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1 **Original Article**

2

3 **Measuring the growth rate of UK dairy heifers to improve future productivity**

4

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6 Katrine J. Bazeley ^{a,*}, David C. Barrett ^b, Paul D. Williams ^c, Kristen K. Reyher ^b

7

8 ^a *Synergy Farm Health, West Hill Barns, Evershot, Dorset DT2 0LD UK*

9 ^b *School of Veterinary Sciences, University of Bristol, Langford House, Langford, Bristol,*

10 *BS40 5DU UK*

11 ^c *MSD Animal Health, Walton Manor, Walton, Milton Keynes, MK7 7AJ UK*

12

13

14

15

16 * Corresponding author. Tel.: +44 193 583682.

17 E-mail address: kat.bazeley@synergyfarmhealth.com (K. Bazeley)

18 **Abstract**

19 Sub-optimal heifer growth is associated with higher disease rates and reduced future
20 performance and longevity in the dairy herd. This manuscript describes a system for
21 measuring heifer growth from birth to first calving used on commercial dairy farms in South
22 West England, in order to gather benchmarking data to feed back to farmers. Weights ($n =$
23 8443) were collected from 20 farms. There was marked variation in individual and herd mean
24 growth rates. Overall, calves gained no weight in the first eight days after birth and had a
25 very low growth rate (median 0.12 kg/day) to 30 days, a period when feed conversion
26 efficiency is high and calves are vulnerable to disease. Heifers whose growth rate up to 180
27 days was low were significantly less likely to achieve target service weight (374 kg) by 420
28 days. Monitoring heifer growth during the rearing period enables farmers to improve heifer
29 growth rates and thus impact both the efficiency of heifer rearing and, potentially, the
30 productivity and performance of the adult herd.

31

32 *Keywords:* Dairy cattle; Calves; Growth rates; Heifers

33 **Introduction**

34 Heifer rearing is the weak link in many dairy enterprises, leading to high mortality
35 and future poor performance in the milking herd. In the UK, 58% of live-born heifers fail to
36 reach their third lactation (Brickell and Wathes, 2011). The cost of rearing heifers is high,
37 representing about 20% of dairy farm expenses, and making it the highest variable cost after
38 feed (Tozer and Heinrichs, 2001). In the UK, the cost of rearing heifers is variable, with a
39 mean of £1,819¹ (DairyCo, 2015), so that replacement costs average around 2.6 pence per
40 litre (ppL). For many herds, costs may be as high as 3.2 ppL of milk produced (DairyCo²). It
41 has been estimated that most farmers should be able to reduce replacement costs to 2.0 ppL,
42 resulting in a financial benefit of £14,400 per annum for a 160-cow herd. Replacement rate
43 and age at first calving (AFC) are also concerns, as these factors are known to affect the
44 carbon footprint of the herd (Hermanson and Kristenson, 2011).

45
46 Poor heifer management thus represents a major loss in both economic and welfare
47 terms. In order to achieve optimal lifetime performance, it is important for heifers to remain
48 healthy, to meet target growth rates and to be well-grown before they calve for the first time
49 (Le Cozler et al., 2008). In the USA, only 2.7% dairy heifers were found to achieve target
50 AFC of less than 24 months, weighing more than 560 kg post-calving (Losinger and
51 Heinrichs, 1997), so there is great potential for improvement. Veterinarians are often called
52 upon to help dairy farmers improve heifer performance, and these clinicians require data to
53 identify problems and their causes in the same way that they require data for investigation of
54 mastitis problems or poor fertility. A variety of key performance indicators for heifer rearing
55 exist, including cull rate of primiparous cows, AFC, mortality rate, number of treatments and
56 growth rate.

¹ £1 = approx. US \$1.47, €1.40 at 15 March 2015.

² See: www.dairyco.org.uk (accessed 15 March 2015).

57

58 Culling of primiparous cows represents a significant loss. The target culling rate is
59 less than 10% (Breen et al., 2012), but in the UK, 19% of primiparous cows have been
60 reported to be culled during their first lactation (Brickell and Wathes, 2011). Primiparous
61 cow cull rate is related to pre-calving performance (Bach, 2011), but does not, in itself,
62 indicate how the heifer rearing process is failing.

63

64 Age at first calving is also an important determinant of performance within the herd,
65 with optimal future performance in heifers calving at 23-25 months of age (Ettema and
66 Santos, 2004; Wathes et al., 2008). Rearing costs are also directly linked to AFC (DairyCo,
67 2015), but, like primiparous cow cull rate, measurement of AFC cannot identify how the
68 rearing process is going wrong, and may be influenced by factors other than a heifer's innate
69 potential (e.g. bull fertility, oestrus detection rate).

70

71 A target heifer mortality rate to first calving has been cited as 7% (Breen et al., 2012),
72 although a survey of UK dairy herds has shown that, on average, 15% of live-born heifer
73 calves fail to survive to first calving (Wathes et al., 2008). Heifer mortality is highly variable
74 between herds at all stages from birth to calving (Brickell et al., 2009a). While heifer
75 mortality is a useful indicator of disastrous heifer management, it is a blunt instrument, since
76 herds may achieve low mortality rates despite significant under-performance.

77

78 Treatment rates or medicines use can be used as a proxy for heifer disease. Target
79 incidence of disease is fewer than 10% of pre-weaned calves requiring treatment (Breen
80 2012), and treatment rates can be linked to heifer growth rate and future performance
81 (Stanton et al., 2010; Stanton et al., 2012). Bach (2011) showed that heifers suffering four or

82 more episodes of bovine respiratory disease (BRD) were 1.9 times more likely to fail to
83 complete first lactation than those with no recorded BRD. However, treatment rate and
84 medicine use is difficult to compare between units because of differences in recording
85 accuracy, criteria for treatment and skill of stockpersons at identification of sick animals.
86

87 Heifer growth provides the most direct evidence of heifer performance throughout the
88 rearing process from birth to calving. Published data are available to provide target weights
89 and growth rates for animals of different ages (Drew, 1998; Heinrichs and Losinger, 1998; Le
90 Cozler et al., 2008). The optimal weight for Holstein-Friesian heifers at first service has been
91 estimated by different authors: Le Cozler et al. (2008) suggest 55-60% mature weight,
92 Heinrichs and Lammers (2008) cite 341-364 kg, Bach (personal communication, 2013)
93 estimates 400 kg at 400 days and Hoffman (1997) recommends 363-390 kg at 14 months.
94 The growing heifer has a number of key stages of development, particularly growth rates to
95 60 days, which is linked to first lactation milk yield (Bach and Ahedo, 2008) and survival rate
96 to second lactation (Bach, 2011). Weights at 180 days and at the beginning of the target
97 service period (420 days) are also important (Dairy Co PD³). Optimal heifer growth rates
98 have been studied in detail, with conflicting results (Le Cozler et al., 2008). Very high pre-
99 pubertal growth rates led to deposition of udder fat (Sejrsen et al., 1982), and have been
100 associated with reduced first lactation milk yield (Van Amburgh et al., 1998). Other studies
101 (Carson et al., 2002) showed no deleterious effect of high plane of nutrition on first lactation
102 yields in high genetic merit heifers. Zanton and Heinrichs (2005), through meta-analysis of
103 eight studies, concluded that heifer growth should be limited to 0.8 kg/day prior to puberty
104 for maximal first lactation milk production. Over-fatness at any stage may jeopardise future
105 milk production (Le Cozler et al., 2008).

³ See: www.dairyco.org.uk (accessed 15 March 2015).

106

107 Body weight (BW) at 30, 180 and 450 days is linked to age at first service and AFC
108 (Brickell et al., 2009b). Poorly grown heifers also require more services per conception, calve
109 later and are more likely to be culled early (Wathes et al., 2008). Growth rate is easy to
110 measure, and results from different rearing units can readily be compared. Various measures
111 of growth can be used, including weight, withers or hip height, width of the pelvis between
112 the left and right greater trochanter and girth around the chest (heart girth) (Heinrichs et al.,
113 1992). However, Dingwell et al. (2006) concluded that weighing heifers on a calibrated
114 electronic scale is the easiest and most accurate method of measuring growth.

115

116 Because of overriding concerns about the impact of heifer management on UK farms, a
117 heifer-monitoring initiative was undertaken that aimed to develop a simple system for
118 measuring heifer growth on commercial dairy farms. The goals of this data-gathering
119 exercise were: to describe the growth rates of a subset of youngstock enrolled in a heifer
120 monitoring programme to inform future benchmarking initiatives; to quantify the association
121 between birth weight and growth rates from 8-60 days; to quantify the association between
122 birth weight and estimated weights at 60 days, 180 days and 300 days and to report
123 probabilities of achieving pre-mating target weight for heifers growing at different rates to
124 31-180 days as well as the probability of achieving pre-mating target weight by overall
125 performance of the group within which the heifer is reared.

126

127 **Materials and methods**

128 *Farm selection*

129 The source population was the clientele of a large farm animal veterinary practice
130 (total 220 eligible dairy herds, 30,000+ cows) in South West England (mainly Somerset and

131 Dorset). A variety of commercial dairy herds using different management systems were
132 included, so there were no selection criteria and no exclusion criteria except that heifers were
133 Holstein-Friesians. The study population comprised herds recruited by the practice into a
134 heifer-monitoring programme, as well as three herds that provided their own heifer weight
135 data. The sample population were herds that were rearing Holstein-Friesian breed heifers and
136 where the herd-owner had agreed to contribute data to the study.

137 .

138

139 *Data collection*

140 Data were collected from May 2008 to September 2012. The equipment used was a
141 Mobile Cattle Crate (David Ritchie) with Tru-Test MP600 load-bars, aluminium platform and
142 Ezi-weigh Indicator (Tru-Test). The accuracy of the weigh scales was checked regularly by
143 weighing the operator, whose weight was known. Three other farms provided weight data
144 collected by farm staff using their own weighing equipment, with accuracy similarly checked
145 on a regular basis.

146

147 *Analysis*

148 Data manipulation and statistical analyses were carried out using Microsoft Excel
149 2010 (Microsoft Corporation) and Stata/IC 12.0 (StataCorp, College Station, TX). Calculated
150 birth weight was the median BW for 348 calves (from six farms) with a weight recorded at 0-
151 7 days of age. Daily growth rate (GR) from birth was calculated using recorded weight less
152 calculated birth weight, divided by age in days since birth.

153

154 Correlations between weights and days of age were initially examined, and lines of
155 best fit were calculated, using polynomial transformation if appropriate. The mean growth

156 rate from birth, (using calculated birth weight) for all weights recorded for each herd was
157 then calculated. Herds were categorised as Upper, Middle or Lower according to into which
158 quartile their mean growth rate fell. Upper herds were those whose mean growth rate fell into
159 the upper quartile, Middle herds were those whose growth rates fell into the middle two
160 quartiles, and Lower herds were those whose growth rates fell into the lower quartile. Further
161 details about calculations and statistical analyses are included in the sub-sections below.

162

163 *Expected weight calculations*

164 Expected weight at 60 days was calculated for all heifers with a recorded weight at
165 42-78 days using the formula: $\text{Expected weight at 60 days} = \text{weight recorded} + [\text{GR} \times (60 -$
166 $\text{age in days when weighed})]$.

167

168 Expected weight at 420 days was calculated in the same way, using all heifers with a
169 recorded weight at 300-539 days. $\text{Expected weight at 420 days} = \text{weight recorded} + [\text{GR} \times$
170 $(420 - \text{age in days when weighed})]$.

171

172 The link between early heifer growth and subsequent development to first service was
173 explored as follows: W1 = weight recorded at 31-180 days; W2 = weight measured at 300-
174 539 days. For animals with a recorded W1 (31-180 days) and a recorded W2 (300-539 days)
175 (582 heifers), expected weight at 420 days was calculated as above, and heifers were grouped
176 (at intervals of 0.1 kg/day) according to their recorded growth rate to W1. If animals had
177 more than one recorded weight in any category, the two weights furthest apart were used in
178 calculations. Data were checked for normality and equal variances, and one-way analysis of
179 variance was performed using Scheffe's method.

180

181 *Target weights*

182 A target weight at first service was set at 374 kg, which was the 75th percentile
183 expected weight at 420 days for all weights measured between 300-539 days. The likelihood
184 of a heifer reaching this target weight by 420 days was calculated for each group (Upper,
185 Middle and Lower herds), and compared using Pearson χ^2 tests. A multilevel univariable
186 logistic regression model accounting for clustering by farm (similarity of animals within a
187 farm as compared to animals between farms) was also used to compare the odds of heifers
188 achieving this target weight between groups.

189

190 *Birth weights and growth rates*

191 The records from all calves with a recorded weight at 0-7 days (Wa) and a recorded
192 weight at 42-78 days (Wb) (69 heifers, all from three of the Upper herds) and/or with a
193 recorded weight at >79 days (Wc) (229 heifers) were analysed. Growth rate was calculated as
194 above, but using individual recorded birth weight rather than calculated birth weight.

195 Correlations between recorded birth weights and these growth rates were calculated using
196 multilevel logistic regression models accounting for clustering by farm. Expected weights at
197 60 days, 180 days and 300 days were also calculated as described above, and correlations
198 using multilevel univariable linear regression models were similarly analysed. Polynomial
199 transformations of the data were investigated in regression models, but linear representations
200 were found to be sufficient.

201

202 **Results**

203 The sample included dairy herds with 120 to > 1,000 cows. Mean 305-day milk yields
204 ranged from 5,071 to 12,575 L (InterHerd+ data, NMR). Four of the herds were managed

205 organically to Soil Association standards⁴, and calving patterns varied from all year to block
206 calving over three months. All herds reared their own heifers, and none withdrew from the
207 data collection. A total of 8,443 weights were recorded from 3,576 heifers, with individuals
208 weighed 1-12 times (median = 2 weighings) (Table 1).

209

210 Mean birth weight (0-7 days) of 348 measured calves on six farms was 40.0 kg
211 (standard deviation (SD) 4.8 kg, range 24-55 kg). Median birth weight (used as calculated
212 birth weight) was also 40.0 kg. (Figure 1). A total of 667 weights were recorded for heifers
213 aged between 0 and 30 days in eight herds (348 weights from 0-7 days and 319 weights from
214 8-30 days). There was no increase in weight until day 8, after which there was a small
215 increase (Figure 2, $r^2 = 0.15$). Median growth rate from 8-30 days was 0.12 kg/day (SD 0.5,
216 319 weights). All weight for age data 0-730 days are shown in Figure 3.

217

218 The overall growth rates of Upper, Middle and Lower herds are presented in Table 2.
219 Mean birth weight for Upper herds was 41.6 kg (95 heifers, SD 5.7) and for Lower herds was
220 39.5 kg (253 heifers, SD 4.5). No weight data were available for calves 0-7 days of age for
221 Middle herds.

222

223 *Target weights*

224 Expected weight at 420 days showed significant differences between Upper, Middle
225 and Lower herds ($P < 0.001$ for all groups; Table 3). The percentage chance of achieving
226 target bulling weight of 374 kg by 420 days was significantly different between all three
227 groups ($P < 0.001$; Table 3). Figure 4 shows the percentage chance of a heifer reaching target
228 service weight of 374 kg by 420 days for heifers growing at different rates to W1 (31-180

⁴ www.soilassociation.org/whatisorganic/organicanimals/dairycattle (accessed 15 March 2015).

229 days). Significant differences between all groups were demonstrated ($P < 0.001$ for all except
230 < 0.5 kg/day vs. 0.5 - 0.59 kg/day ($P = 0.02$), and 0.7 - 0.79 kg/day vs. >0.79 kg/day ($P = 0.04$)).
231 A multilevel logistic regression model also showed that the odds of heifers achieving the
232 target weight of 374 kg by 420 days of age was 2.2 times higher for every 0.1 kg/day increase
233 in daily growth rate between 31 and 180 days. Significant farm-level clustering was also
234 identified, indicating that there was more variability between heifers on different farms than
235 between heifers on the same farm.

236

237 *Birth weights and growth rates*

238 Recorded birth weight showed no significant correlation to growth rate at 42 - 78 days
239 or at >78 days of age. Heavier weight at birth had a positive and significant association with
240 expected weight at 60 days (Figure 5), even when clustering by farm was taken into account
241 ($P < 0.001$). Significant farm-level clustering was seen. There was also a significant
242 correlation at 180 days and at 300 days, even when farm-level clustering was accounted for
243 ($P < 0.001$ for both), with significant farm-level clustering evident both at 180 days and at
244 300 days.

245

246 **Discussion**

247 Key times for weighing heifers are: at birth, at around 60 days (i.e. after weaning) and
248 prior to the start of the service period (360 - 400 days). Birth weight is easily measured and is
249 useful because it allows future growth rates to be calculated accurately. Weight at weaning
250 varies between herds, but is an important determinant of future performance. Accurate
251 measurement of weight prior to service is vital if heifers are to enter the herd at the correct
252 size and weight. Although these key times represent a gold standard, practical experience has
253 shown that any weight data are better than none to enable farmers to make rational decisions

254 about heifer management, so heifer weighing can be slotted in with other husbandry tasks to
255 minimise inconvenience and time. It is also important to identify variation in growth rate
256 within cohorts of calves, since excessive variation is usually linked with disease or husbandry
257 problems. In this sample, even though the Upper herds did not, on average, exceed optimal
258 growth rates of 0.8 kg/day for pre-pubertal heifers, it is suggested that formulating rations for
259 these heifers with enough metabolisable protein for growth without fattening combined with
260 monitoring heifer body condition will ensure that they do not lay down fat.

261

262 There was a large variation in extremes of birth weight at 0-7 days old, although more
263 than 75% of calves weighed between 35 and 45 kg. There was a small, non-significant
264 difference in mean birth weights of Upper and Lower herds, which may reflect genetic
265 differences within the breed. US surveys of Holstein calves reported birth weights of 36.6 kg
266 (Dhakal et al. (2012)) and 37.7 kg (Olson et al. (2009)) from multiparous cows, so median
267 recorded weight was heavier in this study. Factors affecting birth weight are numerous and
268 include genetic variation, pre-calving feeding, gestation length, parity of dam and twinning
269 (Burriss and Blunn, 1952).

270

271 Overall, these data showed no growth of calves in the first eight days of life, and little
272 growth in the first month, although there was substantial variation between herds. Mean
273 growth gradually improved in the second month, as calves started to eat concentrate feed.
274 Cut-off points were chosen to reflect data presented elsewhere in the literature. There was
275 large variation between herds and between individuals within herds, as in other studies
276 (Brickell et al., 2009c). Feed conversion rate of young calves is approximately 50%, so these
277 animals grow very efficiently (Bach and Ahedo 2008); these results, therefore, reveal an
278 enormous waste in potential growth efficiency on dairy farms. Brickell et al. (2009b) showed

279 that mortality to six months was higher in calves whose BW was low at 30 days, and that
280 herds achieving lower mean growth rates to two months had higher mean AFC and more
281 variation in AFC. Lower herd growth rate to 60 days has also been linked to higher
282 primiparous cow cull rates (Bach, 2011) and reduced first lactation milk yield (Bach, 2012).

283

284 Variation in BW and growth rate may, in part, be due to birth weight differences. The
285 data presented here show that daily growth rate was not linked to birth weight, but calves
286 with heavier birth weights achieved higher BW at 60, 180 and 300 days; this may have
287 reflected genetic differences, but may also be because larger calves competed more
288 effectively for food.

289

290 In order to achieve AFC of 23-25 months, age at conception must be 14-16 months,
291 therefore 420 days has been chosen to represent the start of the service period. In this study,
292 the expected 75th percentile weight at 420 days was 374 kg, which was used as the target
293 service weight. The variation in growth rate seen here indicates that there was variation in
294 expected weight at 420 days, with a mean of 353 kg (SD 43.5 kg). Mean expected weight of
295 heifers in the Lower herds was 302 kg and, among these heifers, some would not reach
296 puberty (which occurs at approximately 43% mature weight, according to Van Amburgh et
297 al., 1998) until well after 420 days of age.

298

299 Growth rate from birth to 180 days was seen to affect the likelihood that heifers
300 would achieve 374 kg by 420 days. Less than 10% of heifers with a recorded growth of < 0.5
301 kg/day at any time between 30 and 180 days achieved this target service weight, and less than
302 10% heifers reared in the Lower herds achieved the target (Table 3). Fewer than 20% of those
303 whose growth rate was 0.5-0.69 kg/day, and 23.6% heifers reared in the Middle herds

304 achieved target bulling weight of 374 kg by 420 days (Table 3). Farmers facing this situation
305 must decide either to delay first service or calve their heifers too small. Anecdotal evidence
306 from participating farmers suggested they were likely to serve heifers according to a visual
307 assessment of their size. Since early growth rate and AFC are linked to lifetime performance
308 (as discussed above), heifers that perform poorly up to six months old are likely to perform
309 poorly throughout their lives.

310

311 A significantly smaller percentage of heifers achieved target bulling weight at 420
312 days in each segment of herds as compared to the herd category above (Lower as compared
313 to Middle, Middle as compared to Upper herds). There was no correlation between herd size
314 or milk yield and growth rate of heifers. All three seasonal calving herds were in the Upper
315 group of herds, perhaps reflecting the priority that must be given to achieving AFC around 24
316 months (and therefore heifer growth) in seasonally calving herds.

317

318 **Conclusions**

319 Farmers often invest substantial amounts on improving the genetic potential of their
320 cows, but poor growth rates in heifers on some units mean that many heifers never achieve
321 their genetic potential. Little or no growth was found in the first seven days of life. Seventy-
322 eight percent of heifers in this study did not reach the pre-mating target weight in time to
323 achieve AFC at 24 months, which was likely to jeopardise their future performance in the
324 adult herd. Heifers that grew well in the first one to six months were much more likely to
325 reach pre-mating target weight at the correct time, so monitoring heifer growth during the
326 rearing period can provide excellent information to predict future performance of heifers and
327 enables farmers to improve growth rates and the efficiency of heifer rearing. This survey

328 provides useful practical information about current heifer growth on dairy farms in South
329 West England, which can be used to benchmark performance of other UK herds.

330

331 **Conflict of interest statement**

332 None of the authors of this paper has any financial or personal relationship with
333 people or organisations that could inappropriately influence or bias the content of the paper.

334

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340

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451

452 **Table 1**

453 Number of weighings for individual animals.

454

Number of times animal weighed	Number of animals	Number of weighings
1	1412	1412
2	839	1678
3	655	1965
4	327	1308
5	152	760
6	94	564
7	57	399
8	16	128
9	15	135
10	7	70
11	0	0
12	2	24
Total	3576	8443

455

456 **Table 2**

457 Median recorded growth rates for herds categorised as Upper, Middle or Lower according to
 458 mean growth rate for all weights recorded for that herd.

459

Days	Upper herds			Middle herds			Lower herds		
	kg/day	<i>n</i>	SD	kg/day	<i>n</i>	SD	kg/day	<i>n</i>	SD
8-30	0.52	43	0.34	0.29	30	0.40	0.00	246	0.38
31-60	0.66	72	0.18	0.45	87	0.18	0.34	35	0.20
61-730	0.75	1978	0.03	0.68	4155	0.03	0.59	1211	0.03
>730	0.70	72	0.07	0.67	277	0.08	0.55	49	0.08
Overall	0.75	2168	0.13	0.71	4559	0.14	0.58	1352	0.31

460 *n* is the number of weights recorded, SD, standard deviation.

461

462 The overall growth rate of Upper herds fell into the upper quartile (> 0.71 kg/day; 2168
 463 weights, 7 herds). The overall growth rate of Middle herds fell into the middle two quartiles
 464 (0.63-0.71 kg/day; 4559 weights, 7 herds). The overall growth rate of Lower herds fell into
 465 the lower quartile (< 0.63 kg/day; 1352 weights, 6 herds).

466

467

468

469 **Table 3**

470 Herd data for herds categorised as Upper, Middle and Lower according to mean growth rate
 471 for all weights recorded for that herd.

472

	Upper herds	Middle herds	Lower herds
Number of herds	7	7	6
Mean number of cows	217 (range 127-305)	370 (range 144-1079)	401 (range 120-783)
Mean 305-day yield	7474 L (range 5071-8401 L)	8039 L (range 6902-9759 L)	7893 L (range 5410-12,575 L)
Number of herds seasonally calving	3	0	0
Expected weight at 420 days (kg) calculated from weights at 300-539 days	357* (n=924, SE=1.38)	343*(n=1742, SE=1.13)	302* (n=317, SE=3.24)
% probability of achieving target service weight 374 kg by 420 days, calculated from weights at 300-539 days	33.9*(n=924)	23.6*(n=1742)	9.2* (n=317)

473 * $P < 0.001$ for all comparisons

474

475

476

477

478

479 **Figure legends**

480

481 Fig. 1. Frequency histogram of birth weight for all heifers ($n = 348$) weighed between 0-7
482 days post-partum from six herds enrolled in a heifer weight monitoring scheme in South West
483 England between 2008 and 2012.

484

485 Fig. 2. Weights for all heifers ($n = 667$) weighed from 0 to 30 days from eight herds enrolled
486 in a heifer weight monitoring scheme in South West England between 2008 and 2012.

487

488 Fig. 3. All recorded heifer weights ($n = 8443$) from 20 herds enrolled in a heifer weight
489 monitoring scheme in South West England between 2008 and 2012.

490

491 Fig. 4. The effect of early life growth rate on the probability of reaching target first service
492 weight of 374 kg by 420 days. All differences are significant at $P < 0.001$ except for < 0.5
493 compared to 0.5-0.59 ($P = 0.02$) and 0.7-0.79 compared to > 0.79 ($P = 0.04$). (< 0.5 $n = 115$,
494 0.5-0.59 $n = 98$, 0.6-0.69 $n = 138$, 0.7-0.79 $n = 127$, 0.8+ $n = 104$; total $n = 582$).

495

496 Fig. 5. Relationship between birth weight and expected weight at 60 days for heifers ($n = 69$)
497 with a recorded weight at 0-7 days and a recorded weight at 42-78 days.

Fig. 1

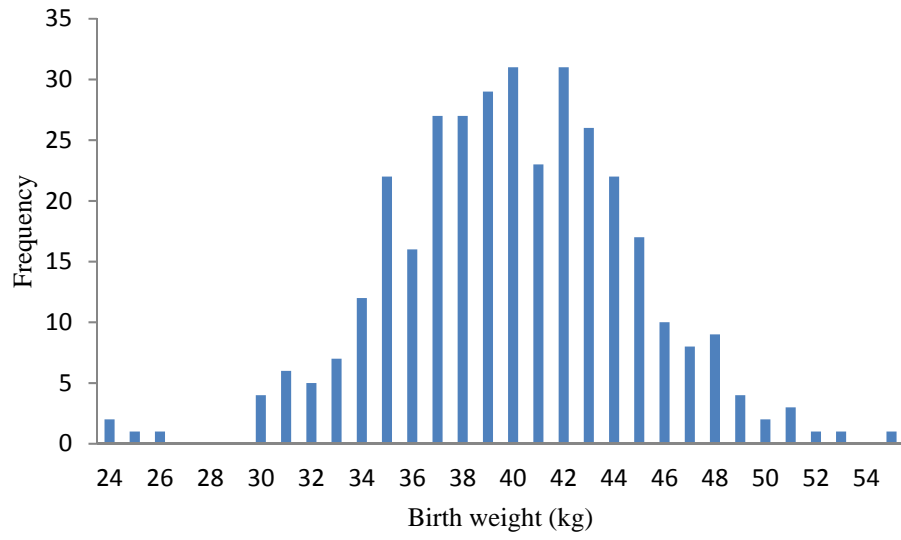


Fig. 2

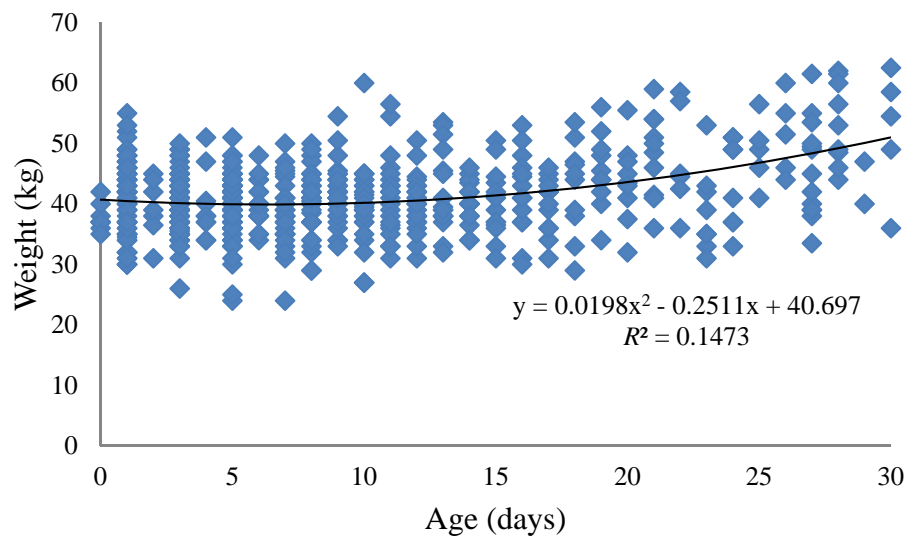
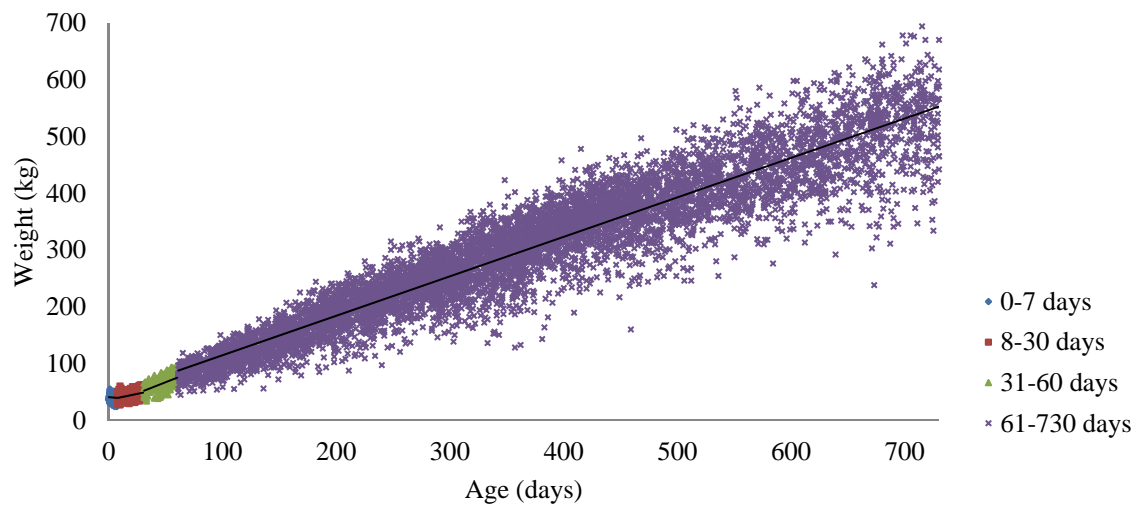


Fig. 3



Age range	Equation for graph slope	r^2
8-30 days	$y= 0.42x+36.02$	0.15
31-60 days	$y=0.79x+27.61$	0.34
61-730 days	$y=0.70x+45.14$	0.89

Fig. 4

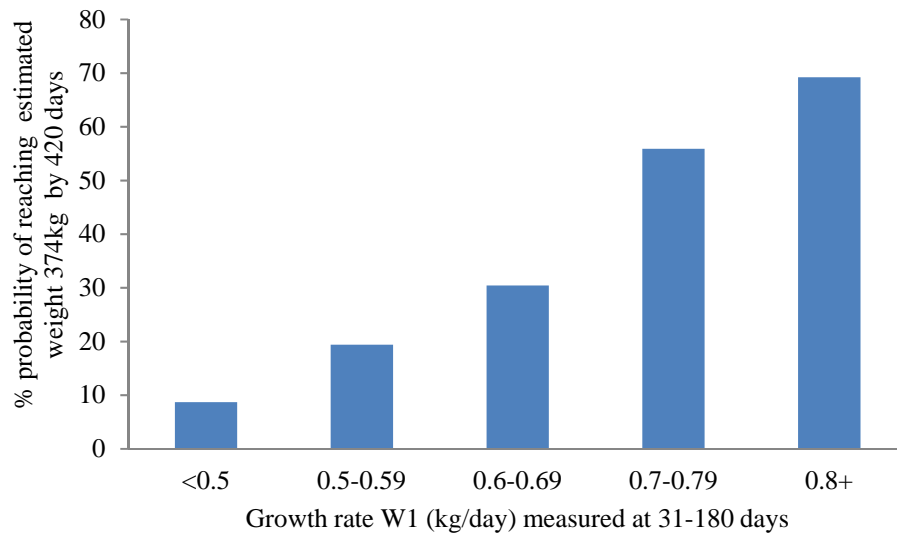


Fig. 5

