1254.9 | 167.3           | NS                            | 0.12  | 0.00           |
| Liveweight BV             | 54.4            | 57.9  | 50.9  | 89.4   | 92.8   | 92.8   | 8.8             | NS                            | 0.16  | 0.00           |
| Fertility BV              | 0.8             | -0.4  | 0.9   | -3.0   | -4.9   | -4.4   | 1.5             | NS                            | -7.93 | 0.01           |
| Residual survival BV      | -12.5           | 13.7  | 28.3  | -294.4 | -219.1 | -206.9 | 55.9            | 0.02                          | -0.58 | 0.09           |
| Total longevity BV        | 182.9           | 175.3 | 211.0 | -156.6 | -112.2 | -100.7 | 59.4            | 0.02                          | -0.53 | 0.10           |
| Production Worth          | 108.9           | 101.0 | 105.9 | 122.7  | 122.8  | 96.2   | 50.3            | NS                            | 0.26  | 0.01           |
| Fat production value (PV) | 35.6            | 29.2  | 29.1  | 37.3   | 35.6   | 36.9   | 13.2            | NS                            | 1.07  | 0.02           |
| Protein PV                | 28.9            | 31.2  | 26.7  | 41.9   | 43.2   | 36.7   | 9.5             | NS                            | 1.58  | 0.00           |
| Volume PV                 | 806.3           | 877.1 | 864.1 | 1364.2 | 1307.3 | 1223.7 | 296.5           | NS                            | 0.09  | 0.01           |
| Liveweight PV             | 56.8            | 68.2  | 50.8  | 86.7   | 99.0   | 93.6   | 16.5            | NS                            | -0.79 | 0.01           |

<sup>1</sup>Within treatment standard deviations for animal evaluation outputs used in correlation analyses.

**Table 3:** Within treatment correlations between milksolids (MS) production (kg/cow) during the extended lactation period (>296 DIM) and postpartum (wk 1-10) plasma hormones and metabolites for New Zealand (NZ) and overseas (OS) Holstein-Friesians grazing pasture and fed 0, 3 or 6 kg concentrate DM/cow/d.

| Variable                     | Treatment means |      |       |       |       |      | sd <sup>1</sup> | Within treatment correlations |         |                |
|------------------------------|-----------------|------|-------|-------|-------|------|-----------------|-------------------------------|---------|----------------|
|                              | NZ0             | NZ3  | NZ6   | OS0   | OS3   | OS6  |                 | P                             | Slope   | r <sup>2</sup> |
| β-hydroxybutyrate            | 0.82            | 0.64 | 0.52  | 0.83  | 0.67  | 0.60 | 0.38            | NS                            | 68.44   | 0.05           |
| Non esterified fatty acids   | 0.64            | 0.49 | 0.59  | 0.77  | 0.71  | 0.80 | 0.17            | <0.01                         | 282.01  | 0.23           |
| Ammonia                      | 1.72            | 1.48 | 1.74  | 1.62  | 1.45  | 1.47 | 0.42            | NS                            | -84.84  | 0.00           |
| Calcium                      | 2.42            | 2.37 | 2.40  | 2.39  | 2.42  | 2.35 | 0.09            | NS                            | -124.99 | 0.03           |
| Urea                         | 6.29            | 5.40 | 4.87  | 6.11  | 5.06  | 4.45 | 0.85            | NS                            | 7.40    | 0.03           |
| Insulin                      | 6.64            | 8.77 | 7.23  | 6.41  | 7.12  | 9.24 | 3.64            | <0.01                         | -18.82  | 0.34           |
| Glucose                      | 3.23            | 3.44 | 3.43  | 3.09  | 3.30  | 3.45 | 0.22            | <0.05                         | -153.83 | 0.19           |
| Leptin                       | 1.11            | 1.12 | 1.17  | 1.04  | 1.07  | 1.05 | 0.18            | NS                            | -56.64  | 0.00           |
| Insulin like growth factor-1 | 6.78            | 9.18 | 10.44 | 6.63  | 6.93  | 7.42 | 2.89            | <0.01                         | -21.90  | 0.26           |
| Growth hormone               | 9.01            | 7.68 | 5.91  | 11.85 | 12.23 | 7.20 | 3.02            | NS                            | 1.36    | 0.02           |

<sup>1</sup>Within treatment standard deviations for plasma hormones and metabolites used in correlation analyses.

In contrast, there was no correlation between animal evaluation system outputs and extended lactation MS production (Table 2) with the exceptions of breeding value (BV) for residual survival and BV for total longevity which demonstrated a weak negative relationship (P<0.05). When animal evaluation system outputs were compared with MS production from the “normal” lactation (<296 DIM) once again there was little significant association with MS production (data not presented).

There was no association between extended lactation MS production and several of the hormones and metabolites measured (GH, leptin, BOH, ammonia, calcium, and urea; Table 3). However, there were negative associations (P<0.05) between plasma glucose, IGF-1 and insulin data (wk 1- 10 postpartum) and extended lactation MS production (Table 3) and a positive correlation (P<0.01) between NEFA data (wk 1-

10 postpartum) and extended lactation MS production (Table 3).

## DISCUSSION

Cows with higher milk and MS yield and lower BCS within seasonal production systems are likely to have increased milk production from an extended lactation. The present study demonstrates that cows that produced more milk and MS during the initial “normal” season (~296 DIM) of the extended lactation also produced more milk and MS during the second season (>296 DIM) of the extended lactation. These successful cows also demonstrated a lower BCS at theoretical dry off date, indicating they were partitioning more available nutrients towards milk production at the expense of body reserves. The diversion of nutrients to support milk production at the expense of body reserves can however be detrimental to

animal health and reproductive performance in a seasonal (12 month) calving system, as peak milk production and negative energy balance (NEBAL) coincide with initiation of a seasonal breeding programme (~80 DIM).

Based on the milk production from the previous lactation, appropriate individual cows may be identified; their mating deliberately delayed until ~450 DIM, and then milked successfully through two lactations. Alternatively, data for milk production from the “normal” lactation, and milk production and BCS at the theoretical dry off date may allow farmers to select thinner, higher producing non-pregnant cows that will continue to produce milk satisfactorily through an extended lactation, as an alternative to culling and replacement.

In contrast, animal evaluation indexes, based on both genetic and production data, did not serve as accurate indicators of a dairy cow’s ability to sustain an extended lactation in this dataset. Although there were small negative relationships between both BV for total longevity and BV for residual survival with extended lactation MS production, these variables only accounted for approximately 10% of the variation in individual response. Additionally there was little correlation between the animal evaluation indexes and the “normal” season MS production. The failure of the animal evaluation indexes to predict milk production in this dataset is most probably due to the small number of cows used in the study.

Cows with higher plasma NEFA content (indicating increased lipolysis and adipose tissue mobilisation) during the first 10 wks postpartum produced more MS during both the “normal” (data not presented) and the extended lactation period. The increased basal NEFA content also indicate these successful cows were in a more severe NEBAL during the postpartum period, increasing the possibility of metabolic disorders and reproductive failures if they were to be mated for a 12-month calving interval (Drackley, 1999; de Vries & Veerkamp, 2000). Insulin, glucose and IGF-1 concentrations during the first 10 wks postpartum were negatively correlated with MS production during the extended lactation period. The lower blood glucose content in these higher producing dairy cows is due to the increased mammary glucose demand (as an energy source and lactose substrate; Bauman & Currie, 1980). The suggestion that these successful cows are partitioning more available nutrients/energy towards mammary gland and not body reserves is supported by the reduced circulating insulin content. The lower insulin concentrations are partially due to the lower glucose content

(homeostatic regulation) and also due to reduced systemic insulin sensitivity in these particular cows. As the mammary gland contains insulin independent glucose transporters (while extra-mammary tissue relies on insulin dependent transporters) low insulin levels and reduced insulin sensitivity ensure that circulating glucose is used primarily by mammary tissue and not directed to body reserves (Bauman & Currie, 1980).

The lower plasma IGF-1 concentrations (wk 1-10 postpartum), associated with increased MS production during extended lactation in the current study, are linked with the lower plasma insulin content. In these successful cows, the lower plasma insulin content reduce liver GH receptor expression which in turn decreases liver IGF-1 synthesis and decreases blood IGF-1 content (Lucy, 2004). This phenomenon is often referred to as uncoupling of the somatotrophic axis, and although this occurs in all dairy cows immediately postpartum (Lucy *et al.*, 2001) an animal’s energetic status influences the recoupling of this axis, with animals in more severe NEBAL remaining uncoupled for longer (McGuire *et al.*, 1992; Lucy, 2004; Radcliff *et al.*, 2006). An unexpected result from this study is the lack of correlation between GH levels and extended lactation MS production. Typically the higher NEFA and lower blood glucose, insulin and IGF-1 levels displayed by the successful extended lactation cows during this postpartum period would have been associated with increased GH levels (Lucy, 2004). The reasons behind the lack of correlation between GH and extended lactation MS production are unclear.

In conclusion, the present study demonstrates the potential to select animals that will maintain increased milk production throughout an extended lactation by using previous milk production, BCS and plasma hormone and metabolite data. Further research is required to validate these indicators by managing selected animals in an extended lactation farm system trial and to utilise these data to develop a practical selection index.

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