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The effects on cow performance and calf birth and weaning weight of replacing grass silage with brewers grains in a barley straw diet offered to pregnant beef cows of two different breeds

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Keywords ruminants, nutrition, protein, energy

Running head: Nutritional responses of spring-calving beef cows

1 **Summary**

2 The effects on cow and calf performance of replacing grass silage with brewers
3 grains in diets based on barley straw and fed to pregnant beef cows are reported.
4 Using a 2 x 2 factorial arrangement of breed and diet, cows pregnant by artificial
5 insemination (n=34) of two breeds (crossbred Limousin, n=19 and pure-bred Luing,
6 n=15) were fed diets *ad libitum* which consisted of either (g/kg dry matter) barley
7 straw (664) and grass silage (325; GS) or barley straw (783) and brewers grains
8 (206, BG) and offered as total mixed rations. From gestation day (GD) 168 until 266,
9 individual daily feed intakes were recorded and cow body-weight (BW) and body
10 condition score (BCS) measured weekly. Calving date, calf sex, birth and weaning
11 BW, and calf age at weaning were also recorded. Between GD 168 and 266,
12 crossbred Limousin cows gained more weight than Luing cows ($p < 0.05$) and cows
13 offered BG gained more weight than cows offered GS ($p < 0.001$). Luing cows lost
14 more BCS than crossbred Limousin cows ($p < 0.05$) but diet did not affect BCS.
15 There were no differences in dry matter intake as a result of breed or diet. Calf birth
16 BW however, was greater for cows fed BG than GS (44 v 38 kg, SEM 1.0, $p < 0.001$)
17 with no difference between breeds. At weaning, calves born to BG-fed cows were
18 heavier than those born to GS-fed cows (330 v 286 kg, SEM 9.3, $p < 0.01$). In
19 conclusion, replacement of grass silage with brewers grains improved the
20 performance of beef cows and increased calf birth and weaning BW. Further
21 analysis indicated that the superior performance of cows offered the BG diet was
22 most likely due to increases in protein supply which may have improved both energy
23 and protein supply to the foetus.

24

25 **Keywords** pregnancy, nutrition, protein

26

27 **Introduction**

28

29 Production systems for spring-calving beef cows rely on matching peak nutrient
30 requirements for lactation with optimum availability of nutrients from grazing in spring
31 and summer (Phillips, 2001). During summer, the cow is also able to replenish body
32 energy (fat) reserves mobilized during winter. In these low input systems, feed
33 nutrients during winter are usually supplied from standing dormant herbage or, if the
34 cows are housed, diets include substantial proportions of low digestibility forage such
35 as barley straw. Thus, the energy supply during pregnancy is less than requirement
36 and thus the cow mobilises body reserves to meet the demands of the foetus. Most
37 reviews upon under-supply of nutrients to the pregnant cow have concluded that only
38 severe and chronic under-nutrition, particularly during the final two-thirds of the 280
39 day bovine pregnancy, has a negative effect on calf birth body-weight (BW, Holland
40 and Odde 1992; Greenwood and Cafe 2007). Further, an energy deficiency is more
41 important than a protein deficiency, although the composition of absorbed nutrients
42 may be important (Radunz et al. 2010). Reductions in calf birth BW have implications
43 not only for pre-weaning mortality (Wu et al. 2006) but are also frequently associated
44 with reduced BW at weaning (Cafe et al. 2006; Stalker et al. 2006) and this may
45 have consequences for subsequent fertility (Martin et al. 2007), carcass yield and
46 quality (Greenwood and Cafe 2007) and therefore enterprise profitability (Miller et al,
47 2001; Quality Meat Scotland 2014).

48 Most recent nutritional studies on pregnant beef cows have been within
49 systems where cows were maintained on pasture (e.g. Cafe et al. 2006; Larson et al.
50 2009) and therefore detailed information on individual maternal feed intakes and
51 changes in maternal BW and body condition score (BCS) is only rarely available

52 (Martin et al. 2007; Klein et al. 2014). Further, genotypes of beef cow have changed,
53 for example, with the introduction of breeds such as the Luing, since current feeding
54 systems for beef cows were last revised (AFRC, 1993). In this study, two different
55 diets in which brewers grains replaced grass silage in a conventional low energy
56 grass silage / barley straw diet were fed to cows of two different breeds (during mid
57 and late pregnancy. Detailed information on individual cow feed intake, BW and BCS
58 and calf birth and weaning BW were recorded. The experimental hypothesis tested
59 was that the breed of the cow would influence cow performance and have
60 consequences for calf birth and weaning BW. Methane emissions from this study
61 have been reported elsewhere (Duthie et al., 2015).

62

63 **Materials and methods**

64

65 Animals, experimental design and diets

66 This study was conducted at the Beef Research Centre of SRUC (6 miles south of
67 Edinburgh, UK) in winter 2011 - 2012. The experiment was approved by the Animal
68 Experiment Committee of SRUC and was conducted in accordance with the
69 requirements of the UK Animals (Scientific Procedures) Act 1986.

70 The cows used were part of a larger group (n=48; Duthie et al., 2015) and
71 ranged from 3 to 13 years in age and which consisted of equal numbers (n=24) of
72 each of two breeds (crossbred Limousin and pure-bred Luing) which were allocated
73 to two diets according to a 2 x 2 (breed x diet) factorial design which was within
74 groups (n=12) balanced for cow BW and age. The cows used in this study (n=34)
75 were those confirmed pregnant to synchronised artificial insemination on 20 June
76 2011, with 14 cows not pregnant to this artificial insemination omitted from the

77 dataset. This ensured that experimental observations were not biased by differences
78 in stage of pregnancy. The accuracy of pregnancy diagnosis was confirmed from
79 actual calving dates. On gestation day (GD) 148 (15 November 2011), the cows
80 were allocated to the two experimental diets and housed in a group in one pen per
81 diet. The diets were fed using electronic feeders (n=16 per pen; HOKO, Insentec,
82 Marknesse, the Netherlands) and individual daily feed intakes recorded. The cows
83 were acclimatized to the pen environment and trained to use feeders until GD 168 (5
84 December 2011) when records of daily feed intake began. Cow BW (kg) and BCS
85 (using a scale of 1 to 5, Lowman et al. 1976) were measured weekly until
86 observations were completed on GD 266 (12 March 2012) when cows were returned
87 to standard farm management. Calving date, calf sex, birth and weaning BW and
88 age at weaning were subsequently recorded. The two experimental diets consisted
89 (g/kg dry matter, DM) of barley straw (664) and grass silage (325, GS) or barley
90 straw (783) and brewers grains (206, BG) which were offered as total mixed rations
91 on an *ad libitum* basis. The ingredient and chemical compositions of the diets are
92 given in Table 1 and chemical composition of the feeding stuffs is given in Table 2.

93

94 Feed analysis

95

96 Dry matter contents of the feeding stuffs were determined twice weekly and bulked
97 feed samples (three per feeding stuff) analysed for DM, ash, crude protein, acid
98 detergent fibre, neutral detergent fibre and starch according to Ministry of Agriculture
99 Fisheries and Food (1992).

100

101 Calculations and statistical analysis

102

103 Daily DM intakes (DMI) were averaged on a weekly basis prior to analysis. Changes
104 in cow BW, BCS and DMI together with data for gestation length and calf birth and
105 weaning BW were analysed using general linear models regression (Genstat Version
106 15.1, Lawes Agricultural Trust, 2012) according to a 2 x 2 arrangement of breed and
107 diet. Cow BW and BCS at allocation (GD 148) were included as covariates in
108 analysis of cow BW or BCS where significant ($p < 0.05$); calf sex, birth BW and age
109 at weaning were included as covariates in the analysis of calf birth and weaning BW
110 where significant ($p < 0.05$). Differences in calf sex ratio between treatments were
111 analysed using a 2 x 2 contingency table and χ^2 test.

112 Weekly data (DMI, BW and BCS) from GD 168 to 266 (15 observations per
113 animal) were analysed using random coefficients regression (Genstat Version 15.1,
114 Lawes Agricultural Trust, 2012). Models were developed for BW, DMI and BCS that
115 included diet, breed and time (linear and quadratic effects) and their interactions
116 where significant ($p < 0.05$) as fixed factors and animal and animal x week as
117 random factors. Cow BW and BCS at allocation (GD 148) were included as
118 covariates where significant ($p < 0.05$).

119

120 **Results**

121

122 Cow performance between gestation days 168 and 266

123 There were no differences (Table 3) in BW, BCS or age between breeds or diets at
124 allocation at GD 148. On GD 168 (Table 3), crossbred Limousin cows were heavier
125 than Luing cows ($p < 0.001$) and cows fed BG heavier than those fed GS ($p <$
126 0.001). These differences were still present on GD 266. BW change between GD 168

127 and 266 was greater for the cows fed BG than GS ($p < 0.001$) and for crossbred
128 Limousin compared to Luing cows ($p < 0.05$). On GD 168, crossbred Limousin cows
129 had greater BCS than Luing cows ($p < 0.01$) and this difference was still present on
130 GD 266 ($p < 0.001$). BCS loss between GD 168 and 266 was greater ($p < 0.05$) for
131 Luing than crossbred Limousin cows. There was no overall effect of diet on BCS.
132 There were no differences in DMI ($p > 0.05$) between breeds or diets.

133

134 Calf birth and weaning weights

135

136 There were no differences between breeds or diets ($p > 0.05$) in length of pregnancy
137 (Table 4). Calf birth BW (adjusted for calf sex, $p < 0.001$) was greater ($p < 0.001$) for
138 calves born to cows fed BG than GS with no difference between breeds. Calf sex
139 ratio did not differ between treatments ($\chi^2=6.6$, $p > 0.05$). At weaning, calves born to
140 BG-fed cows were heavier than those born to GS-fed cows ($p < 0.01$ after
141 adjustment for weaning age). There was also a tendency for calves born to
142 crossbred Limousin cows to be heavier than those born to Luing cows ($p = 0.056$).

143

144 Modelling of cow BW, body conditions score and dry matter intake over time

145

146 Cow BW change over the 15 week period was influenced by breed ($p < 0.001$) and
147 week of experiment (linear and quadratic effects, both $p < 0.001$) and there were
148 interactions between diet and both linear and quadratic effects of week ($p < 0.001$).
149 Cow BW at allocation was also included as a covariate ($p < 0.001$). Thus mean
150 weekly BW was best predicted by the following relationship (SE of coefficients in
151 parentheses) which together with observed BW is shown in Fig. 1:

152

$$\begin{aligned} 153 \quad \text{BW (kg)} &= 647 (3.6) - 5.1 (3.1) * \text{breed} + 8.6 (0.61) * \text{week} - 0.31(0.032)*(\text{week} * \text{week}) \\ 154 \quad &- 6.2(0.89) * (\text{diet} * \text{week}) + 0.20(0.047) * (\text{diet} * \text{week} * \text{week}) \quad (1) \end{aligned}$$

155

156 where the effect of breed is the change from crossbred Limousin to Luining and for
157 diet the change from BG to GS.

158 BCS change during the 15 week experimental period was influenced by diet
159 ($p < 0.05$), breed ($p < 0.001$), week of experiment ($p < 0.01$) and the interaction
160 between week of experiment and breed ($p < 0.01$). Both cow BW and BCS at
161 allocation to treatment were ($p < 0.001$) covariates. Thus BCS was best explained by
162 the following relationship (SE of coefficients in parentheses) which is shown in Fig. 2:
163 with observed BCS.

164

$$\begin{aligned} 165 \quad \text{BCS} &= 3.1(0.04) - 0.27 (0.051) * \text{breed} - 0.22 (0.048) * \text{diet} - 0.0017 (0.00051) * \text{week} \\ 166 \quad &- 0.022 (0.0076) * (\text{week} * \text{breed}) \quad (2) \end{aligned}$$

167

168 where the effect of breed is the change from Limousin to Luining and for diet the
169 change from BG to GS.

170 As there were no differences in DMI due to diet or breed DMI was best
171 explained by the following relationship (SE of coefficients in parentheses) which is
172 shown in Fig. 3 with observed DMI:

173

$$174 \quad \text{DMI (kg/d)} = 13.6 (0.43) - 0.14 (0.026) * \text{week} \quad (3)$$

175

176 **Discussion**

177

178 Metabolisable Energy supply

179 An initial evaluation of metabolisable energy (ME) supply (AFRC 1993) across the
180 entire experiment was made from the data in Table 3. A one unit decrease in BCS
181 was assumed to be equivalent to 3200 MJ of dietary ME (Wright et al. 1986). Total
182 ME supply (feed plus mobilised tissue) between GD 168 and 266 was calculated to
183 be (MJ ME) 6632, Limousin/BG; 7164, Luing/BG; 7666, Limousin/GS and 8080,
184 Luing/GS. Therefore it appeared that GS supplied more energy than did BG. A
185 possible explanation for the difference between diets was that BG-fed cows were
186 observed to attempt to sort the mixed feed to select brewers grains. The maximum
187 effect of selection upon ME supply was estimated by assuming that all refusals
188 consisted solely of barley straw. Based on 216 records, if refusals contained no
189 brewers grains, the ratio of straw to brewers grains consumed would have been (DM
190 basis) 334, brewers grains: 666 straw instead of the ratio of 206 to 783 in feed
191 offered. Therefore, ME intakes would have increased to 7138 and 7676 MJ for
192 Limousin/BG and Luing/BG respectively or 0.93 and 0.95 of ME intake for GS. It is
193 also possible that brewers grains ME (calculated from feed analysis; 10.8 MJ / kg
194 DM) may have been underestimated compared to that given in UK feed tables (11.5
195 MJ ME / kg DM; Thomas 2004). However, using this value would only have
196 increased ME intakes for BG to 0.94 and 0.96 of GS for Limousin and Luing cows
197 respectively. Therefore, the BG diet did not supply more ME than the GS diet.

198

199 Metabolisable protein supply

200

201 The metabolisable protein (MP) supply for the diets fed was therefore calculated
202 according to AFRC (1993). The GS diet supplied approximately 4.5 g MP/MJ ME
203 compared to 6.6 g MP/ MJ ME for BG. This difference was largely due to an increase
204 in digestible undegradable protein (DUP) supply from 1.1 (GS) to 2.8 (BG) g/MJ ME.
205 On both diets, estimated protein supply to the rumen (effective rumen degradable
206 protein, ERDP) was less than requirement and the deficit was greater on GS than
207 BG (0.72 v 0.88 of estimated ERDP requirements respectively). Clearly the main
208 difference between BG and GS was that protein supply both to the rumen microflora
209 (ERDP) and the host animal (MP) was superior on BG and would seem most likely to
210 explain the superior performance on BG.

211

212 Effects of diets

213

214 There is a general consensus that maternal under-nutrition only impacts calf birth
215 BW negatively in mid to late gestation (Holland and Odde 1992; Greenwood and
216 Cafe 2007; Robinson et al. 2013) and that reductions in birth BW have long term
217 consequences for weaning and slaughter BW and these effects are independent of
218 post-natal nutrition (Robinson et al. 2013). It is also accepted that global (energy)
219 nutrition has a greater impact than protein nutrition (Holland and Odde 1992;
220 Greenwood and Cafe 2007) which is contrary to the results reported here. However,
221 recent studies (Stalker et al. 2006; Martin et al. 2007; Larson et al. 2009; Bohnert et
222 al. 2013; Klein et al. 2014) in which protein supplements were fed to beef cows in
223 mid / late gestation have reported increases in calf birth and / or weaning BW,
224 although in some cases responses were not significant. In these studies protein
225 intakes were increased by feeding a supplement to cows grazing low quality forage

226 and therefore not only protein but also energy intakes would have increased (for
227 example by 1.5-fold; Klein et al. 2014). Therefore responses in cow and calf
228 performance could not be solely attributed to increased protein supply.

229 Relatively few studies have attempted to modify nutrient intake to beef cows
230 whilst maintaining energy intakes constant. Radunz et al. (2010) compared either
231 maize grain or distillers dark grains with solubles (DDGS) with hay in late gestation
232 diets and both maize and DDGS diets increased calf birth BW. However, energy
233 intakes were increased when maize and DDGS were fed and the response in birth
234 BW was more closely related to increased energy rather than protein intakes.
235 Recently, Gunn et al. (2014) fed a diet containing excess crude protein (mainly in the
236 form of rumen undegradable protein) to beef cows from GD 192 in comparison with a
237 diet supplying the same amount of energy but with no excess crude protein and
238 observed an increase in birth BW from 32 to 37 kg. Although it is difficult to be
239 precise, it is likely that the diet supplied less ME than that required for maintenance
240 and gestation, and therefore as in the current experiment, a response to
241 undegradable protein supply was observed (Gunn et al. 2014) when overall energy
242 supply was less than requirement and cows were mobilising fat (declining BCS).
243 Thus in relation to maternal nutrient supply to the foetus, amino acids would have
244 contributed a greater proportion of total nutrients on the BG diet. In ruminants (Pere
245 2003), fatty acid uptake by the placenta is low and in contrast, amino acids are both
246 actively transported across the placenta and important oxidative substrates for the
247 foetus. Therefore it is likely that the increases in calf birth BW on diet GS were
248 mediated by utilisation of absorbed amino acids as an energy substrate.

249

250 Effects of breed

251 Luing cattle lost more BCS than crossbred Limousin cows and there were
252 corresponding differences in BW gain / loss. As a result, ME supply (feed adjusted
253 for BW loss) was greater for Luing than crossbred Limousin cows. In part this
254 difference may have arisen from using a common value for the ME equivalent of
255 BCS which assumes both that the composition of mobilised tissue and mobilisation
256 of sub-cutaneous fat was in proportion to other adipose tissue depots were similar
257 between breeds. Wright and Russel (1984) showed that the proportions of fat in
258 different depots did vary with breed and there were differences between breeds in
259 the composition of mobilised tissue. Thus feeding systems for pregnant beef cows
260 that predict the energy value of mobilised tissue from changes in BCS (e.g. NRC
261 1996) use a variable composition of mobilised tissue for different BCS and BW and /
262 or employ breed dependant values for the energy content of mobilised body tissue
263 (CSIRO 2007). Since there are no data on the composition of mobilised tissue of
264 present beef cow genotypes it is difficult to comment on any differences between
265 breeds. The greater loss in BCS and therefore mobilisation of adipose tissue by
266 Luing cows however did not increase calf birth BW. This may be because fatty acids
267 are not readily transported across the bovine placenta (Pere 2003) and therefore
268 additional fatty acids mobilised by the Luing cows would not have contributed to
269 foetal growth.

270

271 Estimation of requirements for beef cows

272

273 Current UK calculations of the ME requirements of beef cows require a knowledge of
274 maternal BW and BW change together with stage of pregnancy (AFRC 1993). The
275 system does not correct maternal BW or BW change for the growth of the gravid

276 uterus. The implications of the above approach were examined at GD 182, 218 and
277 252 using equations 1 to 3. For simplicity calculations are shown only for crossbred
278 Limousin cows fed BG or GS as results were similar for Luing cows. Maternal BW
279 was corrected for conceptus weight according to (NRC 1996) using mean observed
280 calf birth BW and cow BW change (kg/d) was estimated from linear regression of BW
281 upon time for the two weeks before and after each time point. Table 5 shows that
282 partition of maternal BW change into maternal and conceptus components had a
283 large and variable effect on ME requirement particularly when the cow was gaining
284 weight (crossbred Limousin fed BG at GD 182). In contrast, body tissue mobilisation
285 had little effect on requirement as efficiency of use of mobilised tissue energy for
286 conceptus growth is low (0.2, Wright et al. 1986). However, as BW of beef cows is
287 not normally available on farms, Table 5 also shows ME requirements on GD 218
288 calculated from maternal maintenance and conceptus requirement but using the ME
289 equivalent of BCS change (Wright et al. 1986) and BCS change over the entire
290 experiment adjusted to a daily basis instead of BW change to correct for adipose
291 tissue mobilisation. The bias that changes in BW had on ME requirements
292 particularly on the BG diet were largely removed using this approach and
293 discrepancies between ME supply and requirement were small. Clearly, in the
294 absence of BW data, practical rationing systems for beef cows should be based on
295 BCS rather than BW change.

296

297 **Conclusion and Recommendations**

298

299 Replacement of GS with BG improved the performance of beef cows as
300 demonstrated by differences in BW, reduced loss of BCS and greater calf birth and

301 weaning BW. Luing cows mobilised more body tissue, as measured by changes in
302 BCS, than Crossbred Limousin cows. The differences between diets in performance
303 were most likely due to increases in protein supply on diet BG. It is suggested that,
304 when beef cows are fed diets containing large proportions of low quality forage and
305 therefore mobilising adipose tissue, consideration should be given to protein
306 supplementation to supply amino acids to the foetus to improve both foetal energy
307 and protein status.

308

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317

318 **Referencest**

319

320 AFRC, 1993: *Energy and protein requirements of ruminants. An advisory manual prepared*
321 *by the AFRC Technical Committee on Responses to Nutrients*. CAB International,
322 Wallingford, UK

323 Bohnert, D.; Stalker, L.; Mills, R.; Nyman, A.; Falck, S.; Cooke, R., 2013: Late gestation
324 supplementation of beef cows differing in body condition score: Effects on cow and calf
325 performance. *Journal of Animal Science* **91**, 5485-5491.

326 Café, L.M.; Hennessy, D.W.; Hearnshaw, H.; Morris, S.G.; Greenwood, P.L., 2006:
327 Influences of nutrition during pregnancy and lactation on birth weights and growth to
328 weaning of calves sired by Piedmontese or Wagyu bulls. *Australian Journal of Experimental*
329 *Agriculture* **46**, 245-255.

330 CSIRO, 2007: *Nutrient Requirements of Domesticated Ruminants*. CSIRO Publishing,
331 Clayton, Victoria, Australia.

332 Duthie, C.-A., Rooke, J. A., Hyslop, J. J., Waterhouse, A. 2015: Methane emissions from two
333 breeds of beef cows offered diets containing barley straw with either grass silage or brewers'
334 grains. *Animal* (in press: DOI: <http://dx.doi.org/10.1017/S1751731115001251>).

335 Greenwood, P.L.; Café, L.M., 2007: Prenatal and pre-weaning growth and nutrition of cattle:
336 long-term consequences for beef production. *Animal* **1**, 1283-1296.

337 Gunn, P.; Schoonmaker, J.; Lemenager, R.; Bridges, G., 2014: Feeding excess crude
338 protein to gestating and lactating beef heifers: Impact on parturition, milk composition,
339 ovarian function, reproductive efficiency and pre-weaning progeny growth. *Livestock Science*
340 **167**, 435-448.

341 Holland, M.D.; Odde, K.G., 1992: Factors affecting calf birth weight: A review.
342 *Theriogenology* **38**, 769-798.

343 Klein, S., I; Steichen, P.; Islas, A.; Goulart, R.; Gilbery, T.; Bauer, M.L.; Swanson, K.C.;
344 Dahlen, C.R., 2014: Effects of alternate-day feeding of dried distiller's grain plus solubles to
345 forage-fed beef cows in mid-to late gestation. *Journal of Animal Science* **92**, 2677-2685.

346 Larson, D.M.; Martin, J.L.; Adams, D.C.; Funston, R.N., 2009: Winter grazing system and
347 supplementation during late gestation influence performance of beef cows and steer
348 progeny. *Journal of Animal Science* **87**, 1147-1155.

349 Lowman, B.G.; Scott, N.A.; Somerville, S.H., 1976: *Condition scoring of cattle*. Technical
350 bulletin no. 6. East of Scotland College of Agriculture, Edinburgh, UK.

351 Martin, J.L.; Vonnahme, K.A.; Adams, D.C.; Lardy, G.P.; Funston, R.N., 2007: Effects of
352 dam nutrition on growth and reproductive performance of heifer calves. *Journal of Animal*
353 *Science* **85**, 841-847.

354 Miller, A.J., Faulkner, D.B., Knipe, R.K., Strohhahn, D.R., Parrett, D.F. Berger, L.L., 2001:
355 Critical control points for profitability in the cow-calf enterprise. *Professional Animal Scientist*
356 **17**, 295-302.

357 Ministry of Agriculture Fisheries and Food, 1992: *Analysis of Agricultural Materials*. 2nd edn.
358 Her Majesty's Stationary Office., London

359 NRC, 1996: *Nutrient Requirements of Beef Cattle*. Seventh Revised Edition. National
360 Academy Press, Washington, USA

361 Pere, M.C., 2003: Materno-foetal exchanges and utilisation of nutrients by the foetus:
362 comparison between species. *Reproduction Nutrition Development* **43**, 1-15.

363 Phillips, C.J.C., 2001: *Principles of Cattle Production*. CABI Publishing, Wallingford, UK.

364 Quality Meat Scotland, 2014: *Cattle and sheep enterprise profitability in Scotland*, 2014
365 Edition. QMS, Edinburgh, UK.

366 Radunz, A.E.; Fluharty, F.L.; Day, M.L.; Zerby, H.N.; Loerch, S.C., 2010: Prepartum dietary
367 energy source fed to beef cows: I. Effects on pre- and postpartum cow performance. *Journal*
368 *of Animal Science* **88**, 2717-2728.

369 Robinson, D.L.; Café, L.M.; Greenwood, P.L., 2013: Meat Science And Muscle Biology
370 Symposium: Developmental programming in cattle: Consequences for growth, efficiency,
371 carcass, muscle, and beef quality characteristics. *Journal of Animal Science* **91**, 1428-1442.

372 Stalker, L.A.; Adams, D.C.; Klopfenstein, T.J.; Feuz, D.M.; Funston, R.N., 2006: Effects of
373 pre- and postpartum nutrition on reproduction in spring calving cows and calf feedlot
374 performance. *Journal of Animal Science* **84**, 2582-2589.

375 Thomas C., 2004: *Feed into milk: an advisory manual*. Nottingham University Press,
376 Nottingham, UK

377 Wright, I.A.; Russel, A.J.F., 1984: The composition and energy content of empty body-weight
378 change in mature cattle. *Animal Science* **39**, 365-369.

379 Wright, I.A.; Russe,l A.J.F.; Hunter, E.A., 1986: The use of body condition scoring to ration
380 beef cows in late pregnancy. *Animal Science* **43**, 391-396.

381 Wu, G.; Bazer, F.W.; Wallace, J.M.; Spencer, T.E., 2006: BOARD-INVITED REVIEW:
382 Intrauterine growth retardation: Implications for the animal sciences. *Journal of Animal*
383 *Science* **84**, 2316-2337.

Table 1 Component composition (g/kg dry matter) and calculated chemical composition of experimental diets

Diet	Brewers grains	Grass silage
Components (g/kg)		
Barley straw	783	665
Brewers grains	206	
Grass silage		325
Mineral / vitamin mix*	10	10
Composition (g/kg dry matter)		
Dry matter (g/kg)	558	529
Crude protein	68	61
Neutral detergent fibre	779	686
Acid detergent fibre	522	508
Starch	5	0
Water soluble carbohydrates	5	20
Ether extract	36	22
Ash	40	50
ME (MJ/kg DM) [†]	7.3	8.2

* Mineral / vitamin mix (Norvite, Inch, Aberdeenshire) supplied (mg/kg unless stated otherwise) vitamin A, 500000 international units (IU); Vitamin D 100000 iu; Vitamin E 4000; Fe, 5271; Mn, 5000; Zn, 3600; I, 1000; Co, 90; Cu, 3000; Se, 35.

† ME, Metabolisable Energy

Table 2 Analysed chemical composition of feeding stuffs (g/kg dry matter)

	Barley straw	Grass silage	Brewers grains
Dry matter (g/kg)	841	350	259
Crude protein	20	149	253
Neutral detergent fibre	850	373	551
Acid detergent fibre	593	353	278
Starch			22
Water soluble carbohydrates	6	50	3
Ether extract		35	114
Ash	40	72	40
NCGD*	300		566
ME (MJ/kg dry matter)*	6.5	12.1	10.8
pH		4.3	

*NCGD. Neutral cellulose and gamanase digestibility; ME, Metabolisable Energy estimated from analysed composition (Thomas 2004).

Table 3 Body weight (BW) and body condition score (BCS) of crossbred Limousin or Luing cows fed diets containing barley straw and brewers grains (BG) or barley straw and grass silage (GS) at allocation, start and end of experiment and mean dry matter intakes (DMI) throughout experiment.

Breed	Limousin		Luing		SEM	p-value		
	BG	GS	BG	GS		Diet	Breed	Interaction
At allocation (GD 148)								
age (years)	3.9	5.1	6.9	5.7	0.71	ns	ns	ns
BW (kg)	598	628	585	603	29.6	ns	ns	ns
BCS	2.9	3.1	2.5	2.8	0.20	ns	ns	ns
At start (GD 168)								
BW (kg) †	615	591	603	598	3.6	***	***	ns
BCS †‡	3.1	2.8	2.9	2.7	0.08	ns	**	ns
At end (GD 266)								
BW (kg) †	658	609	641	587	7.1	**	***	ns
BCS †‡	3.0	2.8	2.7	2.4	0.09	ns	***	ns
Difference (GD 266 – GD 168)								
BW (kg) †	43	17	37	-12	6.3	***	*	ns
BCS †	-0.15	-0.01	-0.27	-0.29	0.092	ns	*	ns
Dry matter intake (kg/d)								
	8.6	9.5	8.8	8.9	0.46	ns	ns	ns

SEM, standard error of the mean; *, $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

† BW at allocation a significant covariate ($p < 0.05$)

‡ BCS at allocation a significant covariate ($p < 0.05$)

Table 4 Pregnancy length together with calf birth and weaning body weight (BW) for crossbred Limousin and Luing cows when fed diets, between gestation days 168 and 266, containing barley straw and brewers grains (BG) or barley straw and grass silage (GS).

Breed	Limousin		Luing		SEM	p-value		
	BG	GS	BG	GS		Diet	Breed	Interaction
Pregnancy length (days)	278	281	279	276	1.13	ns	ns	ns
Calf BW (kg) ‡								ns
birth	44	36	44	41	1.06	***	ns	ns
weaning	320	287	286	265	11.3	**	†	ns
Calf sex (proportion male)	0.63	0.77	0.22	0.50		ns	ns	ns

SEM, standard error of the mean; † $p < 0.10$; *, $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

‡ Calf birth BW adjusted for sex ($p < 0.001$); calf weaning BW adjusted for age at weaning ($p = 0.09$).

Table 5 Estimated Metabolisable Energy (ME) requirement and supply for crossbred Limousin cows fed diets of either barley straw and brewers grain (BG) or barley straw and grass silage (GS). ME requirements were calculated using mean predicted BW and BCS (see Results, equations 1 and 2) and ME supply using mean predicted dry matter intake (see Results, equation 3).

	BG			GS		
Gestation day	182	218	252	182	218	252
Body weight (BW, kg)	627	653	663	601	606	606
Adjusted BW (kg) [†]	608	621	613	585	580	565
Adjusted BW change (kg /day)	0.7	0.1	-0.6	0.0	-0.3	-0.6
ME (MJ/day)						
Requirement	118	82	85	65	68	76
Supply	75	75	73	75	72	68
Supply - requirement	-43	-7	-12	+10	+4	+8
Condition score change		-0.15			-0.01	
Equivalent ME		5			0.3	
ME requirement [‡]		70			68	

[†]Adjusted BW: BW less calculated conceptus weight.

[‡]ME (maintenance) + ME (conceptus) – ME equivalent from condition score change ((Wright et al. 1986).

Fig. 1 Changes in body weight of crossbred Limousin (solid symbols) and Luing cows (open symbols) between gestation days 168 and 266 when fed diets containing barley straw and brewers grains (BG, round symbols) or barley straw and grass silage (GS, square symbols). Symbols denote actual mean observations whilst lines denote fitted values (crossbred Limousin / BG, solid line; crossbred Limousin / GS, dot-dash line; Luing / BG, long dashes; Luing / GS, short dashes).

Fig. 2 Changes in body condition score of crossbred Limousin (solid symbols) and Luing cows (open symbols) between gestation days 168 and 266 when fed diets containing barley straw and brewers grains (BG, round symbols) or barley straw and grass silage (GS, square symbols). Symbols denote actual mean observations whilst lines denote fitted values (crossbred Limousin / BG, solid line; crossbred Limousin / GS, dot-dash line; Luing / BG, long dashes; Luing / GS, short dashes).

Fig. 3 Changes in dry matter intakes of crossbred Limousin and Luing cows between gestation days 168 and 266 when fed diets containing barley straw / brewers grains or barley straw / grass silage. Mean values (with SE, symbols) are given for all animals together with fitted values (line) as there were no significant differences in dry matter intakes between breeds or diets

Figure 1

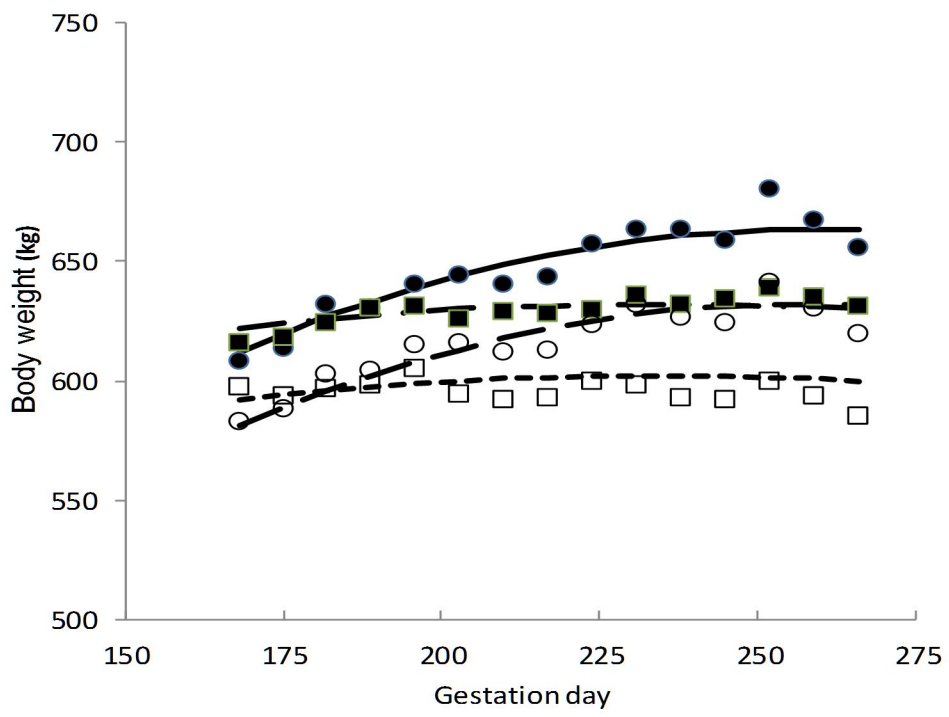


Figure 2

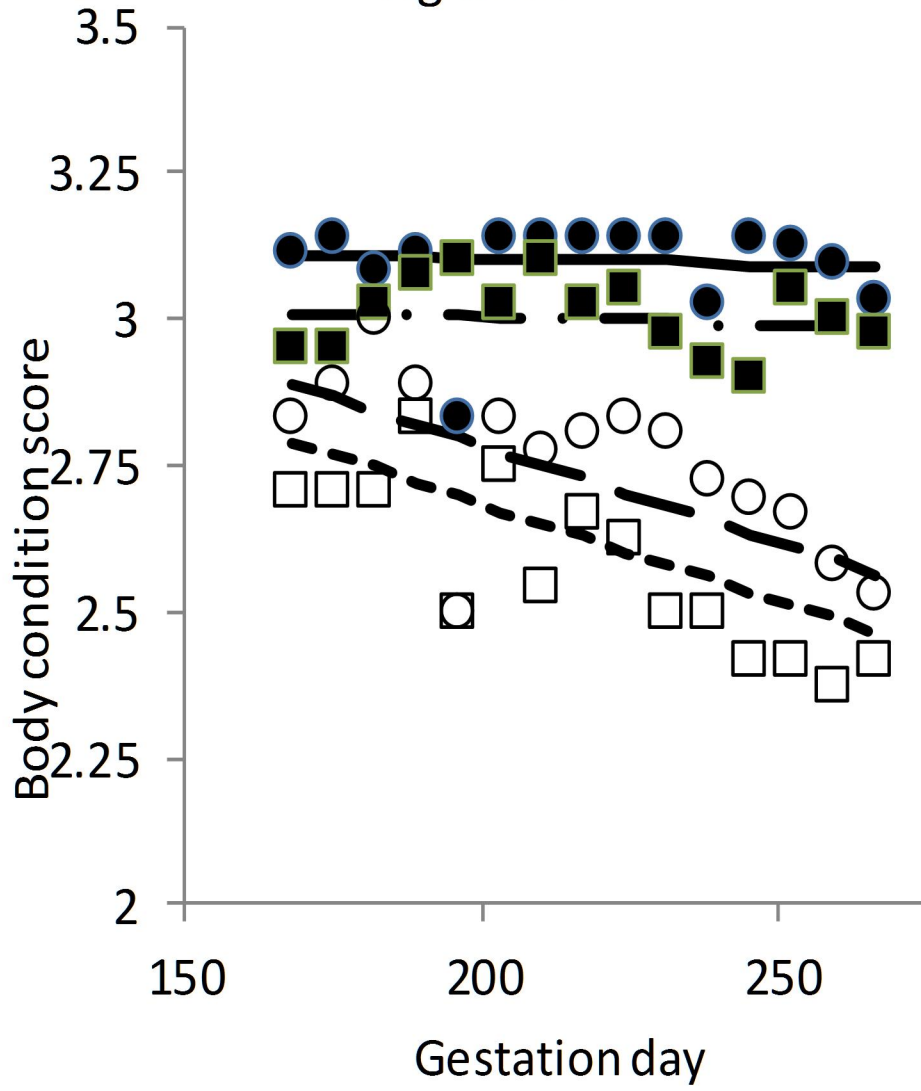


Figure 3

