Factors affecting body condition score, live weight and reproductive performance in spring-calving suckler cows

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The objective was to identify factors affecting live weight (LW), body condition score (BCS), calving rate and calving interval in spring-calving suckler cows. A total of 925 records on 299 cows from the years 1987 to 1999 were used and the data were analyzed using mixed models and generalised estimating equations. Cows calving early in the year (< day 65 of the year) were significantly heavier at the start of winter, had greater BCS at the subsequent calving but lost most LW in winter. Despite having higher LW gain at pasture, annual LW gain of early-calving cows was lower than that of late-calving cows (> day 90 of the year). Trends in BCS were similar to LW but there was no effect of calving date on annual BCS change. Cows in parity 1, 2, 3 to 7 and >7 had initial LW of 523, 549, 614 and 623 kg, winter LW losses of 61, 52, 65 and 67 kg and LW gains at pasture of 81, 99, 94 and 75 kg, respectively. First parity animals had higher BCS at the start of winter but had greater BCS loss in winter and lower BCS gain at pasture than the other three parity groups. Overall pregnancy rate was 93.6% and was not affected by either previous calving date or cow parity. Mean calving interval was 367 days and was affected by previous calving date but there was no effect of either cow parity or previous calving difficulty. Mean calving interval for cows calving early, mid-season or late were 378, 364 and 353 days, respectively. The results show that good reproduction performance can be achieved in spring-calving suckler cows subjected to low feeding levels during the winter period but grazed on well-managed pasture in summer.

Keywords: beef cow; body condition score; live weight; reproduction; suckler cow

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**Introduction**

The most important factors affecting both biological and economic efficiency in suckler cow herds are reproductive performance, incidence of mortality and growth rate of the progeny. Because the cost of providing winter feed for the cow is a substantial proportion of the total costs (Petit *et al*., 1995) the aim, particularly where animals graze well-managed pastures in summer, is to use the body reserves built up in summer to reduce feed inputs in winter (Drennan, 1994; Petit *et al*., 1995). However, it is important that such a practice does not compromise subsequent reproductive performance.

Studies on beef cows have shown that cows offered a higher plane of nutrition before calving (Wiltbank *et al*., 1962) or those in better body condition at calving (Wright *et al*., 1987) have a shorter postpartum anoestrus period. Selk *et al.* (1985) reported that beef cows in better body condition at calving had a higher pregnancy rate. Furthermore, evidence exists relating level of feeding after calving (Wiltbank *et al*., 1964; Dunn *et al*., 1969) and changes in body condition score (BCS) and live weight (LW) post calving (Rutter and Randel, 1984) to both length of the anoestrus period and conception rate. Wiltbank *et al.* (1962) showed that when cows offered a low plane of nutrition pre-calving were also provided with a low level post-calving only 22% showed oestrus up to 90 days post-calving. In contrast, when a high plane of nutrition was provided post-calving 85% of cows showed oestrus in that period indicating the importance of post-calving nutrition. In addition, conception rate was somewhat lower in cows on the low level of energy after calving. Dunn *et al.* (1969) showed that pregnancy rate in 2-year-old heifers nursing their first calf was directly related to post-calving energy level and the onset of heat was delayed in cows receiving the low level of energy before calving. Agabriel, Grenet and Petit (1992), reporting on winter-/spring-calving Charolais and Limousin herds in France, concluded that BCS at the end of winter influenced subsequent reproductive performance where cows calved about 2 months prior to grazing, but had no effect in cows that calved at the start of the grazing season. These results indicate that the high plane of nutrition provided when suckler cows are grazed on lowland pasture in spring ensures good reproductive performance. Nicoll (1979) obtained no effect of restricted grass supplies pre-calving on reproductive performance but a similar level of restriction after calving led to a large reduction in fertility.

Generally, most previous studies fall into two main categories one of which involves a moderate to low plane of nutrition post calving permitting only minimal improvements in LW or BCS. Such conditions apply to animals grazing undeveloped grassland or to autumn-calving cows offered grass silage or hay-based diets during the breeding season. The second category relate to spring-calving cows grazing lowland pastures during the breeding season, which provides a higher plane of nutrition thus permitting rapid recovery in LW in cows rearing one calf (Baker, Le Du and Alvarez, 1981; Drennan, 1994). Body condition at calving influences reproductive performance in animals offered a low/moderate plane of nutrition post-calving but is relatively unimportant where a high nutritional plane is provided.

Furthermore, other factors such as cow genotype (Osoro and Wright, 1992), calf suckling (Williams, 1990; Diskin, 1997), cow age (Wiltbank, 1970; Pleasants and McCall, 1993), time of the year at calving (Osoro and Wright, 1992; Agabriel *et al*., 1992) and the presence of a bull with the
herd (Custer *et al*., 1990; Stumpf *et al*., 1992) have also been shown to influence reproductive performance. The latter has been shown to reduce the time from calving to first oestrus by 6 to over 16 days.

The objective of the present study was to examine the factors affecting LW, BCS and the changes in these variables during the annual production cycle and how these variables impact on reproductive performance, using data collected over a 13-year period on a spring-calving suckler herd.

**Materials and Methods**

**Data**

During a 13-year period (breeding seasons of 1987 to 1999), a total of 978 records were obtained on spring-calving suckler cows presented for breeding at Grange Research Centre. Fifty-three cases were omitted from the analysis due to absence of critical records, casualties, abortions or twin births (short gestation length), leaving 925 records from 299 cows. Records comprised 179 Hereford × Friesian, 545 Limousin × Friesian, 49 Simmental × (Limousin × Friesian) and 152 upgraded Charolais. The cows were used in winter-feeding and grazing-management studies often resulting in substantial imposed differences in BCS and LW changes during the winter period. Breeding was to late maturing continental sire breeds and commenced each year in early May; generally, artificial insemination (AI) was initially used with natural mating towards the latter part of the breeding season. Heat detection for AI mainly consisted of frequent observation (early morning, throughout the day and late evening) but tail-painting was also used to a varying extent. First calving for all animals was at 2 years of age and cows were only retained if they reared a calf during the previous year. Average calving date was mid-March; cows were at pasture from about 19 April to around mid-November (weaning) when they were housed for the winter.

In winter, the duration of which was generally about 150 days (115 days pregnancy and 35 days of lactation), cows that had previously reared a calf were generally offered moderate quality (dry matter digestibility of approximately 640 g/kg) grass silage only. Silage was sometimes restricted prior to calving but was always available to appetite after calving. First-calving animals usually received higher quality grass silage and, in addition, were offered a barley-based concentrate (1.5 kg per head daily) from calving until grazing commenced. All animals were offered 60 g per head daily of a mineral/vitamin supplement (trace elements and vitamins with salt and calcined magnesite used as a carrier) throughout the winter. The only supplement offered at pasture was a 50:50 mixture of molasses/calcined magnesite from about mid-September as a preventative against hypomagnesaemia in the cows. For the same reason, pastures were dusted with calcined magnesite (32 kg/ha) from the start of the grazing season until early June.

The records available included BCS and unfasted LW at critical time points from the start of the winter period prior to the breeding season until the end of the subsequent grazing season. BCS was determined on a scale of 0 (thin, emaciated) to 5 (obese), according to the procedure of Lowman, Scott and Somerville (1976). The critical times for BCS and LW were start and end of the winter period prior to breeding, post-calving prior to breeding, during the breeding season (about mid-June) and start of the subsequent winter. The following changes in LW and BCS were calculated: during the winter, between calving and turnout to pasture, between calving and June, between turnout and June, during the grazing period
and over the year (start of winter to start of subsequent winter). Other information available included cow parity, previous and present calving dates and incidence of calving difficulty at previous calving. Calving difficulty was recorded on a scale of 1 (no problem) to 5 (caesarean).

Data editing
Calving interval was defined as the number of days between consecutive calvings. By definition, cows that do not re-calve will not have a calving interval and, in these cases, calving interval was set to missing. Calving rate was dichotomised as 1 (the animal calved or was pregnant if culled prior to calving) or 0 (the animal was not pregnant). Initial analyses revealed an overall calving rate of 93.6%. Hence, calving in the first 42 days of the calving season (CALV42) was defined as 1 if an animal calved in the first 42 days of the calving season or 0 if the animal did not. No calving inductions were used in the present study. Calving difficulty score was recoded as 0 (no problem) or 1 (some assistance).

Parity was coded into four classes: 1, 2, 3 to 7, >7. Limousin × Friesian and Simmental × (Limousin × Friesian) animals were combined into one breed class.

Preliminary investigation of the data revealed that few observations were at the extremities of the BCS or BCS change variables. Because such data points are likely to have a large impact on the solutions of polynomials fitted through these BCS variables, BCS values at the extremes were merged to the next adjacent level so that at least ten records were available in each extreme BCS class.

Statistical analysis

Body condition score and live weight
Correlations among BCS variables and LW variables were obtained using PROC CORR (SAS, 2006). Mixed model analysis (PROC MIXED; SAS, 2006) was used to investigate the factors affecting BCS and LW throughout the year. Cow was treated as a repeated effect with a first order autoregressive covariance structure assumed among records within a cow. Day of the year at calving (1 January = day 1) was divided into three classes: before day 65 (early), between day 65 and day 90 (mid-season), and after day 90 (late). Variables tested in the model for significance were: year of calving, breed, parity, calving difficulty and day of the year at calving. Only biologically plausible interactions were tested for significance in the model.

Calving rate
Because of the binary nature of calving rate and CALV42, and the availability of multiple records per cow, generalised estimating equations (GEE) were used to model the effect of various explanatory variables on the logit of the probability of calving or of CALV42 = 1. The analyses were carried out in PROC GENMOD (SAS, 2006) utilising a logit link function and a binomial distribution. A first order autoregressive covariance structure was assumed among records within cow; empirical standard errors are reported in the present study.

A two-stage approach was used to generate the multiple regression model. Firstly, a multiple regression model was developed with all the significant (P < 0.05) independent variables except the BCS and LW related variables. The significance level was based on the GEE score statistic. Possible explanatory variables tested in the model were: year of calving, parity, calving difficulty, breed and calving date. All the aforementioned variables were treated as class variables with the exception of day of the year at calving, which was treated as a continuous variable. Biologically plausible two- and
three-way interactions were also tested in the model while simultaneously avoiding quasi-complete separation of the data. All animals in the herd in 1989 calved again in 1990; hence, in order to avoid quasi-complete separation of the data, the year 1989 was recoded as 1988 for the analysis of calving rate.

Following the establishment of the main model, a stepwise forward-backward algorithm was invoked to determine the BCS and LW variables that significantly affected calving rate. Significance threshold levels of $P < 0.25$ and $P < 0.10$ were used for entry and retention in the models, respectively. All BCS and LW variables were treated as continuous, the order of which was determined by graphically examining the relationship between each of the variables and the logit of the probability of calving the subsequent year, as well as the significance of the GEE score statistic for the higher order terms. Odds ratios were derived as the exponent of the partial regression coefficients.

The presence of multi-collinearity was tested at each step using PROC REG (SAS, 2006), whereby a condition index of $> 30$ was assumed to indicate the presence of collinearity among variables. The presence of multi-collinearity was also investigated by evaluating the effect of the inclusion of an additional model term on the solutions of the previously included effects in the model. Also, because of the possible collinearity between BCS and LW, separate analyses were carried out for BCS and LW variables.

**Calving interval**

Fifty-nine (6.4%) cows were not pregnant, leaving a total of 866 records for inclusion in the analysis of calving interval, which was normally distributed. Mixed models (PROC MIXED; SAS, 2006) with cow treated as a repeated effect were used to investigate the factors affecting calving interval. A first autoregressive correlation structure was assumed among records within cow. Possible explanatory variables available that may influence calving interval – other than BCS and LW for the year of breeding – were: parity, breed, year of calving, calving difficulty and calving date. All the aforementioned variables were treated as class variables with the exception of calving date, which was treated as a continuous variable. A two-stage approach similar to that previously described was again undertaken in the development of a multiple regression model. A quadratic regression on calving date was included in the model based on the non-linear relationship between calving interval and calving date, which was obvious when calving interval was plotted against calving date.

**Results**

Table 1 summarises the correlations between BCS and LW related variables. Correlations between BCS at different times of the year varied from 0.43 to 0.69, while the correlations between LW measures at different times of the year were all greater than 0.84. The correlation between BCS and LW at the same point in time varied from 0.38 to 0.51.

Cows that calved in the early and mid-season periods were significantly heavier than late-calving cows at the start of winter (Table 2). Winter LW changes were $-77$, $-59$ and $-40$ kg for the early, mid-season and late-calving groups, respectively, all of which were significantly different from each other. A two-way interaction between calving day of year and parity existed for LW loss between calving and turnout. This reflected the fact that there was no significant difference between calving day of year classes in first calvers while for the other three parity groups the LW
### Table 1. Correlations among body condition score (below the diagonal) and live weight variables (above the diagonal) and correlations between body condition score and live weight variables at the same time point (on the diagonal)

<table>
<thead>
<tr>
<th>Time point</th>
<th>Winter</th>
<th>Calving</th>
<th>Turnout</th>
<th>Autumn</th>
<th>Winter to turnout</th>
<th>Calving to turnout</th>
<th>Calving to June</th>
<th>At grass</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winter</td>
<td>0.42</td>
<td>0.88</td>
<td>0.86</td>
<td>0.88</td>
<td>-0.33</td>
<td>-0.04</td>
<td>0.27</td>
<td>0.07</td>
<td>-0.28</td>
</tr>
<tr>
<td>Calving</td>
<td>0.43</td>
<td>0.38</td>
<td>0.94</td>
<td>0.84</td>
<td>0.04</td>
<td>-0.16</td>
<td>0.02</td>
<td>-0.16</td>
<td>-0.13</td>
</tr>
<tr>
<td>Turnout</td>
<td>0.46</td>
<td>0.69</td>
<td>0.46</td>
<td>0.85</td>
<td>0.20</td>
<td>0.19</td>
<td>0.19</td>
<td>-0.23</td>
<td>-0.05</td>
</tr>
<tr>
<td>Autumn</td>
<td>0.54</td>
<td>0.43</td>
<td>0.51</td>
<td>0.48</td>
<td>-0.12</td>
<td>0.06</td>
<td>0.40</td>
<td>0.31</td>
<td>0.21</td>
</tr>
<tr>
<td>Winter to turnout</td>
<td>-0.49</td>
<td>0.29</td>
<td>0.54</td>
<td>-0.01</td>
<td>0.45</td>
<td>0.44</td>
<td>-0.17</td>
<td>-0.58</td>
<td>0.44</td>
</tr>
<tr>
<td>Calving to turnout</td>
<td>0.09</td>
<td>-0.31</td>
<td>0.47</td>
<td>0.10</td>
<td>0.37</td>
<td>0.24</td>
<td>0.51</td>
<td>-0.25</td>
<td>0.21</td>
</tr>
<tr>
<td>Calving to June</td>
<td>0.19</td>
<td>-0.34</td>
<td>0.03</td>
<td>0.31</td>
<td>-0.17</td>
<td>0.45</td>
<td>0.34</td>
<td>0.39</td>
<td>0.25</td>
</tr>
<tr>
<td>At grass</td>
<td>0.07</td>
<td>-0.27</td>
<td>-0.52</td>
<td>0.50</td>
<td>-0.56</td>
<td>-0.37</td>
<td>0.27</td>
<td>0.51</td>
<td>0.47</td>
</tr>
<tr>
<td>Year</td>
<td>-0.47</td>
<td>0.04</td>
<td>0.05</td>
<td>0.49</td>
<td>0.49</td>
<td>0.01</td>
<td>0.13</td>
<td>0.43</td>
<td>0.42</td>
</tr>
</tbody>
</table>

1Winter, Calving, Turnout, Autumn (= start of next winter period) refer to these time points; Winter to turnout, Calving to turnout, Calving to June refer to change between these time points; At grass = change between turnout to pasture and end of grazing period; Year = change between start of winter and start of subsequent winter.

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Losses were always greater for early calvers than for mid-season and late calvers. From turnout until mid-June, early-calving cows had significantly greater LW gain than those calving in mid-season, which were in turn greater than late-calving cows. LW gain over the entire grazing season of early, mid-season and late-calving cows was 98, 88 and 82 kg, respectively, with the early and late calvers being significantly different from each other.

BCS at the start of winter (average 2.9) was the same for cows calving at different times of the year but winter losses were greater for early calvers than the late calvers, with those calving in mid-season intermediate and not significantly different from either of the other groups. BCS at the start of winter (average 2.9) was the same for cows calving at different times of the year but winter losses were greater for early calvers than the late calvers, with those calving in mid-season intermediate and not significantly different from either of the other groups.

Cows got heavier with age, although there was no significant difference in LW gain over the entire grazing season of parity-2 animals compared to parity-1 and parity-3-to-7 cows. During the calving to mid-June and over the entire grazing season, the LW gain of first parity animals was significantly lower than those of parity-2 or 3 to 7, which were also the same. Over the entire year, LW gain of parity-2 animals was significantly greater than parity-1 and parity-3-to-7 animals. The last 2 parity groups were similar in weight in the winter period, with parity-2 being lower than the other three groups which were similar. BCS of second-parity animals was lower at calving and at the end of the winter period than the other three groups, which were similar. BCS of second-parity animals was lower at calving and at the end of the winter period than the other three groups.
which were similar to each other. First parity animals had greater BCS losses over the winter period than the three groups of older animals, which were similar. During the entire grazing season BCS gain of parity-1 animals was significantly lower than the other three groups while parity > 7 animals had lower gains than the parity-2 animals; the parity-3-to-7 animals were intermediate. Over the year, parity-1 animals had substantial losses in BCS and were significantly different from the other three groups, which were similar.

There was no effect of calving difficulty on the subsequent calving interval, but cows that received assistance had lower (P < 0.01) LW gain in winter, similar gain at grass and lower (P < 0.01) annual gain than cows
that did not require assistance. BCS in June and autumn were significantly lower in cows that received assistance at calving. Cows that were assisted also lost significantly more BCS from calving to turnout than those not assisted (0.26 v 0.18 BCS units).

The overall calving rate was 93.6% and was not significantly affected by previous calving date (Table 2), parity (Table 3) or cow breed type. Change in BCS and LW across the entire year were the only BCS and LW variables that significantly (P < 0.05) affected calving rate. Cows that lost one BCS unit more than the mean had a 1.83 (95% CI: 1.12 to 2.99) times lower odds of becoming pregnant; while cows that lost 10 kg LW over the entire year had a 1.12 (95% CI: 1.05 to 1.20) times lower odds of becoming pregnant.

Calving interval was affected (P < 0.001) by previous calving day of year (Table 2) but there was no significant effect of parity (Table 3) or cow breed type. Treating day of calving as a linear regression in the model revealed that a one day delay in calving reduced (P < 0.001) the subsequent calving interval by 0.43 days. Calving interval for cows calving before day 65 (early), from days 65 to 90 (mid season) or after day 90 (late) were 378, 364 and 353 days, respectively.

None of the BCS change variables significantly affected calving interval after

<table>
<thead>
<tr>
<th>Variable</th>
<th>1</th>
<th>2</th>
<th>3 to 7</th>
<th>&gt;7</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of animals</td>
<td>208</td>
<td>195</td>
<td>439</td>
<td>83</td>
</tr>
<tr>
<td>Calving rate (%)</td>
<td>92.8</td>
<td>93.8</td>
<td>94.3</td>
<td>91.6</td>
</tr>
<tr>
<td>Calving interval (days)</td>
<td>370 (1.8)</td>
<td>366 (1.8)</td>
<td>365 (1.1)</td>
<td>369 (2.5)</td>
</tr>
<tr>
<td>Winter live weight (kg)</td>
<td>523 (4.2)</td>
<td>549 (3.9)</td>
<td>614 (3.8)</td>
<td>623 (7.1)</td>
</tr>
<tr>
<td>Live-weight change (kg)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Winter to turnout</td>
<td>−61 (3.1)</td>
<td>−52 (3.0)</td>
<td>−65 (2.2)</td>
<td>−67 (4.9)</td>
</tr>
<tr>
<td>Calving to June</td>
<td>7 (2.5)</td>
<td>24 (2.5)</td>
<td>27 (1.7)</td>
<td>15 (3.9)</td>
</tr>
<tr>
<td>Turnout to June</td>
<td>31 (2.0)</td>
<td>50 (2.0)</td>
<td>57 (1.4)</td>
<td>49 (3.1)</td>
</tr>
<tr>
<td>At grass</td>
<td>81 (2.8)</td>
<td>99 (2.9)</td>
<td>94 (2.1)</td>
<td>75 (4.7)</td>
</tr>
<tr>
<td>Year</td>
<td>20 (3.1)</td>
<td>52 (3.0)</td>
<td>27 (1.8)</td>
<td>1 (4.1)</td>
</tr>
</tbody>
</table>

**Body condition score (units)**

<table>
<thead>
<tr>
<th></th>
<th>Winter</th>
<th>Calving</th>
<th>Turnout</th>
<th>June</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Winter, Calving, Turnout, June refer to these time points; Winter to turnout, Calving to turnout, Calving to June refer to change between these time points; At grass = change between turnout to pasture and end of grazing period; Year = change between start of winter and start of subsequent winter.</td>
<td>3.30 (0.062)</td>
<td>2.62 (0.046)</td>
<td>2.92 (0.037)</td>
<td>3.03 (0.080)</td>
</tr>
<tr>
<td>2 Winter</td>
<td>Calving</td>
<td>Turnout</td>
<td>June</td>
<td></td>
</tr>
<tr>
<td>3 Winter</td>
<td>−0.76 (0.048)</td>
<td>−0.65 (0.029)</td>
<td>−0.67 (0.067)</td>
<td></td>
</tr>
<tr>
<td>4 Winter</td>
<td>−0.21 (0.040)</td>
<td>−0.20 (0.025)</td>
<td>−0.21 (0.057)</td>
<td></td>
</tr>
<tr>
<td>5 Winter</td>
<td>0.30 (0.046)</td>
<td>0.46 (0.030)</td>
<td>0.44 (0.068)</td>
<td></td>
</tr>
<tr>
<td>6 Winter</td>
<td>0.83 (0.049)</td>
<td>0.72 (0.032)</td>
<td>0.57 (0.072)</td>
<td></td>
</tr>
<tr>
<td>7 Winter</td>
<td>0.87 (0.050)</td>
<td>0.77 (0.036)</td>
<td>0.61 (0.073)</td>
<td></td>
</tr>
<tr>
<td>8 Winter</td>
<td>0.87 (0.050)</td>
<td>0.77 (0.036)</td>
<td>0.61 (0.073)</td>
<td></td>
</tr>
<tr>
<td>9 Winter</td>
<td>−0.78 (0.064)</td>
<td>0.09 (0.045)</td>
<td>0.07 (0.022)</td>
<td>−0.10 (0.050)</td>
</tr>
</tbody>
</table>

**Body condition score change (units)**

<table>
<thead>
<tr>
<th></th>
<th>Winter to turnout</th>
<th>Calving to turnout</th>
<th>Calving to June</th>
<th>Turnout to June</th>
<th>At grass</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Winter</td>
<td>−1.07 (0.066)</td>
<td>−0.76 (0.048)</td>
<td>−0.65 (0.029)</td>
<td>−0.67 (0.067)</td>
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</tr>
<tr>
<td>2 Winter</td>
<td>−0.23 (0.040)</td>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>4 Winter</td>
<td>0.32 (0.047)</td>
<td>0.83 (0.049)</td>
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<td>0.57 (0.072)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 Winter</td>
<td>0.35 (0.050)</td>
<td>0.87 (0.050)</td>
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<td>0.61 (0.073)</td>
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Table 3. Least squares means (s.e.) for the effect of parity on calving rate, calving interval, live weight and live-weight change, body condition score and body condition score change.
accounting for other variables in the model. However, calving interval decreased linearly (P < 0.05) by 3.6 to 4.1 days for each unit increase in BCS at the start of winter, at turnout, in June and autumn. A significant curvilinear relationship was evident between calving interval and BCS at calving (calving interval = 385−16.2 (s.e. 7.01)×BCS+3.06 (s.e. 1.449)×BCS²), with the minimum calving interval observed in cows calving at a BCS of 2.75. Only BCS at calving remained significant in the multiple regression model. Significant (P < 0.05) linear associations were observed between calving interval and LW change from the start of winter to calving, over the winter period, and across the entire year. The linear regression coefficient of calving interval on the LW change variables ranged from −10.0 to −4.5 days per 100 kg increase in LW (i.e., greater LW loss resulted in a longer calving interval). Only LW change across the entire year was significant in the multiple regression analysis. The lack of significant contribution from the other change variables is attributable to the part-whole relationships between them and LW change across the entire year.

Mean incidence of calving within the first 42 days of the following breeding season across the entire dataset was 72% and was significantly affected by a quadratic regression on BCS at calving and BCS at turnout (Figure 1). The linear effect of BCS in June approached significance (P < 0.10) with the odds for CALV42 = 1 being 1.26 times (95% CI: 0.97 to 1.65) greater per unit BCS increase at June. Additionally, the effect of BCS change from turnout to autumn on CALV42 approached significance (P < 0.10). Animals that gained most condition from turnout to autumn had a higher probability for CALV42 = 1 (odds ratio = 0.76). Only the quadratic regression on calving BCS remained significant in the multiple regression model. Of the LW variables investigated, CALV42 was significantly

Figure 1: Predicted probability of calving in the first 42 days of the next calving season as a function of body condition score at calving (-----) and turnout to pasture (-----).
affected by LW at autumn as well as LW change from turnout to autumn and LW change across the year as a whole. The odds for CALV42 = 1 was 1.35 times (95% CI: 1.07 to 1.71) higher per 100 kg LW increase in autumn. The odds of CALV42 = 1 was 0.88 to 0.91 (95% CI: 0.84 to 0.95) times lower per 10 kg increase in LW loss between either turnout to autumn or across the entire year.

Discussion

Body condition score and live weight

The moderate to strong correlations among BCS values at different times of the year and among LW at different times of the year corroborate previous analyses in beef (Osoro and Wright, 1992) and dairy cattle (Berry et al., 2002). The moderate correlations (0.38 to 0.51) between BCS and LW at the same time point imply that BCS explains up to 26% of the variation in LW. A similar conclusion is evident for the proportion of LW change explained by BCS change over the same time interval. Such relationships are consistent with reported correlations in Angus cattle (Northcutt, Wilson and Willham, 1992) after adjusting both variables for herd, year-month and cow age. The negative relationships between both BCS and LW changes in winter and corresponding changes during the subsequent grazing season have been widely documented, particularly in relation to LW in studies dealing with compensatory growth (Drennan and Bath, 1976; Drennan and McGee, 2004). Likewise, the negative relationships between BCS at turnout and the corresponding change at pasture are as expected.

Calving rate

The inability to detect a large number of BCS or LW variables that significantly affected calving rate is probably attributable to the high calving rate (93.6%) observed in the present study. The calving rate was higher than observed in other studies on seasonal-calving beef cows (Osoro and Wright, 1992; DeRouen et al., 1994) and indicates that good reproductive performance can be attained in a spring-calving suckler herd subjected to low winter-feeding levels (BCS and LW losses of over 0.7 units and 60 kg, respectively) and grazed on well-managed lowland pasture in summer.

In agreement with Osoro and Wright (1992), using 321 spring-calving beef cows, no effect of BCS at calving on calving rate was observed although others have reported the contrary (Lake et al., 2005). Similarly, contradictory reports of the effect of BCS at calving on reproductive performance in dairy cattle have been reported (Buckley et al., 2003; Titterton and Weaver, 1999). Nonetheless, the results of the present study highlighted that LW gain at pasture and BCS in mid June (middle of breeding season) were greater in cows which were subsequently pregnant. This would be expected as studies such as Wiltbank et al. (1962) showed that body condition and level of energy provided after calving were important determinants of fertility. Although Osoro and Wright (1992) did not measure LW change across the entire year they failed to identify any significant association between LW change from calving to the start of the breeding season or LW change during the breeding season and calving rate. A similar result was observed in the current study, although a loss in LW across the entire year was positively associated with a reduced odds of becoming pregnant.

Calving interval

There was no effect of cow breed on calving interval but previous studies (Osoro...
and Wright, 1992) documented an effect of breed on this trait following adjustment for differences in BCS at calving. In agreement with the present study, Osoro and Wright (1992) reported no effect of parity on calving interval. However, the higher winter-feeding level of first-parity animals in the present study would be likely to offset any decline in reproductive performance compared to mature animals. Agabriel et al. (1992) reported a delayed calving interval in primiparous Charolais and Limousin cows compared with multiparous cows. Additionally, Wiltbank (1970) reported intervals from calving to first oestrus of 92, 67, 60 and 53 days in 2-, 3-, 4- and ≥ 5-year-old cows, respectively.

The longer calving interval of the earlier calving animals is partially due to the longer period from calving until breeding commenced. This highlights the potential weakness in measures such as calving interval when a seasonal calving system is operated. Nevertheless, Osoro and Wright (1992) found that a 1-day delay in calving reduced the subsequent calving interval by 0.75 days. Agabriel et al. (1992) reported that bringing forward the calving date by 5 days in winter extended the calving interval by 2 days after a first birth and by 1 day after subsequent births; the decisive factor being the timing of calving relative to turnout. In the present study, when day of the year at calving was treated as a continuous variable, a non-linear effect of calving date was observed on subsequent calving interval with day 122 (2 May) being associated with the shortest calving interval. A one day earlier calving date was associated with a 0.43 day increase in the calving interval.

Osoro and Wright (1992), using data from spring-calving herds, reported a reduction in calving interval of 11.2 and 10.6 days per unit increase in BCS (BCS scale was the same as present study) at calving and at the beginning of the mating period (averaged 58 days after calving), respectively, after adjusting for calving date; a correlation of 0.82 existed between BCS at calving and BCS at the start of mating. This effect on calving interval is twice that reported in the present study. DeRouen et al. (1994) also reported a significant effect of BCS at first calving on days to conception, which is expected to be highly correlated with calving interval. However, in contrast, Morrison et al. (1999) failed to identify a significant effect of BCS at calving on the interval from calving to conception. In the present study, improved BCS at calving reduced calving interval by 4.0 days per unit increase in BCS with early calving cows but had no effect on mid-season or late-calving cows. Agabriel et al. (1992) found that BCS (BCS scale was the same as the present study) at the end of winter (around the time of service) had a significant effect on calving interval, which increased by 8 and 3 days per one unit reduction in BCS for multiparous Limousin and Charolais cows, respectively. Agabriel et al. (1992) also reported that the calving interval (362 days) of late calving cows that spent the entire reproduction period at grass was not affected by BCS at the end of winter. In contrast, the calving interval of cows calving earlier was increased by 5 and 8 days per BCS unit where end of winter scores were 2.5 and 0.5, respectively. They concluded that the impact of BCS at turnout on calving interval is only observable below 3.0 for January-calving cows and below 1.5 for cows calving in late March.

Studies with dairy cows have also provided evidence for deleterious effects of large BCS losses post calving on subsequent reproductive performance. Butler and Smith (1989) showed that when cows lost 0.5 to 1.0 units in BCS between parturition and first service, pregnancy rate
to first service was 53%, while the rate for those losing > 1.0 unit was 17%. Buckley et al. (2003) concluded that on a seasonal pasture-based system of milk production it is necessary to maintain BCS at 2.75 or greater during the breeding season. Loss of body condition between calving and first service should be restricted to 0.5 units to avoid a detrimental effect on reproductive performance.

Despite the moderate correlations between BCS and LW in the present study, LW change at key periods of the year significantly affected calving interval while BCS did not. This may be due to the greater objectivity associated with LW than BCS as well as the expected ability of LW to detect subtle changes in body state compared to BCS. Although heavier animals had a longer calving interval the effect was not biologically significant as early and mid-season calvers were heavier than late calvers at the start of winter but had longer calving intervals. Lalman et al. (1997) and Osoro and Wright (1992) reported no significant effect of LW at calving on post-partum interval to first luteal activity. Also Osoro and Wright (1992) obtained no effect of LW change from calving to the start of mating nor LW change during the mating period on calving interval. However, Lalman et al. (1997) reported that pre-partum LW loss was associated with longer post-partum intervals to luteal activity.

**Calving rate in the first 42 days of the calving season**

The non-linear effect of BCS at calving and turnout on CALV42 may be partly attributable to the effect of low BCS at calving on longer intervals to first oestrus and conception compared to cows in moderate condition (Looper, Lents and Wettemann, 2003). Cows in higher body condition at calving can have a greater incidence of calving problems (Drennan, 1979) and may experience more sub-clinical diseases, both of which are likely to affect fertility. The higher estimated value for CALV42 in cows that lost more condition between calving and turnout is probably a reflection of calving date in that the early calvers lost most weight in this period but are the most likely to calve in the first 42 days of the following season. Ciccioli et al. (2003) documented a significantly higher pregnancy rate to first oestrus in Angus × Hereford cows gaining BCS post-partum.

An apparent conflict was evident for the effect of LW on calving interval and CALV42. Heavier animals in the autumn had longer calving intervals but an increased likelihood of calving in the first 42 days of the calving season. This is again probably due to the fact that the early-calving cows were heavier initially than late calvers and had longer calving intervals but because of the longer period from calving to insemination they may have a higher likelihood of a successful pregnancy early in the season. Senatore et al. (1996) showed that pregnancy rate to first service was positively related to the number of ovulatory events prior to first service. Nonetheless, CALV42 also has its disadvantages in multiparous animals as the outcome is also an artefact of the previous calving date of the animal.

Despite the apparent conflict in the effect of LW across the three reproductive variables analysed, inferior fertility was associated with greater LW loss across the entire year.

**Conclusions**

The results show that good reproductive performance can be attained in a spring-calving suckler herd subjected to a low winter feeding level and grazed on well-managed lowland pasture in summer.
The prevailing management involved good BCS (average 2.9) at the start of the 5-month winter period and a high nutritional level during the first two months at pasture in spring (LW and BCS gains of 49 kg and 0.51 units, respectively). However, particular attention must be given post-calving to animals calving at 2 years of age because, despite a higher feeding level indoors, these animals gained substantially less LW (7 v 15 to 27 kg) and BCS (0.07 v 0.30 to 0.46) than mature cows in the period from calving to mid June.

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