Prediction of body condition score in dairy cows using routine electronic data capture

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Abstract

Body condition scoring is a widely accepted practical herd management technique used for assessing the impact of changes in energy status of adult dairy cows. Achieving optimum cow condition scores throughout lactation is necessary to maximise milk production, reproductive performance and health status and indirectly optimising overall farm profitability. However, the traditional visual body condition scoring system is subjective and can result in substantial inter and intra scorer variability. An objective and automated method of body condition scoring would be a valuable tool for the management of modern dairy herds.

The objective of this study was to predict cow body condition score from measurements of body weight and body stature, taking into account confounding factors such as rumen fill and gestation stage and days in milk. Body weight, body condition score and body stature measurements of Holstein-Friesian dairy cows (n = 68) were obtained 2-4 weeks prior to expected calving date and repeat measurements of body weight and body condition score taken monthly thereafter. Body stature measurements included heart girth, belly girth, diagonal and horizontal length, hip width at the level of the tuber coxae and the pin bones, leg circumference and withers height. These were not repeated and assumed to stay the same throughout for all cows. Data analysis comprised fitting multiple predictive algorithms and conducting cross validation to identify the best model. The Support Vector Machine model with a polynomial kernel was the best performing model, with the mean absolute error (MAE) in cross validation being 0.3. When body condition scores were rounded up to the nearest 0.5 and compared with the observed conditions score, the model allowed us to differentiate between 2, 3, 3.5 and 4 however there was no differentiation between 2.5 and 3. The results suggest that the relationship between cow body weight, stature and body condition score is not straightforward or sufficiently similar between cows to allow a generalised prediction to be made. Additional research is needed to explain and understand these results, including exploring the ratio of subcutaneous and visceral fat and the relationship to body condition score in different animals.

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Chapter 1: Introduction

The role of the farm animal veterinary surgeon has changed dramatically over the last decade and is ever evolving with a primary focus now on preventive health and herd health management. This approach involves systematic analysis of data and constant monitoring at cow level to maximise farm efficiency and profitability whilst maintaining welfare. Body condition scoring is a key interest area to regularly monitor. Achieving optimum cow condition scores and minimising condition loss during the production cycle optimises production, health, and welfare without predisposing the cow to excessive fat mobilisation (Green *et al.*, 2012). Body condition score (BCS) refers to the relative amount of subcutaneous fat or energy reserve in the cow. Body condition score is a measurable parameter obtained by inspection of the stock and assists with the understanding of the herds nutritional status. BCS analysis at a herd level provides an insight into BCS distribution and the modal value whilst highlighting the extremes. Dairy cattle are reliant on a combination of body reserves and available feed to meet demands of producing milk (Roche *et al.*, 2009). Body reserves, primarily adipose tissue, play an important role in early lactation with up to 1/3 of total milk production being produced from body reserves (Bauman and Bruce Currie, 1980). Post calving cows enter a state of negative energy imbalance; requirements for production exceed the energy input from feed (Mao *et al.*, 2004). This is exacerbated by dry matter intake increasing at a slower rate than milk production. The dry matter intake post calving is directly influenced by body condition score at calving. Cows that have a higher body condition score at calving (3.5 to 4) eat less and reach maximum dry matter intake later than cows with lower condition scores (< 3.5) (Garnsworthy and Topps, 1982). Additional research further highlights this negative association between body condition score and dry matter intake (Treacher, Reid and Roberts, 1986). The impact of body condition score on future performance of the cow is discussed below.

1.1 The impact of BCS on production, health, and welfare

1.1.1 Body condition score and milk yield

The dairy industry has undergone significant changes over decades, the average milk production per cow has increased by 100% from 4,100 litres in 1975 to 8,200 litres in 2020 (Barkema *et al.*, 2015). The overall total domestic production has increased by 14%. These changes are attributed to improved nutrition and management but primarily an intense genetic selection and growing interest in dairy cattle breeding programs (Barkema *et al.*, 2015). Such genetic selection pressures have resulted in a variety of physiological changes such as an increased activity of lipolytic enzymes, and a greater expression of the genes involved in fat mobilisation (Roche *et al.*, 2009). Roche, Berry and Kolver (2006) proposed that the body condition score profile closely resembles a horizontally inverted milk yield lactation curve. With body condition score declining to a nadir at 40 to 100 days in milk, corresponding to peak lactation, before replenishing body reserves as milk production declines at a constant rate (Nebel and McGilliard, 1993).

There are inconsistencies in the literature between the associations with BCS at calving, nadir BCS, BCS change between time points and milk production. In a New Zealand pasture-based study a positive effect of pre calving body condition score was reported on peak, 60 day and 270-day milk and 4% fat corrected milk (FCM) yield. Each unit increase in body condition score 8 weeks pre calving was associated with a 32.5 and 55.86kg/ cow increase in 60-day milk and 4% FCM yield and 89.2 and 114kg/cow increase in 270-day milk and 4% FCM yield (Roche, Lee, *et al.*, 2007). Contreras, Ryan and Overton (2004) work identified that cows with an initial BCS ≤3 at dry off produced an increased milk yield in the first 5 months of lactation when compared to cows with an initial BCS at dry off ≥3.25. In contrast, Domecq et al. (1997) reported 300kg less milk in the first 120 days of lactation for each unit increase of body condition score on a five-point scale at dry off. Conversely, a Czech study on Flekvieh cows highlighted no significant relationship between the body condition score one-month pre calving and subsequent production (Jílek *et al.*, 2008).

Body condition score change between two time points has been shown to be important. An American study reported that a one-point increase in body condition score, on a five-point scale, from dry off to parturition was associated with 545 kg more milk in the first 120 days in lactation (Domecq *et al.*, 1997). Body condition score loss is often marked in early lactation, with cows in the low yielding group generally experiencing less condition score loss than the high yielding group (Ruegg and Milton, 1995). Body condition score loss in the peri parturient period is exacerbated in over conditioned cows at point of calving. In a UK study of Friesian cows, over conditioned cows >4 lost 48kg and 1.2 BCS units in early lactation compared to under conditioned cows <2.5 which lost 27kg and 0.52 BCS units. This study concluded that cows that are over conditioned at calving mobilise more body weight and condition after calving (Treacher, Reid and Roberts, 1986).

The relationship between calving body condition score and milk production is conflicting. Garnsworthy and Topps (1982) reported that thinner cows at calving (BCS 1.5 to 2) had an increased milk yield when compared to two groups of cows with a medium BCS (2.5 to 3) and high BCS (3.5 to 4). However, Waltner, McNamara and Hillers (1993) reported that increasing the calving body condition score from 2.0 to 3.0 and 3.0 to 4.0 increased the 90-day production by 322kg and 33kg respectively. Likewise, an Irish study reported an increased body condition score at calving being associated with a higher milk lactation profile (Berry, Buckley and Dillon, 2007). The variation in the literature may be explained by the curvilinear relationship between body condition score and milk production, with increases occurring up to a threshold and decreasing after that. Berry, Buckley and Dillon (2007), identified that the 305-day yield was maximised at a calving body condition score of 4.25. Waltner, McNamara and Hillers (1993) showed that a reduction in 90-day production of 233kg was seen when body condition score, on a five-point scale, was increased from 4 to 5. Roche et al. (2009) concluded that the optimum body condition score at point of calving for milk production is 3.5 and 6.5 on the five- and ten-point scale respectively.

1.1.2 Body condition score and reproduction

The most important nutritional influence on fertility is negative energy balance with a calving condition score of > 3.5 being associated with a 2.5 times increased risk of ketosis (Gillund *et al.*, 2001). In addition, animals with no ketosis event in the post-partum period were 1.6 times more likely to conceive than those with a ketosis event (Gillund *et al.*, 2001). Negative energy balance in the first 3 weeks and the nadir is highly related to timing of first ovulation with an associated delayed onset of ovarian activity (Reist *et al.*, 2000; Butler, 2003). Negative energy balance does not affect the follicle population or development of the first dominant follicle (Diskin *et al.*, 2003). However, on the contrary, negative energy balance is associated with a disruption in LH surge and sensitivity, decrease in glucose, insulin, insulin like growth factor 1 (IGF-1) and these collectively limit oestrogen production and affect the ovulatory fate of the follicle (Diskin *et al.*, 2003).

Body condition score loss post-partum has been extensively associated with reproductive outcomes. The main reproductive outcomes discussed below and summarised in Table 1 are resumption of luteal function post-partum, days to first ovulation and first service and subsequently the first service conception rate. Cows losing ≥1 body condition score after calving had a delayed commencement of luteal activity and a greater risk of delayed ovulation (Shrestha *et al.*, 2005). Additionally, cows losing body condition score in week 4 and 5 post-partum had a delayed postpartum luteal function (Reksen *et al.*, 2002). Cows losing more in body condition score during the first and second month after calving were significantly more at risk of developing a delay in ovarian function in the immediate post-partum period. Cows with delayed ovarian function lost 0.13 BCS points more during the first month of calving and 0.2 BCS points more during the second month after calving when compared to cows with a normal progesterone profile (Opsomer et al., 2000). The loss in body condition score post-partum also appears to have a strong relationship with days to first service and first service conception rate. A marked condition score loss (1-1.5) from dry off to pre-calving was reported to have longer days to first service when compared to a moderate condition score loss (0-0.75), 103 and 87 days respectively (Kim and Suh, 2003). A significant increase in days to first service associated with cows losing > 1.0 body condition score unit was also reported (Butler and Smith, 1989). A severe body condition score loss in early lactation over one body condition score resulted in a significant increase in days open (10.6), however any condition score loss less was not significant (López-Gatius, Yániz and Madriles-Helm, 2003). A pasture-based study also reported that the probability of pregnancy within 21 and 84 days of planned start of mating decreased by 4 and 3% respectively when condition score loss from calving to nadir was one unit greater than the calculated mean of 0.73 BCS units on a 10-point scale (Roche, Macdonald, *et al.*, 2007). Calculating a mean from ordinal data is a point of contention and some academics believe that the mean cannot be used as a measure of central tendency as it has no meaning and therefore the most appropriate measure is mode. In another pasture-based study, a manipulated data set that only included cows with a pre calving body condition score of > 3, reported that cows experiencing excessive losses > 0.5 of a condition score were less likely to conceive by day 42 (PR42) of the breeding season (0R = 0.75). This equated to an estimated reduction of 8% in the PR42 when compared to the reference range of < 0.25 condition score loss (Buckley *et al.*, 2003). Scientific evidence emphasises the importance of body condition score monitoring to unsure early identification of condition score loss at an intervention level of 0.5 of a score (Reksen *et al.*, 2002).

The association with body condition score at calving and reproduction in comparison to body condition score at other time points through the lactation profile such as pre-calving and nadir is less well documented. Cows with a higher body condition score at calving when compared to lower condition cows, were less likely to have an unobserved oestrus (OR 0.5 for each additional BCS unit) and to have inactive ovaries (OR 0.4 in multiparous cows for each additional BCS unit) and therefore lower body condition score animals had reduced fertility due to delayed ovarian activity (Markusfeld, Galon and Ezra, 1997). Cyclicity prior to planned start of mating was higher in cows that had a higher pre calving body condition score, however the highest predicted probability (84%) was seen in animals with a condition score of 5.5 on the 10-point scale. Any extremes of condition either way was associated with an impacted cyclicity (Roche, Macdonald, *et al.*, 2007).

A low body condition score (<2.5) between 60 to 100 days of lactation when compared to a reference group of 2.75 to 3 had a reduced chance of submission in the first 21 days of the breeding season (OR = 0.59) and were less likely to conceive by day 42 of the breeding season (OR = 0.75). Likewise, cows with a lower nadir body condition score < 2.5 had a reduced likelihood of a pregnancy to first service (Buckley *et al.*, 2003). Additionally, a 7% decrease in pregnancy within 42 days of planned start of mating was report when nadir body condition score declined by one unit from mean 3.8 (Roche, Macdonald, *et al.*, 2007).

Overall, most science reports a positive association between increased body condition score at calving and nadir, reduced post calving loss and an earlier successful pregnancy.

Table 1: A summary of the relevant literature showing the effect of post-partum body condition score loss on reproductive outcomes

Reproductive outcome	**Researchers**	**Research findings**
1. Resumption of luteal function post-partum	(Shrestha *et al.*, 2005)	Cows losing ≥1 body condition score after calving had a delayed commencement of luteal activity
	(Reksen *et al.*, 2002)	Cows losing BCS in week 4 and 5 post-partum had a delayed post-partum luteal function
2. Days to first ovulation	(Shrestha *et al.*, 2005)	Cows losing ≥1 body condition score after calving had a greater risk of delayed ovulation.
	(Opsomer et al., 2000)	Delayed ovulation for cows losing more body condition score during the first and second months of lactation.
3. Days to first service	(Kim and Suh, 2003)	A marked BCS loss (1-1.5) from dry off to pre-calving was reported to have longer days to first service when compared to a moderate BCS loss (0-0.75), 103 and 87 days respectively.
	(Butler and Smith, 1989)	A significant increase in days to first service with cows losing >1 BCS.
	(López-Gatius, Yániz and Madriles-Helm, 2003)	A severe BCS loss in early lactation >1 resulted in a significant increase in days open (10.6).
4. First service conception rate	(Roche, Macdonald, *et al.*, 2007)	Probability of pregnancy within 21 and 84 days of planned start of mating decreased by 4 and 3% respectively when BCS loss was one unit greater than the calculated mean of 0.73 BCS units.
	(Buckley *et al.*, 2003)	Cows experiencing excessive BCS losses > 0.5 of a condition score were less likely to conceive by day 42 (PR42) of the breeding season (0R = 0.75). Equating to an 8% reduction in PR42.

1.1.3 Body condition score and disease

The greatest benefits of maintaining optimal cow body condition score are likely to come from improvements in animal health. Periparturient disease can lead to reduced milk production and removal of the animal from the herd, therefore it is imperative to prevent disease and optimise cow health. Research indicates that over conditioned cows at point of calving suffered more periparturient disease (Treacher, Reid and Roberts, 1986). Exact relationships between BCS and subsequent diseases are discussed below.

The most consistent relationship from published studies is the association between body condition score and ketosis. Busato et al. (2002) reported that cows with an ante partum body condition score > 3.25 and that lost > 0.75 of a condition score during the first 8 weeks in lactation, classified as 'FAT LOSS' cows exhibited signs of sub clinical ketosis. In 'FAT LOSS' cows signs of subclinical ketosis were present between 20- and 30-days post-partum with a β-hydroxy-butyrate (BHBA) concentration of 1.5mmol/l taken as the threshold value for diagnosis. Vanholder et al. (2015) reported that over conditioned cows > 4 body condition score when compared with thin cows ≤ 3, had a 2.7 higher odds of sub clinical ketosis and 8.7 higher odds of clinical ketosis. Duffield (2000) also reported an increased incidence of both subclinical and clinical ketosis with an increasing calving body condition score, with a BCS of 4 or higher being associated with the highest risk.

Body condition score loss and extremities of body condition score have been associated with metritis and endometritis. A German study reported that a low body condition score at calving <3 when compared with a body condition score ≥ 3 was associated with an increased risk of developing endometritis (OR 2.95) (Hoedemaker, Prange and Gundelach, 2009). Similarly, an American study reported that uterine discharge scores were higher in the extremities of condition score < 2.5 and ≥ 3 .5 when compared to an optimum body condition score of 2.5 to 3 (Titterton and Weaver, 2001). Butler and Smith (1989) categorised the cows based on body condition score loss in the first 5 weeks of lactation, BCL1 minor <0.5, BCL2 moderate 0.5 to 1 and BCL3 severe >3. Metritis incidence was higher in BCL2 and BCL3 (22 and 47%) than BCL1 (6%). Kim and Suh (2003) carried out a more recent study to further support this finding with the occurrence of metritis being greater in cows that experienced a marked body condition score loss (1-1.5 of a score) when compared to a moderate body condition score loss (0 – 0.75 of score), 62% and 27% respectively.

The relationship between body condition score and milk fever appears to be non-linear. Heuer, Schukken and Dobbelaar (1999) identified a 3.3 times higher risk of milk fever for over conditioned cows ≥ 4 when compared to the reference range of BCS >2 and <4. Roche et al. (2013) also reported that the odds of a case of milk fever were 13% and 30% greater when body condition score was < 2.5 and > 3.5 when compared with a body condition score of 3. Association with fat cows is likely due to the greater degree of dry matter intake reduction and the increased milk production. The explanation for thinner cows is not as well clear cut and a general malaise may be the reason.

The relationship between body condition score and mastitis is weak and evidence is limited. Berry, Lee, Macdonald, Stafford, et al. (2007) showed a reduced somatic cell count in 1st and 2nd parity animals and an increased somatic cell count in 3rd parity with an increasing body condition score at calving. This relationship persisted throughout lactation. Breen, Bradley and Green (2009) further supports this as cows that were recorded with a BCS >3.5 or < 1.5 at a monthly visit had increased odds ($p < 0.05$) of SCC >199,000 cells/mL at the next milk recording in lactation, compared with other condition scores. Clinical mastitis was not associated with body condition score. The biological significance of this is unknown and a high likelihood this is merely an association rather than a causation. A plausible explanation could be due to immune suppression and increased susceptibility to disease. Numerous other pieces of literature found no relationship between body condition score and mastitis (Gearhart *et al.*, 1990; Heuer, Schukken and Dobbelaar, 1999).

There is numerous risk factors associated with an increased incidence of displaced abomasa and the aetiology is multifactorial and not completely understood. Over conditioned cows at calving are associated with an increased risk of development of a DA, the incidence rate has been reported to increase from 3.1% to 8.1% for low body condition score cows (2.75 to 3.25) to high body condition score cows (>4) (Dyk, 1995). The increased incidence is likely to be related to the greater degree of dry matter intake reduction association with over conditioned cows, and the subsequent fat mobilisation and increase in fatty liver and type II ketosis (Garnsworthy and Topps, 1982).

Maintaining an optimum body condition score is imperative for reducing the risk of lameness. A German study reported that cows with a low body condition score at calving (<3) and during early lactation (4 – 10 weeks post-partum) had an increased risk of lameness (OR 2.9-9.4) (Hoedemaker, Prange and Gundelach, 2009). It has been further suggested by Green et al. (2014) that cows with a body condition score < 2.5 had an increased risk of treatment for lameness in the following 0 – 2 months and > 2 – 4 months for all causes of lameness and specifically sole ulcer and white line disease. Loss of body condition has also been shown to precede the onset of lameness. Cows losing body condition post calving had an increased risk of future lameness (OR = 1.21 for severely lame) and a lower probability of recovering in the next 15 days (Randall *et al.*, 2015). The importance of body condition score change at a herd level and its effects on the total amount of lameness was investigated and 5.99% of all lameness events could be prevented by not exposing the herd to a loss of 0.5 across all body condition score categories (Newsome *et al.*, 2017b). One explanation for these findings is because body condition score is positively associated with digital cushion thickness (Bicalho, Machado and Caixeta, 2009). A thin sole soft tissue (a combined measure of thickness of the digital cushion and the corium) increased the likelihood of the development of lesion occurrence such as sole ulcers or sole haemorrhage and subsequent lameness events (Newsome *et al.*, 2017a). Back fat thickness did not completely explain the variation in the sole soft tissue thickness and therefore there are likely other factors that influence the thickness of sole soft tissue (Newsome *et al.*, 2017b).

1.2 Measuring body condition score

Body condition scoring is an important herd management technique used for assessing changes in the energy status of adult dairy cows and for optimising cow health. Body condition scoring is a subjective, visual, or tactile examination of the proportion of subcutaneous fat. Methods and techniques for body condition score assessment differs worldwide and between livestock breeds. Body condition score systems have evolved worldwide with a 6-point system used in the United Kingdom and Ireland (Mulvany, 1981), a 5-point system used in the United States (Wildman *et al.*, 1982; Edmonson *et al.*, 1989; Ferguson, Galligan and Thomsen, 1994) , an 8-point system in Australia (Earle, 1976) and a 10-point system used in New Zealand (Macdonald and Roche, 2004). These are summarised in Table 2 by the scale, interval, primary researchers, and method of evaluation.

Table 2: International body condition scoring systems, summarised by the scale, interval, primary researchers and method of evaluation.

Country	**Scale**	**Interval (points)**	**Primary researchers**	**Visual or Palpation**
United Kingdom, England	0 to 5	0.5 (11)	(Lowman, Scott and Somerville, 1973; Mulvany, 1981)	Palpation
United States	1 to 5	0.25 (17)	(Wildman *et al.*, 1982; Edmonson *et al.*, 1989; Ferguson, Galligan and Thomsen, 1994)	Visual
New Zealand	1 to 10	0.5 (19)	(Macdonald and Roche, 2004)	Palpation
Australia	1 to 8	0.5 (15)	(Earle, 1976)	Visual

All body condition scoring systems incorporate numerical scales with a low score reflecting emaciation and a high score obesity. The New Zealand, United Kingdom and Ireland systems rely on palpation of specific body parts whereas the Australia and United States systems are based on visual evaluation. The anatomical locations of significance are the thoracic and vertebral region of the spine, the ribs, the spinous process, tuber sacrale (hip or hook bone), tuber ischii (pin bone), the anterior coccygeal vertebrae (tail head) and the thigh region (Roche *et al.*, 2004). Identification of specific changes at anatomical locations can indicate score categories and minimise the need for assessment of all areas. A decision tree incorporating these descriptors can be utilised to simplify the system and maximise agreeability between scorers (Ferguson, Galligan and Thomsen, 1994). The appearance of the thurl region, whether it is a "U" or "V" shape, can classify the cow into body condition score ≥ 3.25 and ≤ 3 respectively (Ferguson, Galligan and Thomsen, 1994). The prominence and appearance of the pin bones whether angular or rounded are important in distinguishing cows into body condition score categories 3, 2.75 and ≤ 2.5 (Ferguson, Galligan and Thomsen, 1994). However, the pin and hip bones provide no contribution when the cow is ≥3.25 as they are always both rounded in appearance. The presence or absence visually of the sacral and coccygeal ligaments are important when cows have a body condition score ≥ 3.25 (Ferguson, Galligan and Thomsen, 1994). For each body condition score class, the typical descriptors of each body region are described in depth in Table 3.

Table 3: Decision chart for body condition score (BCS) based on principal descriptors of each body region. Unique classifiers for each body condition score category.

	Body condition score (BCS)												
Body Regions	**2.00**	**2.25**	**2.50**	**2.75**	**3.00**	**3.25**	**3.50**	**3.75**	**4.00**	**4.25**	**4.50**	**4.75**	**5.00**
Thurl	V					U					flat		rounded
Ileal Tuberosity	angular				rounded							just visible	not visible
Ischial Tuberosity	angular		fat pad palpable	rounded							not visible		
Transverse process of lumbar vertebrae	>.5 visible	.25 to .50 visible				.10 to .25 visible		only tips visible		tips not visible			
Coccygeal ligament	visible						just visible	not visible					
Sacral ligament	visible							just visible	not visible				

The most utilised international standard scoring system is a 1 to 5 scale with 0.25 increments relying on a visual assessment (Wildman *et al.*, 1982; Edmonson *et al.*, 1989; Ferguson, Galligan and Thomsen, 1994). Body condition score is reported to be highly representative of subcutaneous fat but poorly predictive of intermuscular and intramuscular fat (Wright and Russel, 1984). This is suggestive that condition scoring may be less accurate in cows with less subcutaneous fat and as a result that cow variability in fat distribution has a considerable impact on the variance of scores (Edmonson *et al.*, 1989). Therefore, it has been suggested that body condition score should be separated by 0.25 units between 2.5 and 4, but only 0.5 units below 2.5 or above 4 (Ferguson, Galligan and Thomsen, 1994). Roche et al. (2004) investigated the relationship between the New Zealand 10-point scoring system and the scoring systems used in the United States, Ireland and Australia. A significant positive linear relationship ($P < 0.001$) was found for all systems, with the relationship between New Zealand and Ireland (r2 = 0.72) being closer, most likely due to the fact both scoring systems involve palpation of individual body parts. These results are useful for comparing body condition scoring systems in different countries referred to in the literature. Utilising the conversion equations from this research, it is suggestive that body condition score should therefore be separated by 0.5 units between 3 and 7.5 and 3.5 and 6 for the 10-point New Zealand system and 8 point Australian system, with only 1 unit separation outside of these scores.

There is a high level of inter and intra scorer variability of scoring. Ferguson, Galligan and Thomsen (1994) assessed the variation between 3 experienced assessors and 1 less experienced assessor when using the 5-point scale body condition scoring system. The observers agreed with absolute score 58.1% of the time and deviated by 0.25 by 32.6% of the time. This differed substantially among classifiers based on experience with only 27% agreement in a less experienced scorer. Kristensen et al. (2006) evaluated the consistency and quality of body condition scoring among 51 practicing dairy vets and 6 highly trained instructors. A group of cows were repeatedly scored with training sessions between scoring periods. Kappa coefficient was used to assess agreement among and within classifiers; the agreement was highest (kappa ≥ 0.86) between repeated body condition scores recorded for the same cows by the highly trained instructors but in the group of practicing vets the within classifier and between classifier kappa values were 0.22 to 0.75 and 0.17 to 0.78 respectively. This provides the evidence for the value and importance of training. Additionally, the across classifier agreement was higher than previously reported at 83%.

The validation of body condition score has been well documented and is an accurate method when compared with ultrasound measurements of subcutaneous fat of dairy cows and multiple measurements obtained at slaughter (Domecq *et al.*, 1995; Gregory *et al.*, 2010). Ultrasound is a more objective measure however success relies heavily on accurate and reliable standardisation of measurements (Mizrach *et al.*, 1999). Numerous ultrasound measurements have been obtained for verification of body condition score. Domecq et al. (1995) measured subcutaneous fat at six locations, lumbar, thurl and tailhead on both the right- and left-hand side with the study focusing on the body areas assessed in body condition scoring. All six locations were significantly associated with body condition score (R^2 = 0.36 to 0.65). No significant difference was identified between the left and right side and the association did not improve with multiple measures. This is suggestive that one measurement would suffice. Similarly, Zulu et al. (2001) evaluated the same six locations and identified correlation coefficients between body condition score and the six locations of 0.62 – 0.72. The highest correlation coefficient was for the mean of the lumbar measurements.

Back fat thickness has been used extensively alone or alongside other measurements such as the longissimus dorsi muscle thickness (LDT) for verification of body condition score. Back fat thickness, the measure of the layer of subcutaneous fat that lies between the skin and the deep fascia in the area located above the gluteal and longissimus dorsi muscles, is highly correlated with total body fat content (r = 0.90) (Schröder and Staufenbiel, 2006). Schröder and Staufenbiel (2006) identified the sacral region as having the highest amount of adipose tissue in the back. Hussein, Westphal and Staufenbiel (2013) used Pearson’s correlation procedure to determine the relationship between back fat thickness alone and body condition score at four stages throughout lactation. The correlation between BCS and back fast thickness (BFT) was lower when the BCS was <2 and >4.5. BCS values <2 and >4.5 had correlation coefficients (r) of 0.6 and 0.4 respectively. Cows with a BCS of 5 had more variable BFT measurements, highlighting the limitations of body condition scoring in obese cows due to the fact it is a discrete variable ranging from 1 to 5 (maximum limit) when compared to BFT which is a continuous variable. This research is suggestive that extremes of body condition score may not be as well associated with measures of body fat. Schwager-Suter et al. (2000) looked at the association of body condition score with ultrasound measurements of back fat and longissimus dorsi muscle thickness in Holstein Friesian, Jersey, and Holstein Jersey cows. Identifying high coefficients of determination (0.84 and 0.85). Siachos et al. (2021) looked at the same association however this study uniquely focused on seven time points during the periparturient period and animals across six different commercial farms. In agreement with other studies a high positive correlation between body condition score and back fat thickness was identified (r = 0.839- 0.867). Skeletal muscle was shown to contribute to body condition score to a lesser degree. One unit of body condition score was associated with 8.2mm of back fat and 10.9mm of longissimus dorsi muscle. This highlights a greater degree of contribution from adipose tissue than skeletal muscle towards body condition score estimation. The incorporation of ultrasound back fat thickness measurement into automatic monitoring systems is unrealistic because of the necessary contact of the probe with the cow for an extended period.

Despite the importance of body condition scoring a large proportion of dairy farms do not incorporate it routinely into their management practices. A survey of 153 herds in America showed that only 45% of herds body condition scored their cows and the majority of this was carried out by external nutritionists rather than farm staff (Caraviello *et al.*, 2006). The main limitations to manual body condition scoring are that its time consuming and requires trained individuals. Interestingly, if farming systems are body condition scoring this is most likely to be by visual assessment of a sample population and not necessarily quantitative in nature. Therefore, there is limited industry quantifying of farm body condition scores with further data analysis.

1.3 The impact of body weight on production, health, and welfare

Significant associations have been reported between body weight change and fertility and health. Heinonen, Ettala and Alanko (1988) reported that cows that lost > 10% body weight within 60 days of calving had a 6 day longer calving to first oestrus interval, 8 day longer calving to pregnancy interval and a lower pregnancy rate to first insemination of 53.1% vs 74.4% when compared to cows that lost < 10%. A more recent Israeli study supported this finding, reporting that a body weight loss of ≥ 7% from calving to 10 days in milk was associated with a decreased reproductive performance, specifically 21% reduced odds of artificial insemination on a given day and 24% reduced odds of conception on a given day (van Straten, Shpigel and Friger, 2009). Variables representing relative loss (%) rather than actual loss (kg) were identified to be better predictors. An Irish study highlighted the inverse, that cows that gained body weight from the start of breeding and 90 days thereafter had a higher likelihood of breeding in the first 21 days (SR21) and pregnancy to 1st service (PREG1), and cows that gained body weight between first service and 90 days thereafter had a higher likelihood of pregnancy 42 days after onset of breeding (PREG42) (Buckley *et al.*, 2003). Roche, Macdonald, et al. (2007) also reported that a body weight gain post planned start of mating was positively associated with pregnancy at 21, 42 and 84 days post planned start of mating.

Calving body weight and body weight change between calving and nadir has also been significantly associated with milk production traits. Cumulative 60 day and 270-day milk yield were reported to be positively associated with greater body weight loss to nadir (Roche, Lee, *et al.*, 2007). Likewise, Sieber, Freeman and Kelley (1988) reported that each kg increase in body weight for cows was associated with a 7.8kg decrease in fat corrected milk (FCM). These studies are consistent in demonstrating a positive effect of calving body weight on milk yield.

Change in body weight is significantly associated with post parturient disease. Cows losing more body weight between the first and fourth weeks of lactation had higher odds of displaced abomasum (1.42:1), ketosis (2.24:1) and metabolic disease (1.62:1) (Marion and Dechow, 2006). However, body weight pre calving, calving or change in body weight do not significantly affect the likelihood of dystocia or stillborn. Conversely cows that experience dystocia or stillborn experience a greater loss of body weight from calving and are significantly lighter at nadir (Berry, Lee, Macdonald and Roche, 2007).

1.4 Advances in technology

The increase in precision technology in the dairy industry provides the potential for automation of body condition score along with an increase in accuracy and objectivity. A variety of technology options have been explored, and the value of digital images has been documented. Bewley et al. (2008) obtained digital images from above the cow to determine 23 useful anatomical points and 15 calculated angles. Hook angle, posterior hook angle and tail head depression were identified as significant predictors for US body condition scoring systems. When testing the model on the data set only the hook angles were used, 100% of predicted body condition score were within 0.5 of point of actual body condition score and 92.7% of predicted body were withing 0.25 of a score. Adding tail head did not further improve the findings. A commercial automatic body condition score camera is currently available, DeLaval Body Condition Scoring. A study in the USA validated the implementation of this automated camera and compared agreement between automated and manual scoring. Automated scoring was strongly correlated with manual scoring, with a correlation of 0.78. The camera was found to be accurate between body condition score 3 and 3.75 on a five-point scale, but less accurate for either extreme of body condition score (Mullins *et al.*, 2019). Angel and Mahendran (2024) compared manual body condition scoring from three practising veterinary surgeons with a commercially available automated system in the UK (Herdvision, Agsenze). The automated (AUT) system utilises an algorithm to auto generate BCS on a continuous scale in 0.01 increments. The AUT system only agreed with manual scores at a BCS of 3 and failed to detect animals classified as under conditioned and underestimated the cow classified as over conditioned by the veterinary surgeons. This study highlighted the lack of clinical usefulness of this commercially available automated BCS system currently and the limitations of technology in detection of extremes of BCS. A possible explanation being that the key focal points being assessed and used in the algorithms are either more or less distinguished in under and over conditioned animals. The acceleration in technology on dairy farms and the introduction of robotic milking systems in the 1990s has generated a large proportion of cow level data. This has enabled the industry to have commercially available daily cow body weight data.

1.5 Relationship between body weight and body condition score

Body weight is confounded by numerous factors such as parity, stage of lactation, frame size, body condition score, gut fill, gestation and breed (Barkema *et al.*, 2015). Body condition score has been reported in two separate New Zealand studies to explain only a proportion of the variation of body weight, 30% across all stages of lactation (r = 0.55) (Roche, Berry and Kolver, 2006) and 10% at point of calving (r = 0.32) (Roche, Macdonald, *et al.*, 2007). It is known that the correlation between body condition score and body weight is variable throughout different stages of lactation. Body condition scores have been related to body weight with variable results. Using a 10-point scale, one unit of body condition score was associated with a change of body weight of 31kg (Berry *et al.*, 2006). Using a 5-point scale, one unit of body condition score was associated with a change of body weight of 35kg in the dry period and 21kg in lactation (Jaurena *et al.*, 2005). Using a 6-point scale, one unit of body condition score was associated with a change of body weight that varied from 22 to 57kg (Enevoldsen and Kristensen, 1997). A rule of thumb of 50kg per unit in BCS is often applied. However, the relationship between body weight and body condition score is not as well understood and it is confounded by numerous factors, including skeletal development and stature.

1.6 Relationship between body weight, body condition score and stature measurements

Heinrichs, Rogers and Cooper (1992) identified heart girth, withers height, hip width and body length as predictors for body weight ($R^2 > 0.95$). Out of these stature measurements heart girth has been reported to have the highest correlation to body weight (0.62 to 0.88) (Yan *et al.*, 2009). Plus, withers height and hip width are the best skeletal parameters and least influenced by changes in body condition score (Wickersham and Schultz, 1963). In contrast belly girth and heart girth are the two stature variables that more closely reflect body condition score; however, belly girth is influenced considerably by gut full (feed intake) (Yan *et al.*, 2009). Additionally, knee width has variable correlation with body weight, but associations have been identified (Gruber *et al.*, 2018).

1.7 Conclusion and aims of the research.

Body condition scoring is an important factor in cattle management to optimise body reserves and maximise productivity, reproductive and health. This review of the literature has highlighted the concerns regarding subjectivity and the need for standardisation to insure consistency across scores. An ideal system would be one that can be practically applied in the field and provides an objective measure of fat content of the animal, allowing for absolute value and changes over time. The relationship between body condition score and body weight is variable with numerous confounding factors. The understanding of body condition score alongside cow stature and body weight has yet to be explored and the role of this research was to determine whether body condition score could be accurately predicted from body weight if confounding factors are accounted for. Therefore, the hypothesis was that, after quantitatively accounting for measurements of cow stature, parity, days in milk and rumen fill, body condition score could be accurately predicted from body weight. An additional secondary aim of this study was to evaluate the direct relationship between body condition score and body weight.

Chapter 2. Materials and methods

2.1 Study Design

The current study assessed body weight, body stature measurements, rumen fill score and body condition score. The study period was from October 2019 to March 2020. Cows were enrolled on a fortnightly basis, two to four weeks before their expected calving date. Repeated measures of body weight, body condition score and rumen fill score were obtained at monthly intervals during the study period. Body stature measurements were assumed to stay the same throughout the study period and were measured once at point of enrolment. Local ethical approval was granted by the University of Nottingham School of Veterinary Medicine and Science ethical approval committee.

2.2 Study Population

The study population comprised a single 350 Holstein Friesian cow dairy farm. This farm was selected for convenience to ensure access to cows, good handling facilities and willingness to participate in the study. The study herd consisted of high producing Holstein Friesian cows with a 305-day milk yield of 13,000 litres. The cows were fed a nutritionally calculated total mixed ration and were housed all year round in deep sand cubicles. Cows were robotically milked through Lely A4 robots. All animals were weighed consistently at the start of each milking visit by the inbuilt weight floor in the milking robots.

2.3 Sample size and subject enrolment

A minimum sample size was estimated by a power analysis prior to enrolment. The calculation was based on an effect size of 0.35, 95% confidence and 80% power. An effect size is a standardized way to report the strength of an apparent relationship and the effect size chosen equates to a medium effect. Sample size was calculated as an estimate for a linear regression model because sample size estimation methods for machine learning algorithms are not readily available. A minimum sample size of 61 animals was determined, based on 12 predictor variables. Cows eligible for enrolment into the study were identified by generating an expected calving date list on the farm management system (UNIFORM, UNIFORM-Agri, Assen, Netherlands). This was calculated using the last insemination date and a subsequent positive pregnancy diagnosis. On each enrolment day, all cows in the herd that were two to four weeks before their predicted calving date were deemed eligible for selection. Any animal that exited the herd prior to the end of the study period, March 2020, was excluded from final data analysis.

2.4 Data collection points

The overview of the study design is graphically represented in the Figure 1.

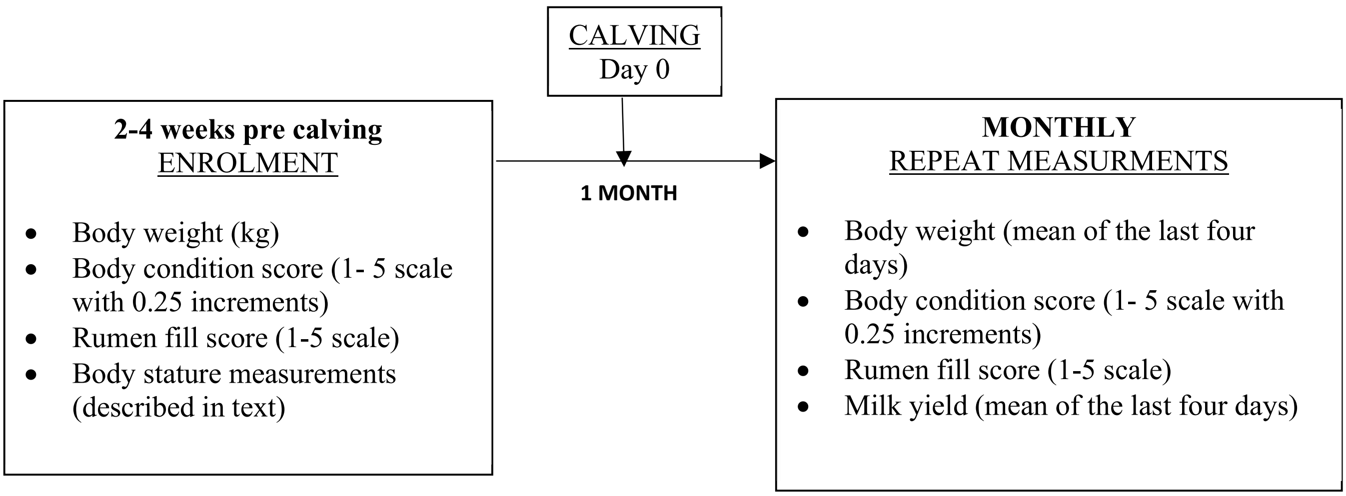

Figure 1: Study design and measurements obtained at each time point.

At point of enrolment (2- 4 weeks pre calving) cows were restrained in a head yoke in a raceway and were weighed, a body condition score and rumen fill score were assigned (see below) and body measurements were obtained.

2.4.1 Body weight

All cows were weighed using a Tru-Test, Datamars, Agri UK Ltd, weigh platform and weight was recorded in kilograms (kg). Prior to use in the study, the Tru-Test scales were calibrated by the manufacturer to within a 0.5% of a known weight.

2.4.2 Body condition score

Body condition scores were determined using a one-to-five-point scale with increments of 0.25 (Edmonson et al., 1989), relying on a visual assessment of key anatomical areas such as the thurl region, the hip and pin bones and the sacral and coccygeal ligaments. The body condition scoring system flow chart utilised is included in the Appendix. The body condition scoring was carried out by the same scorer throughout the study to limit inter observer variability.

2.4.3 Rumen fill score

Rumen fill score was estimated by visual evaluation of the paralumbar fossa on a scale of 1 to 5, with 1 being empty and 5 indicating rumen distension (AHDB Dairy, 2019). The boundaries for the paralumbar fossa were behind the last rib, beneath the transverse process of the spine and in front of a fold of skin and muscle which runs down from the hook bone. Visual appearance associated with each score is depicted in Figure 2 below. The scoring card utilised is included in the Appendix.

Figure 2: AHDB Rumen fill score chart displaying appearance of the paralumbar fossa for each score.

2.4.4 Body stature measurements

Body stature measurements obtained were heart girth, belly girth, leg circumference, withers height, body length (oblique and horizontal) and hip width (tuber coxae and pins). These body stature parameters were selected because of their significance in the literature. These were all measured in a metric of centimetres. The definition of these measurements and the ways in which these were measured are described in detail below:

- Heart girth: measurement of the circumference of the cow behind the shoulder
- Belly girth: measurement of the circumference at the caudal border of the 4th lumbar process
- Leg circumference: measurement of the circumference midway between the elbow and the carpus
- Withers height: the highest part of the back, located between the shoulder blades. A measuring stick was used that had a folding arm incorporating a spirit level, it was positioned at the point of the withers with the base of the ruler flat to the floor.
- Body length oblique: measurement taken from the distal aspect of the spine of the scapula to the tail head fold over the tuber coxae
- Body length horizontal: measurement taken from the withers to the rearmost point of the pin bone
- Hip width tuber coxae: measurement taken between the two tuber coxae
- Hip width pin bones: measurement taken between the two pin bones

2.4.5 Repeat measurements

Repeat measurements (BCS, body weight, rumen fill score) were taken at monthly intervals throughout lactation and within the study period. Daily body weight measurements and daily milk yield were collected from the robot milking facility via the (‘Time-for-cows’ (T4C), Lely) software for consecutive four-day periods; on the day of data collection and from the three days prior to data collection. The inbuilt weigh floor in the milking robots were checked for accuracy by the Lely technician four times a year and they were calibrated at the beginning of the study with a known weight.

2. 5 Descriptive statistics

Data handling, descriptive statistics and statistical modelling were conducted in "R" version 3.6.2 (R Development Core Team, 2019). Variable recoding comprised calculating the number of days in milk at each point of data collection and calculating an average yield and average weight from the four daily consecutive data points. Actual days pre calving at point of enrolment was calculated using the enrolment date and the actual calving date. In the analysis the number of days pre calving at point of enrolment is referred to as the minimum days in milk. Body condition score change for each cow between any two time points throughout the study was identified and the corresponding change in weight was calculated. Graphical representation of the basic linear relationship between body condition score and body weight was visualised. Descriptive statistics were used to evaluate characteristics and distributions within the data, focusing on the distributions of body condition score, body weight and rumen fill score. Correlation coefficients between pairs of variables in the data set were identified.

2.6 Statistical analysis

2.6.1 Linear regression

A linear regression model (Model 1) was constructed to explore the basic relationship between change in body condition score and change in body weight without any stature measurements involved. The residuals were graphically represented to assess model fit and a correlation coefficient was determined.

2.6.2 Data modelling

Predictive modelling using machine learning algorithms was carried out using the caret package in R (Kuhn, 2020). Details of the analytic pipeline and standard machine learning methods used are displayed in Figure

3. The dependent variable in the model was body condition score. The predictor variables in the model were: lactation number, days in milk, rumen fill score (1-5), body weight (kg), withers height, cow length horizontal, cow length diagonal, hip width tuber coxae, hip width pin, heart girth, belly girth and leg circumference. Additionally, yield was included as a thirteenth predictor variable however the final model did not include yield as this did not improve model performance. Several machine learning (ML) algorithms were used to explore the relationship between body condition score and the explanatory variables (Figure 3). Model ML hyperparameter values were explored to maximise model performance as specified in Figure 3; leave one out (at cow level) cross validation was carried out to identify hyperparameter values that produced the best performance. Final hyperparameter value and hence model selection was based on minimising mean absolute error for continuous outcome models. For graphical representation of the final model, BCS predictions ≥ 4.5, which represented a low number of data points, were re-classified and combined into the neighbouring data point of BCS 4, therefore creating a maximum predicted body condition score of 4. Final model predictions were rounded up to the nearest 0.5 of a condition score and compared with observed BCS.

Model Tuning
Manual manipulation of model hyperparameters.
Tuning parameters in each model were:

- Model 2: Support vector machine: **polynomial or radial**; the kernel selects the type of hyperplane used to separate the date. **C** is the penalty parameter, controls the trade-off between decision boundary and miss-classification.
- Model 3: Decision tree: **cp complexity parameter** controls the size of the decision tree and selects the optimal size
- Model 4: Random forest: **mtry** the number of variables randomly sampled at each split
- Model 5: Mars model**: nprune** the maximum degree of interactions and **degree** the number of terms retained in the final model
- Model 6: Elastic net: **alpha** the mixing parameter and **lambda** a numeric value determining the amount of shrinkage
- Model 7: Linear mixed effects model

The process was repeated for the following models:

- Model 2: Support vector machine can produce non-linear boundaries in a large, transformed version of the feature space. with a polynomial kernel and a radial kernel.
- Model 3: Decision tree
- Model 4: Random forest
- Model 5: Mars model
- Model 6: Elastic net
- Model 7: Liner mixed effects model

Cross Validation
10-fold repeated 10 times
Excluding a whole cow out at a time to predict a whole cow.
Best method to estimate out of sample error for predictive modelling.

Final Model Selection
Assessment of model performance based on:
Discrete models: **Cohen's kappa coefficient**, a measure of agreement.

Continuous models: **Mean absolute error (MAE),** the average magnitude of the errors in a set of predictions.

Model Predictions
Cross validation predictions, each whole cow left out every time.
Final model performance reported is from cross validation fit.

Figure 3: Statistical analysis and the analytic pipeline explaining each step in the modelling.

Chapter 3. Results

3.1 Descriptive statistics

The final data set included repeated measurements from 68 cows with a total of 386 body condition scores and body weight measurements recorded.

3.1.1 Body Condition Score

The median recorded body condition score (BCS) for the whole of the data set was 3.5, with the minimum and maximum BCS being 1.75 and 4.75 respectively. The mean value was 3.33; the BCS data was normally distributed as displayed in Figure 4. The exact number of recordings of each condition score and the percentage contribution to the data set are explained in detail in Table 4. Sixty recordings, 15.5% of scores had a BCS ≥ 4 and 68 recordings, 17.6% of scores had a BCS ≤ 2.5.

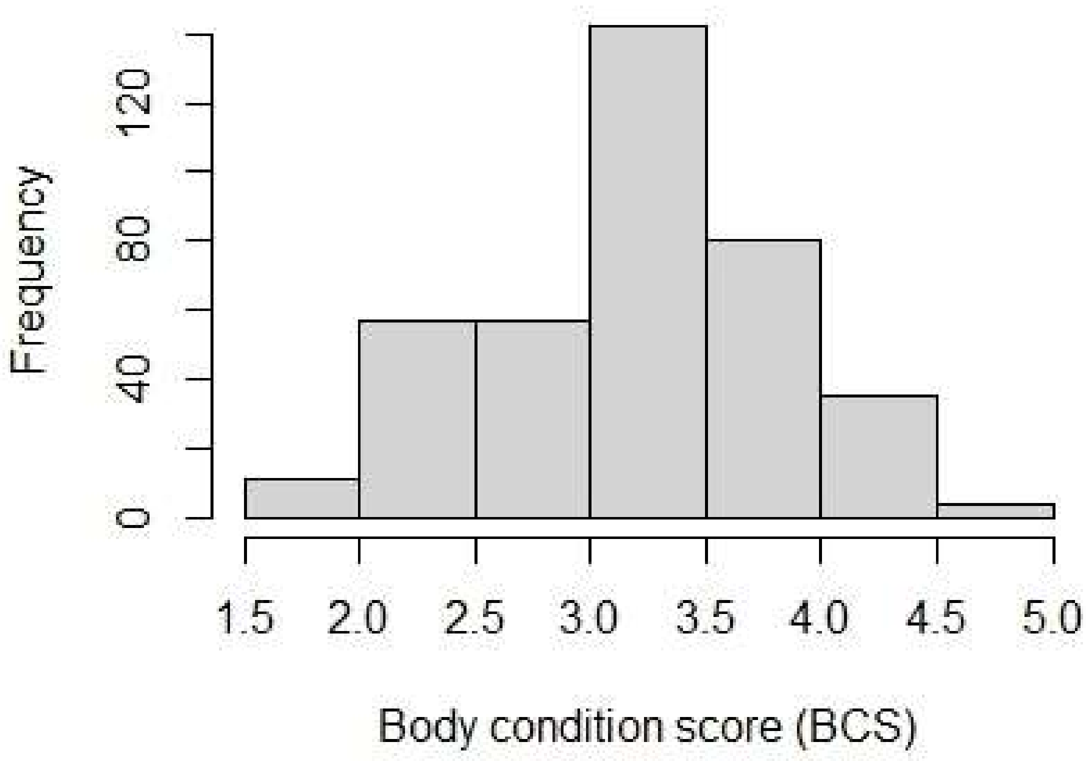

Figure 4: Histogram to show the frequency of all body condition scores within the study (n = 386)

Table 4: The distribution of body condition scores (n = 386) within the data set and the % contribution to the total data set

Body condition score	Number	% of total dataset
1.75	1	0.3
2	10	2.6
2.25	26	6.7
2.5	31	8.0
2.75	20	5.2
3	37	9.6
3.25	52	13.5
3.5	90	23.3
3.75	59	15.3
4	21	5.4
4.25	22	5.7
4.5	13	3.4
4.75	4	1.0
Total	386	

The median recorded body condition score (BCS) for the scores measured prior to calving was 3.5, with the minimum and maximum being 2.25 and 2.75 respectively. The mean value was 3.57. The pre calving body condition score data was negatively skewed as displayed in Figure 5. 23 body condition score recordings out of 68, 33.8% had a body condition score ≥ 4 and 7 body condition score recordings out of 68, 10.3% had a body condition score ≤ 2.5.

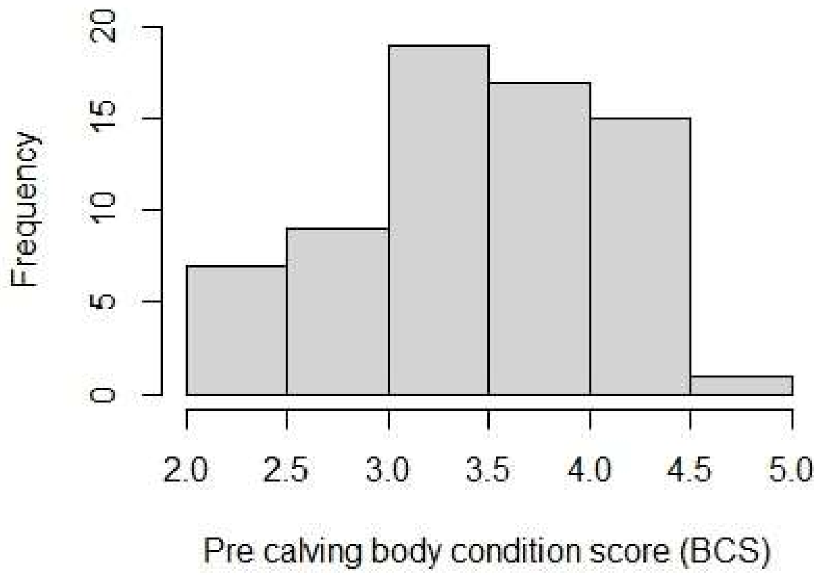

Figure 5: Histogram to show the frequency of pre calving body condition scores within the study (n = 68)

3.1.2 Body Weight

The mean body weight of all the cow recordings (n = 386) was 701.6kg and the range was 416.7kg. The normal distribution of the all the cow recordings body weight data is displayed in Figure 6.

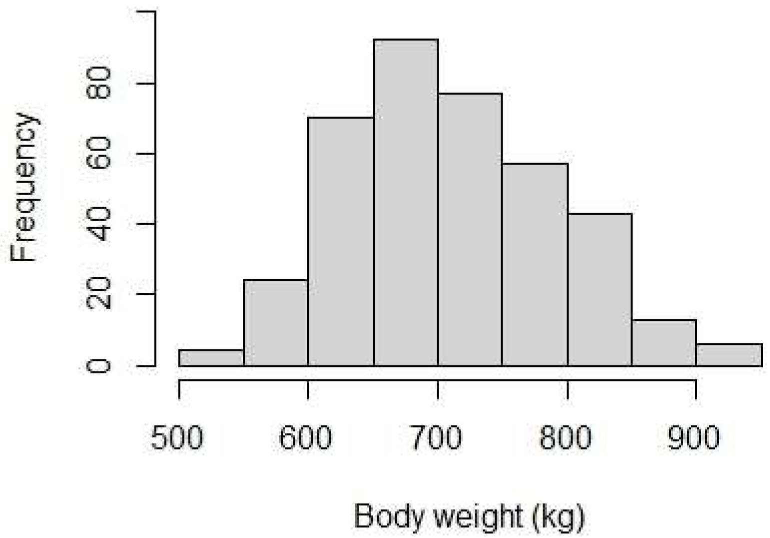

Figure 6: Histogram to show the body weight for all the cow recordings.

The mean body weight for the cows pre calving (n = 68) was 753kg and the range was 312kg. The distribution of the pre calving body weights is displayed in Figure 7.

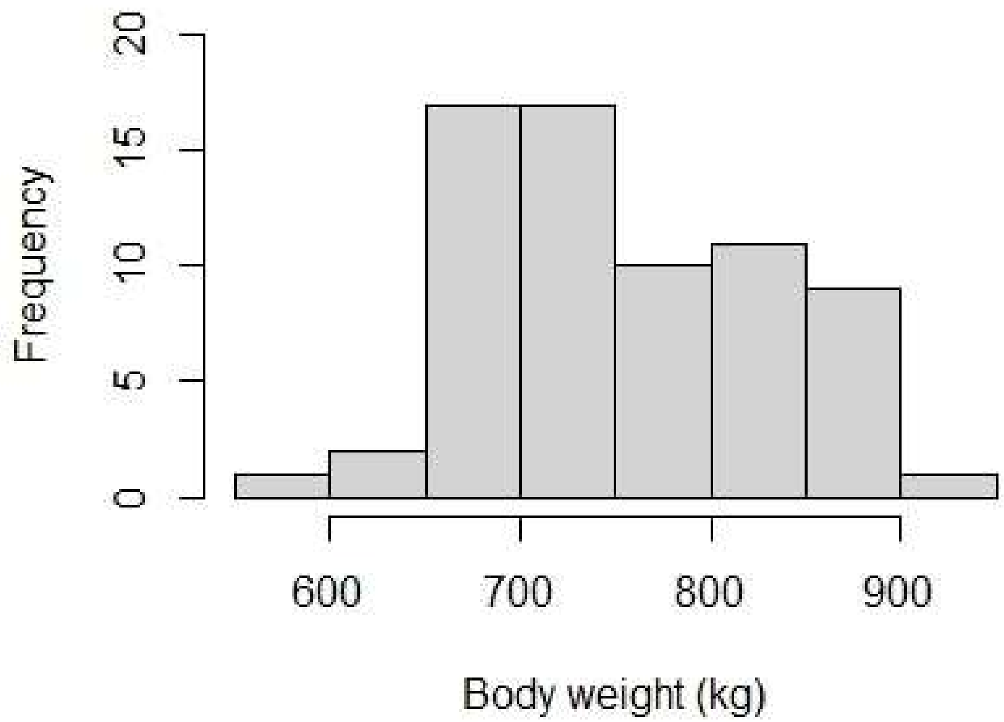

Figure 7: Histogram to show the body weight for pre calving cows.

Figure 8 shows the positive association between body condition score and body weight, with parity one representing low body weight and high body condition score animals in the data set. A line displaying a smoothed conditional mean is shown for heifers and cows separately.

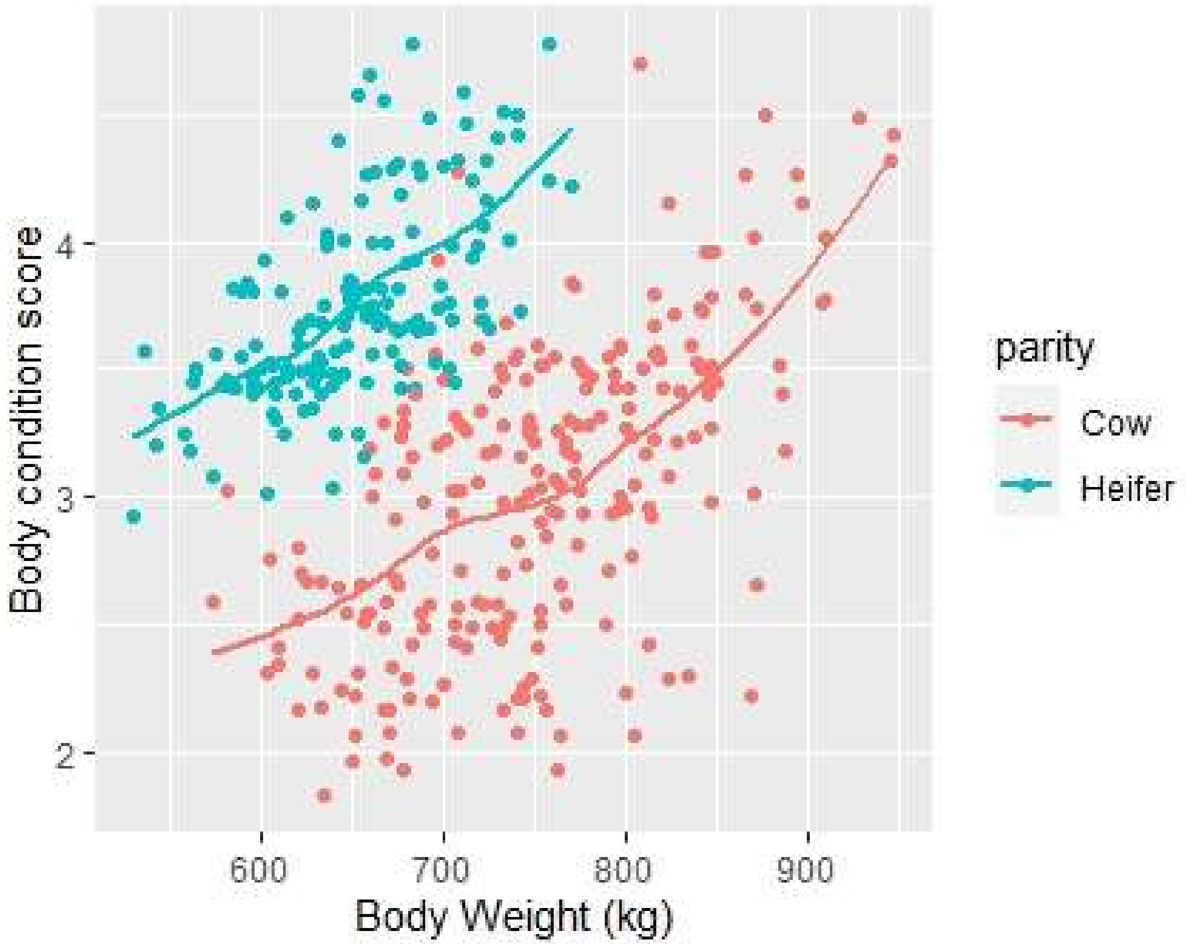

Figure 8: A scatter plot showing the relationship between body weight and body condition, highlighting the effect of parity (Red = cow and Blue = Heifer).

3.1.3 Body condition score and body weight change

The positive linear relationship between body condition score and body weight change is displayed in Figure 9.

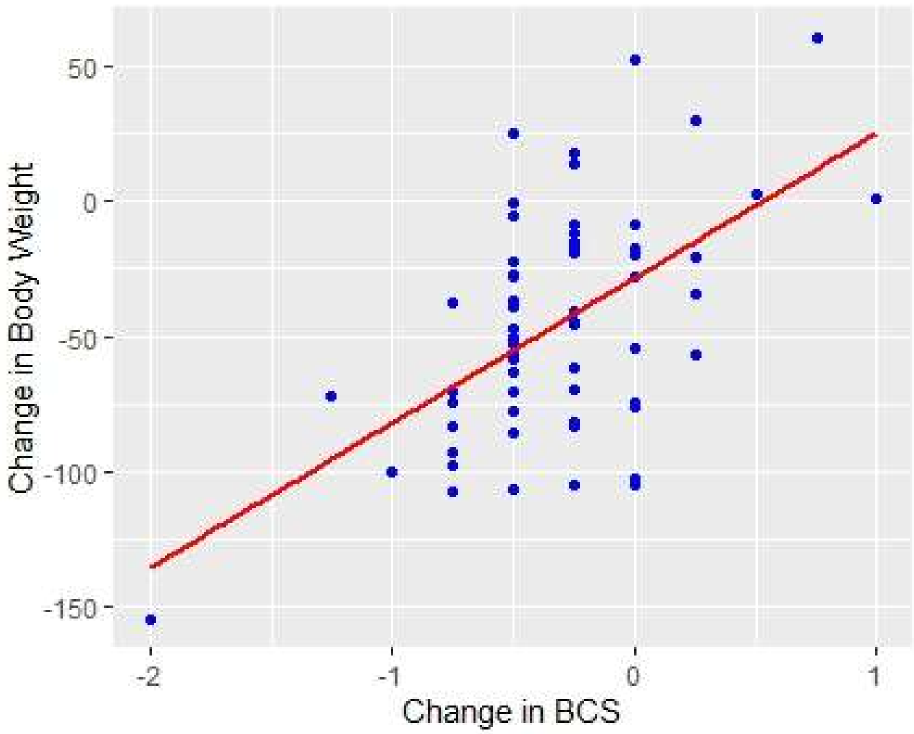

Figure 9: A scatter plot to show the relationship between change in body weight and body condition score.

Out of the total data set (n = 64), 10 cows had no change in body condition score, this resulted in the change in body condition score data set including 54 cows. Out of the total 54 cows that experienced a change in body condition score, 41 cows gained or lost ≤ 0.5 of a condition score, equating to 75.9% of body condition score change. Specifically, 5 cows gained ≤ 0.5 of a body condition score and 36 cows lost ≤ 0.5 of a body condition score. The remaining 13 cows out of the total 54 cows experiencing a change in body condition score gained or lost >0.5 of a condition score. The frequency of cows within each body condition score change category is displayed in Figure 10.

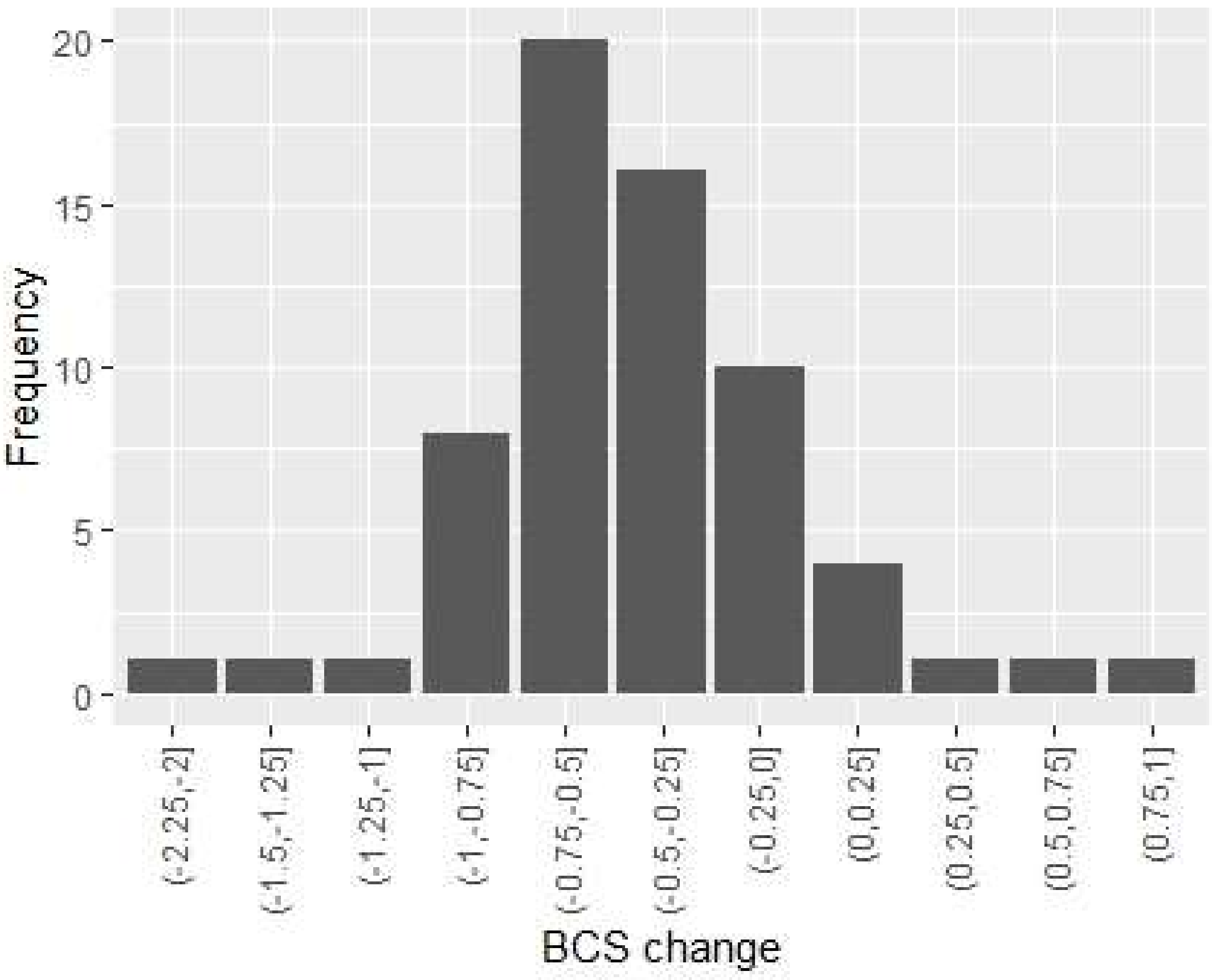

Figure 10: A bar chart to show the frequency cows within each body condition score change category, separated by 0.25 of a condition score

3.1.4 Days in Milk

The mean days in milk (DIM) at point of enrolment was 19.3 days prior to calving, with the maximum and minimum values being 32 days and 2 days prior to calving. The days in milk at point of enrolment for each cow is referred to as the minimum days in milk. For each cow the days in milk for the last repeat measurement was noted and recorded as the maximum days in milk. The maximum days in milk (DIM) inter quartile range (IQR) was 49.75 days (q1 = 93.75, q3 = 143.50) and the median maximum DIM was 123 days. This minimum and maximum days in milk are displayed in the box plot in Figure 11.

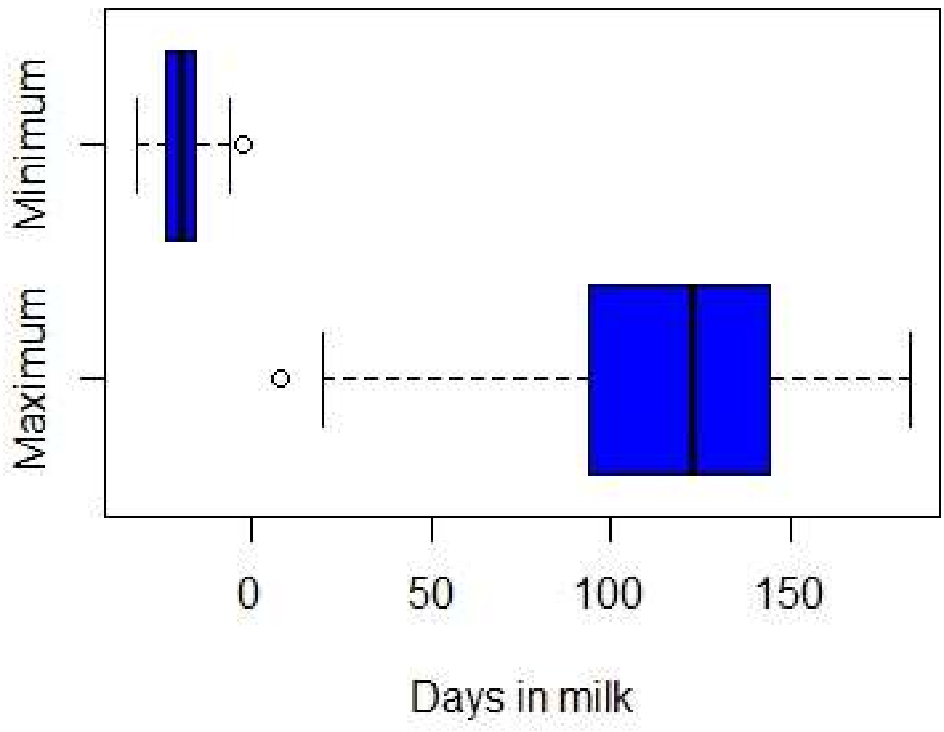

Figure 11: A box plot illustrating the distribution of the minimum and maximum days of milk in the study.

3.1.5 Milk Yield

The relationship between daily milk yield and days in milk is shown in Figure 12. The mean days in milk for the high yielding animals, > 60 litres, was 72.59 days in milk, with the days in milk for these animals ranging from 30 to 134 days. Between 0 and 73 days in milk, the calculated mean for peak yield, the median daily milk yield was 40.9 litres, with the minimum and maximum values being 16 litres and 69.3 litres respectively. No clear relationship was found between daily yield and body condition score as displayed in Figure 13. The effect of parity is highlighted, with heifers being in higher condition than cows and cows yielding more than heifers.

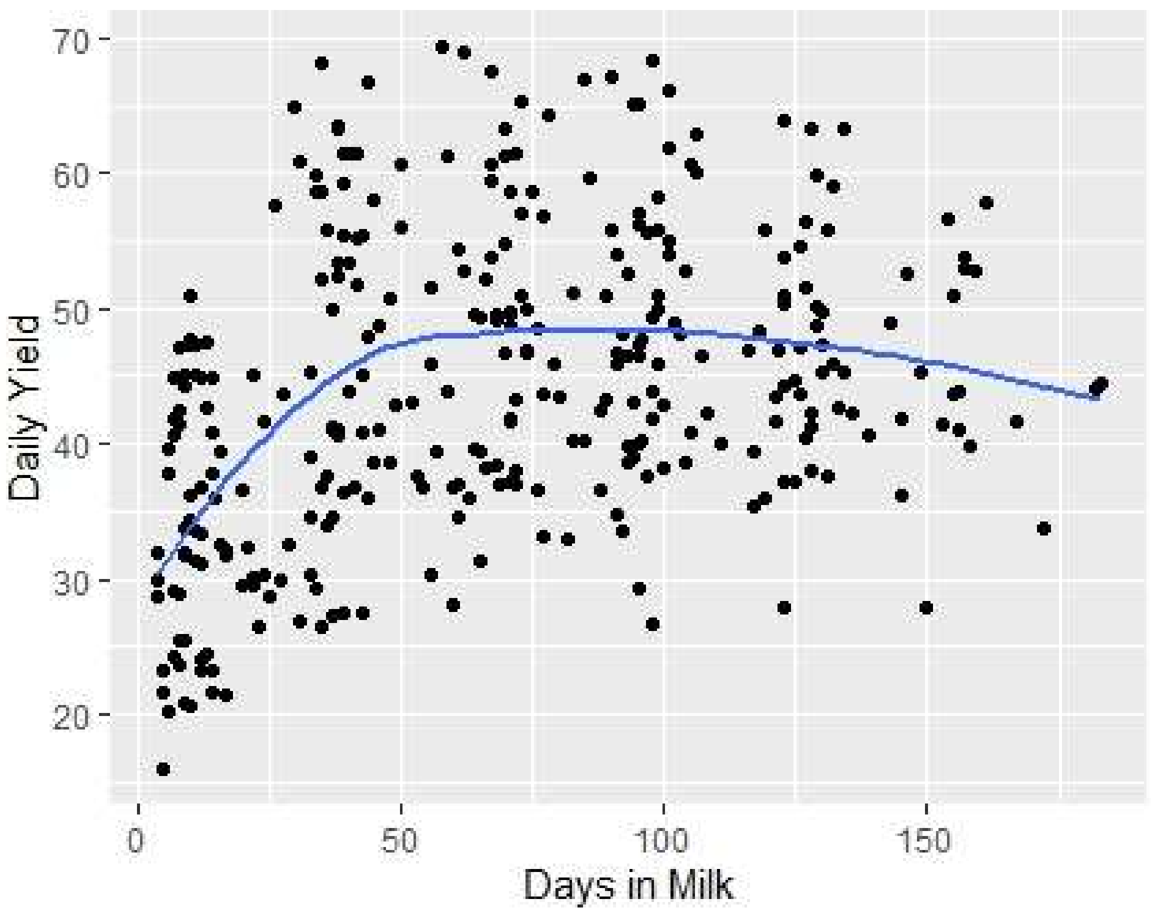

Figure 12: A scatter plot showing the relationship between daily yield (litres) and days in milk

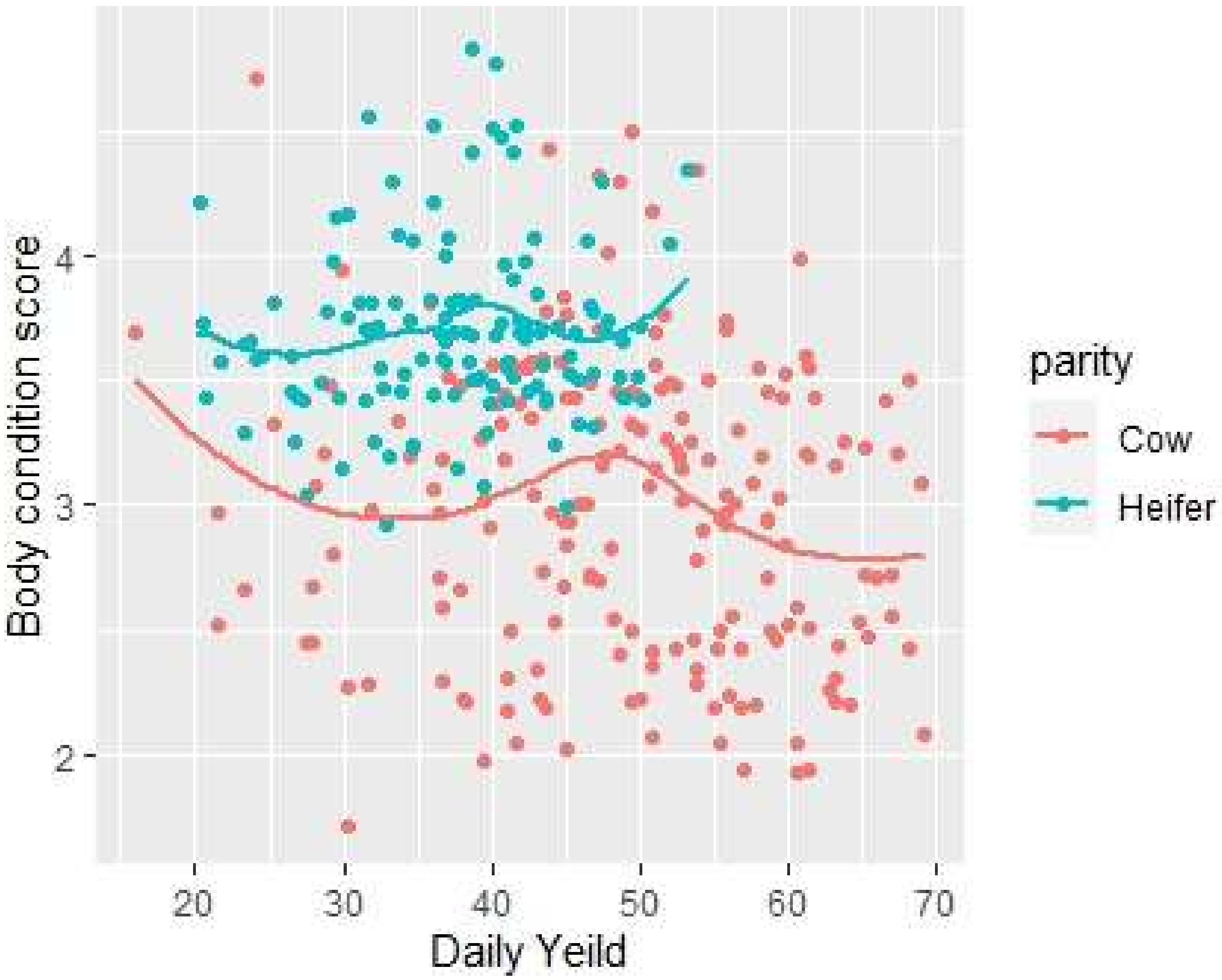

Figure 13: A scatterplot showing the relationship between daily yield and body condition score, highlighting the effect of parity (Red = cow, Blue = Heifer)

3.1.6 Rumen Fill Score

The distribution of the rumen fill score (RFS) for the whole data set is displayed in Figure 14. 326 recordings had a rumen fill score ≥ 3, corresponding to 84.5% of the total of rumen fill score recordings (n=386). Rumen fill score 3 is most represented in the data set with 60.9% of total rumen fill score recordings being rumen fill score 3.

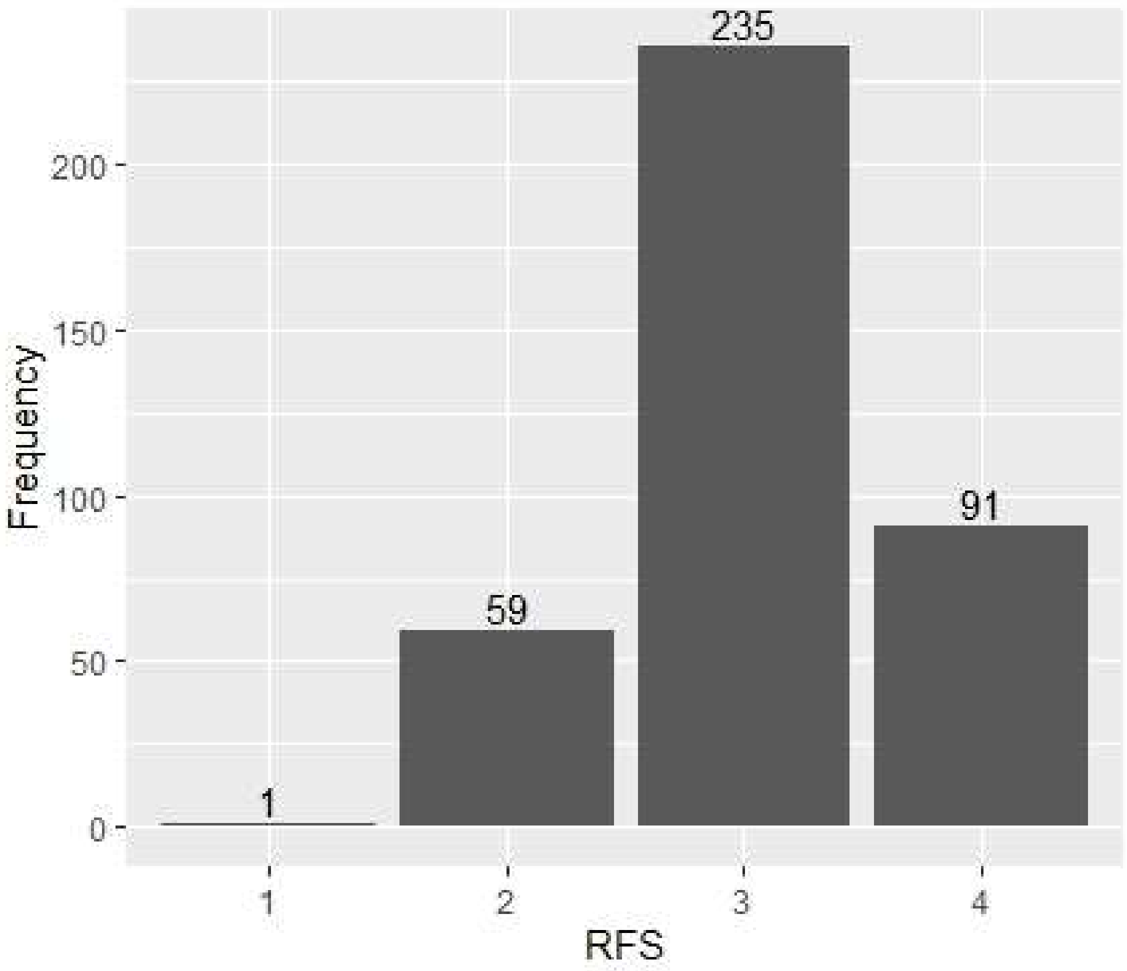

Figure 14: A bar chart showing the distribution of rumen fill scores across the whole data set.

Figure 15 provides a visualisation of the distribution and density of body condition score across each rumen fill score. The median body condition score for rumen fill score 2 was lower than that for score 3 and 4. The shape of distribution for rumen fill scores 3 and 4 indicates that the body condition scores for these scores are highly concentrated around the median.

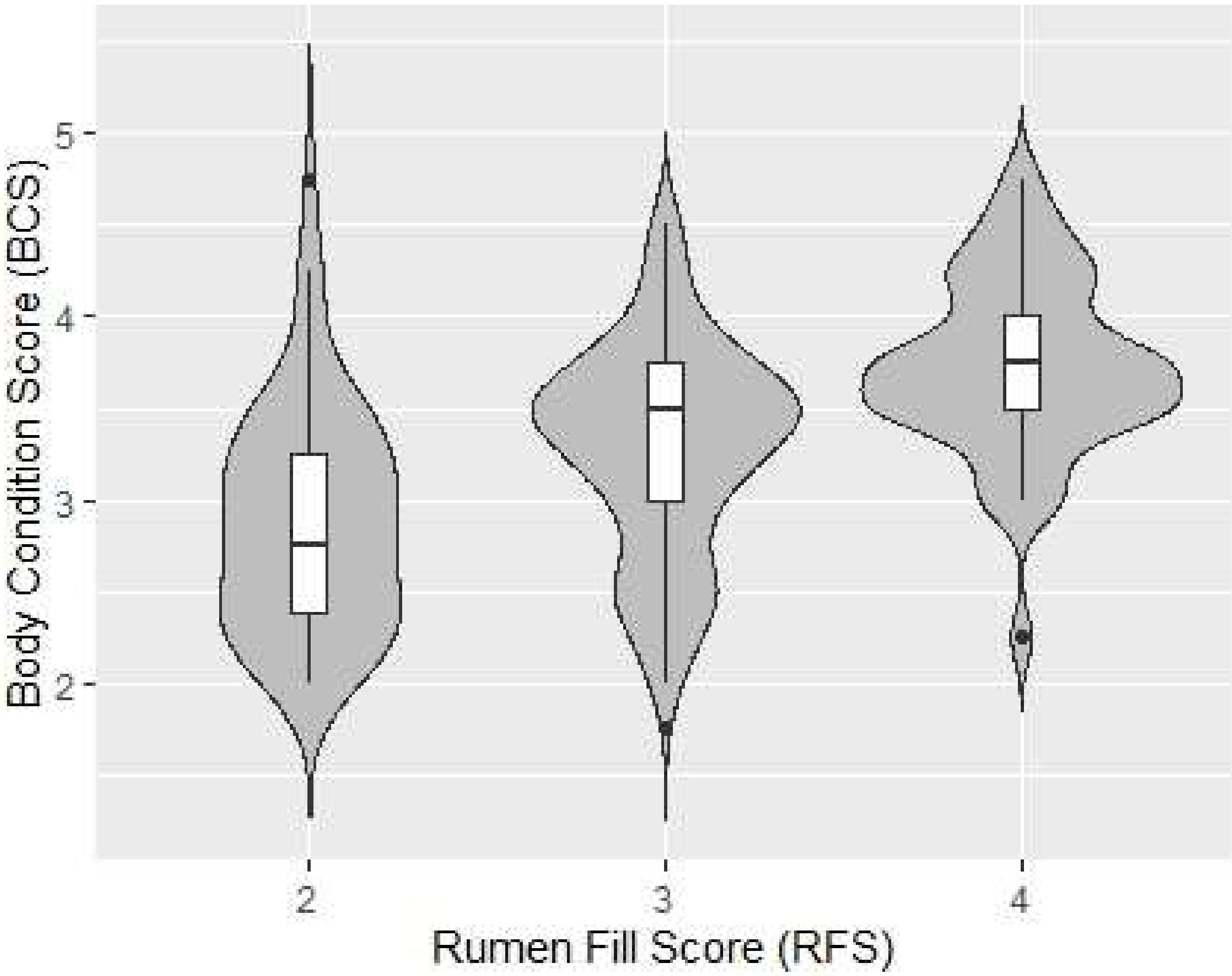

Figure 15: Box and violin plot showing the distribution of body condition scores for each respective rumen fill score.

3.1.7 Body condition score and stature measurements

A correlation matrix was calculated to determine correlation coefficients between pairs of variables in the dataset. Variables with a correlation coefficient of > 0.7 were put into the final matrix. Variables with a positive correlation and a correlation coefficient of > 0.7 were belly girth and heart girth (0.77), body weight and length diagonal (0.70) and body weight and heart girth (0.76). Bivariate scatter plots and histograms of these variables and the absolute value of the Pearson correlation are displayed in Figure 16.

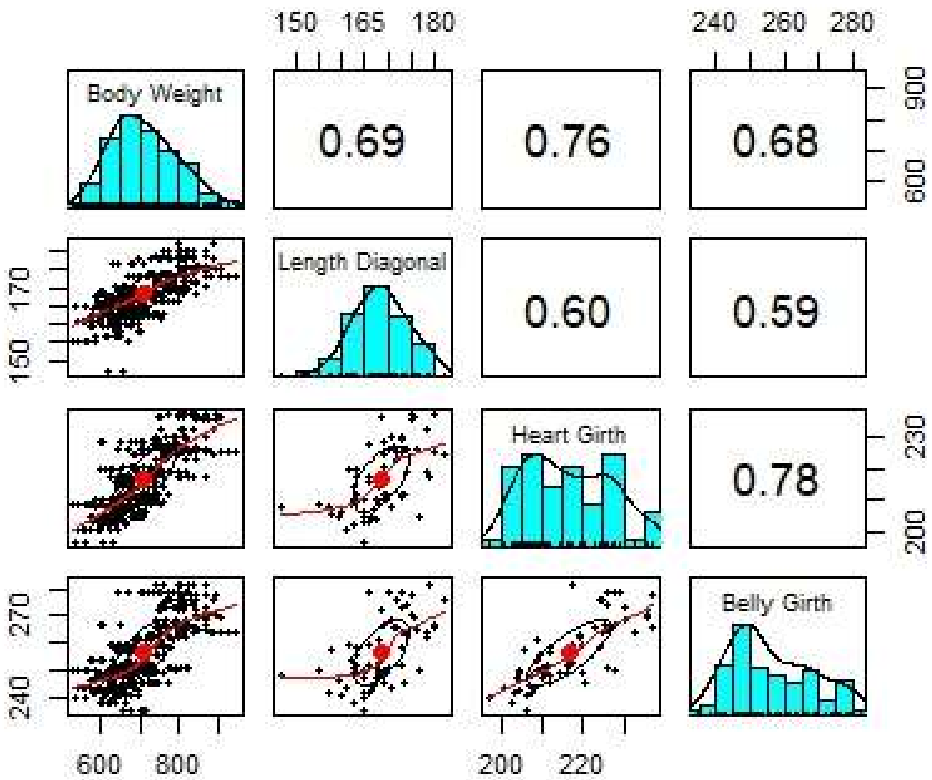

Figure 16: A pairs panel allowing visualisation of the correlations between variables, bivariate scatter plots below the diagonal and pearson correlation above the diagonal with histograms of variables on the diagonal.

3.2 Statistical analysis

3.2.1 Linear regression

The linear regression model (Model 1) was used to explore the relationship between change in body condition score and change in body weight. A regression coefficient of 53.59 was calculated, meaning that, in this model, with each additional unit of body condition score a cow's body weight would increase by 53.59kg. The overall regression was identified to be significant. The calculated R^2 variable for the model was 0.317, 32% of the variance found in the response in body weight could be explained by body condition score. The residuals were symmetrically disturbed as presented in Figure 17, indicating good model fit.

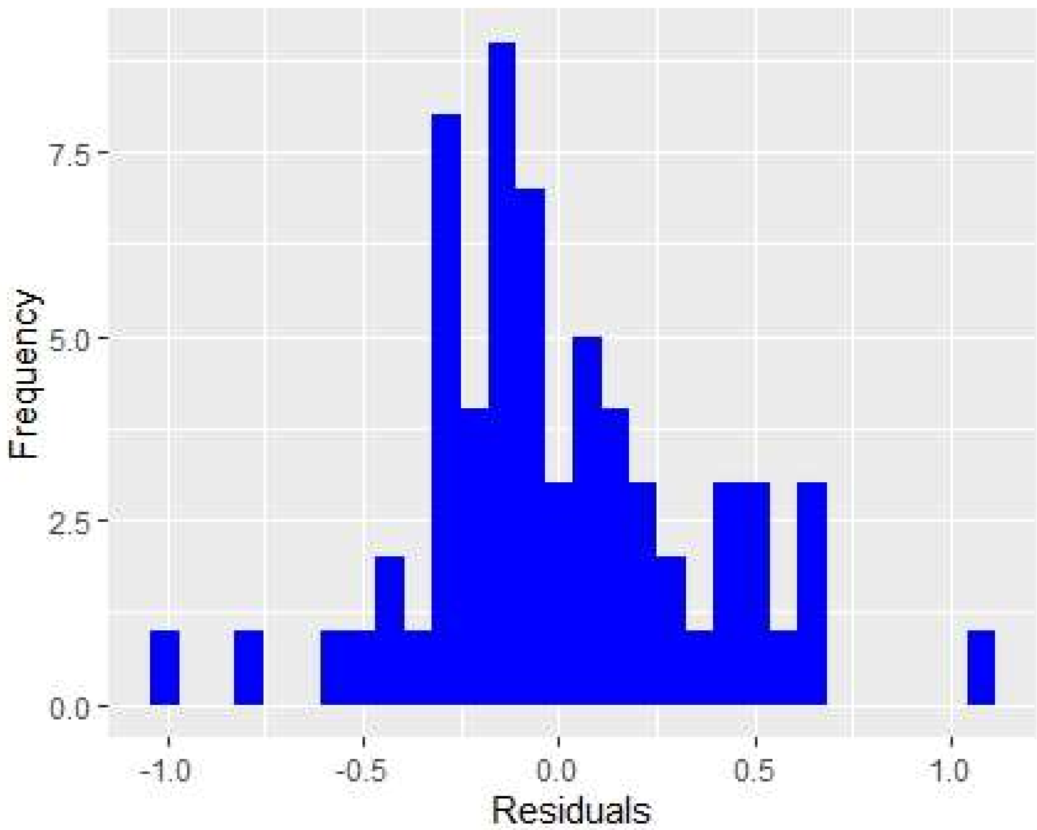

Figure 17: A histogram to show the residuals for the linear regression model (Model 1)

3.2.2 Data modelling

Model 2, the support vector machine with a polynomial kernel, was the best performing model to predict body condition score from 12 predictor variables. The mean absolute error (MAE) in cross validation for this final model was 0.3; that is on average the model predicted to within 0.3 of a body condition score. Figure 18 shows a plot of observed BCS values against cross validated predictions.

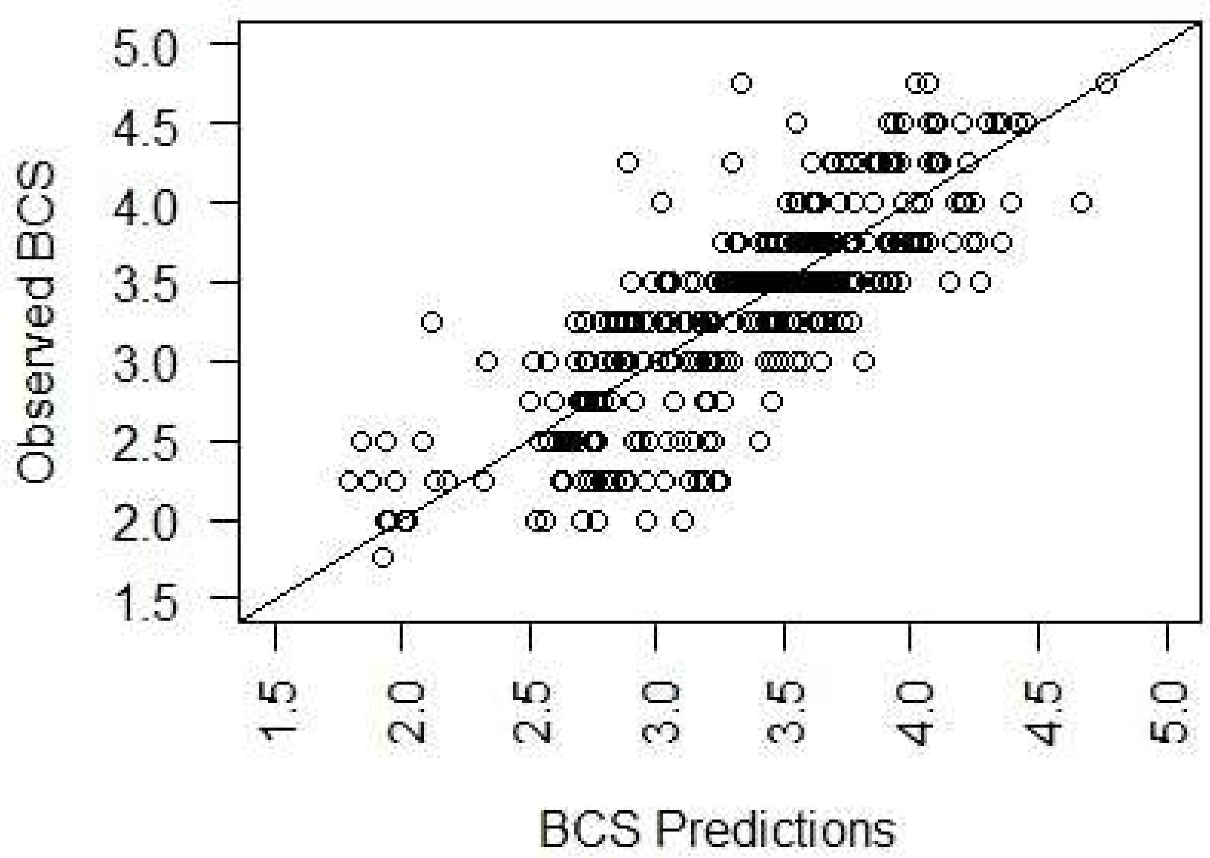

Figure 18: A scatter plot displaying the relationship between the observed and final model predicted body condition score (BCS)

The final model 2 is illustrated in Figure 19. Figure 19 displays the predictions to the nearest 0.5 and the distribution of data based on minimum, first quartile (Q1), median, third quartile (Q3) and maximum. The outliers are represented by a solid point and are determined using the interquartile range (IQR) criterion. The

IQR criterion means that all observations above q0.75 + 1.5 IQR or below q0.25 – 1.5 IQR are considered as potential outliers. The final model allows us to differentiate between 2, 3, 3.5 and 4 with no overlap between the middle 50% of all predictions of each of those body condition score. The spread of observed body condition scores relative to the predictions is greatest at BCS 3, displaying the greatest IQR range. The smallest IQR range at BCS 2.5 and 3.5 with the median the same as the first quartile. There is no differentiation between 2.5 and 3 and an overlap in the middle 50% of 2.5 BCS predictions with BCS 3. In the actual data set, there were only 37 BCS 2 animals and 31 BCS 2.5 animals, with 82% of body condition scores being ≥ BCS 3.

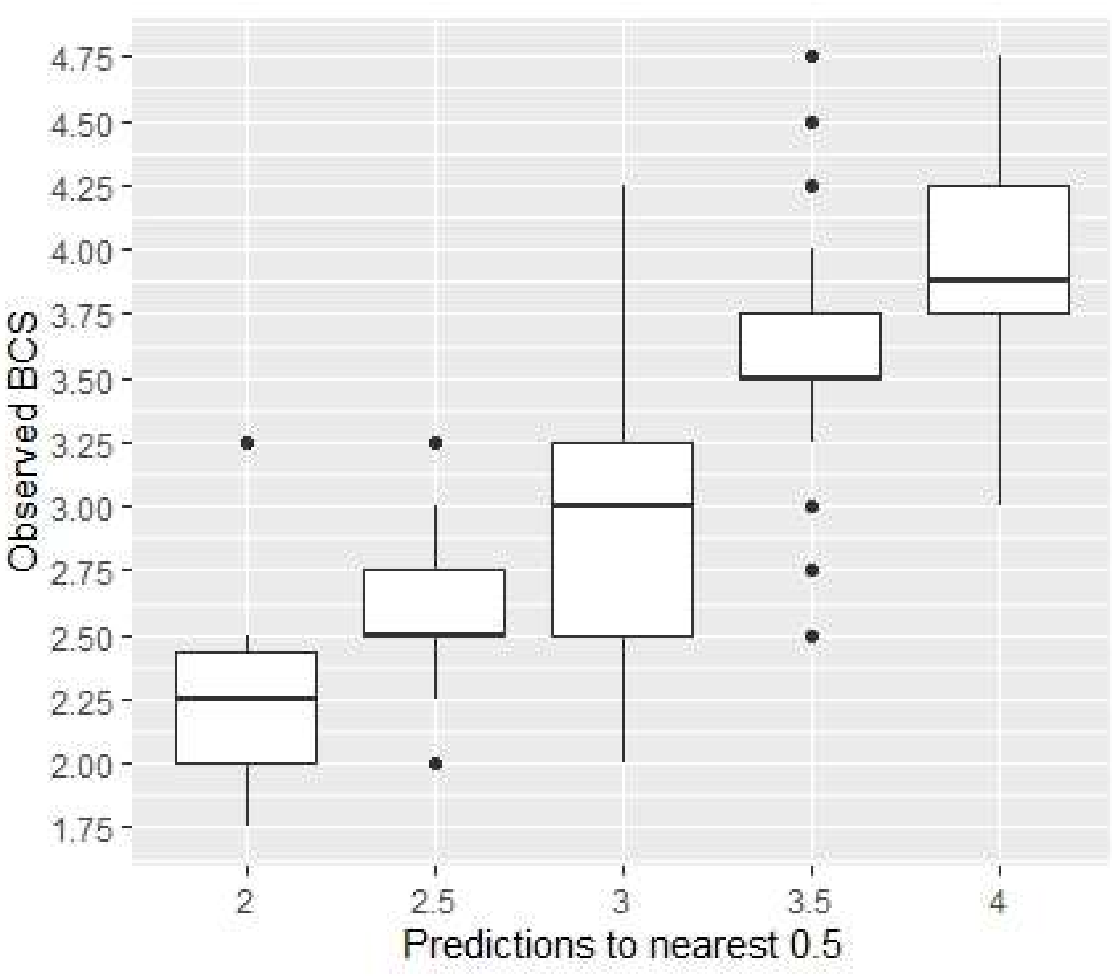

Figure 19: A boxplot displaying the final model predicted body condition scores to the nearest 0.5 against observed body condition score.

Chapter 4: Discussion

The study investigated whether body condition score could be accurately predicted from body weight and cow stature measurements when accounting for lactation number, days in milk and rumen fill score. The cow stature measurements chosen in this model were based largely on previous research and the relationship to either body weight or body condition score. This is the first study to develop a machine learning model to predict body condition score by combining cow stature measurements and body weight. An accurate prediction of body condition score is invaluable due to the known effects of absolute body condition score or body condition score loss on reproductive performance and transitional disease (Roche *et al.*, 2009). The best performing cross validated model had a mean absolute error of 0.3, meaning on average the model predicted body condition score (on a scale of 1-5) to within 0.3 of a body condition score.

Body condition score model predictions were rounded up to the nearest 0.5 of a body condition score and compared to the actual observed body condition scores. Scientific evidence emphasises the importance of early identification of condition score loss at an intervention level of 0.5 of a score (Reksen *et al.*, 2002). When model predictions to the nearest 0.5 of a body condition score were compared to actual observed body condition score it was possible to differentiate between body condition scores 2, 3, 3.5 and 4, meaning that there was no overlap between the middle 50% of all predictions of each of those body condition scores. There was no ability to differentiate between 2.5 and 3 with an overlap in the middle 50% of all the 2.5 BCS predictions with BCS 3. The relationship between cow body weight, stature and body condition score is not straightforward or similar between cows, especially when trying to predict under conditioned animals < 3.0.

Body fat is distributed into two main compartments known as subcutaneous adipose tissue (SAT) and visceral adipose tissue (VAT). In human medicine the SAT deposit represents 80% of healthy individuals total fat mass (Lafontan and Girard, 2008). Body condition score in cows is a measurement of subcutaneous fat coverage and lacks sensitivity to detect visceral fat deposition, this is of particular importance in over conditioned cows (Drackley *et al.*, 2014). The different proportions of VAT and SAT in human medicine has been shown to be dependent on many factors including sex, age, race, ethnicity, genotype, diet, physical activity, hormone levels and medication (Shuster *et al.*, 2012). It is known that dairy cattle accumulate larger proportions of visceral fat than subcutaneous fat when compared to beef cattle (Wright and Russel, 1984). However, little is known in veterinary medicine about changes in mass or function of proportions of different fat compartments. It has been suggested that a greater proportion of abdominal fat is mobilised in negative energy balance compared with subcutaneous fat (Raschka *et al.*, 2016). In addition, in the newly calved cow fat represents 69% of total body energy and 20% of total fat is associated with the digestive tract (omental and mesenteric) (Gibb *et al.*, 1992). Bines, Butler-Hogg and Wood 1985) highlighted the proportion of subcutaneous fat was greater for non-pregnant cows and the proportion of intermuscular fat was greater for pregnant cows. Drackley et al. (2014) experimentally fed a high energy diet compared to a low energy diet to non-lactating cows for 8 weeks. This resulted in greater bodyweight and increased omental, mesenteric and peri renal adipose tissue masses without significant difference in body condition score. This highlights the importance of being able to quantify abdominal fat stores. Adipose tissue is now well recognised to be a very important and active endocrine organ, with different adipose tissue depots reacting differently to metabolic stimuli (Mittal, 2019). In the medical sector, increasing importance is being attributed to visceral adipose tissue (VAT) and its relationship with various diseases and association with developing metabolic signs with extensive VAT accumulation. The inaccuracy to predict cow body condition scores at the extremes from bodyweight and stature measurements in this study could be due to the lack of understanding in distribution of subcutaneous and visceral adipose tissue in cattle. Gregory et al. (1998) suggested a curvilinear relationship between condition score and body fat, with no real change in fatness until condition score 3 is reached. Historically in research studies comparisons have been made between body condition score and output measures such as reproductive performance and transitional disease risk. However, it is questionable whether this is the right comparative measure to use as this is a late and blunt tool to determine energy reserves and is mostly likely to reflect the extremes of animals, the underconditioned cachexic animals and the over conditioned extended lactation animals. Additionally, body condition score has high inter observer variability and poor sensitivity for detection of visceral fat. As an industry should we be utilising more of the readily available objective measurements such as body weight.

A secondary aim of this study was to evaluate the direct relationship between body condition score and body weight. Body condition score was positively correlated with body weight and a significant relationship was identified. In the current work, a one-unit difference in BCS when using a 5-point scale corresponded with a 53.6kg body weight increase. Berry, Buckley and Dillon (2011) reported a similar relationship in Irish Holstein Friesian cows where a one-unit BCS difference on a 5-point scale represented 50kg. The relationship found in this study and the Irish study were considerably less than reported in Holstein Friesian cows in New Zealand which reported a 31kg live body weight change for every unit of change in BCS on a 10-point scale, equating to 77.5kg/BCS unit on a five-point scale (Berry *et al.*, 2006). It is known that the correlation between body condition score and body weight is variable between different parities, stages of lactation and breeds of cow. A study of Holstein Friesian cows in New Zealand reported the weakest correlation between live body weight and body condition score in primiparous cows (0.49), whilst the strongest was in 2nd parity (0.63) and the correlation declined thereafter as parity increased (Berry *et al.*, 2006). The weak correlation in primiparous cows between live weight and body condition score, could be explained by the fact at first calving and post calving they are only 94% and 85% of mature body weight (Akins, 2016). The relationship between live body weight and BCS varies with stage of the inter calving interval. Berry, Buckley and Dillon (2011) reported the strongest correlation (0.59) at 10 – 50 days post calving and the weakest correlation (0.50) at 101-200 days post calving. Likewise, Jaurena et al. (2005)

reported that when using a 5-point scale, one unit of body condition score was associated with a change of body weight of 35kg in the dry period and 21kg in lactation. This difference between the findings reported in this study in comparison to other studies could be because the current study examined body condition score change across the dry period and mid-lactation.

4.1 Study design limitations

In this study body condition scoring was used as the gold standard measurement alongside no other comparative measure. Hussein, Westphal and Staufenbiel (2013) showed back fat thickness (BFT) to have a high correlation with BCS and therefore in this study a BFT measurement could have been included to assist with standardisation and validation of the BCS measurements. Improvements of accuracy at the extremes of body conditions score could have been further improved by helping to determine the distribution of visceral adipose tissue in the predictive model. Raschka et al. (2016) describes a technique of carrying out a series of ultrasound measurements of the retroperitoneal, mesenteric and omental adipose tissue. Throughout the study the assumption was made that stature measurements remained the same and these measurements were obtained only once at enrolment. There is limited research investigating the change in body measurements over time to support this assumption. Berry et al. (2005) looked at horizontal length, heart girth and withers height from birth to 100 days and 600 days. Average daily increase in length, girth and withers height at 100 days was 0.11cm, 0.24cm and 0.17cm respectively. The average daily increase in length, girth and withers height between 100 and 600 days was smaller in comparison to the first 100 days and was 0.09cm, 0.14cm and 0.08cm respectively. The time frame identified in this study corresponds to sexual maturity and associated skeletal development and although stature measurements were obtained throughout the first three lactations no analysis was conducted beyond 600 days. Research has suggested that when assessing overall carcass weight no trend was identified with carcass length and that the increase in weight was found to be attributed to soft tissue rather than skeletal size (Gregory *et al.*, 1998). Supporting the assumption that any change in body measurements is significant or in fact occurs in sexually mature animals. It is important to consider that this study was based on one high yielding Holstein Friesian dairy herd that were housed year-round, and characteristics may vary on different farms and with different breeds. Additionally, the study population mean pre-calving body condition score was 3.5, this is above the industry target for body condition score at calving of 2.5 – 3 (Garnsworthy, 2006). These study animals reflect an over conditioned herd and therefore the findings may not be representative of the dairy herd population. Over conditioned cows may further exacerbate the condition score loss in early lactation due to the suppressed appetite and excessive fat mobilisation (Reid *et al.*, 1986). Therefore, further validation of these results is required in different farming systems to ensure consistency of the prediction.

4. 2 Future work

The findings and limitations of the study have highlighted the opportunities for future research. There is value in gaining a better understanding of fat distribution in cattle, with analysis of body condition score and body weight at the live animal level and total body fat, inter muscular fat, visceral fat (omental, mesenteric and perinephric) at a carcass level. This would help to determine proportional fat distribution and the relationship with body condition score. Adding a measurement of visceral fat such as inter muscular fat into the ribs may help to improve a predictive model performance. The advancement of technology may enable measurement of some internal fat stores instead of determining this at a carcass level. An understanding of the importance different adipose sites and their response to metabolic stimuli plus associations with various diseases in the medical sector raises the importance of this in the veterinary sector. Additionally, determining the change in stature measurements over time with age and the subsequent effect on body condition score may be of value.

4.3 Conclusion

The literature highlights the significant impact of body condition score on production, health and welfare and the benefit of an optimal body condition score profile to minimise body condition score loss and to ensure maximal production and minimal peri parturient disease and lameness. This study found that body condition score could be predicted to within 0.3 of a body condition score from body weight and cow stature measurements. However, the final model had poor differentiation between BCS 2.5 and 3 and BCS >4 was poorly represented. A lack of understanding of the relationship between subcutaneous fat and visceral fat and the impact of it on condition may help to explain the poor differentiation at a low body condition score. More research is required to further investigate the distribution of fat deposits in cattle and the role and significance of different adipose depots.

Body condition scoring is a valuable management tool that is currently underutilised in an on-farm setting but used in numerous research projects as a risk factor for health and production outcomes. The rising profile of animal welfare in the media is putting pressure on the industry to optimise cow health and condition and ensure optimal condition score. The reported poor sensitivity and inter observer variability of body condition score calls for the need for an advancement in technology to determine condition score accurately or a shift in the parameter used to compare to health and production outcomes. The advancement in technology in the veterinary field is an exciting space and one that is rapidly growing. These advancements are promising and may facilitate regular body condition score monitoring on farm.

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6. Appendix

AHDB

Body condition scorecard

What is body condition scoring (BCS)?

BCS was developed around 20 years ago and is widely accepted as a practical means of assessing the impact of negative energy balance in early lactation. Scores range from 1 to 5 in increments of 0.25.

This system concentrates on the accurate determination of scores between 2.0 and 4.0 as these are the most critical for management decisions. Scores outside these values are extreme; those below 2.0 are seriously underconditioned and require immediate attention, as do those at 4.0 and above which are overconditioned and require controlled weight loss.

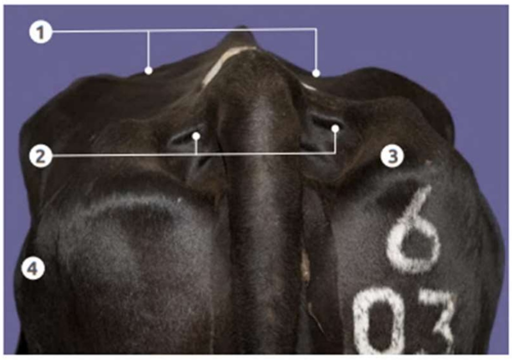
Scorers using this system will be able to assign BCS consistently and accurately.

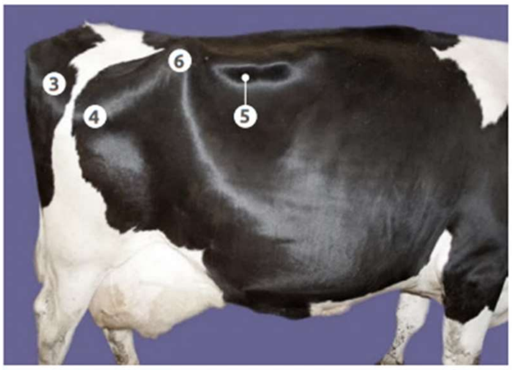
When to condition score

The change in body condition score is more important than the absolute value, therefore scoring should be undertaken regularly. A good routine involves scoring:

Stage of lactation	Target BCS
At calving	2.5–3.0
60 days post-calving	2.0–2.5
100 days before drying off	2.5–3.0
At drying off	2.5–3.0

Further information on how to body condition score can be found on the AHDB website, including a short training video, see: **ahdb.org.uk/knowledge-library/body-condition-scoring**





1. Sacral ligament **2.** Tailhead ligament
3. Pins **4.** Thurl **5.** Short ribs **6.** Hooks

1 Assess the angle between the hooks and pins.

The first decision you make will divide cows into two groups: those with a BCS less than or equal to 3, and those with a BCS greater than 3.

This decision may be the most difficult one in the BCS process, especiallyif the cow is near a 3.0 or 3.25 BCS.

V – angle has a BCS less than or equal to 3. Follow the dark blue steps on page 2, in the left-hand column.

U – angle has a BCS greater than 3. Follow the green steps on page 2, in the right-hand column.

BCS less than or equal to 3

2 Standing at the rear of the cow, assess whether the hooks are rounded or angular.

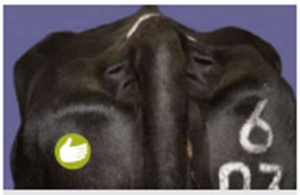

Rounded hooks: BCS = 3.0


Angular hooks: BCS = 2.75 or less

3 Refine the score '2.75 or less' by evaluating the pins.


Padded pins: BCS = 2.75

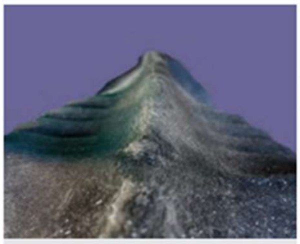
4 Now we need to feel the pins to assess the presence of a palpable fat pad (one that is not visible to the eye but can be felt) to refine the score of '2.5 or less'.


Palpable fat pad on pins: BCS = 2.5


No palpable fat pad on pins: BCS = 2.25 or less

5 Evaluate the visibility of the short ribs:

- Look for the bony ridges of the short ribs
- Estimate the distance these ridges are easily seen from the tip of the short ribs to the spine
- Are the ridges visible half of the distance, three-quarters of the distance, or more?


Ribs visible halfway to the spine: BCS = 2.25


Ribs visible three-quarters of the distance to the spine: BCS = 2.0

6 Cows with sawtooth spine and ribs are severely underconditioned and will score less than 2.0.

BCS greater than 3

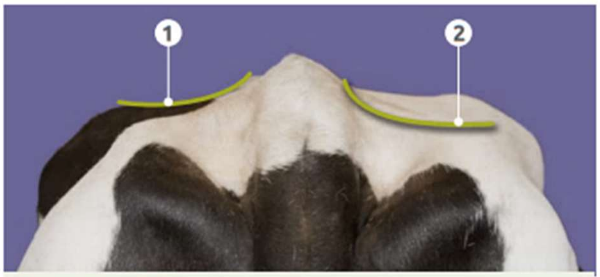
2 Standing at the rear of the cow, assess whether both the sacral and tailhead ligaments are fully visible.

1. Sacral ligament 2. Tailhead ligament

Sacral visible. Tailhead visible. Both ligaments easily seen. BCS = 3.25

3 Continue to assess the visibility of the ligaments. The tailhead ligament will become covered in fat first.

1. Sacral ligament 2. Tailhead ligament



Sacral visible. Tailhead barely visible. Tailhead ligament partly covered in fat. BCS = 3.50

4 The tailhead is now completely covered. Assess the visibility of the sacral ligament to determine a score of 3.75 or 4.0 or more.

- Sacral barely visible
- Tailhead not visible
- Neither ligament easily seen
- BCS = 3.75

- Sacral not visible
- Tailhead not visible
- Neither ligament visible
- Will score 4.0 or more

- All bony prominences rounded and covered in fat
- Tailhead buried in fat
- Fat deposits readily seen on rump and legs
- BCS = 5.0

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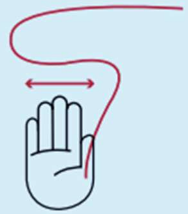
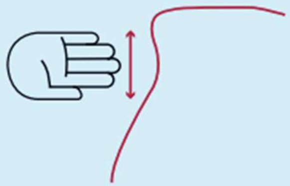
Score 1		Deep dip in left flank, more than one hand width deep after last rib. Skin curves under lumbar vertebrae one hand's width. Skin fold from hook bone falls vertically, so hollow shape looks rectangular. This cow has eaten nothing in the last 24 hours.	
Score 2		Dip in left flank, one hand with deep after last rib. Skin curves under lumbar vertebrae, half a hand's width. Skin fold from hook bone runs diagonally, so hollow shape looks like a triangle. Not unusual in 1st week after calving, but after that it signifies a problem/too little intake. The 'danger triangle'.	
Score 3		Slight dip visible in left flank, after last rib. Skin under lumbar vertebrae runs vertically down for one hand's width before bulging out slightly. Skin fold from hook bone is hardly visible. This is the desired score for milking cows having sufficient intakes.	
Score 4		No dip is visible in left flank, after last rib. Skin under lumbar vertebrae curves outwards. Skin fold from hook bone is not visible. This is the correct score for milking cows at the end of lactation and through the dry period. It is the target minimum score for pre-calvers.	
Score 5		Skin is flat, or slightly bulging, on the left flank, after last rib. Skin under lumbar vertebrae curves outwards, so that bones are not visible. The skin over the whole belly is quite tight, and there is no visible transition between the flank and the ribs. This score is often seen in dry cows.	

7. Clinical Portfolio

The content in this chapter will demonstrate the clinical developments and professional achievements throughout the clinical training scholarship. The clinical training scholarship has focused on dairy herd health and production with particular focus to fulfil the requirements for the European college of Bovine Health and Management residency program.

The main requirements of the residency training program are completion of a three-year full time supervised training postgraduate education under direction of a supervising diplomate. During this period, it is necessary to complete the following:

- 65% of the programme spent in clinical activity, either at herd of individual level
- 20% of programme undertaking research and scholarly activities
- Seminars and teaching responsibilities
    - Present a minimum of 6 seminars
- Attendance of conferences, seminars and workshops:
    - Attend and participate in at least 2 ECBHM Resident Workshops
    - Attend a minimum of 3 national or international veterinary or animal science conferences
    - Give at least one presentation/ paper at a national or international scientific conference
- Ancillary topics:
    - One week of active participation in a clinical pathology laboratory
    - Participation in at least 30 bovine necropsies
- Research and scholarly output
    - Completion of a research project
    - Two publications in the field of bovine health management
    - Five case reports (Max 5 herd health and Max 2 Individual animals)
- Evaluation of progress
    - Weekly meetings with primary supervisor

Details of how each criterion was met and supporting evidence is included in depth below.

7.1 Individual and herd health cases

Individual animal cases were gained through a mixture of teaching University of Nottingham undergraduates at the University dairy farm and the associate farm practice Scarsdale. Every three months I undertook a clinical period at the associate farm practice. Further exposure to clinical cases was obtained through externships at Bishopton Vets, North Yorkshire and Green Counties Vets, Surrey working alongside Oli Maxwell an ECBHM diplomat. This helped expand the breadth of cases and gave me the opportunity to work alongside certificate holders and diplomats. The majority of my herd health cases were obtained by assisting the core and advanced herd health final year rotations. This involved in depth analysis of health and production data, a primary farm visit followed up by a on farm presentation of findings of analysis and recommendations plus a written report. The role of the resident was to facilitate analysis and support the students as well as complete more in-depth analysis projects themselves. The individual and herd health cases completed throughout the three-year residency program are included below.

	Individual cases	**Herd Health cases**
Year 1	114	100
Year 2	100	106
Year 3	87	79

7. 2 Seminars, conferences and workshops

The seminars presented and attended throughout the three-year residency program are listed below, detailing the duration, the type of the event and the participants present. Additionally, the conferences attended are stipulated, no international conferences were attended due to completion of the residency during a pandemic. My research findings from this masters was presented at the ECBHM Online Science Conference.

7.2.1 Seminars and teaching responsibilities

Date	Duration and Location	Topic	Type of event	Participants
19/06/20	45 mins plus 15 mins questions	Laboratory evaluation of a novel rapid tube test system for differentiation of mastitis causing pathogen groups	Journal Club	Clinical staff + Postgraduates
05/06/20	45 mins plus 15 mins questions	Pasture access affects behavioural indicators of wellbeing in dairy cows	Journal Club	Clinical staff + Postgraduates
09/04/20	45 mins plus 15 mins questions	Effect of student transrectal palpation on early pregnancy loss in dairy cattle	Journal Club	Clinical staff + Postgraduates
19/06/20	45 mins plus 15 mins questions	On farm culture literature review and update	Presentation	ECBHM Diplomates, Clinical staff and Residents
31/07/20	45 mins plus 15 mins questions	Comparison of bronchoalveolar lavage fluid bacteriology and cytology in calves classified based on combined clinical scoring and lung ultrasonography	Journal Club	Diplomates, PhD students + ECBHM Residents
18/01/20	45 mins plus 15 mins questions	An investigation into the relationship between body weight and body condition scoring	Ruminant Population Health AGM	Farm veterinarians, UoN clinicians, ECBHM Diplomates, PhD students + ECBHM Residents
12/03/21	45 mins plus 15 mins questions	Update on the university dairy farm	Presentation	ECBHM Diplomates, Clinical staff and Residents
14/07/21	45 mins plus 15 mins questions	Update on synchronisation and resynchronisation programs	TRP Presentation	ECBHM Diplomates + Residents
06/04/22	45 mins plus 15 mins questions	How bovine vaccines create an immune response and what that means for certain type of infections?	TRP Presentation	ECBHM Diplomates + Residents
15/06/22	45 mins plus 15 mins questions	Overview of mode of action, toxicity and pharmacology of commonly used antimicrobial classes in cattle	TRP Presentation	ECBHM Diplomates + Residents

7.2.2 Seminars and workshops attended

Date	Duration	Topic	Type of event	Speaker	Participants
3/6/2019-26/6/2020	3	Various	Farm animal rounds Fortnightly	Final year students, clinical staff	Clinical staff + Postgraduates
06/08/19	1	A new method of administering local anaesthesia for calf disbudding: Findings from a comparative on-farm study in New Zealand	Journal Club	Emily Payne/ Rebecca Nelson (Me)	Farm vets + residents
03/09/19	1	Predicting the probability of conception in dairy cows with clinical endometritis based on a combination of anamnestic information and examination results	Journal Club	Emily Payne/ Rebecca Nelson (Me)	Farm vets + residents
18/09/19	1	Cattle Foot Trimming: Research and Regulation	Webinar	Nick Bell, Gerard Cramer	BCVA Members
27/11/19	1	Abortion	Webinar	Pr. Michael Hassig	ECBHM residents
26/01/20	1.5	Quarter PRO: A new initiative for udder health	Webinar	James Breen	BCVA Members
26/03/20	2	Selective and deferred treatment of clinical mastitis in seven New Zealand dairy herds	Journal Club	James Breen	Clinical staff + Postgraduates
31/03/20	1.5	Clinical pathology workshop	Seminar	Peter Graham	Clinical staff + Undergraduates
06/04/20	1.5	Advanced nutrition seminar	Seminar	Chris Hudson	Clinical staff + Undergraduates
08/04/20	1	Left displaced abomasum discussion re different surgical approaches	Seminar	Ginny Sherwin, John Remnant	Clinical staff + Residents
14/04/20	1	Health planning and KPIs in suckler herds	Webinar	Joe Henry	BCVA Members
17/04/20	1.5	Lameness current literature discussion	Seminar	John Remnant	Clinical staff + Residents
21/04/20	1	Transition ration discussion	Seminar	Chris Hudson	Clinical staff + Residents

22/04/20	1.5	Clinical pathology workshop	Seminar	Peter Graham	Clinical staff + Undergraduates
23/04/20	1	Milking audit: the interaction between the machine - the milkers - the cows	Webinar	Dr. Ellen Schmitt	ECBHM residents
24/04/20	1	Impact of Endometritis on post-partum ovarian cyclicity in dairy cows	Journal Club	Emily Payne	Clinical staff + Postgraduates
28/04/20	1.5	Clinical Pathology workshop	Seminar	Peter Graham	Clinical staff + Undergraduates
30/04/20	1	Mastitis control with robotic milking	Webinar	Dr Peter Edmonson	ECBHM residents
01/05/20	1	Farm Maths: Survival Analysis	Seminar	Luke O'Grady	Postgraduates
06/05/20	2	Calf Milk Replacers and Oral Rehydration therapy	Seminar	Laura Tennant	Trouw Nutrition + Residents
07/05/20	1	A stochastic estimate of the economic impact of oral calcium supplementation in post parturient dairy cows	Journal Club	Jess Reynolds	Clinical staff + Postgraduates
12/05/20	1	On farm culture - is it a good idea?	Webinar	Rachael Hayton	BCVA Members
13/05/20	1	Sensitivity and Specificity	Seminar	John Remnant	Residents
20/05/20	1	Positive and Negative predictive values	Seminar	John Remnant	Residents
21/05/20	1.5	Beef Seminar - KPIs and Fertility intervention	Seminar	Sarah Hewitt	Clinical staff + Residents
22/05/20	1	The BRD 100 study and The BRD 10K study	Journal Club	Robert Hyde	Clinical staff + Postgraduates
26/05/20	1	Reducing the risk of medicine residues in milk: why is it important; how you can help by delivery Milk Sure training to your farmers	Webinar	Owen Atkinson	BCVA Members
26/05/20	1	The big data revolution and the cattle vets	Webinar	Chris Hudson	BCVA Members
27/05/20	1	Lameness in heifers	Webinar	Dr Nick J Bell	Farm vets
27/05/20	1	AMU recording and reporting	Webinar	Jan Lievaart	Farm vets
27/05/20	1	Fluid therapy in ruminants	Webinar	David Renney	Farm vets
28/05/20	1	Life after formalin	Webinar	Dr Nick J Bell	Farm vets

29/05/20	1	Farm Maths: Poisson Regression	Seminar	Naomi Prosser	Postgraduates
04/06/20	1	Calf barn design and ventilation	Webinar	Dr. Courtney E. Halbach	ECBHM residents
11/06/20	1	Evidence based medicine discussion	Seminar	Marnie Brennan	Clinical staff + Residents
18/06/20	2	Approach to on-farm PMs	Seminar	Katie Waine	Clinical staff + Residents
23/06/20	1	Transition health, management and monitoring	Webinar	Phil Elkins	BCVA Members
03/07/20	1	High urea and pregnancy or conception in dairy cows: A meta-analysis to define the appropriate urea threshold	Journal Club	Jessica Reynolds	Diplomates, PhD students + ECBHM Residents
28/01/21	1	Congenital malformation in ruminants	Webinar	Sandra Scholes	Farm veterinary practitioners
17/07/20	1	Effect of pegbovigrastim treatment on the incidence of post-calving antimicrobial treatments in four UK dairy herds	Journal Club	Emily Payne	Diplomates, PhD students + ECBHM Residents
03/09/20	2	Gross farm animal pathology	Seminar	Katie Waine	UoN ECBHM residents
20/10/20	1	Maximising returns from growing heifers	Webinar	AHDB Dairy	Dairy sector - farmers, consultants, veterinarians
03/11/20	1	Ionised calcium as a metric for post calving cow health	Ruminant Population Health Seminar	Jess Reynolds	UoN clinical staff, ECBHM diplomates and ECBHM residents
27/11/20	1	Minerals and Vitamins: Workshop	Seminar	Nigel Kendall	UoN ECBHM residents
10/12/20	2	Blood gas analysis	Seminar	Gayle Hallowell	UoN ECBHM residents
11/12/20	2	Cytology	Seminar	Katie Waine	UoN ECBHM residents
13/01/21	1	Hypocalcaemia	RTP	Linde Gille	ECBHM residents and diplomates
22/01/21	2	Infectious diseases in beef herds	Seminar	Sarah Hewitt	UoN ECBHM residents
27/01/21	1	Nutritional causes of low milk yield	RTP	Andrea Francesio	ECBHM diplomates and residents

19/02/21	1	Welfare and cattle housing PhD findings	Seminar	Jake Thompson	UoN Diplomates, residents and farm postgraduates
24/02/21	1	Case farm update for AHDB Healthy Feet Programme	Webinar	Sara Pedersen	Dairy sector - farmers, consultants, veterinarians
10/03/21	1	Control of mycoplasma bovis in dairy cattle	RTP	George Lindley, John Donolon	ECBHM diplomates and residents
24/03/21	1	Technopathies in dairy cattle related to housing	RTP	Melanie Schaeren	ECBHM diplomates and residents
04/03/21	1	Investigation of bovine stillbirth	Webinar	Tim Geraghty	Farm veterinary practitioners
05/03/21	1	Approach to bovine caesarean	Seminar	Ed Hayes	UoN Diplomates, residents and farm postgraduates
09/06/21	3	BCVA - Transition workshop	Seminar	Stephen Le Blanc	British Cattle Veterinary Association Members
16/06/21	3	BCVA - Transition workshop	Seminar	Stephen Le Blanc	British Cattle Veterinary Association Members
07/07/20	1	Respiratory disease in adult dairy cows, where infectious diseases mix with management factors	Webinar	Colin Mason	British Cattle Veterinary Association Members
15/09/20	1	Analgesia and anaesthesia in farm animals	Webinar	Gayle Hallowell	British Cattle Veterinary Association Members
07/08/20	1	Short communication: Hypernatremia in diarrheic calves associated with oral electrolyte administration in water and milk replacer in absence of access to water	Journal Club	Emily Payne	Diplomates, PhD students + ECBHM Residents
19/11/20	2	Bactoscan	Seminar	James Breen	UoN ECBHM residents
03/12/20	2	Milk Culture and Sensitivity	Seminar	James Breen	UoN ECBHM residents
27/01/21	1	Future of farm practice	Webinar	John Remnant	ECBHM diplomates and residents

27/01/21	14	SRUC CPD 2d event: Infectious disease in cattle	Seminar	George Caldow	Farm veterinary practitioners
10/02/21	1	Bull breeding soundness examination	RTP	Lilli Bittner, Emily Payne	ECBHM diplomates and residents
11/02/21	2	Strep uberis and microbiology: PhD findings	Seminar	Ginny Sherwin	UoN ECBHM residents
25/02/21	2	Minerals and Vitamins: Workshop	Seminar	Nigel Kendall	UoN ECBHM residents
08/07/21	2	Diagnostic imaging cases	Seminar	Gayle Hallowell	UoN ECBHM residents
11/08/21	3	AHDB - Fertility improvements for impact	Seminar	James Breen	Farm veterinary practitioners, farmers
08/09/21	13	Map of Ag CPD - Youngstock Nutrition and Management Course	Seminar	Richard Cooper/ Julia Moorhouse	Farm veterinary practitioners
16/09/21	1	Farm maths - Test interpretation	Seminar	Robert Hyde	Diplomates, PhD students + ECBHM Residents
28/09/21	13	Map of Ag CPD - Dry Cow Feeding and Management	Seminar	James Husband/ Alastair Hayton	Farm veterinary practitioners
06/10/21	4	Cow Signals	Seminar	Owen Atkinson	Farm veterinary practitioners
16/11/21	2	Book club - Rebhun's Chapter 3 Part 1	Book club	UCD and Notts residents	UCD and Notts residents
22/11/21	2	Book club - Rebhun's Chapter 3 Part 2	Book club	UCD and Notts residents	UCD and Notts residents
08/12/21	1.5	Bovine Abdominal Surgery: Tips to Improve Surgical Outcomes	Webinar	Eoin Ryan	British Cattle Veterinary Association Members
15/12/21	2	Book club - Rebhun's Chapter 4	Book club	UCD and Notts residents	UCD and Notts residents
16/12/21	1	Getting high yielding cows back in calf	Webinar	Nial O'Boyle	Farm veterinary practitioners, farmers

27/01/22	1.5	What winter challenges do our calves face?	Webinar	Trouw Nutrition	Farm veterinary practitioners, farmers, industry representatives
05/05/22	1	Early prediction of respiratory disease in preweaning dairy calves using feeding and activity behaviours	Journal Club	Charles Carslake	Diplomates, PhD students + ECBHM Residents
28/06/22	13	Map of Ag CPD - Fundamentals of Dairy Cow Nutrition and Ration Formulation	Seminar	James Husband/ Julia Moorhouse	Farm veterinary practitioners

7.2.3 Conferences attended

Date	Name of Conference
11/09/2019	Dairy day, Telford
19/10/2019	British Cattle Veterinary Association Congress, Southport
29/09/2020	ECBHM Online Scientific Conference, Abdominal surgery
01/10/2020	ECBHM Resident Workshop
23/09/2021	ECBHM Online Scientific Conference
05/10/2021	ECBHM Resident Epidemiology and Mastitis Workshop
14/10/2021	British Cattle Veterinary Association Congress

7.2.4 Presentations given

Date	Name of the meeting	Title, type and duration of the presentation
23/09/2021	ECBHM Online Science Conference	An investigation into the relationship between body weight and body condition scoring. 15-minute presentation and Q & A

7.3 Ancillary Topics

It is a requirement of the resident to undertake a period of anatomical and clinical pathology. The minimum requirements are completion of 30 postmortems, these were obtained by spending a week with Ben Strugnell at Farm Post Mortems which are carried out in a lab facility on site at Warrens fallen stock yard in Bishop Auckland. Further case details of each postmortem performed are described below. The one-week clinical pathology experience was obtained by spending time at both in house laboratories, such as Nottingham University Veterinary Nutritional Analysis (NUVETNA), and external laboratories. The external laboratories were Pride Veterinary centre laboratory and RAFT solutions ltd in Ripon, North Yorkshire.

7.3.1 Post mortems performed

Date	Animal Category	Diagnosis	Activity of the resident
12/09/19	Bovine, Female HF Adult cow	Peritonitis	Full post mortem examination (PME)
28/10/19	Bovine, Female HF Adult cow	Traumatic reticuloperitonitis	Full PME
28/10/19	Bovine, Female HF Adult cow	Septicaemia	Full PME
04/02/20	Bovine, Female HF Calf, 10 days old	Enteritis - Cryptosporidium	PME + faecal testing
21/08/20	3-year-old, HF Cow	Pulmonary thromboembolic localisation	Full PME + samples taken for histology (formalin fixed)
24/09/20	7-year-old, HF Cow	Haemorrhage, laryngeal/epiglottic displacement, misadventure	Full PME + samples taken for histology (formalin fixed)
24/09/20	4-year-old, HF Cow	Enteritis	Full PME + samples taken for histology (formalin fixed)
11/10/20	HF Calf	Abomasal Bloat	Full PME
18/11/20	Beef Calf	Heart Failure	Full PME
25/02/21	7d old LRX Calf	Diarrhoea (mixed infection of crypto and coronavirus), leading to dehydration and death	Full PME + samples taken for histology (formalin fixed)
11/03/21	8-week HF Heifer Calf	Abomasal Ulceration	Full PME + samples taken for histology (formalin fixed)
13/09/21	1 month old, HF Heifer Calf	Pentalogy of Fallot (Tetralogy of Fallot with atrial septal defect) + Persistent ductus arteriosus	Full PME + samples taken for histology (formalin fixed)
18/11/21	HF Heifer Calf	Bile duct atresia	Full PME
06/12/21	HF Calf, 6-month-old	Subacute bronchopneumonia with likely mycoplasma bovis	Full PME + samples taken for histology (formalin fixed) + fresh lung for PCR
06/12/21	Hereford X calf, 8-month-old	Bronchopneumonia due to PI3 (Subacute) with bacterial infection	Full PME + samples taken for histology (formalin fixed) + fresh lung for PCR

06/12/21	Adult HF Cow	Acute Bacterial Bronchopneumonia	Full PME + samples taken for histology (formalin fixed) + fresh lung for PCR
06/12/21	Limousin X suckler calf	Mycoplasma bovis Bronchopneumonia. Selenium Deficiency	Full PME + samples taken for histology (formalin fixed) + fresh lung for PCR + liver for trace element testing
06/12/21	Suckler calf 4–5-week-old	Abomasal Ulceration. Fibrino-purulent Peritonitis. Selenium deficiency	Full PME + liver for trace element testing
06/12/21	Limousin X stirk, 7-8 months old	Possible Malignant Oedema	Full PME
07/12/21	Holstein Cow, Dry Cow	Udder Oedema	Full PME
07/12/21	Holstein Cow	Hock abscess LH plus bilateral broken ribs	Full PME
07/12/21	Wagyu Calf, 1 month old	Abomasal Ulcer	Full PME
07/12/21	In Calf Holstein Heifer	Clostridia Myositis	Full PME
07/12/21	Angus Cow, In Calf	Listeria (Dry rumen contents, trauma to the head with haemorrhage into the sinuses)	Full PME + samples taken for histology (formalin fixed)
07/12/21	Holstein Heifer Calf, 3-month-old	Anaemia (origin unknown)	Full PME
07/12/21	Holstein Heifer Calf, 3-month-old	Pleurisy and peritonitis - Navel ill	Full PME
07/12/21	HF Heifer Calf, 5 days old	Intestinal atresia	Full PME
07/12/21	HF Cow	Splits and femoral artery rupture	Full PME
07/12/2021	Red poll Bullock	Intestinal torsion	Full PME
08/12/2021	18-month-old in calf Heifer	Bacterial Pneumonia	Full PME + samples taken for histology (formalin fixed) + fresh lung for PCR
08/12/2021	Angus Bull	Head Trauma and Haemorrhage	Full PME

08/12/2021	10-month-old Bullock	Pneumonia	Full PME + samples taken for histology (formalin fixed) + fresh lung for PCR
08/12/2021	29-month-old Bullock	Tracheitis, suspect IBR	Full PME + LN and ear tag for BVD + Tracheal ring for IBR + samples taken for histology (formalin fixed)
08/12/2021	HF Bull Calf	Pneumonia	Full PME + samples taken for histology (formalin fixed) + fresh lung for PCR
08/12/2021	HF Bull Calf	Pneumonia	Full PME + samples taken for histology (formalin fixed) + fresh lung for PCR

7.3.2 Clinical laboratory experience

Date	Duration	Location
04/08/2021	1d	University of Nottingham with a clinical pathologist Peter Graham
25/05/2022	1d	RAFT Solutions
20/06/2022	1d	Nottingham University Veterinary Nutritional Analysis (NUVETNA)
22/06/2022	1d	Pride veterinary practice diagnostic laboratory
01/07/2022	1d	NUVETNA

7.4 Five case reports

One of the outputs of the training program is five case reports related to bovine health management and displaying an analytical approach. There must be a maximum of 4 herd health reports or a maximum of 2 individual animal reports. One must be completed in the first year and then two in each year thereafter. During my residency program I completed 4 herd health reports and one individual animal. The following titles for each are described below and the case reports are included in this document.

1. Increased incidence of LDAs
2. Increased somatic cell count in a dairy herd
3. Sub-fertility in a 3-year-old Simmental bull
4. Increased lameness prevalence
5. Salmonella outbreak in a dairy herd

Increased incidence of LDA’s

ECBHM Year 1 Case Report

Rebecca Nelson, University of Nottingham

16/6/2020

Word Count: 3,527

Figures: 2

Tables: 2

History

Presentation

A herd with an increased incidence of left displaced abomasa (LDA). Typically presenting as a cow <21 days in milk with a reduction in milk yield and the presence of a tympanic ping on percussion of the left abdomen. The characteristic ping is most commonly located between ribs 9 and 13 and in the middle to upper third of the left abdomen. Farmer and veterinarian both concerned and further investigation into incidence warranted.

Farm summary

A 340 cow Holstein Friesian herd with an average 305 day adjusted yield of 13, 344 litres and an average daily yield of 43 litres. Cows are housed all year round with no access to pasture grazing and are robotically milked through 7 Lely robots. The farm supplies milk for a supermarket aligned contract. Bulk milk somatic cell count is consistently below 100,000 cells/ml and 12 monthly average bulk milk constituents are 3.54% butterfat and 3.32% protein. The farm are an all year-round calving herd and the mean calving index is 381 days (median is 361 days).

Housing and Feeding

Milking cow are housed in deep sand cubicles and fed a total mixed ration based on maize silage, whole crop wheat and grass silage and are rationed for M + 30 litres (cows) and M + 26 litres (lactation one heifers). Robot feeding is introduced at a rate of 0.45kgs of concentrate per litre over what is rationed. Pre-first calving heifers were fed milking cow refusals. Rations are formulated by an independent nutritionist. Dry cows are managed in two separate groups, far off (60 to 28 days before calving) and close to (28 days to calving) with different rations. Far off cows are housed in cubicles with rubber mattresses and sawdust and close to calving cows are moved onto straw-bedded yards where they calve down. Freshly calved cows are moved into another loose straw yard for a week post calving and are returned to cubicle housing when milking well in the robot.

Routine visits and monitoring

Routine fertility visits are carried out fortnightly. Cows are presented for pregnancy diagnosis (>30 days from the last service) or oestrus not observed (after the voluntary wait period of 40 days); no routine post-calving checks are performed. Any cows at <21 DIM which are identified by the robot milking system as potentially abnormal (based on decreased milk yield, drop in rumination, delayed return to the robot) are also presented for examination. Whole herd body condition and mobility scoring is carried out monthly by an independent accredited scorer. Uniform Agri is used as an on-farm recording system and comprehensive records of routine management and disease events are available. Farm performance data is monitored and analysed monthly using TotalVet (Sum-IT Software, QMMS Ltd).

Infectious disease status

The heard vaccinate annually against bovine viral diarrhoea, infectious bovine rhinotracheitis and leptospirosis. Individual cow milk antibody testing for paratuberculosis (Johne's disease) is carried out every three months. Herd prevalence is very low with >95% of animals at most tests being in the "likely negative" category reported by the lab. Johnes control is in line with the UK National Johnes Management Plan (NJMP).

Outbreak summary

Between June 2019 and November 2019 there were 9 LDAs. In this time period 130 cows have calved; this equates to an estimated lactational incidence rate of 7%. This is high, at more than double the target of <3% lactations affected for a herd yielding over 10,000 litres proposed by (Green *et al.*, 2012). 2 out of the 9 LDAs have occurred in first lactation heifers.

Herd Assessment

Close to calving cow yard

The close to calving cows are housed in three separate loose straw yards and are moved here 4 weeks prior to expected calving date with new cows joining each pen every 1 – 3 days. At the time of initial presentation, the straw yards were 92m², 108m² and 139m² in area, and were restricted to housing 7, 8 and 11 cows respectively in order to meet a stocking density of 12.5m²/cow. This was based on the recommendation of 1.25m²/1000l/cow (Green *et al.*, 2007), but calculated several years ago when the herd average was 10,000 litres/cow/year. The current farm yield of >13,000 litres means that there should be a stocking density of 16.25m²/cow. Based on this, the existing yards can hold a maximum of 5, 6 and 8 cows totalling 19 cows in the close to calving yard at one time. Therefore, these yards are substantially overstocked.

High stocking density of the close to calving yards will influence the feed space allowance per cow. Feed space availability in these yards is 7.5m, 8.4m and 8.2m. Based on current stocking numbers of 7, 8 and 11 cows this would equate to a feed space allocation of 1m, 1m and 0.74m per cow respectively. The current recommendation for feed space allocation in transition is 0.9m per Holstein Friesian cow (Green *et al.*, 2012).

TMR is fed once daily (in the morning) and the feed is pushed up frequently, four to six times a day and at a night check. Refusals are not currently measured and therefore actual daily intake weren't being monitored at the time.

Fresh cow management

Once calved the freshly calved cows are housed on a straw bedded yard for a week. At the time of assessment there were 9 cows in the 306m² of straw yard achieving a stocking density 34m²/cow. This is well above the recommendation of 1.25m²/1000l/cow (Green *et al.*, 2007).

Dry cow ration analysis

The dry cows are managed as two management groups with different rations which are formulated by an independent nutritionist. Components of the ration, dry matter (DM) %, metabolizable energy ME (MJ/kg) and total dry matter (DM) in kg are displayed in Table 1. The DM % and ME density reported are from monthly forage analysis for maize silage and whole crop wheat; standard figures are used for other components (AHDB, 2012)**.**

The close to calving ration would supply a total ME of 118MJ/ day and a DM of 12.2kg/cow/day. The dry matter intake (DMI) suggested by this ration is in line with reported achievable targets for DMI as 1.6-1.8 % of body weight, for a 750kg cow this would equate to 12 -13.5kg of DM (van Saun and Sniffen, 2014). Likewise, the late dry period energy requirements are in line with the suggested 120MJ for a 750kg cow, calculated as maintenance (10% body weight + 5 MJ) plus 40MJ(Chamberlain, 1996). The stocking density could have a knock-on effect on intakes however these are currently not measured so true effect unknown.

The far-off dry cow ration has a total ME of 103.5 MJ/day and a DM of a 12.2kg/cow/day. The far off dry cows are rationed for a similar total DM as the close to calving cows, although this group likely have the capacity to eat more with reported achievable targets for DMI being 1.9 – 2.1% of body weight, for a 750kg this equates to 14.25-15.75 kg of DM (van Saun and Sniffen, 2014)**.** The total ME requirements for far off dry cows are maintenance (10% BW + 5MJ) plus 20MJ, this equates to 100 MJ/day in a 750kg cow (Chamberlain, 1996). The total ME of the ration would be ok if the cows were restricted to 12.2kg DM//day but on this farm, this is not the case as they were feeding to intake, expected DMI for this group would be ~ 15kg and if they ate that the calculated total ME would be 127 MJ/ day. Therefore, the high total ME being provided to the far-off cows is of concern. A high energy dense ration pre-calving can result in unnecessary weight gain and increase in BCS in the lead up to calving, with both of these risk factors being reported to be significant for the development of a LDA. (Cameron *et al.*, 1998)

Table 1: Nutritional analysis of dry cow rations, far off and close to.

Dry cows – CLOSE TO CALVING	Amount in Transition Cow (kg)	DM (%)	ME (MJ/kg)	Energy in the diet (MJ/day)	DM in ration (kg DM/ day)
Maize silage 2019	7	41.4%	11.1	32.2	2.9
Wholecrop Wheat 2019	8	39.7%	9.9	31.4	3.2
Straw - Wheat (Chopped)	3.5	87%	6.1	18.6	3.0
Water	5				
Protein Meal Blend	2.2	87%	12.9	24.7	1.9
ReaShure (Protected Choline)	0.06	100%	0	0.0	0.1
SoyChlor	1	90%	12.5	11.3	0.9
Trans+Biotin Mineral	0.15	100%	0	0.0	0.2
Biotal SC Toxisorb	0.025	100%	0	0.0	0.0
Total				**118.1**	**12.2**
Dry cows – FAR OFF	**Amount in Transition Cow (kg)**	**DM (%)**	**ME (MJ/kg)**	**Energy in the diet (MJ/day)**	**DM in ration (kg DM/ day)**
Wholecrop Wheat 2019	11	39.7%	9.9	43.2	4.4
Straw - Wheat (Chopped)	6.5	87%	6.1	34.5	5.7
Water	7				
Protein Meal Blend	2.3	87%	12.9	25.8	2.0
Trans+Biotin Mineral	0.12	100%	0	0.0	0.1
Biotal SC Toxisorb	0.025	100%	0	0.0	0.0
Total				**103.5**	**12.2**

First serve conception rate

The first serve conception rate (CR), the proportion of first serves that have resulted in a pregnancy, since March 2019 has been consistently between 20-25%. This has dropped gradually since Winter 2017/18 when it was around 35%. The current first serve CR is below the target of 35% for a herd yielding 13,000 litres. **REF: AHDB Fertility Booklet** In November 2019 the first serve CR was 24% and the return serve CR was 37%. One of the differentials for a below target first serve CR compared to the return serve CR could be negative energy balance (NEB). In cows that experienced high levels of BHBs in both week 1 and 2 post calving, over 1.2mmol/L and 1.4mmol/L, pregnancy rate reduced by 50% (Walsh *et al.*, 2007)**.** Additionally clinical ketosis is associated with a 4 to 10% lower CR at first service (Fourichon, Seegers and Malher, 2000). Ketosis also has subsequent effects on other fertility performance parameters, it has been reported to result in an extended calving to conception interval (Walsh *et al.*, 2007) and an increased mean number of inseminations (Rutherford, Oikonomou and Smith, 2016).

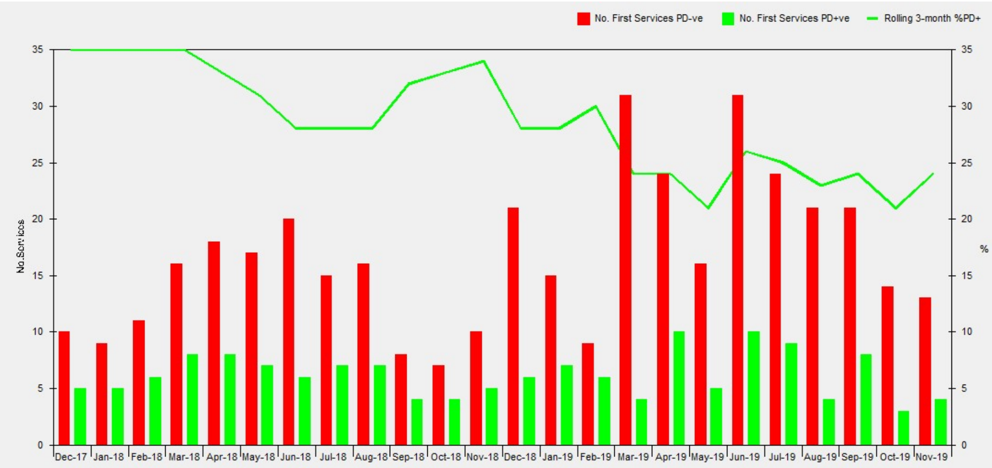


Figure 2: Conception Rate (First Serves): This graph shows the conception rate with regards to a cow's first serve. The horizontal axis shows Dec 17 – Nov 19 split into monthly increments. The red bars represent the absolute number of unsuccessful 1st serves in that month, and the green bars represent the absolute number of successful 1st serves in that month (both left hand axis). The green line represents the proportion of 1st serves resulting in a pregnancy averaged over a three-month period (right hand axis).

Problem List

The problem list can be divided into outcome problems and farm management problems which would contribute to these.

The two outcome problems are:

- High incidence of LDAs
- Poor first serve CR

These are both likely to be linked to problems with early lactation NEB, which is influenced by dry cow feeding and management, more specifically over stocked close to calving cow yards and high ME in the far-off dry cow diet.

Diagnostics and differentials

There are numerous risk factors associated with an increased incidence of LDAs and the aetiology is multifactorial and not completely understood. The transition period is the risk period for development of a DA, and it is characterised by a drop in pre partum DMI paired with an increase in energy demand in early lactation and a resultant degree of NEB. DMI is reported to decrease by 25% for first and second parity cows and 52% for > parity 3 during the final 14 days before parturition (Grummer, Mashek and Hayirli, 2004). The decline in DMI leads to elevated lipid mobilisation and release of NEFAs into circulation. The predominant metabolic pathway for NEFAs in this circumstance is oxidation to ketones bodies or storage as triglycerides in the liver resulting in fatty liver and ketosis. Ketotic cows are eight times more likely to develop a DA (LeBlanc, Leslie and Duffield, 2005).

Other post-partum disorders are reported as risk factors for increased DA incidence: cows with a retained placenta and metritis are respectively 6.8 and 4.7 more likely to develop an LDA. **REF** Hypocalcaemia is also considered to be a likely risk factor resulting in hypomotility of the abomasum and accumulation of gas. Cows that were hypocalcaemic at parturition were 4.9 times more likely to develop a DA (Shaver, 1997). A high prevalence of lameness within a herd could also contribute towards increased DA incidence because of associated reduction in DMI with lameness (Van Winden and Kuiper, 2003). Additionally significant risk factors associated with DAs are high NEFA concentrations pre-partum, high BCS, high energy in the pre partum diet and suboptimal feed space (Cameron *et al.*, 1998).

Further Diagnostics

Body Condition scoring

The milking cows are scored on a monthly basis using the Penn State University scoring method (James D Ferguson, Galligan and Thomsen, 1994). Figure 1 displays the body condition score taken from the December scoring event. This shows that there is a huge variation in body condition score relative to days in milk in this herd. Additionally, a large proportion of the cows in late lactation are over conditioned. Target for at dry off is 2.5-3 and most cows at 250-300 days in milk are BCS 3.5-4 (Dairy Co, 2015). Over-conditioned cows at calving are associated with an increased risk of development of a DA, the incidence rate has been reported to increase from 3.1% to 8.2% for low BCS cows (2.75 to 3.25) to high BCS cow (>4) (Dyk, 1995). The increase in incidence is likely to be related to the greater degree of DMI reduction association with over conditioned cows, and the subsequent fat mobilisation and increase in fatty liver and type II ketosis (Garnsworthy and Topps, 1982b).

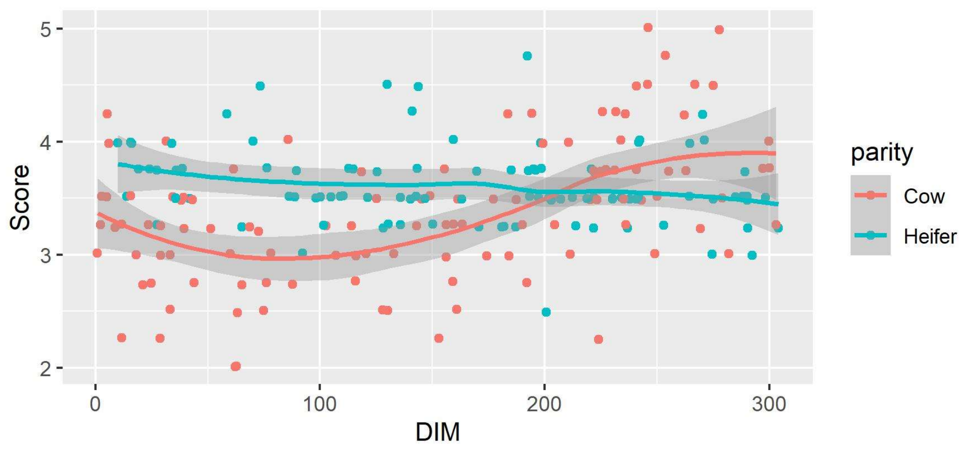


Figure 1: Graph showing the body condition score (Score) by days in milk (DIM). Cows are represented by red dots and heifers by blue dots. The lines should the trend of BCS throughout lactation and the grey shaded area represents the 95% confidence interval.

NEFAs and BHBs

Following initial herd assessment individual serum pre partum NEFAs and post-partum BHBs were taken at two fortnightly routine fertility visits in September 2019 (Table 2). The sampling time frame used was 14 to 3 days pre partum and 3 to 14 days post-partum (Ospina *et al.*, 2013). BHBs were measured using the cow side Precision Xtra Meter (Abbot Laboratories). This test has an 88% sensitivity and 96% specificity when using the cut off value of 1.2mmol/L. The blood ketone meter was found to perform better when compared to milk and urine ketone tests (Iwersen *et al.*, 2009). Sub-clinical ketosis was defined as a BHB > 1.2mmol/L and clinical ketosis as a BHB > 3mmol/L (McArt, Nydam and Oetzel, 2012). 18 blood samples were taken in September 2019, 7 had a BHB > 1.2mmol/L and 2 out of the 7 had a BHB > 3mmol/L this equates to a sub clinical ketosis prevalence of 39% on this farm. The reported mean prevalence calculated across multiple herds is highly variable with a range of 20%, 31% and 18% (LeBlanc, Leslie and Duffield, 2005; Ospina *et al.*, 2010c; Seifi *et al.*, 2011). Herd levels of > 15% of tested animals BHB > 1.2mmol/L are at greater risk of the consequential effects of NEB (Ospina *et al.*, 2010a).

10 blood samples were sent to a diagnostic laboratory to determine NEFAs, 10% (1/10) of samples had a NEFA concentration > 0.4 mEq/L. 10% has been suggested as a threshold prevalence to trigger investigation. **REF** The NEFAs were surprisingly low considering that the over conditioned cows and inappropriate stocking densities both suggested there would be a high risk of a pre-calving NEB issue. There are several possible reasons for these results not being reflective of the herd status. When evaluating prevalence, it has been suggested to sample at least 12 cows in order to provide confidence that the results are reflective of the herd status (Oetzel, 2004)**.** Repeating these NEFA blood samples with a larger number of cows may be indicated to provide better confidence in the results. Another factor to consider would be the time at which NEFAs bloods are obtained; they are believed to reach nadir 4-5 hours post feeding however achieving this testing timing interval may be difficult to achieve in a once a day TMR feeding herd (Oetzel, 2004). Additionally it has been reported that post-partum BHBs are more sensitive and specific than pre- partum NEFAs at predicting the risk of developing a DA (LeBlanc, Leslie and Duffield, 2005).

Collectively, these results show a high prevalence of sub clinical ketosis, which could plausibly be a cause for the high incidence of LDAs. Despite NEFAs not being elevated to the same degree of BHBs the area of concern on this farm is over conditioned cows and primarily close to calving cow management.

Date	DIM	Lactation No	BHB
10/09/2019	3	3	0.8
10/09/2019	3	1	0.6
10/09/2019	5	4	1
10/09/2019	6	1	**1.2**
10/09/2019	6	1	**1.4**
10/09/2019	5	1	0.8
10/09/2019	6	3	1.1
10/09/2019	7	2	0.9
10/09/2019	8	3	0.9
10/09/2019	9	6	0.7
25/09/2019	5	2	**3.6**
25/09/2019	5	1	0.7
25/09/2019	6	5	**3.9**
25/09/2019	7	2	**1.3**
25/09/2019	7	1	0.8
25/09/2019	8	5	**1.4**
25/09/2019	8	1	**1.9**
Date	**Days pre partum**	**Lactation No**	**NEFA**
10/09/2019	8	1	0.17
10/09/2019	7	4	0.24

10/09/2019	7	5	0.21
25/09/2019	5	6	**0.5**
25/09/2019	6	3	0.12
25/09/2019	7	2	0.22
25/09/2019	5	4	0.29
25/09/2019	8	3	0.12
25/09/2019	3	3	0.19
25/09/2019	9	1	0.15

Table 2: BHB and NEFA results from two routine visits in September 2019. Values highlighted in bold are above the threshold values of NEFA > 0.4 mEq/L and BHB > 1.2mmol/L.

Prevention and Follow up

One identified problem on this farm was that animals were joining the dry cow group over-fat with a large proportion of the cows being dried off at a BCS > 3.5. In order to address this, it was advised that the following recommendations were implemented:

- Management of a separate low yielding/ late lactation milking group, which are fed a reduced density ration; this was considered feasible as these animals were already managed separately (but had been fed the standard milking cow diet previously).
- Cessation of feeding milking cow refusals to the pre-calving heifers and formulation of a new heifer ration.
- Routine monthly monitoring of BCS was to be continued in order to assess the outcomes of these changes.

In order to further negate other factors that exacerbate the over conditioned cows it was important to review the energy density of the far-off dry cow diet and the concerns over possible over feeding. It was advised that the farm started to record intakes to ensure we knew how many cows worth of ration they were eating.

In order to improve close to calving cow stocking density and feed intake, and to make better use of the existing facilities, a new close to calving cow group housing strategy was proposed. This involved creating two new straw yard pens (space was available for this in another building), to provide a total of 5 similar sized close to calving pens. Each of these could then be stocked with a max of 6-7 cows each (providing > 15m² and > 1m feed space per cow), with enough capacity to stock these in an all-in-all-out system. This ensured that each pen was filled with the next 6-7 cows due to enter the close to calving cow group and this group stayed together until all had calved and then the pen was cleaned out and re-bedded for the new group. This management change was important to minimise group changes, maintain a stable social hierarchy and maximise DMI (Grant and Albright, 2001). Additionally, it was agreed to aim for the optimum time of 18-21 days in this group for each cow; previously the farm management had aimed to keep cows as long as possible in this group due to the perception of this reducing NEB – so these had been full evening in the quieter calving months.

In order to improve fresh cow management and minimise group changes over a short period of time we agreed to aim for a longer stay of 21 days in the fresh cow lactating straw yard. Additionally, the inclusion of protected choline (ReaShure) in the post-partum ration was agreed, this is already fed in the close to calving cows and there is benefit in continuing to feed this in the post-partum period (Lima *et al.*, 2012).

Targeted treatment approaches to control sub-clinical ketosis were also advised; these were the treatment of all fresh cows routinely with propylene glycol (Pro-Keto, Trouw Nutrition) from 3 days in milk for 5 days (Ospina *et al.*, 2013) and the use of continuous release monensin capsules (Kexxtone, Elanco) in cows with a BCS > 3.5, 3-4 weeks prior to expected calving (Duffield *et al.*, 2003). Both of these approaches were discussed as initial short term measures to improve indicators of energy balance both pre and post-calving (Duffield *et al.*, 2003) and to decrease the risk of developing a DA (McArt, Nydam and Oetzel, 2012).

Follow up

There was poor farmer compliance with these measures and very few recommendations were implemented on farm. The only recommendations, as of June 2020, that have been applied are the use of monensin release capsules (Kexxtone, Elanco) in pre-calving cows with a body condition score > 3.5 and the addition of protected choline (ReaShure) in the post-partum fresh cow ration. The recommendations not implemented required no major investment and mainly focused on improving management by making better use of existing facilities, so it was frustrating to realise no changes had been made. I believe barriers to making further changes are time restraints and farm workers having no financial involvement in the business. In between December 2019 and June 2020 there have been 7 LDAs. In this time period 225 cows have calved; this equates to an estimated lactation incidence rate of 3%. This has improved in comparison to an estimated lactational incidence rate at the start of the investigation of 7%.

<u>Implications/Conclusion</u>

Economic Implications

The economic impact of sub clinical ketosis and related diseases can be subdivided into direct and indirect costs. The direct costs being treatment costs; the surgical correction and postoperative management of the LDA plus treatment of any concurrent post-partum disease. Indirect costs would include a reduction in milk production, decreased reproductive efficiency and a prolonged calving interval and removal (culling or dying of cows) (Mostert *et al.*, 2018). Ketotic cows are reported to have a decreased mature equivalent 305d yield by 647kg (Ospina *et al.*, 2010b) and are 3 times more likely to be culled or die within the first 30 DIM (McArt *et al.*, 2011).

It has been reported that the total cost of sub clinical ketosis is €130 (£117) per case per year with the cost increasing the parity. The cost of sub clinical ketosis alone was calculated to be €58 (£52) per case per year (Mostert *et al.*, 2018). With a calculated herd prevalence of 38% in a 340-cow herd this would equate to a total cost per year of £15,116 therefore prevention of ketosis is economically relevant on this farm.

Conclusion

This case highlights the importance of a veterinarian not only dealing with the individual LDA case but also determining the herd level incidence rate and highlighting the value of on farm diagnostics and investigation in order to identity farm specific risk factors and achieve prevention of LDAs in the first instance in order to benefit in terms of economics and cow welfare. This approach inevitably reflects the way the role of the cattle vet is changing with a shift towards a consultancy type role and an increasing focus on preventative herd health approach and less firefighter vet work. An important and necessary shift to adapt to increased herd size in the UK and the strive for efficiency of production.

Increased Somatic Cell Count in a Dairy Herd

ECBHM Year 2 Case Report

Rebecca Nelson, University of Nottingham

2020-2021

Word Count: 2,827

Figures: 2

Tables: 2

History

Presentation

A herd with a calculated herd average test-day bulk milk somatic cell count (BMSCC) consistently over 400,000 cells/ml. Farmer at risk of penalisation and loss of milk contract. No current analysis of individual cow cell count data or clinical mastitis data performed by the current veterinarian. Independent advisor contacted with the farmers desire to seek better control of udder health and milk quality.

Farm Summary

A 220 cow Holstein Friesian herd with an average 305 day adjusted yield of 8,500 litres and an average daily yield of 28 litres. A predominantly autumn block calving herd but an extended calving block from August to April, with a mean calving index of 416 days (median 385 days). Cows are housed on deep sand cubicles in winter and grazed in the spring and summer, with turnout typically being from April. Cows are milked twice daily in a 12/24 herringbone parlour. Six-weekly whole herd milk recording is currently undertaken with national milk records (NMR, Chippenham, UK). The calculated herd average somatic cell count at the previous milk recording was 517,000 cells/ml. The reported rate of clinical mastitis averaged 47 cases per 100 cows/year in the last 3 months, well above the reported UK herd median in 2020 from 500 NMR milk recording herds of 26 cases per 100 cows/year (Hanks and Kossaibati, 2020). No electronic data recording on farm currently. Farm milk recording data was analysed using the TotalVet software (SUM-IT Computer Systems Ltd and QMMS Ltd).

Housing and Feeding

Dry cows are managed in two groups, far off (60 to 21 days before calving) and close to calving (21 days to calving). The far-off dry cows are managed at pasture based on proximity to the milking parlour. Cows are kept in the same paddock until residuals are achieved so time frame of stay is variable. Close to calving cows are housed in two loose yards bedded with straw where they also calve down and are fed dry cow concentrate and haylage. Freshly calved cows are moved to another loose straw yard which is near the parlour, additional sick cows are also housed here. Cows are returned to the milking cow accommodation, deep sand cubicles when milking well.

Infectious disease status

The herd does not vaccinate against bovine viral diarrhoea, infectious bovine rhinotracheitis or leptospirosis. No regular infectious disease monitoring is implemented so disease status is unknown. Individual cow milk antibody testing for *Mycobacterium avium paratuberculosis* (MAP; Johnes Disease) has been carried out, with 10% of the herd reported as antibody positive. Subsequent herd tests have been advocated to allow for categorisation of those cows that are more likely to be infected and shedding, so consecutive antibody positive, as well as identification of any new positive cows in the herd.

Outbreak summary

An increased BMSCC of 517,000 cells/ml at the May 2019 milk recording. Increasing concern due to EU regulations and standards that must be met by producers. At the time of collection the raw milk must have somatic cell count (SCC) <400,000 cells/ml, otherwise it is deemed unsaleable and unacceptable for human consumption (European Union, 1992).

Herd Assessment

The three-month rolling SCC average is 367, 000 cells/ml and this has consistently sat between 300,000 cells/ml and 400,000 cells/ml over the last 12 months. The herd average cell count at the last milk recording in May 2019 was 517, 000 cells/ml, although it is important to be mindful of the stage of lactation as this may represent a small proportion of high yielding cows contributing heavily to the overall herd average cell count. The cows contributing the most in terms of cell count based on the May milk recording and current milk yield is displayed in Table 1. Cow 40 is contributing 15% of the overall herd average cell count and was recorded as giving 28 litres with a cell count of almost 10 million cells/ml. The top 6 cows listed collectively contribute 43% of the calculated herd average cell count. A short-term measure could be to consider the management of these high SCC cows; cull if not pregnant and in late lactation, consider treatment during lactation or dry off early with dry cow therapy and teat sealant if been pregnancy diagnosed positive. However, It is less favourable to treat sub-clinical mastitis during lactation because it is not economically viable due to treatment costs and milk withdrawal and it is also associated with lower cure rates (Deluyker *et al*, 2005). In contrast a 90% cure can be achieved across the dry period (Bradley *et al.*, 2010). This approach only provides a short-term solution to the current high average herd SCC but does not address the root cause of the high prevalence in the herd and does not focus on prevention of new high cell count infections.

Cow ID	Lactation No	Days in Milk (DIM)	SCC (21/5/19)	Yield	Contribution to Herd (%)
40	2	232	9999	28.0	15.3
112	2	89	9999	17.3	9.5
27	2	15	2494	41.0	5.6
130	7	95	2244	39.6	4.9
67	9	167	2343	32.6	4.2
105	8	154	1459	49.7	4.0

Table 1: *The top six high SCC cows at the last milk recording on 21st May 2019, their respective yield and overall contribution to the calculated herd average somatic cell count displayed as a percentage.*

The herd average SCC target level is dictated by individual milk contract penalty levels, but a herd average cell count > 200,000 cells/ml would generally warrant further investigation. The herd average SCC is a crude measure of intramammary infections (IMIs) in a herd and it has been suggested that for every 100,000 cells/ml increase there is 10% increase in the prevalence of infection in the herd (Bradley and Green, 2005).

In this herd, 40% of the cows at the last milk recording (May 2019) had a cell count >200,000 cells/ml (target < 20%) likewise, indicating a high prevalence of infection. The lactation new infection rate (proportion of cows moving from below 200,000cells/ml to above 200,000 cells/ml between two consecutive milk recordings) was 14.3% averaged over the last 3 months (target <5%). This is an area of concern but many of these cows were in late lactation and therefore cell count may be distorted by reduced yield.

Importantly, further data analysis highlighted an increased dry period new infection rate (the proportion of cows being dried off with a SCC <200,000 cells/ml and are >200,000 cells/ml at the first milk recording < 30 days after calving), with a rolling annual average of 27%, nearly three times the target of <10% (Green *et al.*, 2012). The dry period infection rate over time from May 2017 to June 2019 is displayed in Figure 1. Table 2 further splits the dry period new infections for first calved heifers and cows, highlighting that both cows and heifers contribute to the overall high dry period new infection rate. For example, in September 2018 there were 16 first calved heifers < 30 DIM at the milk recording and five of these had a SCC > 200,000 cells/ml, equating to a dry period new infection rate of 31%, three times the target of <10%. A high rate of infection in heifers is a good marker for overall dry period environment management, as no dry cow therapy is implemented in heifers.

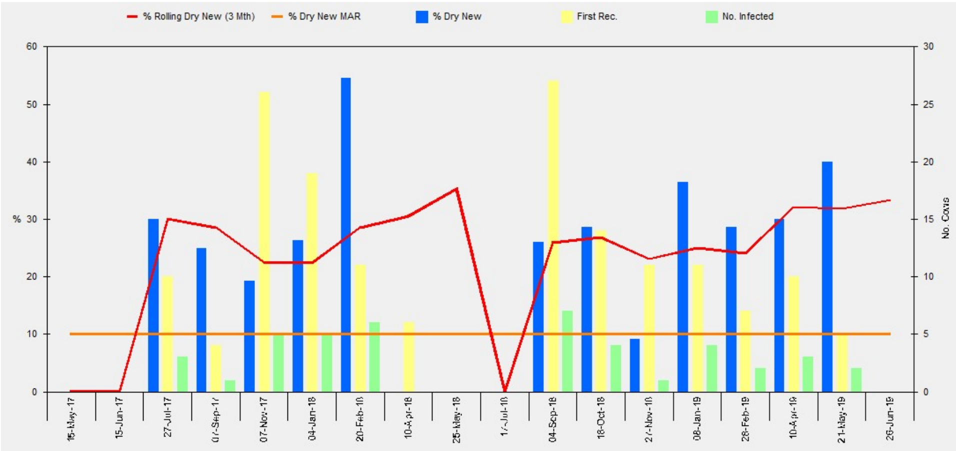


Figure 1: Dry period new infection rate (cows and heifers)*: This graph shows the number of cows dried off with a low SCC (<200,000 cells/ml) that were less than 30 days in milk at this milk recording, the eligible population (yellow bars), the number of cows that were dried off with a low SCC and calved in with a high cell count (green bars) and the % dry period new infection rate (blue bars), with the target line of 10% (red line). The milk recording dates are displayed on the x axis from May 2017 to June 19 (©TotalVet, SUM-IT/QMMS Ltd).*

	HEIFERS ONLY			**COWS ONLY**		
	No. at 1st Recording	No. > 200,00 cells/ml	DPNI (%)	No. at 1st Recording	No. > 200,00 cells/ml	DPNI (%)
Sept 2018	16	5	31	11	2	18
Oct 2018	4	1	25	10	3	30
Nov 2018	2	0	0	9	1	11
Jan 2019	0	0	0	11	4	36
Feb 2019	1	0	0	6	2	33
April 2019	6	2	33	4	1	25
May 2019	3	2	67	2	0	0

Table 2: The dry period new infection rate (percentage of cows dried off with a low SCC < 200,000 cells/ml and have a high SCC > 200,000 cells/ml at the first milk recording < 30 days in milk) split into heifers and cows and displayed as the number <30 days in milk at the May 2019 milk recording, the number classified as infected and the dry period new infection (DPNI) as a percentage. The DPNI above the target of 10% are highlighted in red.

The dry period cure rate (the proportion of cows being dried off with a SCC >200,000 cells/ml and are subsequently <200,000 cells/ml at the first milk recording < 30 DIM) was 73.3% over the last 12 months and 60% at the last milk recording in May 2019, both below the target of >85%. The effect on the apparent dry period cure rate is most likely to be in light of the high DPNI rate and is most likely as a result of cured quarters becoming re-infected throughout the dry period (Bradley, Breen and Green, 2007).

Bacteriology

Ten milk samples were taken from high SCC cows and submitted for bacteriology. The results were 5 *Streptococcus Uberis*, 1 *Klebsiella sp*, 1 *Staphylococcus Aureus*, 1 *Streptococcus Dysgalactiae and* 2 *E. coli.*

Problem List

The primary problems identified were a high BMSCC and a high dry period new infection rate with a concurrent reduced dry period cure rate.

The bacteriology of the high SCC cows provided evidence for the likelihood of an environmental pathogen involvement (Green *et al.*, 2012). The high dry period new infection rate highlights the need for further assessment of the dry cow management both at pasture and in the dry cow yard. The purpose of the farm visit was to identify risk factors relevant to the environmental dry period diagnosis.

Diagnostics and differentials

Following initial data analysis an on-farm visit was arranged with the farm manager and head herdsman. A discussion had around general farm management practices with a particular focus on dry cow management and current dry off technique. The following findings were discovered:

Drying off approach

Current practice is that cows are dried off during milking with little or no teat disinfection prior to infusion of dry cow therapy. Additionally, a selective dry cow therapy (DCT) is implemented using the >250,000 cells/ml threshold for antibiotic therapy and teat sealant combination, the antibiotic therapy currently used is a broad-spectrum product (Penethamate, framycetin, procaine benzylpenicillin; “Ubro Red”, Boehringer Ingelheim). Selective DCT decisions are made based on the last three milk recordings and clinical mastitis data.

Hygienic infusion at dry off is paramount to prevent introduction of new infections. Drying cows off at the end of milking, pre-milking teat disinfection with a thirty second contact time and use of surgical spirit scrubs are associated with reduced likelihood of infection at calving (Green and Bradley, 2007; Green *et al.*, 2008; AHDB Dairy, 2021). Likewise, it is indicated that partial insertion of the nozzle is preferable and is associated with an improved treatment efficacy rate of 85.7% from 57.9% when compared to full insertion. Full insertion results in keratin removal and teat canal dilation, effecting the development of the keratin plug and a resultant increased susceptibility to bacterial penetration (Boddie and Nickerson, 1986).

A lower threshold for cows that require antibiotic dry cow therapy alongside a teat sealant at dry off is indicated in high BMSCC herds where the primary aim is to identify cows that are infected and to eliminate any existing infections. Lowering the threshold from 250,000 cells/ml to 100,000 cells/ml in the high SCC herd will increase the sensitivity from 80% to 95% (Bradley and Green, 2005).

Dry cow management

Far off dry cows are managed at pasture with no strategic pasture resting implemented. Dry cows three weeks off calving are housed in two straw yards with the bedded area of each year being 24 metres by 8m equating to a total area of 384 m^2. An inadequate space allowance per cow was provided. The bedded yard was cleaned out twice throughout the calving season and the straw was stored outside exposed to poor weather.

A space allowance of 1.25m^2/1000l/cow bedded area would equate to 11.25m^2 per cow, and 15m^2 for a calving cow is recommended (Green *et al.*, 2008).

Three of the herd management factors associated with an increased somatic cell count after calving were, bedding management, stocking densities and grazing management (Green *et al.*, 2008). Organic bedding such as straw is less favourable than inorganic bedding such as sand and is associated with a higher bacterial load due having higher moisture and more nutrients for bacterial growth and an associated bacterial load 100-fold greater than organic bedding (Hogan and Smith, 2012). With the bacterial load in the bedding being directly related to bacterial load on teat ends and therefore the rate of mastitis (Zdanowicz *et al.*, 2004). When using organic bedding material, it should be mucked out monthly and fresh bedding applied daily (Peeler *et al.*, 2000; AHDB Dairy, 2021). Additionally straw should be stored in a dry place to limit moisture content to < 15% (Ward and Hughes, 2002).

Poached and trampled paddocks are associated with a high bacterial load and a grazing paddocks for two weeks and resting them for greater than four weeks is beneficial in mastitis control (Green and Bradley, 2007; Green *et al.*, 2008).

<u>Prevention and follow-up</u>

Prevention

It is important to identify risk factors as new infections in the dry period are associated with negatives downstream effects. A high SCC early in first lactation heifers is associated with an increased risk of culling, increased SCC in that lactation and a negative effect on milk production during that lactation (De Vliegher *et al.*, 2004; De Vliegher, Barkema, Opsomer, *et al.*, 2005; De Vliegher, Barkema, Stryhn, *et al.*, 2005). Additionally, acquisition of new intramammary infections in the dry period can increase the likelihood of a clinical mastitis event with the same pathogen in the subsequent lactation. Likewise it has been reported that 50% of all environmental mastitis in early lactation (first 100 days in milk) was as a result of an infection in the dry period (Bradley and Green, 2004).

The main management risk factors identified on this farm were the current dry off technique and the existing management strategies of the dry cows. Given the time of year and stage of lactation, the importance of curing existing infection and minimising environmental re-infection was emphasised. The key steps to prevention are to minimise the environmental challenge and maximise the cows own defence mechanisms. In order to achieve these objectives, the following recommendations were advised to be implemented:

Dry cow therapy

- An aseptic and partial infusion technique to be ensured when administering the antibiotic and teat sealant and the practices of all individuals involved in this process to be reviewed at regular intervals.
- A reduction of the somatic cell count threshold for antibiotic dry cow therapy at drying off to be reduced to 100,000 cells/ml.
- An internal teat sealant to be used in all cows at drying off.

Dry cow management

- For early dry cows at pasture, no more than two weeks in one paddock area, with a four-week rest period for each are before cows return.
- Far off and close to calving cows to be housed in the empty lactating cow deep sand cubicles to reduce stocking density in the dry cow yards.

- Sand cubicle passageways to be scraped daily and put new clean sand into the cubicles every other day.
- Cows close to the expected calving date (days) or at time of calving should be moved to the straw pen to calve.
- Stocking density to not exceed calculated total cow allowance of 14 cows per straw yard to allow for 15m² of lying space per cow.
- The straw calving yard to be bedded daily and cleaned out completely every 3-4 weeks.
- Straw must be stored under cover using tarpaulin.

Follow up

A review of the 2019-2020 calving season and the DPNI rate was carried out in August 2020. A large proportion of the recommendations were implemented by the farmer. Heifers and cows were housed 3 weeks prior to calving on deep sand cubicles, these were bedded up fresh once a week and passageways scraped out every other day. Cows were moved at point of calving to the deep straw yard and suggested stocking density recommendations were adhered to. Fresh straw bedding was applied once a day and complete clear out of the yard was done every 3 weeks. Straw at point of storage remained uncovered. At the time of the visit the dry off technique was reviewed again. These changes implemented resulted in a vast improvement in the DPNI rate and this is shown in Figure 2. The DPNI rate averaged below the target of 10% for 2019-2020 with only 4 cows or heifers becoming infected out of an eligible population (< 30 DIM at the milk recording) of 59, this equates to a DPNI rate of 6.8%. This is a vast improvement on 2018-2019 season where it was 27%, 23 infected out of an eligible population of 85.

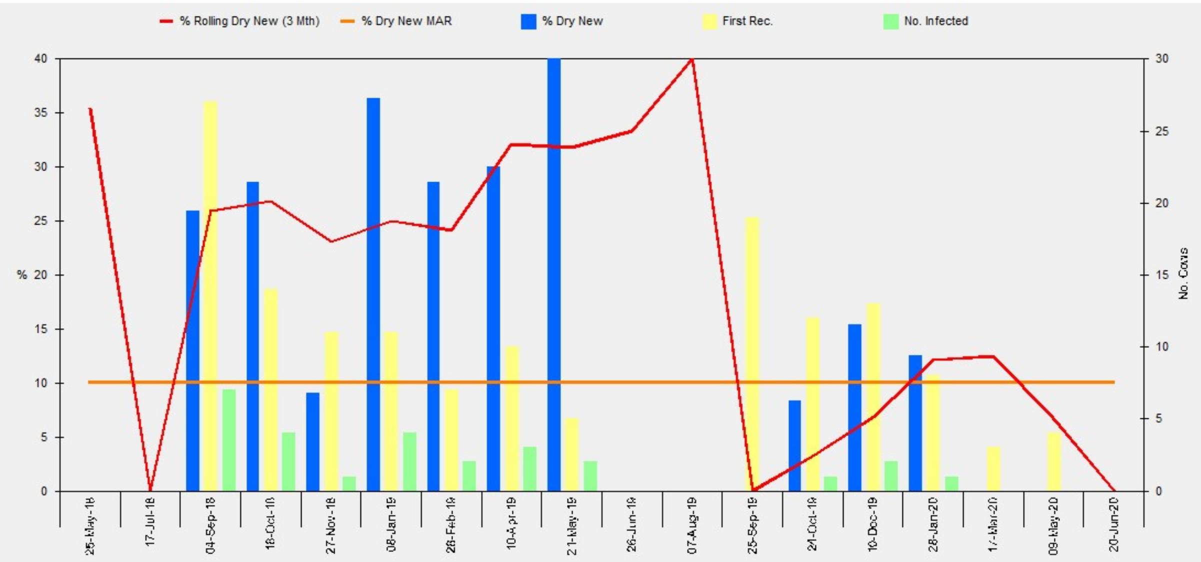


Figure 2: Dry period new infection rate (cows and heifers)*: This graph shows the number of cows dried off with a low SCC (<200,000 cells/ml) that were less than 30 days in milk at this milk recording, the eligible population (yellow bars), the number of cows that were dried off with a low SCC and calved in with a high cell count (green bars) and the % dry period new infection rate (blue bars), with the target line of 10% (red line). The milk recording dates are displayed on the x axis from May 2019 to June 2020.*

Implications/Conclusion

Economic Implications

The economic impact of sub-clinical mastitis can be subdivided in four main categories: lost milk production, cost of premature culls and milk quality penalties or loss of bonuses. The associated yield reduction and value of the lost milk production accounts for approximately 60-70% of the total overall cost. With the total financial cost being understandably greater in herds with a high average somatic cell count when compared to a low somatic cell count herd (YALÇIN, 2000). The economic impact of the sub-clinical mastitis rate and current BMSCC on this herd was investigated using the AHDB mastitis cost calculator. The total sub-clinical mastitis cost was £37,414 per year equating to £170.06 per cow per year, therefore implementation of prevention methods using existing infrastructures to reduce the sub-clinical mastitis in particular the dry period new infection rate is of cost benefit. This cost calculation did not factor in milk quality penalties and therefore on this farm the degree of cost would have been even greater if all milk were deemed unsaleable.

Conclusion

This case highlights the need for analysis of farm data and in particular somatic cell count data. This herd needed immediate investigation considering the consistently high BMSCC and the concern regarding EU regulations and the fact the current milk produced is considered unsaleable milk unsuitable for public consumption and this would have a major economic impact to the farmer. This level of farm data analysis is becoming increasingly important especially considering the changing role of the cattle vet within the UK, with an increasing focus on data handling (Woodward, Cobb and Remnant, 2019).

Sub-fertility in a 3-year-old Simmental Bull

ECBHM Year 2 Case Report – Individual animal

Rebecca Nelson, University of Nottingham

Word Count: 2, 897

Figures: 0

Tables: 1

History

Presentation

A farm recently purchased a 3-year-old replacement Simmental bull to replace the existing 8-year-old Simmental bull and a pre breeding soundness examination was carried out.

Farm Summary

A 54-cow spring calving beef suckler herd, made up of Limousin, Shorthorn and Simmental crosses. One 8-year-old Simmental bull that has been used consecutively for the last 6 seasons. 325-acre farm with 285 acres of grazing land and a mixed livestock enterprise farm with an additional established flock of 450 breeding sheep. Cattle are turned out to grass in the spring/summer and housed in loose yards bedded with straw in the autumn/winter. The production aims of the beef enterprise is to sell stores, half at six months of age when weaned and half at 12 months of age. In the 2020 calving season 51 out of 54 cows were pregnancy diagnosed (PD) positive. Pregnancy diagnosis occurred 6 weeks after the bull was taken out. 28 of the 51 cows calved within the first 3 weeks, this equates to a percentage of 55% (Target = 65%), with a total calving block of 12 weeks. In this season there was one abortion (fungal placentitis associated with spoiled silage diagnosed) and two calf deaths (poor colostrum intake), resulting in a total of 48 calves weaned. This equates to a percentage of the number of calves weaned of 88% (Target = 94%).

Infectious disease status

They have operated as a close herd since 2017 and no purchased stock have been bought in. The herd is in a low-risk bovine tuberculosis (*Mycobacterium bovis)* area and are on a current 4-year testing regime with no history of Bovine Tuberculosis (TB) on the farm. The herd vaccinates against Bovine Viral Diarrhoea (Bovela, Boehringer Ingelheim) annually. An annual Bovine Viral Diarrhoea (BVD) check test is carried out in animals aged nine to eighteen months old, this involves five animals from each separate management group being tested for BVD antibody. BVD testing to date is clear. No regular disease monitoring or vaccination is implemented against Infectious Bovine Rhinotracheitis and Leptospirosis. Whole herd *Mycobacterium avium paratuberculosis* (MAP; Johnes Disease) testing was carried out in 2020 following a confirmed positive case in a second calver. No MAP antibodies were detected. The current strategy implemented for Johnes control is improved farm management, test, and cull.

Individual Animal Assessment

Poor fertility differentials

The numerous factors that impact on beef herd fertility were discussed briefly with the farm these being cow factors, overall herd management, infectious disease, and bull factors.

Cow factors that influence overall fertility are nutritional management and endemic disease. Endemic diseases such as lameness and mastitis both have direct and indirect effects on pregnancy rate and are associated with a delayed return to cyclicity post calving. The effect of lameness is most likely because of a drop in dry matter intake and a resultant state of negative energy balance (Green *et al.*, 2012). Body condition scoring is a valuable tool for measuring beef cow nutrition and body condition score at calving is the best predictor in beef herds of time for return to cyclicity. In this herd body condition scoring is carried out at point of winter housing, where they are separated into management groups according to body condition score (BCS) and fed accordingly, and at calving. The overall average BCS of 54 cows at point of calving in 2020 was 2.8 and this is around the target of BCS 2.5 for spring calving herds (Caldow, Lowman and Riddell, 2005).

Herd management factors that can impact on herd fertility are heat stress and housing and resultant group stress. A high temperature and high humidity are associated with a less marked oestrus and a reduced pregnancy rate (De Kruif, 1978). These effects are of less relevance due to the cattle only being housed in the winter months and there being surplus shed space for the number of stock.

The most common infectious diseases associated with a decrease in pregnancy rate are Bovine Viral Diarrhoea (BVD), Infectious Bovine Rhinotracheitis (IBR) and Leptospirosis. BVD and IBR exposure have a direct negative impact on the survival of the embryo whereas the exact effect of Leptospirosis is unknown. Leptospirosis seroconversion is associated with lower pregnancy rates but there is limited evidence for a causal link (Green *et al.*, 2012). This herd annually vaccinated and monitor for BVD however IBR and Leptospirosis status is unknown. The impact of infectious disease in the herd is less likely due to the herd operating as a closed herd since 2017 with no in bought stock for the last three years. As well as the infectious diseases discussed above bulls also provide a risk of introduction of venereal diseases such as *Campylobacter fetus venerealis*, *Trichomonas fetus* and urea plasma species. A diagnosis can be reached by sampling the prepuce either by lavage or scraping (BonDurant, 2005).

Bulls contribute significantly to poor fertility performance with over third of bulls being reported to be sub-fertile (Walters and Thomson, 2011). A fertile bull is defined as one that gets 90% of normal cycling females in 9 weeks and 60% in the first 3 weeks (McGowan, 2004). The causes of sub fertility incorporate poor libido, sperm quantity and quality defects and physical factors affecting bull mobility or mating ability.

Clinical examination of the bull

Observation of the bull at a distance revealed the animal to have an excitable demeanour and to be bright and alert with a body condition score of 4 out of 5. Prior to restraint an assessment was made on a smooth level surface of the bull's posture and gait. The bull was a mobility Score 0 using the AHDB scoring system (AHDB Dairy, 2004), he distributed weight evenly between limbs, tracked up on limb placement and walked with a flat back. No musculoskeletal (MSK) conformation abnormalities were present. Heart rate was 84 beats per minute with no arrythmias heard on auscultation. Mucous membranes were pale pink and moist with a capillary refill time of < 2 seconds. Respiratory rate was 30 breaths per minute with no abnormalities detected on lung auscultation on both the right- and left-hand side. The eyes were checked for any abnormalities such as cataracts, corneal lesions, or squamous cell carcinomas and none were present, and a positive menace response was elicited on both sides. Observation of the oral cavity confirmed a good incisor and dental pad alignment. Rectal temperature was 38.9°C and rectal examination was unremarkable.

Assessment of the following were made in line with the British cattle veterinary association (BCVA) breeding soundness certificate (Penny, 2010) ; body condition score, heart/lungs, eyes, incisor/dental pad alignment and musculoskeletal examination. This is a formal recognised certificate finalised in 2010 for veterinary examination of a bull which is approved by the BCVA and comes with accompanying printed guidelines.

An MSK examination is important as 11.9% of animals are reported to fail the breeding soundness examination on MSK findings. The presence of any abnormalities is associated with a reduced ability to mount alongside a reduced sperm quality (Barth and Waldner, 2002).

Optimal bull body condition score is between 2.5 and 3.5 and extremes of body condition score such as too thin <2 and too fat >4 affect breeding soundness classification. With over conditioned animals being associated with an increased fat deposition in the scrotum, altered thermoregulation and decreased quality of sperm (Barth and Waldner, 2002).

Initial problem List

On this farm the cow, infectious disease, and herd management risk factors for potential poor fertility in the upcoming season were considered low.

Based on the clinical examination of the bull the initial problem list is an over conditioned bull with a BCS of 4 out of 5 with an unknown infectious disease and fertility status. To rule out sub-fertility a pre-breeding soundness examination was carried out. This is a pro-active way to rule out bull factors prior to the start of the breeding season.

Diagnosis and differentials

Bull breeding soundness examination.

Physical Examination

The scrotum was palpated and was deemed symmetrical with no notable areas of hyperkeratosis. The testicles were freely movable, and the body of the testicles, spermatic cord and epididymis were palpated with testicular tone being noted as poor and soft to touch. The scrotal circumference (SC) was obtained around the widest part of the testes and a measurement of 32cm was obtained. Scrotal circumference is important to obtain as it is a predictor of testicular weight and sperm output and has a positive correlation with sperm quality (Barth and Waldner, 2002). It is also a moderately heritable trait and is associated with age of puberty in offspring (Penny, 2010). There is some breed variation associated with scrotal circumference and breed specific minimum acceptable recommendations for two-year-olds have been established, as at 24 months of age 90% of scrotal circumference should be readable (McGowan, 2004).The acceptable SC for a two year old Simmental bull is 36cm (Coulter *et al.*, 1987). The sheath was palpated for any abnormalities such as swellings and none were examined. A rectal examination was carried out and the internal accessory glands were palpated with no abnormalities noted and no pain elicited.

Semen Examination

Semen collection was achieved by use of an electro ejaculator whilst the bull was restrained within a crush. Lower concentrations of sperm are often found in electro ejaculation samples compared to an artificial vagina so two samples were collected to ensure they were representative of the bulls' normal sample deposited in natural service. During the procedure, the penis was visualised, and no abnormalities were noted. Macroscopically on both samples the ejaculate produced was milky in appearance. A microscopic examination was carried out to allow assessment of sperm motility and morphology. Gross motility was observed under a low power (10x) and progressive motility under a higher magnification (400x). Gross motility on both the sperm samples was 3 out of 5 (score 0 to 5 scale) and progressive motility was 55%. This is below the minimum BCVA standard of > 60% progressive motility (Penny, 2010). An established minimum standard was decided as progressive motility is positively correlated with fertility (Utt, 2016). It is important to note that poor motility in a sample can be attribute to a multitude of factors such as poor collection technique, an extended period of inactivity and contamination of the sample with urine so raising the important of collecting several samples to provide an overall assessment. The motility analysis is highly subjective and reliant on some level of skill, there has been significant inter and intra observer observation variability noted

(Vincent *et al.*, 2014). Morphological assessment was made on an Eosin-Nigrosin stained sperm smear under high magnification (1000-1200x). Table 2 displays the sperm morphology results with overall 55% normal morphology. This is below the minimum BCVA standard of >70% morphologically normal sperm (Penny, 2010).

Sperm Morphology	Percentage (%)
Normal	55%
Head defects	20%
Coiled Tail/ dag defects	1%
Distal midpiece reflex/ bent tails	5%
Proximal Droplets	4%
Detached Heads	10%
Other	5%

Table 2: Sperm Morphological abnormality count of the semen sample collected from the bull by electro ejaculation displayed as a percentage (%)

Assessment of semen as part of a breeding soundness examination is important as 18.6% of bulls have questionable or unsatisfactory semen quality (McGowan, 2004) and out of an unsatisfactory bull population 47.5% failed based on semen abnormalities (Walters and Thomson, 2011) and over half of them are attributed to unsatisfactory morphology (Carson and Wenzel, 1995).

Assessment of mating ability

No assessment of mating ability was performed and therefore no comments can be made on libido or mating ability. This part of the assessment provides lots of difficulties and assessment of normal libido is difficult to define objectively. This part can be opted out on the BCVA certificate (Penny, 2010).

Classification

This bull was classified as 'unsuitable for breeding' based on the fact the SC was 32cm below the breed specific minimum acceptable measurement of 36cm and that the semen sample only had a 55% progressive motility and only 55% normal sperm with most of the defects being head and midpiece. The main differential diagnoses indicated in this specific case are testicular hypoplasia and testicular degeneration. Hypoplasia is less likely as bilateral hypoplasia sperm collection will most likely confirm a complete absence of sperm. Likewise, unilateral hypoplasia is less likely considering the symmetrical appearance of the scrotum. Testicular hypoplasia is a congenital cause of infertility and one that due to the age of the bull would have most likely been noted prior to sale. The high percentage of primary defects of head and mid pieces within the semen samples is supportive of a diagnosis of testicular degeneration (Scott, D. Penny and Macrae, 2011). In this case to assist with reaching a definitive diagnosis ultrasound could have been considered, in testicular degeneration there is loss of normal architecture and a greater appearance of hyperechoic shadowing representative of the fibrosis. Whereas in testicular hypoplasia the testicular tissue appears hypoechoic (Gnemmi and Lefebvre, 2009). The most likely differential in this case is testicular degeneration with unknown insult. It Is difficult to distinguish if an increased proportion of sperm morphological abnormalities is transient or permanent and therefore it is suggested to repeat the bull breeding soundness examination > 61 days, the length of a sperm cycle.

Prevention and follow up.

Bull fertility is a crucial part of beef farm efficiency and a subject area that is often neglected. Performing a pre breeding soundness examination is considered a pro-active approach to screening sub fertile bulls which in turn will help improve beef efficiency. It is a more favourable approach compared to a reactive approach of investigating poor fertility because of poor reproduction figures at the end of the breeding season. The BCVA approved certificate provides a guidance framework that highlights all areas that are important and ensures that no key elements are missed or overlooked (Penny, 2010). A discussion had with the farmer about the fact it is a low-cost screening method and one that should be implemented routinely every year due to the bigger financial implications a sub fertile bull can have without a pre assessment, and this was agreed by the farmer to be included in the annual herd health report.

In this herd following identification of a sub-fertile 3-year-old replacement bull it was suggested to re-test and to perform the bull breeding soundness examination and sperm evaluation in > 61 days. In the short term it was suggested to the herd that they could look for a suitable replacement bull that could replace or run alongside this bull if deemed fertile at the re-rest. It was important that any replacement bull likewise had a pre-sale breeding assessment and that the disease status of the bull against IBR, BVD and Johnes was known, with current recommendations for BVD control being to purchase from an accredited herd with known status, to get the bull individual serum tested and to quarantine for 30 days on arrival and to vaccinate.

Follow up

Re-assessment and a pre breeding examination of the bull was repeated in 65 days and the bull was still classified as sub-fertile, with the sperm sample having only 58% normal sperm morphology, below the target of >70% morphologically normal sperm. The decision was made by the farm to source another replacement Simmental bull and to cull the sub-fertile bull. The farmer managed to source a replacement bull from a disease-free accredited herd which was tested free from BVD, IBR and Johnes prior to purchase and had been deemed satisfactory at a pre-sale breeding assessment. The bull achieved a three week in calf rate of 65% in the first 3 weeks and a calving period of 11 weeks in the 2021 calving season.

Implications/Conclusions

Conclusions

Complete bull infertility is rare however subfertility has been reported as high as 29.5% in a population of 339 fertility tested bulls in the South of England (Walters and Thomson, 2011). Bull subfertility is likely to be under recognised as these animals are likely to still perform in low cow to bull ratios and extended calving blocks. Identification of bull sub fertility in a herd is paramount and satisfactory bulls have been found to achieve a 9% higher pregnancy rate when compared to a sub-fertile bull. This case further highlights the positive effects veterinary intervention and encouragement of carrying out a bull breeding soundness examination can have on reproductive efficiency in the herd.

Economics

A primary objective of a beef enterprise is to achieve a 365-day calving interval and for every cow to rear a calf a year. An extended calving interval is associated with less weight of beef per cow bred per year and uneven weaner weights. A failure to breed therefore has direct impact on the economic viability of a beef herd and every day above a 365 day interval is associated with a financial loss of £1/cow per day (Statham, 2011). A financial key performance indicator used on beef herds is total cost/ kg output, total cost incorporates fixed and variable costs and kg output in a suckler herd is total 200d weaning weights (Hudson, 2018). The most common factor likely to influence 200d weaning weight is poor fertility performance and the knock-on effect on variable calf growth rates. A bull breeding examination cost including a visit is £160 to the farmer. This farmer reports average cost of 6-month-olds stores being sold to be £730 and £1040 respectively for the 12-month-old. A 9% associated increased pregnancy rate associated with a fertile bull in a 54-cow herd is 4 calves which equates to £2,920 if these animals are sold as 6-month-old stores. Therefore, a pre breeding assessment and determination of a sub-fertile bull prior to the start of the breeding will directly increase profitability of the herd.

Increased lameness prevalence

ECBHM Year 3 Case Report

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30/5/2022

Word Count: 2,999

Figures: 2

Tables: 2

History

Presentation

A herd with increased lameness prevalence. Farmer is concerned due to the requirements of his supermarket contract, lameness prevalence should be <10% and intervention is mandatory if > 20%. Veterinarian is concerned about the cow welfare and economic cost of lameness to the herd. Further investigation is warranted.

Farm summary

A 370 Holstein Friesian cow herd, with a predicted 305 day yield of 13, 417 litres. Cows are housed all year round and are robotically milked through 7 Lely robots. Monthly whole herd milk recording is undertaken with QMMS (Quality Milk Management Services). The farm operates an all-year-round calving herd with a mean calving index of 369 days and median of 357 days.

Housing and feeding

Milking cows are housed on deep sand cubicles and fed a total mixed ration of whole crop wheat and maize and grass silage and rationed for M + 30 litres (cows) and M + 26 litres (lactation one). Robot feeding is introduced at a rate of 0.45kgs of concentrate per litre over this. The dry cows are managed in two groups, far off (54 to 21 days before calving) and close to calving (21 days to calving) with separate rations. Pre milking heifers are currently being fed milking cow refusals. Rations are formulated by an independent nutritionist. Far off cows are housed in cubicles with rubber mattresses and sawdust. Close to calving cows, 2 weeks before calving, are moved onto bedded transition yards. Freshly calved cows are moved into another loose straw yard for a week post calving and heifers and cows are mixed from the point of calving. Pre milking heifers are managed on rubber mattress cubicles with rubber matted floor on the passageways.

Lameness control

Milking cows are mobility scored monthly using the DairyCo mobility score system, a zero to four scale. Score 2 and 3 cows being classified as lame animals. Quarterly mobility scores are a requirement of the supermarket aligned contract, however these are not required to be performed by an independent accredited scorer. Cows that are visually determined lame by the farm staff are presented to the foot trimmer monthly. Milking cows are foot-bathed regularly on exit from the robot in 4% formalin. Foot baths are positioned in the cross passageways in the rearing heifer sheds. The herd operates as a closed herd. Automatic scrapers operate in all sheds and are on a constant rate.

Infectious disease

The heard vaccinate annually against Infectious Bovine Rhinotracheitis with a marker live vaccine and Leptospirosis. Johnes individual milk Mycobacterium avium paratuberculosis ELISA testing is carried out every 3 months. Johnes control is in line with the UK National Johnes Management Plan (NJMP). Quarterly bulk milk monitoring is undertaken for IBR gE antibody, and BVD antibodies.

Outbreak summary

At the latest mobility score in February 2021 of the 318 cows scored, 100 were score 2 (31.4%) and 23 were score 3 (7.2%). 38.7% of the herd (n = 123) were classified as lame. This lameness prevalence is higher than the mean prevalence of lameness reported in the UK of 36.8% and the range was 0 to 79.2% (Barker et al., 2010). A zero percent lameness should be a target for farmers to aim towards because of the associated pain and welfare concerns and the impact on the five main freedoms (Whay & Shearer, 2017).

Herd/ animal assessment

Mobility score data

Figure 1 graphically displays the monthly mobility score results, there is any obvious lapse in mobility scoring and this is as a result of the covid-19 lockdown. At the mobility score in March 2020, 260 cows were mobility scored, 30 cows were identified as lame (score 2 or 3) equating to a lameness prevalence of 11.5%. 2 out of the 30 cows lame were a severely lame (score 3), 0.8%. In August 2020, 300 cows were scored and 71 cows were lame (score 2 or 3), 23.6%. 6 cows were identified as severely lame (score 3), 2%. During this time frame the lameness prevalence doubled and was highest in November 2020 at 44%.

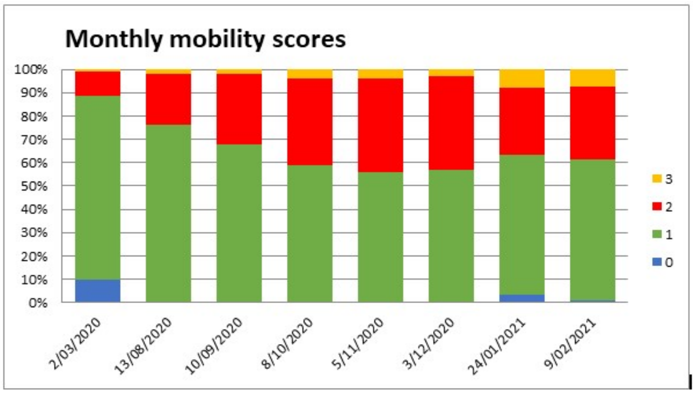

Figure 1: Monthly mobility scores, cows scored using the DairyCo mobility scoring criteria. Score 0 = walks evenly, Score 1 = uneven steps or shortened stride, leg not identifiable, Score 2 = uneven weight bearing on a limb that is identifiable, Score 3 = Unable to keep up with the rest of the herd.

Lesion data

Trimming records are recorded on a software program All4Feet. Apparent lames identified by the farmer are presented to the foot trimmer. 57 cows were trimmed and the most predominant lesions were sole horn lesions and these were responsible for 77.4% of the lesions. This was followed by the categories Other = 11.3%, Digital Dermatitis = 7.5% and White Line lesions = 3.8%. Claw horn distribution lesions are reported to account for 65% of all lesions diagnosed (Bicalho et al., 2007). No new lame lists are generated from the mobility score data and therefore lesion data is not representative of the complete picture. Reported barriers to early prompt treatment are suggested to be the farmer perception of a lame cow and the hesitation around using the term lame due to the negative connotations. UK farmers have been shown to underestimate lameness prevalence in their herd by at least a factor of four (Archer et al., 2010). Additional barriers are the lack of hoof trimming skills, poor quality foot trimming facilities and the time consuming nature of the job (O. Maxwell et al., 2015).

Milk yield data

When looking at the milk yield data (Table 1) compared to last year there has been a 4.3 litre reduction in the yield/cow/day (Litres). For the milking herd of 370 cows, this loss could equate to an approximate 305 day loss of 485, 255 litres of milk. If the milk pay-out is 29p/L this works out as an annual loss of £140, 724. A study on UK farms showed that cases of clinical lameness were associated with a decreased milk yield from four months prior to detection until five months after, resulting in a mean reduction of 360kg per 305 day lactation (Green et al., 2002). This further highlights the incentive for early detection and treatment. The cause of milk yield drop is multi factorial however a proportion of this milk yield drop highlighted in this herd could be attributed to the increased lameness prevalence.

Parameter	19th Feb 2021	15th Jan 2021	3 recordings average	14th Feb 2020
Total yield/day (L)	11,644	11,662	11,475	10,968
Yield/cow/day (L)	38.2	38.6	38.6	42.5
Average no. days in milk	143	158	151	168
Average no. of days dry	61	58	58	67
305 day yield: Cow (L)	14,345	14,219	14,216	14,081
305 day yield: Heifer (L)	11,415	11,522	11,542	11,928

Table 1: Milk yield data comparing 2021 to 2020

Initial problem list

- A lameness prevalence higher than the reported UK prevalence at 38.7%
- No early prompt treatment of score 2 or 3 cows or an appropriate trimming list generated for the foot trimmer.
- A 4.3 litre milk yield/ cow/ day drop over a twelve month period

The main problem is the high lameness prevalence and the associated welfare concerns and production losses.

Diagnostics and differentials

During the farm visit the farm manager was interviewed about all aspects of management relevant to lameness. An on farm assessment of current housing conditions and associated lameness risk factors was carried out and further analysis made of additional data received at the time of the visit. The number of sand cubicles and cows were assessed in order to gain a quantitative representation of stocking density on the farm (Table 2).

Robot Number	Number of cubicles	Number of cows	Stocking Rate
1	54	52	0.96
3	56	58	1.04
4	56	57	1.02
5	Bedded area	27	15 Sqm
6	56	58	1.04
7	47	51	0.92
8	49	51	0.96

Table 2: The calculated stocking densities in each robot. Robot 5 is a straw bedded area.

Cow comfort is paramount to minimise biomechanical forces at the claw environmental surface interface, two important factors that influence this is the surface the cow is standing on and the duration of time spent standing. Increased standing times in the 2 weeks before and 24 hours after calving are associated with sole lesions in mid lactation (Proudfoot et al., 2010). Lameness control should therefore focus on maximising lying times. Multiple factors influence standings times such as cubicle design, bedding surfaces, stocking density and social and behavioural interactions(Randall, Green, & Huxley, 2018). Cubicle measurements were adequate and cows were bedded on deep sand therefore on this particular farm cubicle overstocking is a considerable risk factor and one that has been reported to be associated with reduced lying times and increasing lameness incidence(Cook & Nordlund, 2009).

Further analysis between the two consecutive mobility scores (24/1/21 and 9/2/21) helped us identify chronic lame cows and new lame cows. 318 cows were scored at the 9th February 2021 mobility score, 123 cows were scored lame (score 2 or 3). 75 of those cows were chronic cows and had consecutive scores of mobility score 2 or 3. 30 cows were classified as new lames, cows were score 0 or 1 at the previous mobility score (24/1/21) and were now score 2 or 3 at the current mobility score (9/2/21). The rate of new score 2 cows was 19% of the eligible population between the two scores and a rate of chronic score 2 cows was 18%. Of the 30 new lame cows, 30% of them were in lactation one animals. This level of lameness in the heifers is of particular concern.

Body condition score (BCS) data from two scoring events in February and March 2021 were collated for analysis. BCS were determined using a one-to-five-point scale with increments of 0.25 (Edmonson et al., 1989; Ferguson et al., 1994; Wildman et al., 1982). Out of the 518 BCS events, 241 cows were BCS > 3.5 and categorised as over conditioned (47%). BCS is gained during late lactation (300+ DIM), with a shift from BCS 3.5 to BCS >3.75. An apparent loss of BCS at point of calving is displayed by the greater proportion of BCS <3.25 54% in 0-49 days in milk vs 35% in 300+. Body condition score as a risk factor for lameness and claw horn lesions in particular has been reported in several studies. Periparturient BCS loss and a subsequent BCS < 3 at point of calving and during early lactation (4-10 weeks postpartum) is associated with a higher risk of suffering from a lameness event (OR 2.9-9.4) than cows in better BCS > 3(Hoedemaker et al., 2009). Additional research has shown that cows with a BCS <2 are at great risk of future mild or severe lameness, including first lifetime events in second or higher dairy cows and long term repeated lameness events in all parities (Randall et al., 2015). BCS has a significant effect 12 to 16 week previously in mild cases and 8 to 12 weeks for severe lameness. Both these studies highlight the importance of minimising BCS loss in early lactation and maintaining optimal BCS throughout lactation as a control measure for minimising lameness events. BCS is one of many factors that contribute to a thin digital cushion and other contributing factors proven to have an effect are the calving effect and the influence on the suspensory apparatus, herd factors and previous lesions history(Newsome et al., 2017a). A thin sole thickness predisposes the cow to lameness and lesions later in lactation whereas thinning of sole soft tissue thickness did not (Newsome et al., 2017b).

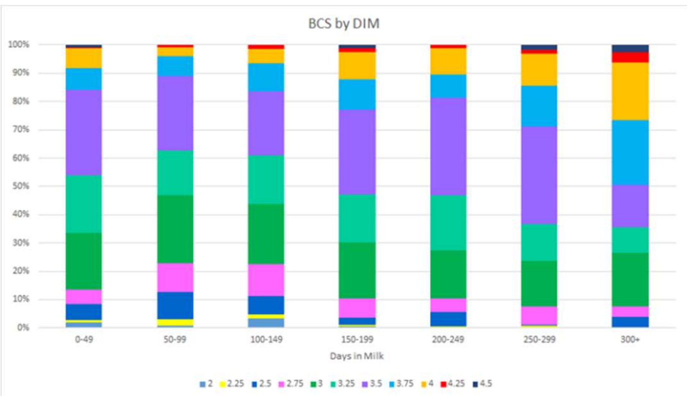

Figure 2: ***The graph indicates the body condition scores (BCS) of the cows recorded throughout February and March 2021, categorised in terms of days in milk (DIM)***

Prevention and follow up

There are numerous suggestive action points following the initial visit:

- Fortnightly mobility scoring to allow early detection of lameness and a new lame cow listed generated using previous mobility score results
- Prompt treatment of new score 2 and 3 cows

Early detection of lameness through fortnightly mobility scoring and prompt treatment within 48 hours is imperative to maximise cure rates and minimise chronic pathological changes. Implementation of fortnightly scoring and treatment has been shown to reduce lameness prevalence (Groenevelt et al., 2014). The most effective treatment is a therapeutic trim, application of a block and a three-day course of NSAIDs; this was found to have a significantly better cure rate when compared to a trim only, 85.4% vs 68.9% (Thomas et al., 2015). Conversely treatment of chronic lame cows with at least two weeks duration was shown to have only a 15 percent cure rate, thereby highlighting the need for early detection (Thomas et al., 2016). Cows with repeated bouts of lameness are key drivers of lameness prevalence on farm and contribute significantly to total number of lameness treatments (Randall et al., 2018)so prevention of the first case is paramount.

- Preventative foot trimming of the milking herd at dry off and mid lactation

Twice yearly trimming is associated with significantly lower odds of sole haemorrhages (OR=0.86), white line disease (OR=0.71) or sole ulcers (OR=0.59) than one trim only. No interaction was found between times of year and trimming success therefore these two trims may be beneficial at any stage in the year (Manske et al., 2002). Potential benefit and reduction in lameness incidence has been shown in late lactation following routine trims of non-lame cattle in mid lactation (Manning et al., 2016). A preventative hoof trim at dry off has been proven to reduce the odds of soul ulcers by approximately 20% (Thomsen et al., 2019).

- Altered management of heifers prior to calving in order to prevent a first case of lameness

A critical control point for management of lameness in dairy cattle is preventing the first lameness event in heifers (Bell et al., 2009). Severe sole lesions in heifers are associated with an increased risk of lameness by 2.6 times across all future lactations, a reduction in average daily yield of 2.68kg and premature culling (Randall et al., 2016). The current management of heifers on rubber matted walkways in cubicle housing doesn't allow claw adaptation to the hard concrete surface they will experience in the milking herd. A study looking at the effect of the change of hard and soft floors on the sole and white lesion prevalence in rearing heifers and it showed that the management strategy of heifers being reared on a soft floor system and then going to a hard floored system was been associated with the highest prevalence and only 37% of heifers in this group remained free from sole haemorrhage (Bergsten et al., 2015). Removing the rubber matting from the heifer areas will allow the claws to adapt and help with prevention. There is less research to support the value of routine trimming of heifers. An early lactation trim on primiparous heifers and the production benefits on milk yield was demonstrated to be not be significant and therefore there is limited cost benefit to trim all heifers but a suggested targeted intervention approach would be to focus on lame animals and prompt treatment (Maxwell et al., 2015). Additionally a randomised control trial showed the effects of a 3 week pre calving trim and 100 day post calving on the first lactation lameness and lactation productivity were not significant. The odds of heifer lameness was greater influenced by environment and management systems and therefore focus on these area will have a greater effect on heifer foot health (Mahendran et al., 2017). The use of non-steroidal anti-inflammatory and control of the inflammatory change in the foot around calving, following administration of ketofen within 24- 36 hours of calving consecutively for 3 days, has been proven to lead to an absolute reduction in population lameness prevalence of approximately 10% and severe lameness prevalence of 3% (Wilson et al., 2022). Implementation of this approach on this farm is indicated.

The lameness data was reviewed 15 months later. On the 14/05/22, 318 animals were mobility scored, 3 animals were score 3 and 29 animals were score 2, 10% lameness prevalence. When looking at two consecutive scores 03/05 and 14/05/2022, 15 cows were chronic (4.7%) and 9 new cases (2.8%) with only 2 being heifers (22%). The lameness prevalence and new lame rate have reduced significantly and is now at a level accepted by the supermarket contract. The main recommendations that were implemented on farm were fortnightly mobility scoring and prompt treatment of new cases with a trim, block and NSAID. The preventative measure put in place was the NSAID three day treatment to heifers 24 hours post calving. No preventative trims were implemented so far and the main reason for this was lack of time because of the foot trimmer focusing on lame trims. This is a measure that the farm is hoping to put in place in the next 6 months.

Implications and conclusion

There are indirect and direct costs associated with the total costs of lameness; direct costs including treatment, time/labour and indirect costs would include reduced milk yield, effect on fertility and increased risk of culling. The degree of milk drop experienced varies depending on the lesion type and severity. Animals with sole ulcer and white line disease had a decrease in milk yield per lactation of 574 kg vs. 369 kg. The lame cows' average calving interval compared to that of healthy cows was 19 days longer and this again varied based on the lesion type. Lameness can result in premature culling and the overall culling rate in the UK attributed to lameness is 5.6%. The value of the cull cow is reduced due to poor condition and poor body weight (Ózsvári, 2017). The cost of individual lameness lesions is found to be; sole ulcer £518.73, white line disease £300.05, digital dermatitis £75.57 (Willshire & Bell, 2009). A simpler way to calculate the economic impact is £/day/lame cow. Mobility score 2 cows cost an average of £1.50 per day that they are lame and mobility score 3 cows cost an average of £4.50 per day that they are lame. Based on the February 2021 mobility score 100 score 2 cows and 23 score 3 cows equates to a cost of £253.50/day and if this prevalence remains constant the total cost would be £92,527.50. Prevention of lameness is economically relevant on this farm.

This case highlights the value of herd level data analysis, identification of risk factors and the importance of prevention. A reduction in lameness prevalence on this farm would have a massive benefit in terms of both cow welfare and economically for the farmer.

Salmonella outbreak in a dairy herd

ECBHM Year 3 Case Report

Rebecca Nelson, University of Nottingham

2022

Word Count: 3,000

Figures: 1

Tables: 2

History

Presentation

A herd with an increased incidence of abortion in the last trimester. Typically, cows presented with no other concurrent clinical signs. No previous concern regarding abortion rate prior to this. Farmer and veterinarian concerned about the direct and indirect financial losses and the knock-on effects to the health status and productivity of those animals. Investigation into the causal agent warranted to identify herd level risk factors and minimise the ongoing impact.

Farm summary

A 550 Holstein Friesian herd with an average 305 day adjusted yield of 11,000 litres. 68% of the milking herd are lactation 1 or 2 animals due to an expanding herd over the last couple of years. Cows are housed all year round with no access to pasture and are milked three times a day through a 36-point rotary parlour, involving two operators and an automatic dip and flush (ADF) system. The farm supplies milk for a supermarket aligned contract and to a local ice cream company. Monthly whole herd milk recording is undertaken with the cattle information service (CIS). Bulk milk cell count is consistently below 180,000 cells/ml and 12-month average bulk milk constituents are 3.96% butterfat and 3.3% protein. The farm operates an all-year-round calving herd with a mean calving index of 381 days and median of 362 days. Heifers are reared off site by two operators from the age of 5 months of age and return to the home farm one month prior to calving. Heifer rearers both have own stock that are managed and mixed. Infectious disease status of heifer rearers own stock unknown.

Housing and Feeding

Milking cows are housed in cubicles with mattresses and are bedded twice daily with sawdust. Cows have access to outside feeding and loafing areas. Living space per cow in shed 1 is 8.2m² and in shed 2 and 3 is 5.1m². Living space being defined as the additional space availability within dairy cow accommodation above that deemed to be a baseline requirement. This is above the mean living space per cow of 2.5m², that was calculated on 53 randomly selected farms (Thompson et al., 2020). The cows are fed a TMR and a maize silage predominant diet. The silage is stored in well maintained clamps. Two mixes are made a day to avoid the spoiling risk of the ration in the summer months. The dry cows are managed in two groups, far off (42 to 21 days before calving) and close to calving (21 days to calving). The far-off dry cows are managed in mattress cubicles with sawdust and the close to calving cows are on straw bedded yards where they calve down. Both cows and heifers are managed in the same way. Freshly calved cows are moved to the milking cow cubicles straight after calving.

Reproductive and Young stock management

All heifers and cows are served using artificial insemination, no natural service is used. The animal's profitable lifetime index (£PLI) dictates whether sexed or beef semen is used. All progeny of Johnes dams is served to beef semen. At point of calving, calves are removed from their dams immediately and given 4 litres of colostrum by a teat bottle or stomach tube. During their first week of life, they are fed pasteurised transition milk starting at 3L twice daily. Adult cows and heifers are vaccinated against rotavirus and coronavirus at dry off, 6 weeks prior to calving for the cows and when they return home, 30 days prior to calving for the heifers. At two weeks of age, they switch to calf milk replacer (CMR) at a rate of 4L twice a day. Calves are individually housed for the first week of life and then go into group housing with multi teat feeders. A step-down weaning approach is implemented when the concentrate intake exceeds 1kg/heifer/day for at least 3-4 days.

Infectious disease status

The herd vaccinates annually against Bovine Viral Diarrhoea, Infectious Bovine Rhinotracheitis and Leptospirosis. Quarterly bulk milk monitoring is undertaken for IBR gE antibody, Neospora and BVD virus PCR. The status at the last test was IBR gE positive, Neospora positive and BVD PCR negative. The herd has been IBR gE positive since the onset of bulk milk monitoring and this is believed to be because of historic use of non-marker vaccines as youngstock. All newborn calves are tag and tested for BVD antigen testing and these have all been negative so indicating no active BVD in the herd. The supermarket contract stipulates that all aborted cows between 60-270d gestation are required to be blood tested for Neospora antibody. Individual cow milk antibody testing for paratuberculosis (Johne's disease) is carried out every three months. Herd prevalence is very low with only 7 out of 500 cows (1.4%) in milk currently not antibody negative. Johnes control is in line with the UK National Johnes Management Plan (NJMP) and the current strategy implemented is improved farm management, test and cull.

Outbreak summary

In between August and September 2020 there were 8 abortions, all occurring in the third trimester. In this time 101 cows and heifers calved; this equates to an estimated abortion incidence rate of 8%. This is high and investigation is warranted where the rate of abortion is above 3-5% of pregnancies (M. Green & Bradley, 2012).

<u>Herd assessment</u>

The herd is an all-year-round calving herd with a six-monthly rolling abortion rate of 2.4% in July 2020. Table 1 outlines the spread of calving's over a 12-month period and the number of abortions that occurred in each month and the associated abortion rate. Between January and July 2020, the abortion rate is consistently below 3%. In August there were 3 abortions and 46 calving's equating to an abortion rate of 6.5% and in September there were 5 abortions and 55 total calving's equating to an abortion rate of 9.1%. Table 2 highlights the details of the individual cows that aborted during that time frame. Obtaining additional information on the age of the dam (heifer or cow) and approximate stage of gestation is helpful in providing clues about the possible pathogen (Cabell, 2007).

This estimated rate of abortion is based on 'observable abortions', an identifiable foetus that is expelled. It is estimated that only 20-30% of abortions are observed and the first case is likely to be the first case observed but not occurred (Mee, 2020). The period of risk for observed abortions is 120 to 260 days and the majority of submitted cases to the diagnostic laboratory (95%) are from the fourth month of pregnancy (>120 days). This indicates that many abortion cases in the first two trimesters are missed, and it is therefore likely that the true abortion rate on this farm would be substantially higher.

	No. of abortions	No. of calving's	Abortion rate (%)
Jan	0	37	0.0
Feb	1	39	2.6
March	0	42	0.0
April	1	31	3.2
May	1	27	3.7
June	1	37	2.7
July	1	45	2.2
Aug	3	46	6.5
Sept	5	55	9.1
Oct	2	53	3.8
Nov	0	67	0.0
Dec	1	54	1.9

Table 1: The number of reported abortions over the 12-month period January to December 2020. The number of calving's each month and the calculated abortion rate.

	Cow ID	Lactation	Days pregnant	Months pregnant
AUG	493	5	168	5.5
	1989	2	237	7.8
	2025	2	228	7.5
SEPT	1592	2	185	6.1
	1600	2	220	7.2
	2018	2	184	6.0
	2051	1	198	6.5
	2111	2	213	7.0

Table 2: The individual cows that aborted lactation number and stage of gestation, in both days and months, at time of abortion

Herd level risk factors

Following assessment of the farm and considering the history discussed above, numerous herd level potential risk factors for infectious causes of abortion were identified:

- Heifers retuned to the herd after off farm activity, particularly after direct contact with other animals
- Recent increase in herd size and the potential associated risk of stress
- High yielding cows and the level of immunosuppression
- No enforcement of biosecurity measures for visitors

Bacteriology

Scour samples were taken from young calves (14-21d of age), indicated by an increase in the scour morbidity rate in July 2020. Farm has a history of cryptosporidium and now routinely uses halofuginone. Samples were taken and sent away to an external laboratory for a young cattle enteritis profile testing for coronavirus, rotavirus, cryptosporidium, and salmonella. Enrichment culture yielded a Group D Salmonella and strain typing confirmed Salmonella Dublin.

Problem list

The primary problems identified were a high rate of abortion 6.5% and 9.1% in July and August, with the majority occurring in the third trimester which is 90-95 days prior to calving. Identification of several herd level risk factors with particular concern re direct contact with other animals at offsite heifer rearers. Previous isolation of Salmonella Dublin in the youngstock.

Diagnostics and differentials

Diagnostic rate of abortion determined from Veterinary Investigation Diagnosis Analysis (VIDA) Annual Report in 2020 is 23%. Likewise a study in Denmark investigated mid to late term abortions and the likely aetiology of abortion and had a diagnostic rate of 33% (Wolf-Jäckel et al., 2020). The low diagnostic rate is thought to be because of the delay between death and expulsion and the resultant degree of autolysis. The three main abortion infectious disease agents in 2020, as determined by submissions to the SRUC and APHA diagnostic services in the UK, were Salmonella Dublin, Neospora Caninum and Bacillus Licheniformis. These three infectious agents accounting for 45% of the diagnosed abortions (VIDA, 2020).

One foetus and placenta were submitted for diagnostic investigation. Gross pathology was nonspecific and suggested a mild placentitis. The MZN-stained smear of the placenta identified no organisms resembling Brucella, chlamydia or Coxiella. Microscopic examination of foetal stomach contents and placenta showed no fungal hyphae spores or yeast cells. Bacteriological testing of the foetal stomach contents showed mixed flora containing a very heavy growth of Salmonella spp. group D, later identified as Salmonella Dublin.

Pooled faecal samples and vaginal mucus swabs alongside blood samples were submitted from the aborted cows. Suspect Salmonella serogroup D was isolated from the pooled vaginal mucus swabs on both direct and enrichment culture. This was later identified as serotype Salmonella Dublin.

Salmonella Dublin may be shed through milk, urine, saliva, vaginal discharge, and faeces. Faecal culture is associated with a poor sensitivity due to intermittent shedding in infected animals or low concentrations of bacteria in re-infected or subclinical animals(Nielsen, 2013). Faecal shedding in the face of an outbreak occasionally can be cultured from clinically normal animals that shed the organism but don't develop clinical signs (Holschbach & Peek, 2018). In animals without clinical disease the sensitivity of individual faecal culture in animals without clinical disease is found to be between 14 and 32 % and pooling reduced this by 57%. Composite faecal sampling, collecting manure from areas where it accumulates such as collecting yards and slurry lagoons has been shown to be more sensitive than individual and pooled faecal samples, primarily because of the increased number of cattle sampled indirectly through this method (Lombard et al., 2012). Composite faecal sampling could provide a less costly and time-consuming alternative to determine herd level status.

An on-farm assessment was carried out and a risk assessment tool was utilised where management practices were assigned a score from zero to max. The maximum score is then weighted according to the importance of the risk factor. The output generated was a risk matrix as displayed in Figure 1. The main identified herd level risk factors on this farm are the calving area and the rearing heifers.

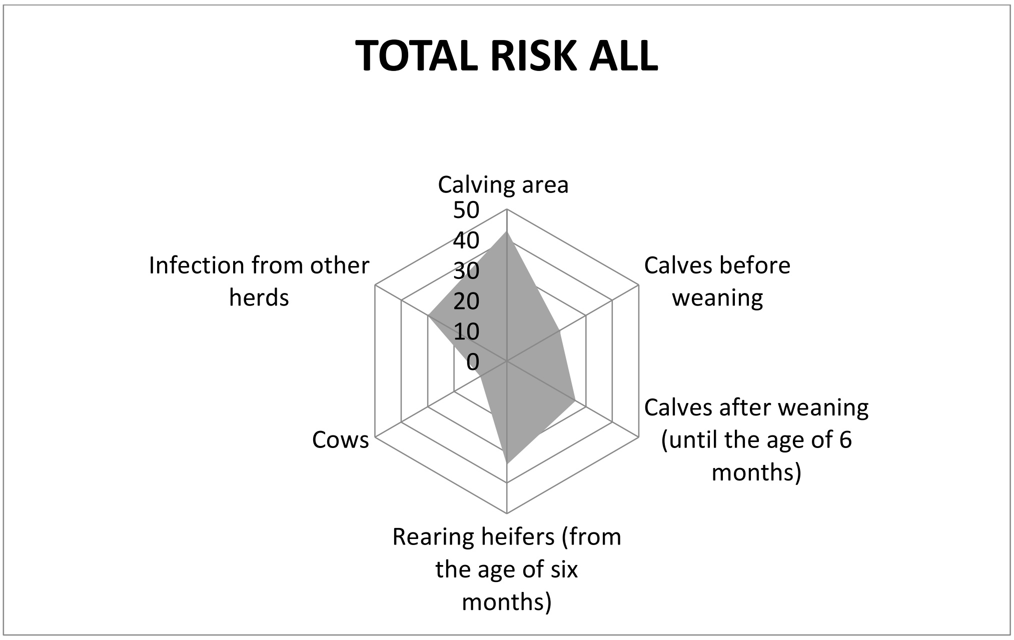

Figure 1: Risk matrix highlighting the risk areas for salmonella and the level of importance in the herd

<u>Prevention and follow up</u>

Once a herd is infected with Salmonella Dublin there is approximately a 50% chance that they will become persistently infected. A proportion of infected animals have a latent infection with intermittent bacterial shedding in faeces and some animals become active carriers and shed bacteria more or less continually. Salmonella Dublin is a host adapted strain so infected cattle present the main risk to a naïve herd.

An expanding herd and purchase of other replacement animals that are infected and actively shedding is the likely route of introduction into this herd and the unknown disease status of incoming heifers that are reared off site. The client may gain added value by performing slurry composite samples at the heifer rearers to determine disease status and risk of infection to the main herd.

Calving pen management is paramount as latent infections can re activate around calving and active carriers shed in greater numbers. Point of calving is associated with a decrease in immune status and an associated increased risk of infection. Carrier status is a complication of infection and carriers are most likely to develop in heifers between one year and old and point of calving and when infection occurs in cows close to calving (Carrique-Mas et al., 2010). The main contributing risk factors for the calving pen in this herd are the level of contamination in the calving area and frequency of cleaning and disinfection and the time the calf spends in the calving yard. Younger animals below the age of 3 months are most susceptible to disease and therefore are associated with a higher incidence rate of acute infection and bacterial shedding. Therefore, preventing transmission of disease to young calves is a critical control point and minimising the time spent in the calving year is optimal (L. R. Nielsen & Nielsen, 2012). Implementation of appropriate disinfection when undertaking a complete clean out is paramount as there is a long persistence of salmonella in the environment and it can survive for months in organic matter such as slurry, cattle manure and soil and years in dried faecal matter (L. R. Nielsen, 2013). Specific recommendations on this farm involve removal of calves away from the dam ideally within one hour but no more than six hours later and that the calving pen is bedded daily and cleaned out fortnightly.

Implementing management and vaccine measures on farm were paramount to limit the spread of disease. Elimination is difficult to achieve due to the carrier animals that intermittently shed within a herd, with shedding frequency likely to increase during periods of stress like at the point of calving. Although control of salmonella Dublin is challenging, the application of standard methodology has been shown to reduce herd level prevalence: the Danish eradication scheme achieved a drop in infected dairy herds from 26 per cent to 6 per cent (Henderson & Mason, 2017). Additionally, it took on average three years from initiation of control actions until monitoring suggested there was no longer spread of disease and seroprevalence was low in all age groups (L. R. Nielsen & Nielsen, 2012). Vaccination is useful for reducing clinical signs and shedding of bacteria from affected animals. It does not entirely stop bacteria from spreading to the environment and between animals.

A follow up assessment was carried out a year later to determine the current abortion rate and what recommendations were implemented on farm. The abortion rate was consistently below 4%. The main recommendation implemented was the administration of a whole herd annual salmonella vaccine. However, the timing of this should be reviewed as it is stated in the data sheet that in order to maintain a sufficient level of active immunisation is advisable for re-vaccination to be administered 3-4 weeks before calving. Therefore, instead of annual vaccination that is suitable in a spring calving herd, the farm should consider pre dry off vaccination. The frequency of calving pen maintenance and clean out had been changed to bedded daily and cleaned out monthly. The most likely reason for this is the time consuming and the reduced labour units on the farm meaning that fortnightly clean out was not achievable. The disease status of the heifer rearers own stock was not determined.

Implications/Conclusion

Economic implications are split into direct losses such as reduced milk yield, dead stock, treatment costs and abortions as well as indirect losses such as reduced income from sold heifers and calves and lower milk replacement of replacement animals. Milk yield decrease associated with a Salmonella Dublin infection is significant and the effect is apparent for a prolonged period of time. A study in Danish herds investigated the effect of introduction of salmonella in a herd, detected by a raise in bulk milk antibodies, on energy corrected milk yield (ECM) and to determine the duration of the effect. Mean daily yield was decreased by 1.4 kg ECM per cow per day for first parity animal during the period 7 -15 months after the estimated herd infection date, while it was further reduced by 3 kg ECM per cow per day for parity 3+ animals. In contrast parity 2 animals mainly had a reduced yield 13 to 15 months after infection (Nielsen et al., 2012). The cost of an outbreak to a UK dairy herd of 100 animals with the clinical picture or abortions, decreased milk yield in cows and diarrhoea and death amongst calves was estimated to be approximately £7870 of which £3600 were due to reduced milk yield (Bazeley, 2006). Estimated gross margin losses have been shown to be greatest in the first year after infection and increased with poorer management and herd size. This indicates that it is even more important to control salmonella in large herds and more resources can be spent on control measures. The greater effects in larger herds can be attributed to the infection persisting in herds and partly and due a great number of at-risk animals in the population. Average annual gross margin losses were estimated to be 49 euros per stall for the first year and to 8 euros per stall annually averaged over 10 years following infection (Nielsen et al., 2013). The cost implication to this 550 cow milking herd is massive and there is huge economic gain in implementation of control measures.

This case highlights the importance of a salmonella outbreak in terms of animal welfare and human health. Salmonellosis in food animals is reportable under the Zoonoses order 1989 in the United Kingdom. The route of infection is most likely through direct contact with cattle or infected faeces or through drinking unpasteurised milk or dairy products, with the majority of cases being acquired through food borne exposure. The indirect costs of reduced milk yield associated with disease accounts for 46% of the total cost therefore this case highlights the importance of determining the herd status of all dairy farms in the UK in order to allow implementation of control measures.

7.5 Publications

- NELSON, R., KERBY, M. & REMNANT, J. (2022) Clinical examination of cattle. Part 1: Adult dairy and beef cattle. *In Practice* **44**, 292–300
- SHERWIN, G., NELSON, R., KERBY, M., REMNANT, J. (2022) Clinical examination of cattle. Part 2: calves, technology and ancillary testing, In Practice, 10.1002/inpr.237, **44**, 7, (403-419), (2022).