Original Article

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

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Abstract

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

Keywords: Dairy cattle; Calves; Growth rates; Heifers

Introduction

Heifer rearing is the weak link in many dairy enterprises, leading to high mortality and future poor performance in the milking herd. In the UK, 58% of live-born heifers fail to reach their third lactation (Brickell and Wathes, 2011). The cost of rearing heifers is high, representing about 20% of dairy farm expenses, and making it the highest variable cost after feed (Tozer and Heinrichs, 2001). In the UK, the cost of rearing heifers is variable, with a mean of £1,819[1] (DairyCo, 2015), so that replacement costs average around 2.6 pence per litre (ppL). For many herds, costs may be as high as 3.2 ppL of milk produced (DairyCo[2]). It has been estimated that most farmers should be able to reduce replacement costs to 2.0 ppL, resulting in a financial benefit of £14,400 per annum for a 160-cow herd. Replacement rate and age at first calving (AFC) are also concerns, as these factors are known to affect the carbon footprint of the herd (Hermanson and Kristenson, 2011).

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

[1] £1 = approx. US $1.47, €1.40 at 15 March 2015.
[2] See: www.dairyco.org.uk (accessed 15 March 2015).

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

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

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

Treatment rates or medicines use can be used as a proxy for heifer disease. Target incidence of disease is fewer than 10% of pre-weaned calves requiring treatment (Breen 2012), and treatment rates can be linked to heifer growth rate and future performance (Stanton et al., 2010; Stanton et al., 2012). Bach (2011) showed that heifers suffering four or more episodes of bovine respiratory disease (BRD) were 1.9 times more likely to fail to complete first lactation than those with no recorded BRD. However, treatment rate and medicine use is difficult to compare between units because of differences in recording accuracy, criteria for treatment and skill of stockpersons at identification of sick animals.

Heifer growth provides the most direct evidence of heifer performance throughout the rearing process from birth to calving. Published data are available to provide target weights and growth rates for animals of different ages (Drew, 1998; Heinrichs and Losinger, 1998; Le Cozler et al., 2008). The optimal weight for Holstein-Friesian heifers at first service has been estimated by different authors: Le Cozler et al. (2008) suggest 55-60% mature weight, Heinrichs and Lammers (2008) cite 341-364 kg, Bach (personal communication, 2013) estimates 400 kg at 400 days and Hoffman (1997) recommends 363-390 kg at 14 months. The growing heifer has a number of key stages of development, particularly growth rates to 60 days, which is linked to first lactation milk yield (Bach and Ahedo, 2008) and survival rate to second lactation (Bach, 2011). Weights at 180 days and at the beginning of the target service period (420 days) are also important (Dairy Co PD+[3]). Optimal heifer growth rates have been studied in detail, with conflicting results (Le Cozler et al., 2008). Very high pre-pubertal growth rates led to deposition of udder fat (Sejrsen et al., 1982), and have been associated with reduced first lactation milk yield (Van Amburgh et al., 1998). Other studies (Carson et al., 2002) showed no deleterious effect of high plane of nutrition on first lactation yields in high genetic merit heifers. Zanton and Heinrichs (2005), through meta-analysis of eight studies, concluded that heifer growth should be limited to 0.8 kg/day prior to puberty for maximal first lactation milk production. Over-fatness at any stage may jeopardise future milk production (Le Cozler et al., 2008).

[3] See: www.dairyco.org.uk (accessed15 March 2015).

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

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

Materials and methods

Farm selection

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

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

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Data collection

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

Analysis

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

Correlations between weights and days of age were initially examined, and lines of best fit were calculated, using polynomial transformation if appropriate. The mean growth rate from birth, (using calculated birth weight) for all weights recorded for each herd was then calculated. Herds were categorised as Upper, Middle or Lower according to into which quartile their mean growth rate fell. Upper herds were those whose mean growth rate fell into the upper quartile, Middle herds were those whose growth rates fell into the middle two quartiles, and Lower herds were those whose growth rates fell into the lower quartile. Further details about calculations and statistical analyses are included in the sub-sections below.

Expected weight calculations

Expected weight at 60 days was calculated for all heifers with a recorded weight at 42-78 days using the formula: Expected weight at 60 days = weight recorded + [GR x (60 - age in days when weighed)].

Expected weight at 420 days was calculated in the same way, using all heifers with a recorded weight at 300-539 days. Expected weight at 420 days = weight recorded + [GR x (420 - age in days when weighed)].

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

Target weights

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

Birth weights and growth rates

The records from all calves with a recorded weight at 0-7 days (Wa) and a recorded weight at 42-78 days (Wb) (69 heifers, all from three of the Upper herds) and/or with a recorded weight at >79 days (Wc) (229 heifers) were analysed. Growth rate was calculated as above, but using individual recorded birth weight rather than calculated birth weight. Correlations between recorded birth weights and these growth rates were calculated using multilevel logistic regression models accounting for clustering by farm. Expected weights at 60 days, 180 days and 300 days were also calculated as described above, and correlations using multilevel univariable linear regression models were similarly analysed. Polynomial transformations of the data were investigated in regression models, but linear representations were found to be sufficient.

Results

The sample included dairy herds with 120 to > 1,000 cows. Mean 305-day milk yields ranged from 5,071 to 12,575 L (InterHerd+ data, NMR). Four of the herds were managed organically to Soil Association standards[4], and calving patterns varied from all year to block calving over three months. All herds reared their own heifers, and none withdrew from the data collection. A total of 8,443 weights were recorded from 3,576 heifers, with individuals weighed 1-12 times (median = 2 weighings) (Table 1).

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

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

Target weights

Expected weight at 420 days showed significant differences between Upper, Middle and Lower herds ($P < 0.001$ for all groups; Table 3). The percentage chance of achieving target bulling weight of 374 kg by 420 days was significantly different between all three groups ($P < 0.001$; Table 3). Figure 4 shows the percentage chance of a heifer reaching target 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 (accessed15 March 2015).

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

Birth weights and growth rates

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

Discussion

Key times for weighing heifers are: at birth, at around 60 days (i.e. after weaning) and prior to the start of the service period (360-400 days). Birth weight is easily measured and is useful because it allows future growth rates to be calculated accurately. Weight at weaning varies between herds, but is an important determinant of future performance. Accurate measurement of weight prior to service is vital if heifers are to enter the herd at the correct size and weight. Although these key times represent a gold standard, practical experience has shown that any weight data are better than none to enable farmers to make rational decisions about heifer management, so heifer weighing can be slotted in with other husbandry tasks to minimise inconvenience and time. It is also important to identify variation in growth rate within cohorts of calves, since excessive variation is usually linked with disease or husbandry problems. In this sample, even though the Upper herds did not, on average, exceed optimal growth rates of 0.8 kg/day for pre-pubertal heifers, it is suggested that formulating rations for these heifers with enough metabolisable protein for growth without fattening combined with monitoring heifer body condition will ensure that they do not lay down fat.

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

Overall, these data showed no growth of calves in the first eight days of life, and little growth in the first month, although there was substantial variation between herds. Mean growth gradually improved in the second month, as calves started to eat concentrate feed. Cut-off points were chosen to reflect data presented elsewhere in the literature. There was large variation between herds and between individuals within herds, as in other studies (Brickell et al., 2009c). Feed conversion rate of young calves is approximately 50%, so these animals grow very efficiently (Bach and Ahedo 2008); these results, therefore, reveal an enormous waste in potential growth efficiency on dairy farms. Brickell et al. (2009b) showed that mortality to six months was higher in calves whose BW was low at 30 days, and that herds achieving lower mean growth rates to two months had higher mean AFC and more variation in AFC. Lower herd growth rate to 60 days has also been linked to higher primiparous cow cull rates (Bach, 2011) and reduced first lactation milk yield (Bach, 2012).

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

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

Growth rate from birth to 180 days was seen to affect the likelihood that heifers would achieve 374 kg by 420 days. Less than 10% of heifers with a recorded growth of < 0.5 kg/day at any time between 30 and 180 days achieved this target service weight, and less than 10% heifers reared in the Lower herds achieved the target (Table 3). Fewer than 20% of those whose growth rate was 0.5-0.69 kg/day, and 23.6% heifers reared in the Middle herds achieved target bulling weight of 374 kg by 420 days (Table 3). Farmers facing this situation must decide either to delay first service or calve their heifers too small. Anecdotal evidence from participating farmers suggested they were likely to serve heifers according to a visual assessment of their size. Since early growth rate and AFC are linked to lifetime performance (as discussed above), heifers that perform poorly up to six months old are likely to perform poorly throughout their lives.

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

Conclusions

Farmers often invest substantial amounts on improving the genetic potential of their cows, but poor growth rates in heifers on some units mean that many heifers never achieve their genetic potential. Little or no growth was found in the first seven days of life. Seventy-eight percent of heifers in this study did not reach the pre-mating target weight in time to achieve AFC at 24 months, which was likely to jeopardise their future performance in the adult herd. Heifers that grew well in the first one to six months were much more likely to reach pre-mating target weight at the correct time, so monitoring heifer growth during the rearing period can provide excellent information to predict future performance of heifers and enables farmers to improve growth rates and the efficiency of heifer rearing. This survey provides useful practical information about current heifer growth on dairy farms in South West England, which can be used to benchmark performance of other UK herds.

Conflict of interest statement

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

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Table 1

Number of weighings for individual animals.

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

Table 2

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

	Upper herds			Middle herds			Lower herds		
Days	kg/day	*n*	SD	kg/day	*n*	SD	kg/day	*n*	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

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

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

Table 3

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

	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)

* $P < 0.001$ for all comparisons

Figure legends

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

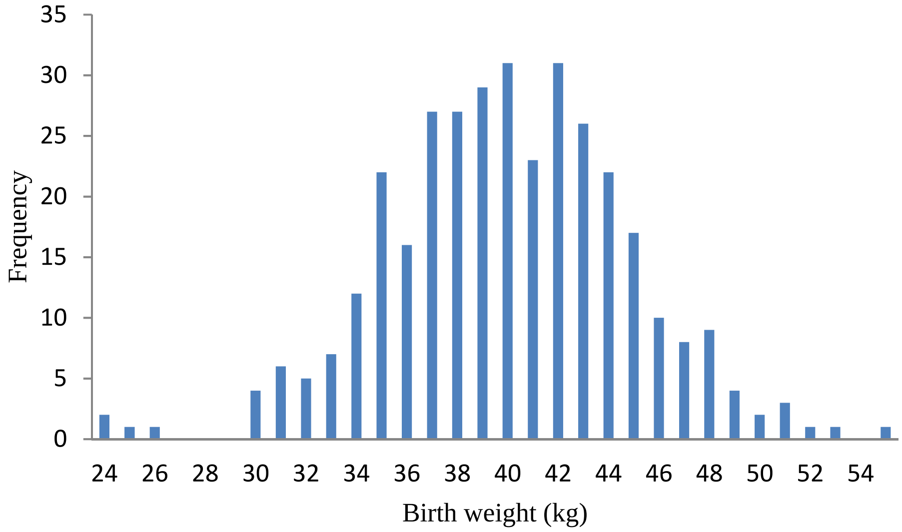
Fig. 2. Weights for all heifers (n = 667) weighed from 0 to 30 days from eight herds enrolled in a heifer weight monitoring scheme in South West England between 2008 and 2012.

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

Fig. 4. The effect of early life growth rate on the probability of reaching target first service weight of 374 kg by 420 days**.** All differences are significant at $P < 0.001$ except for < 0.5 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, 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).

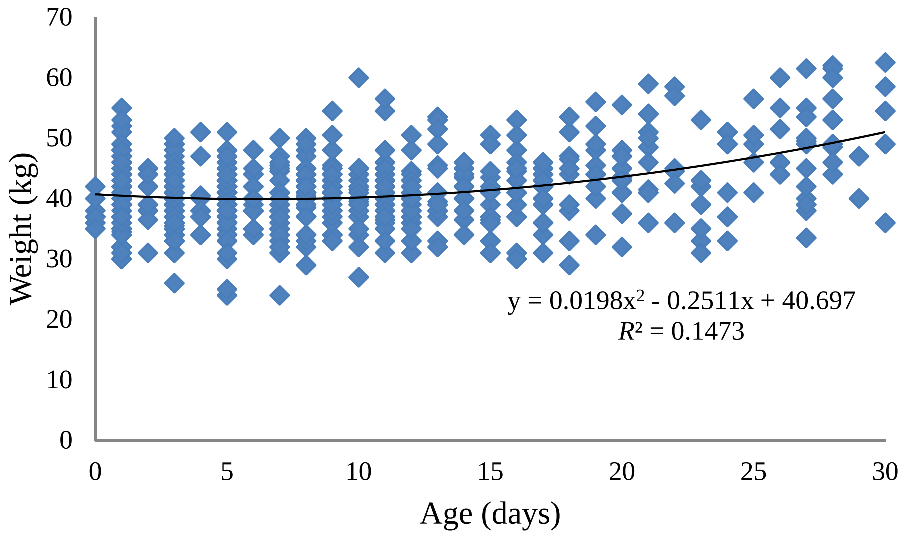
Fig. 5. Relationship between birth weight and expected weight at 60 days for heifers (n = 69) with a recorded weight at 0-7 days and a recorded weight at 42-78 days.

Fig. 1



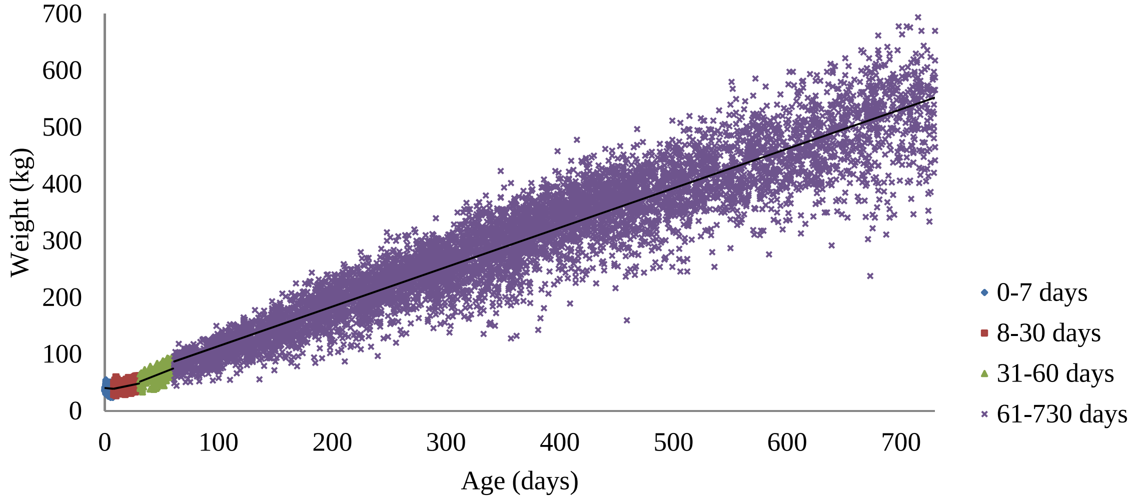
35
30
25
20
15
10
5
0
Frequency
24
26
28
30
32
34
36
38
40
42
44
46
48
50
52
54
Birth weight (kg)

Fig. 2



70
60
50
40
30
20
10
0
Weight (kg)
0
5
10
15
20
25
30
Age (days)
y = 0.0198x2 - 0.2511x + 40.697
R² = 0.1473

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

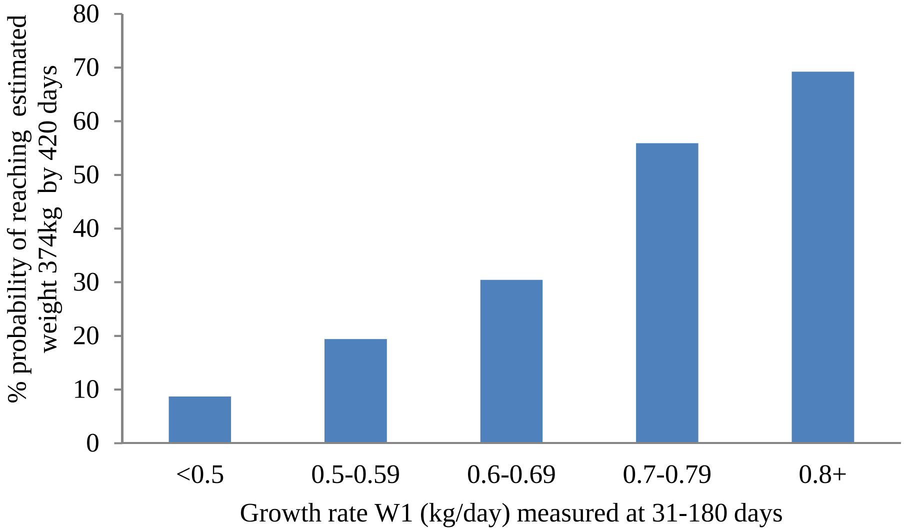
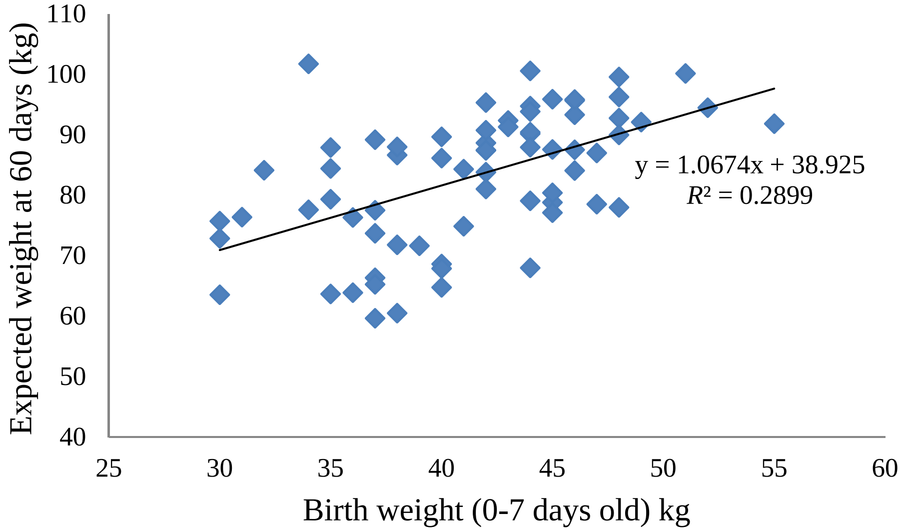

% probability of reaching estimated weight 374kg by 420 days
80
70
60
50
40
30
20
10
0
<0.5
0.5-0.59
0.6-0.69
0.7-0.79
0.8+
Growth rate W1 (kg/day) measured at 31-180 days

Fig. 5


110
100
90
80
70
60
50
40
Expected weight at 60 days (kg)
25
30
35
40
45
50
55
60
Birth weight (0-7 days old) kg
y = 1.0674x + 38.925
R² = 0.2899