Research Article • DOI: 10.1515/ijafr-2016-0016 IJAFR • 55(2) • 2016 • 159-168

Irish Journal of Agricultural and Food Research

Electronic feeding behavioural data as indicators of health status in dairy calves

D. Johnston[1,2], D.A. Kenny[1], M. McGee[3], S.M. Waters[1], A.K. Kelly[2], B. Earley[1†]

[1]Animal and Bioscience Research Department, Animal and Grassland Research and Innovation Centre, Teagasc, Dunsany, County Meath, Ireland
[2]University College Dublin, College of Agriculture, Food Science and Veterinary Medicine, Dublin, Belfield, Dublin, Ireland
[3]Livestock Systems Research Department, Animal and Grassland Research and Innovation Centre, Teagasc, Dunsany, County Meath, Ireland

Abstract

The objectives of this study were (i) to characterise clinical health in dairy calves on an Irish research farm during the artificial calf-rearing period and (ii) to determine whether calves' pre-weaning intakes and feeding behaviour, recorded by electronic calf feeders, changes in response to incidents of bovine respiratory disease (BRD). Holstein–Friesian (H–F) and Jersey (J) calves were fed by automatic milk replacer (MR) and concentrate feeders. Feeding behaviour, including MR consumption, drinking speed, number of rewarded and unrewarded visits to the feeder as well as concentrate consumption, was recorded by the feeders. A modified version of the Wisconsin calf health scoring criteria chart was used to score calves' clinical measurements and identify incidences of BRD. Thus, 40% of calves were found to have at least one incident of BRD. Feeding behaviour was altered during incidents of BRD. The number of unrewarded visits to the feeder was reduced, by approximately four visits, for calves with BRD during the 3 d prior to the identification of BRD ($P < 0.05$) and tended to be reduced during the 7 d following the identification of BRD ($P = 0.05$), compared with healthy calves. Additionally, calves with BRD had a tendency for reduced net energy intake (approximately 8%) during the 3 d prior to the identification of BRD, compared with healthy calves. Therefore, calf feeding behavioural data, recorded by electronic feeders during the pre-weaning period, can indicate cases of BRD.

Keywords

dairy calves • electronic feeder • health • respiratory disease

Introduction

Enteritis and bovine respiratory disease (BRD) are the most common diseases resulting in mortality in neonatal calves and calves from 1 mo to 6 mo of age, respectively (Sivula *et al.*, 1996b; Svensson *et al.*, 2006; Gulliksen *et al.*, 2009). Diseases during the calf-rearing period are known contributors of substantial economic losses to the dairy industry (Waltner-Toews *et al.*, 1986; Raboisson *et al.*, 2013).

Dairy calf mortality rates vary among countries, with estimates as low as 3.1% being reported in Sweden and Denmark (Svensson *et al.*, 2006; Gulliksen *et al.*, 2009), and rates ranging from 7.9% to 9.4% reported in the United States (Losinger and Heinrichs, 1997; Lombard *et al.*, 2007). In Ireland, the mortality rate for dairy calves during the first year of life is high, at 7.5% (DAFM, 2014). Furthermore, with the recent abolishment of milk quotas, herd sizes are set to increase, and larger herds tend to have increased mortality (Gulliksen *et al.*, 2009; Torsein *et al.*, 2011). However, a broad range of mortality rates can be observed across farms, which suggests that reductions could be achieved via improvements in management, health and husbandry practices (Torsein *et al.*, 2011; Raboisson *et al.*, 2013).

Recognised risk factors for dairy calf morbidity and mortality during the rearing period include calf birth weight, colostrum intake, milk feeding practices, housing, age at weaning and exposure to infectious disease (Sivula *et al.*, 1996a; Brickell *et al.*, 2009). However, the impact of these risk factors on calf mortality is often found to be inconsistent across studies (Brickell *et al.*, 2009). Due to differences in production and rearing systems relative to those practiced in Ireland, importation of findings from many international studies (Sivula *et al.*, 1996a; Losinger and Heinrichs, 1997; Svensson *et al.*, 2003; Lundborg *et al.*, 2005; Torsein *et al.*, 2011) is not always possible nor appropriate.

Recent research has shown that breed can affect immune responses in Holstein and Jersey (J) calves (Ballou, 2012; Johnston *et al.*, 2016a, 2016b). Furthermore, Montbeliarde and Normande heifers have been observed to have higher mortality rates than Holstein–Friesian (H–F) calves (Raboisson *et al.*, 2013). However, studies investigating the effect of plane of nutrition have produced varying results, with some authors suggesting improved immune responses from calves on higher planes of nutrition (Ballou, 2012) and others suggesting the opposite (Foote *et al.*, 2007; Obeidat *et al.*, 2013). As level of nutrition and breed can influence the activity of the immune system in dairy calves, it is hypothesised that these factors may affect the frequency of disease incidences during the artificial rearing period.

†Corresponding author: B. Earley
E-mail: Bernadette.Earley@Teagasc.ie

DE GRUYTER OPEN

It may be possible to identify sick calves using feed-related data generated by electronic calf milk replacer (MR) and concentrate feeding systems. It has previously been shown that decreases in concentrate consumption, recorded by an electronic calf concentrate feeding system, were correlated with decreased health status and increased veterinary treatments (Roth *et al.*, 2009). Sick calves have been observed to decrease their unrewarded visits to the MR feeder (Svensson and Jensen, 2007). Furthermore, calves on high allowances of MR decreased their number and duration of visits to the MR feeder and decreased their milk consumption when sick, while calves on lower allowances decreased the duration of their visits at the MR feeder when sick (Borderas *et al.*, 2009). Therefore, changes in net energy (Unité Fourragère Lait (UFL)) consumption, MR consumption, concentrate consumption, number of visits to the feeder and drinking speed may be related to the incidence of disease. Consequently, data from electronic calf feeders have the potential to highlight sick calves that require treatment. Through early identification of sick calves using this feeding behaviour data, morbidity and mortality may be reduced. Therefore, the objectives of this study were (i) to characterise clinical health in H–F and J calves on an Irish research farm on three different planes of nutrition during the calf rearing period and (ii) to determine whether calves' feeding behaviour, recorded by electronic calf feeders, changes in response to incidents of BRD, during the pre-weaning period.

Materials and methods

All animal procedures performed in this study were conducted under experimental licence from the Irish Department of Health and Children (licence number B100/2869). Protocols were in accordance with the Cruelty to Animals Act (Ireland 1876, as amended by the European Communities regulations 2002 and 2005) and the European Community Directive 86/609/EC.

Animal management

This experiment was conducted as part of a larger study, and therefore, the animal model and management have previously been described by Johnston *et al.* (2016a). For clarity, it is also briefly outlined here. The study was structured as a factorial design with two breeds (H–F and J) and three planes of nutrition (High [H], Medium [M] and Low [L]) within a breed. Forty-six H–F and 37 J clinically healthy bull calves were purchased at approximately 2.7 wk of age and group-housed indoors at Teagasc, Grange Beef Research Centre, on sawdust-floored pens (balanced for breed) from day –56 to day 28 of the study. All H–F calves came from a single farm and J calves were sourced from three farms. Calves were immunised on arrival against infectious bovine rhinotracheitis, bovine parainfluenza 3 virus, bovine respiratory syncytial virus, *Mannheimia haemolytica* serotypes A1 and A6 as well as *Salmonella dublin* and *S. typhimurium* using Rispoval IBR-Marker live, Bovipast RSP and Bovivac S vaccines, respectively.

Within each breed, calves were stratified on the basis of live weight, age at the first day of the study (day –56) and sire, and these were subsequently assigned to a nutrition treatment. The planes of nutrition for each breed were devised using the National Research Council (NRC, 2001) guidelines to achieve a target growth rate of ≥1 kg/d, 0.7 kg/d and <0.5 kg/d for H–F calves on the H, M and L planes of nutrition and a target growth rate of 0.7 kg/d, 0.5 kg/d and ≤0.3 kg/d for J calves on the H, M and L planes of nutrition.

Study periods

The pre-weaning, weaning and post-weaning periods were defined as days –56 to –14, days –13 to 0 (milk feeding ceased) and days 1 to 28, respectively. The pre-weaning period was further divided into three sub-periods (start = days –53 to –37; mid = days –36 to –25; end = days –24 to –14).

Feeding behaviour recorded by the electronic feeders

Calves were fed a 23% crude protein (CP), 18% lipid MR (Blossom Easymix; Volac, Co., Cavan, Ireland) and concentrate (26.5% barley, 25% soya, 15% maize, 12.5% beet pulp, 12.5% soya hulls, 5% molasses, 2.5% minerals, 1% vegetable oil [18.8% CP, 22.4% neutral detergent fibre and 11.06 MJ metabolisable energy {ME}/kg dry matter {DM}]) using automatic MR (Vario Powder; Förster-Technik GmbH, Engen, Germany) and concentrate (KFA3-MA3; Förster-Technik GmbH) feeders.

During the pre-weaning period, H–F calves on the H, M and L planes of nutrition were offered 1.2 kg MR (8 L at 150 g/L) with *ad libitum* concentrate, 0.8 kg MR (6 L at 133.33 g/L) with a maximum of 1.5 kg concentrate and 0.5 kg MR (4 L at 125 g/L) with a maximum of 1 kg concentrate, daily, respectively. The J calves on the H, M and L planes of nutrition were offered 0.8 kg MR (6 L at 133.33 g/L) with *ad libitum* concentrate, 0.5 kg MR (4 L at 125 g/L) with a maximum of 1.5 kg concentrate and 0.35 kg MR (3.5 L at 100 g/L) with a maximum of 1 kg concentrate, daily, respectively.

During the weaning phase, daily MR was gradually reduced, and by day –1, all calves were consuming at least 1 kg of concentrate/d for three consecutive days. On day 0, MR was eliminated from the diet of all calves. Concentrate allocation increased post-weaning to 2 kg and 1.7 kg, for H–F calves for M and L nutrition treatments, respectively, and increased to 1.7 kg and 1.4 kg, for J calves on the M and L nutrition treatments, respectively. Animals on the H treatment within both breeds received *ad libitum* access to concentrate feed.

Calves on the H and M planes of nutrition were allowed a maximum of 2 L MR in a 2-h period and calves on the L plane of nutrition were allowed a maximum of 1.5 L MR in a 2-h period. The electronic feeders recorded the following daily parameters: MR consumption (L/d), drinking speed (mL/min), number of rewarded visits, number of unrewarded visits and concentrate consumption (kg/d) for each calf. The number of rewarded visits was calculated as the number of times a calf entered the MR feeder and received MR. The number of unrewarded visits was the number of times a calf entered the MR feeder but was not entitled to any MR.

The daily net energy (UFL) intake values were calculated for each calf by summing its daily MR and concentrate intake values. The UFL value of the MR and concentrate was determined from the net energy (Mcal/kg) values of the ingredients stated in NRC (2001).

Environmental measurements

The daily air temperature was recorded at the on-site meteorological recording station. Average air velocity was taken with the anemometer every weekday for the duration of the study. The anemometer was held in each place for 20 s, and the average air velocity was recorded. Average air velocity was recorded at three different heights: ground level, 1 m above ground level and 2 m above ground level, in three different areas of the pen: the front opposite the automatic feeder, the middle and the back, diagonally opposite to the measurement taken at the front of the pen.

Blood sample collection

At arrival, blood samples were collected from all calves via jugular venipuncture into 8.5 mL BD Serum Separator Tube II™ Advance tubes (BD Vacutainer®; Unitech, Dublin, Ireland). The serum was harvested, and samples were stored at –20°C pending analysis by the zinc sulphate turbidity (ZST) test. The ZST test (proxy for immunoglobulin status) was performed at 20°C, and the turbidity was subsequently measured at 520 nm using a UVmini-spectrophotometer (Shimadzu, Japan) (McEwan *et al.,* 1970).

Clinical assessment of calves

Clinical assessments of the calves were taken twice a week during the pre-weaning and weaning periods and once per week during the post-weaning period. These assessments included monitoring of rectal temperature, faecal consistency (normal, semi-formed, loose and watery), presence of cough (none, induced or spontaneous cough; or repeated induced coughs or repeated spontaneous coughs), ear position (normal, ear flick or head shake, unilateral droop, head tilt or bilateral droop), presence of nasal discharge (none, small amount of unilateral discharge, bilateral or excessive discharge or copious bilateral discharge) and ocular discharges (none, small amount, moderate amount of bilateral discharge or heavy discharge) (McGuirk and Peek, 2014). A modified version of the Wisconsin calf health scoring criteria was used to score the calves' clinical measurements and determine the incidents of the BRDC (McGuirk and Peek, 2014). A respiratory score was devised from the cumulative score from nasal discharge, eye or ear score (whichever is greater), cough and rectal temperature (McGuirk and Peek, 2014). A calf was considered to have a BRDC event if it had a Wisconsin respiratory score greater than or equal to 5.0, in addition to having a rectal temperature of at least 39.5°C. When a calf presented with a faecal score of 3.0 or if it had a faecal score of 2.0 for ≥2 d, it was considered to have enteritis.

Veterinary treatments

When calves presented with a rectal temperature ≥39.5°C, their feed intake and clinical records were monitored. Antibiotic treatment was administered if clinical manifestations of disease were present and/or feed intake was reduced. Electrolytes and/or antibiotics were administered if a calf presented with a faecal score of 3.0 or if it had a faecal score of 2.0 for ≥2 d.

Removal of calves from the study

One H–F (L plane of nutrition) calf and one J (L plane of nutrition) calf died from BRD during the pre-weaning period. Seven J (one from the H, three from the M and three from the L planes of nutrition) and two H–F (one from the H and one from the L planes of nutrition) calves were removed from the study on the recommendation of the veterinary practitioner and placed in isolation pens due to severe BRD. One J (L plane of nutrition) and four H–F (three from the H and one from the M planes of nutrition) calves were removed from the study as they had more than two incidences of BRD during the entire artificial rearing period.

Statistical analysis

All data analysis was performed using SAS (2003) version 9.3 (SAS Institute Inc., Cary, NC, USA). The calf was the experimental unit in all analyses. All data were initially examined for adherence to a normal distribution (PROC UNIVARIATE). Data not normally distributed were transformed by raising the variable, as appropriate, to the power of lambda. The required lambda value was calculated by conducting a Box–Cox transformation analysis using the TRANSREG procedure.

A pre-weaning health category was devised for the ZST analysis. In this health category, calves were categorised as having developed BRD during the pre-weaning period or not having developed BRD during the pre-weaning period. Differences in ZST values between calves from each breed, plane of nutrition and pre-weaning BRD health category were analysed using the mixed models procedure (PROC MIXED). The model included breed, plane of nutrition and pre-weaning BRDC health category as the fixed effects.

Differences in the number of calves that died during the study period, the number of calves with BRD incidents per period and sub-period, the number of calves with enteritis incidents and the number of calves removed from the study due to severe BRD between the two breeds and the three planes of nutrition were analysed using logistic regression (PROC LOGISTIC).

Three different sickness periods (BRD day, pre-BRD days and post-BRD days) were devised for analysing the effect of health status (having BRD versus healthy matched control) on pre-weaning feeding behaviour variables. The BRD day was assigned as the day that BRD was identified using clinical health assessments, the pre-BRD period included the 3 d before BRD was identified and the post-BRD period comprised the 7 d following identification of BRD. Pre-BRD and post-BRD averages were calculated for each BRD event for all feeding behaviour variables (net energy [UFL] consumption, MR consumption, drinking speed, number of visits to the feeder rewarded with MR, number of visits to the feeder unrewarded with MR and concentrate consumption) during the pre-weaning period. For each calf with BRD event, a healthy calf (matched control) that was of the same breed, offered the same plane of nutrition and was of a similar age and starting weight was identified. The healthy calf had to have no incidents of BRD during the pre-weaning sub-periods (start, mid and end), which encompassed the 3 d before the BRD event, the day of the BRD event and the 7 d following the BRD event. The equivalent BRD day, pre-BRD days and post-BRD days were assigned to the healthy matched control and the equivalent pre-BRD averages and post-BRD averages for all the feeding behaviour variables were also calculated for the matched healthy control.

The pre-BRD averages, the BRD day data and the post-BRD averages for the feeding behaviour variables were tested separately using mixed models (PROC MIXED). The model included plane of nutrition, breed, health status (calf with BRD or healthy matched control) and their interactions as fixed effects. Non-statistically significant interactions were sequentially removed from the models. Calf was included as a random effect. Differences between the means were tested using the PDIFF option within the MIXED procedure and a Tukey post hoc analysis. Means were considered statistically significantly different at a probability level of $P < 0.05$.

Results

Environmental measures

The average (s.d.) air temperature recorded while the calves were reared was 9.2 (5.0)°C. The average (s.d.) air velocity in the calves' rearing pens was 0.18 (0.36) m/s.

Zinc sulphate turbidity test

The ZST test performed on serum collected on arrival of the calves showed that J calves had greater maternally derived passive immunity – mean (s.d.): 19.7 (0.56) units – than H–F calves – mean (s.d.): 16.7 (0.49) units ($P < 0.001$). Passive immunity was not different between nutrition treatments or between calves that developed or that did not develop the BRDC during the pre-weaning period.

Clinical health

The mortality rate was 2.4% for this group of calves. The mortality rate was not affected by breed or plane of nutrition ($P > 0.05$). Moreover, 10, 11, nine, eight and four calves had an incident of BRD during the pre-weaning sub-period start, the pre-weaning sub-period mid, the pre-weaning sub-period end, the weaning period and the post-weaning period, respectively (Table 1). The likelihood of a calf having BRD during any of the periods or sub-periods was not affected by breed or plane of nutrition. Three calves had an incident of BRD during two pre-weaning sub-periods. Overall, 27 calves developed BRD (40%) at least once during the entire pre-weaning period. Five calves (7%) and one calf (1%) developed enteritis and a gastrointestinal disorder during the pre-weaning period, respectively (Table 1). No calves developed enteritis or a gastrointestinal disorder during the weaning or post-weaning period. Eight calves (12%) and four calves (6%) had an incident of BRD during the weaning and post-weaning periods, respectively.

Changes in feeding behaviour due to the BRDC

Several feeding behaviour variables were altered in calves that had BRD. Health status affected the number of unrewarded visits to the MR feeder during the pre-BRD period (3 d prior to identification of BRD and the equivalent period for the matched healthy calves) ($P < 0.05$) and tended to affect the number of unrewarded visits to the MR feeder during the post-BRD period (7 d post-identification of BRD and the equivalent period for the matched healthy calves) ($P = 0.05$) (Table 2). Calves with BRD had reduced numbers and tended to have reduced numbers of unrewarded visits to the MR feeder compared with healthy matched controls during the pre-BRD and the post-BRD periods, respectively.

Health status tended to affect the net energy consumption during the BRD day (day that BRD was identified and the equivalent day for the matched healthy calves) ($P = 0.09$) (Table 2). Calves with BRD tended to have reduced net energy consumption compared with healthy matched control calves. Health status also tended to affect concentrate intake during the pre-BRDC period ($P = 0.09$) (Table 2). Calves with BRD tended to have reduced concentrate consumption compared with healthy matched control calves.

Table 1. The number of calves from each breed and plane of nutrition with a sickness event (BRD, enteritis or gastrointestinal disorder) during the pre-weaning sub-periods, as well as the weaning and post-weaning periods

Breed	H–F[1]			J[2]		
Plane of nutrition[3]	H (n = 11)	M (n = 14)	L (n = 14)	H (n = 10)	M (n = 9)	L (n = 9)
Pre-weaning period (start)[4]						
Calves with a BRD event	1	3	2	0	2	2
Calves with an enteritis event	1	1	0	1	0	0
Calves with a gastrointestinal disorder event	0	0	0	0	0	0
Pre-weaning period (mid)[4]						
Calves with a BRD event	0	4	2	1	3	1
Calves with an enteritis event	0	1	0	0	1	0
Calves with a gastrointestinal disorder event	0	0	0	0	0	0
Pre-weaning period (end)[4]						
Calves with a BRD event	3	2	0	2	1	1
Calves with an enteritis event	0	0	0	0	0	0
Calves with a gastrointestinal disorder event	0	1	0	0	0	0
Weaning period[4]						
Calves with a BRD event	2	1	0	2	1	2
Calves with an enteritis event	0	0	0	0	0	0
Calves with a gastrointestinal disorder event	0	0	0	0	0	0
Post-weaning period[4]						
Calves with a BRD event	0	1	2	1	0	0
Calves with an enteritis event	0	0	0	0	0	0
Calves with a gastrointestinal disorder event	0	0	0	0	0	0

[1]H–F = Holstein–Friesian calves.
[2]J = Jersey calves.
[3]H = high plane of nutrition; M = medium plane of nutrition; L = low plane of nutrition.
[4]Pre-weaning period (start) = days –53 to –37, relative to weaning (day 0); pre-weaning period (mid) = days –36 to –35, relative to weaning (day 0); pre-weaning period (end) = days –24 to –14, relative to weaning (day 0); weaning period = days –14 to –1; post-weaning period = days 0 to 28.

There was an interaction between health status and plane of nutrition for drinking speed during the pre-BRDC period and the BRDC day ($P < 0.05$) (Table 2). Calves with BRD on the M plane of nutrition had a reduced drinking speed compared with matched healthy control calves on the M plane of nutrition during the pre-BRD period and the BRD day ($P < 0.05$).

Many feeding behaviour variables were affected by breed and plane of nutrition as would be expected due to the design of the animal model (Table 2). Net energy (UFL) was affected by breed during the pre-BRD ($P < 0.001$) and post-BRD ($P < 0.05$) periods (Table 2). The H–F calves had greater net energy consumption during the pre-BRD and post-BRD periods. Net energy was affected by treatment during the pre-BRD period, the BRD day and the post-BRD period ($P < 0.001$) (Table 2). Net energy consumption was different between calves on the H, M and L planes of nutrition during the pre-BRD period ($P < 0.05$), the BRD day ($P < 0.001$) and the post-BRD period ($P < 0.001$).

There was an interaction for breed and plane of nutrition for MR intake during the pre-BRD period, the BRD day and the post-BRD period ($P < 0.001$) (Table 2). MR intake differed between H–F and J calves on each plane of nutrition ($P < 0.05$) and also among the planes of nutrition within breed ($P < 0.001$).

There was an interaction for breed and plane of nutrition for concentrate intake during the pre-BRD period, the BRD day and the post-BRD period ($P < 0.05$) (Table 2). The J calves on the H plane of nutrition had greater concentrate intakes than J calves on the M and L planes of nutrition during the BRD day and the post-BRD period ($P < 0.05$); J calves on the H plane of nutrition had greater concentrate intakes than H–F calves on the H plane of nutrition during the pre-BRD period, the

BRD day and the post-BRD period (*P* < 0.05). Furthermore, J calves on the M plane of nutrition had greater concentrate intakes than H–F calves on the M plane of nutrition during the BRD day (*P* < 0.05).

Breed affected the number of unrewarded visits to the MR feeder during the BRD day, with J calves having more unrewarded visits to the MR feeder (*P* < 0.05) (Table 2). There was also an effect of breed on the number of rewarded visits on the BRD day, with H–F calves having more rewarded visits than J calves (*P* < 0.01) (Table 2). Additionally, there was an effect of plane of nutrition on the number of rewarded visits during the pre-BRD period, the BRD day and the post-BRD period (*P* < 0.001) (Table 2). Calves on the H plane of nutrition had a greater number of visits rewarded with MR compared with calves on the M and L nutrition treatments during the pre-BRD period, the BRD day and the post-BRD period (*P* < 0.05). Calves on the M plane of nutrition had a greater number of visits rewarded with MR compared with calves on the L nutrition treatment during the pre-BRD period (*P* < 0.01).

Breed affected drinking speed during the BRD day and the post-BRD period, with H–F calves having greater drinking speeds than J calves (*P* < 0.05) (Table 2). Drinking speed was affected by plane of nutrition during the post-BRD period (*P* < 0.01) (Table 2). Calves on the M plane of nutrition had a greater drinking speed than calves on the H or L plane of nutrition (*P* < 0.05).

Discussion

This is the first study to examine the effects of incidents of BRD on feeding behaviour recorded by electronic feeders in Irish dairy calves. The mortality rate for this group of artificially reared H–F and J calves was low compared with those reported in other studies (Losinger and Heinrichs, 1997; Svensson *et al.*, 2006; Lombard *et al.*, 2007; Gulliksen *et al.*, 2009). However, morbidity – and in particular, incidents of BRD – was greater in this study than that generally observed for artificially reared dairy calves (Svensson *et al.*, 2003; Lundborg *et al.*, 2005; Gay and Barnouin, 2009). Nevertheless, morbidity generally varies between farms, and rates similar to and greater than that observed in this study have been identified in Ireland (Conneely *et al.*, 2014) and in some farms internationally (Lundborg *et al.*, 2005; Svensson and Jensen, 2007; Borderas *et al.*, 2009). Furthermore, consistent with previous studies, plane of nutrition had no effect on the number of incidents of disease (Conneely *et al.*, 2014). This is probably because all calves received adequate nutrition (i.e., more than maintenance). This study and our previous study (Johnston *et al.*, 2016a) have demonstrated that feeding greater amounts of MR and concentrate does not appear to augment immune function in dairy calves.

Passive transfer of maternal immunoglobulin is important in determining the subsequent health and level of morbidity in the pre-weaned calf (Donovan *et al.*, 1998; Dewell *et al.*, 2006; Godden, 2008; Berge *et al.*, 2009; Furman-Fratczak *et al.*, 2011; Lorenz *et al.*, 2011; Murray *et al.*, 2014). However, consistent with other studies (Sivula *et al.*, 1996b; Virtala *et al.*, 1996), the level of maternally derived serum immunoglobulin (measured by the ZST test) did not affect the likelihood of a calf developing BRD during the pre-weaning period in this study. However, no calves had failure of passive transfer (<12 ZST units). Moreover, J calves had greater levels of maternally derived passive immunity than H–F calves and this is consistent with the results of other published studies (Tennant *et al.*, 1969; Jones *et al.*, 2004; Ballou, 2012; Villarroel *et al.*, 2013; Vogels *et al.*, 2013). Despite having greater maternally derived passive immunity, more J calves were removed from the experiment following the advice of the veterinarian due to severe symptoms of BRD compared with H–F calves. This observation, along with reports of J calves being more susceptible to infections with *Mycobacterium paratuberculosis* (Çetinkaya *et al.*, 1997; Jakobsen *et al.*, 2000) and *S. typhimurium* (Wray and Sojka, 1978) than H–F calves, suggests differences in immune activity between these two breeds.

One reason for the high morbidity observed in this study may be the use of the on-farm respiratory screening tool, along with rectal temperature, for the identification of BRD. The Wisconsin health screening tool was designed for use twice a week to facilitate early detection of pre-weaned calves with BRD (McGuirk and Peek, 2014). We used a minimum rectal temperature of 39.5°C, in addition to respiratory scoring, for the identification of sick calves as rectal temperature has a higher specificity than respiratory scoring (Schaefer *et al.*, 2007). Therefore, it was more accurate to include it along with the more subjective clinical score for the true identification of a BRD case (White and Renter, 2009). However, BRD screening may identify more cases of BRD than would be routinely detected by farmers. Indeed, high morbidity rates have been reported in studies routinely using on-farm screening tools for the identification of BRD (Svensson and Jensen, 2007; Borderas *et al.*, 2009; Conneely *et al.*, 2014; McGuirk and Peek, 2014; Peña *et al.*, 2016). Furthermore, many BRD cases can go undetected, and a study has reported that 69.5% of calves presenting with lung lesions at slaughter had never been treated for BRD (Thompson *et al.*, 2006). As the average daily live-weight gain for calves from each feeding treatment was not compromised (Johnston *et al.*, 2016a), the incidents of BRD detected using on-farm BRDC screening did not appear to have adversely affected growth. Therefore, it is possible that these calves would not be identified as BRD cases without thorough on-farm screening.

Table 2. The effect of health status, plane of nutrition, breed and their interactions on feeding behaviour

Feeding behaviour	Health status (HS)[1]		SEM[2]	Plane of nutrition (N)[3]			SEM[2]	Breed (B)[4]		SEM[2]	P values			Interactions[5]		
Variable[6]	**BRDC**	**Control**		**H**	**M**	**L**		**H–F**	**J**		**HS**	**N**	**B**	**HS ´ N**	**HS ´ B**	**N ´ B**
UFL																
Pre-BRD	1.71	1.85	0.09	2.43	1.60	1.32	0.10	1.94	1.63	0.09	Te	***	***	NS	NS	NS
BRD day	1.80	1.91	0.08	2.55	1.71	1.30	0.09	1.90	1.81	0.08	NS	***	NS	NS	NS	NS
Post-BRD	1.85	1.97	0.09	2.63	1.76	1.34	0.10	2.02	1.80	0.09	NS	***	*	NS	NS	NS
Milk																
Pre-BRD	5.22	5.26	0.08	7.00	4.98	3.75	0.09	5.96	4.52	0.08	NS	***	***	NS	NS	***
BRD day	5.10	5.05	0.06	6.74	4.92	3.56	0.08	5.86	4.29	0.06	NS	***	***	NS	NS	***
Post BRD	5.03	5.03	0.05	6.68	4.80	3.62	0.06	5.86	4.20	0.05	NS	***	***	NS	NS	***
Concentrate																
Pre-BRD	0.44	0.56	0.10	0.58	0.39	0.53	0.11	0.37	0.62	0.10	NS	NS	**	NS	NS	*
BRD day	0.56	0.68	0.08	0.77	0.52	0.58	0.09	0.36	0.88	0.08	Te	*	***	NS	NS	*
Post BRD	0.65	0.77	0.09	0.90	0.61	0.62	0.10	0.51	0.92	0.09	NS	*	***	NS	NS	*
Unrewarded visits																
Pre-BRD	9.95	13.55	1.50	10.05	12.20	13.00	1.68	12.04	11.46	1.50	*	NS	NS	NS	NS	NS
BRD day	10.13	12.49	1.57	9.42	12.12	12.39	1.77	9.70	12.92	1.56	NS	NS	*	NS	NS	NS
Post-BRD	9.06	11.96	1.28	7.82	10.75	12.96	1.51	10.24	10.78	1.28	Te	Te	NS	NS	NS	NS
Rewarded visits																
Pre-BRD	3.39	3.19	0.16	3.95	3.47	2.45	0.20	3.47	3.11	0.16	NS	***	NS	NS	NS	NS
BRD day	3.55	3.51	0.25	4.34	3.43	2.83	0.28	3.87	3.19	0.25	NS	***	**	NS	NS	NS
Post BRD	3.32	3.33	0.20	4.22	3.07	2.69	0.25	3.53	3.12	0.20	NS	***	NS	NS	NS	NS
Drinking speed																
Pre-BRD	1026.12	1059.62	47.91	1109.32	1068.70	950.58	53.30	1045.53	1040.21	48.35	NS	*	NS	*	NS	NS
BRD day	964.76	1003.72	30.07	1023.59	1031.63	897.50	37.21	1034.59	933.89	30.74	NS	*	*	*	NS	NS
Post-BRD	951.55	977.80	30.38	918.10	1064.21	911.72	37.58	1019.29	910.07	30.11	NS	**	*	NS	NS	NS

[1]Health status: BRD = calf with bovine respiratory disease; control = matched healthy calf.
[2]SEM = standard error of the mean.
[3]Plane of nutrition: H = high plane of nutrition; M = medium plane of nutrition; L = low plane of nutrition.
[4]Breed: H–F = Holstein-Friesian calves; J = Jersey calves.
[5]Interactions: HS ´ N is an interaction between "health score (HS)" and "plane of nutrition (N)"; HS ´ B is an interaction between "health score (HS)" and "breed (B)"; N ´ B is an interaction between "plane of nutrition (N)" and "breed (B)".
[6]UFL = net energy intake (Unité Fourragère Lait); milk = milk replacer consumption per day (in litres); concentrate = concentrate consumption per day (in kilograms); unrewarded visits = number of visits with no milk replacer per day; rewarded visits = number of visits rewarded with milk replacer per day; drinking speed = rate of drinking (millilitres per minute); Pre-BRD = the average value for the 3 d before the BRD event was recorded; BRD day = the day the BRD event was recorded; post-BRD = the average value for the 7 d after the BRD event was recorded. The values are expressed as least square means (Lsmeans) and SEM.
* = $P < 0.05$; ** = $P < 0.01$; *** = $P < 0.001$; NS = not significant ($P > 0.05$); Te = statistical tendency ($P > 0.05$ but <0.10).

Automatic MR and concentrate feeders can provide producers with feeding behaviour data, including MR and concentrate consumption, number of visits to the feeder and drinking speed. These data may be used to identify sick calves (Svensson and Jensen, 2007; Borderas *et al.*, 2009; Roth *et al.*, 2009). Decreases in concentrate consumption have been correlated with decreased health status (Roth *et al.*, 2009). Indeed, we found a tendency ($P = 0.09$) for decreased concentrate consumption in calves with BRD compared with that in healthy matched controls on the day BRD was identified. Concentrate consumption was decreased by approximately 18% in calves that were identified as BRD cases. Furthermore, we identified a tendency ($P = 0.09$) for decreased net energy (UFL) consumption by calves with BRD compared with the consumption by healthy matched controls on the 3 d prior to the identification of BRD by clinical examination. Net energy intake in calves with BRD was decreased by approximately 8% during this period. Sick calves have also previously been reported to decrease their number of unrewarded visits to the MR feeder (Svensson and Jensen, 2007). The results of this study are consistent with this previous observation. Calves with BRD had decreased numbers of unrewarded visits (decreased by approximately four visits) to the MR feeder during the 3 d prior to and tended ($P = 0.05$) to have decreased numbers of unrewarded visits to the MR feeder during the 7 d following a BRD event being identified by clinical examination, compared with healthy matched controls. Similarly, Borderas *et al.* (2009) observed that on the day of sickness and on days 1–3 post-sickness, sick calves on the H plane of nutrition decreased their number and duration of total visits to the MR feeder, and sick calves on the L plane of nutrition decreased the duration of visits to the MR feeder. Borderas *et al.* (2009) also reported reduced milk intakes for sick calves on the H plane of nutrition. However, consistent with the results of the study by Svensson and Jensen (2007), reduced milk consumption was not observed for calves with the BRDC in this study.

Calves with BRD had decreased unrewarded visits during the 3 d prior to a BRD event being recorded and tended to have decreased unrewarded visits during the 7 d following identification of BRD, compared with healthy calves. Furthermore, there was a tendency for decreased net energy intake on the 3 d prior to BRD being identified and a tendency for decreased concentrate consumption on the day BRD was identified for calves with BRD compared with healthy calves. Therefore, feeding behaviour can be an identifier of respiratory disease in pre-weaned calves. Consequently, this study has demonstrated that feeding behaviour recorded by electronic feeders, in particular, unrewarded visits to the MR feeder, can be examined in order to help producers identify calves with BRD. However, feeding behaviour data was variable as unrewarded visits to the MR feeder were significantly reduced for calves with BRD during the 3 d prior to the BRD event being identified and tended to be reduced for calves with BRD during the 7 d following the identification of BRD, but they were only numerically reduced for calves with BRD on the day of identification of BRD. Therefore, in addition to the monitoring of feeding behaviour data, observation of the clinical health of pre-weaned calves is essential for identification of calves with BRD.

Conclusions

This study characterised the effects of clinical health on feeding behaviour, recorded by electronic feeders, of Irish artificially reared, pre-weaned H–F and J dairy calves. A high number of incidents of BRD was observed in these calves. This may be due to the increased detection of BRD cases through the use of an on-farm respiratory disease screening tool. Feeding behaviour can be used for identifying calves with BRD as calves with BRD had decreased unrewarded visits during the 3 d prior to a BRD event being recorded and tended to have reduced unrewarded visits during the 7 d after the BRD event was identified. Furthermore, there was a tendency for decreased net energy intake for calves with BRD on the 3 d prior to the BRD being identified and a tendency for decreased concentrate consumption for calves with BRD on the day BRD was identified.

References

Ballou, M.A. 2012. Immune responses of Holstein and Jersey calves during the preweaning and immediate postweaned periods when fed varying planes of milk replacer. *Journal of Dairy Science* **95**: 7319–7330.

Berge, A.C.B., Besser, T.E., Moore, D.A. and Sischo, W.M. 2009. Evaluation of the effects of oral colostrum supplementation during the first fourteen days on the health and performance of preweaned calves. *Journal of Dairy Science* **92**: 286–295.

Borderas, T.F., Rushen, J., von Keyserlingk, M.A.G. and de Passillé, A.M.B. 2009. Automated measurement of changes in feeding behavior of milk-fed calves associated with illness. *Journal of Dairy Science* **92**: 4549–4554.

Brickell, J., McGowan, M., Pfeiffer, D. and Wathes, D. 2009. Mortality in Holstein-Friesian calves and replacement heifers, in relation to body weight and IGF-I concentration, on 19 farms in England. *Animal* **3**: 1175–1182.

Çetinkaya, B., Erdogan, H.M. and Morgan, K.L. 1997. Relationships between the presence of Johne's disease and farm and management factors in dairy cattle in England. *Preventive Veterinary Medicine* **32**: 253–266.

Conneely, M., Berry, D.P., Murphy, J.P., Lorenz, I., Doherty, M.L. and Kennedy, E. 2014. Effects of milk feeding volume and frequency on body weight and health of dairy heifer calves. *Livestock Science* **161**: 90–94.

Department of Agriculture, Food and the Marine. 2014. "AIM Bovine Statistics Report 2014". Available online: https://www.agriculture.gov.ie/media/migration/animalhealthwelfare/animalidentificationandmovement/cattlemovementmonitoringsystem/AIMBovineStatisticsReport2014050615.pdf [Accessed 15 April 2016].

Dewell, R.D., Hungerford, L.L., Keen, J. E., Laegreid, W.W., Griffin, D.D., Rupp, G.P. and Grotelueschen, D.M. 2006. Association of neonatal serum immunoglobulin G1 concentration with health and performance in beef calves. *Journal of the American Veterinary Medical Association* **228**: 914–921.

Donovan, G.A., Dohoo, I.R., Montgomery, D.M. and Bennett, F.L. 1998. Associations between passive immunity and morbidity and mortality in dairy heifers in Florida, USA. *Preventive Veterinary Medicine* **34**: 31–46.

Foote, M.R., Nonnecke, B.J., Beitz, D.C. and Waters, W.R. 2007. High growth rate fails to enhance adaptive immune responses of neonatal calves and is associated with reduced lymphocyte viability. *Journal of Dairy Science* **90**: 404–417.

Furman-Fratczak, K., Rzasa, A. and Stefaniak, T. 2011. The influence of colostral immunoglobulin concentration in heifer calves' serum on their health and growth. *Journal of Dairy Science* **94**: 5536–5543.

Gay, E. and Barnouin, J. 2009. A nation-wide epidemiological study of acute bovine respiratory disease in France. *Preventive Veterinary Medicine* **89**: 265–271.

Godden, S. 2008. Colostrum management for dairy calves. *Veterinary Clinics of North America: Food Animal Practice* **24**: 19–39.

Gulliksen, S.M., Lie, K.I., Løken, T. and Østerås, O. 2009. Calf mortality in Norwegian dairy herds. *Journal of Dairy Science* **92**: 2782–2795.

Jakobsen, M.B., Alban, L. and Nielsen, S.S. 2000. A cross-sectional study of paratuberculosis in 1155 Danish dairy cows. *Preventive Veterinary Medicine* **46**: 15–27.

Johnston, D., Kenny, D.A., Kelly, A.K., McCabe, M.S., McGee, M., Waters, S.M. and Earley, B. 2016a. Characterisation of haematological profiles and whole blood relative gene expression levels in Holstein-Friesian and Jersey bull calves undergoing gradual weaning. *Animal* **10**: 1547–1556.

Johnston, D., Earley, B., Cormican, P., Kenny, D.A., McCabe, M.S., Kelly, A.K. McGee, M. and Waters, S. M. 2016b. Characterisation of the whole blood mRNA transcriptome in Holstein-Friesian and Jersey calves in response to gradual weaning. *PLoS One* **11**: e0159707.

Jones, C.M., James, R.E., Quigley 3rd, J.D. and McGilliard, M.L. 2004. Influence of pooled colostrum or colostrum replacement on igg and evaluation of animal plasma in milk replacer. *Journal of Dairy Science* **87**: 1806–1814.

Lombard, J.E., Garry, F.B., Tomlinson, S.M. and Garber, L.P. 2007. Impacts of dystocia on health and survival of dairy calves. *Journal of Dairy Science* **90**: 1751–1760.

Lorenz, I., Mee, J., Earley, B. and More, S. 2011. Calf health from birth to weaning. I. General aspects of disease prevention. *Irish Veterinary Journal* **64**: 10.

Losinger, W.C. and Heinrichs, J.A. 1997. Management practices associated with high mortality among preweaned dairy heifers. *Journal of Dairy Research* **64**: 1–11.

Lundborg, G., Svensson, E. and Oltenacu, P. 2005. Herd-level risk factors for infectious diseases in Swedish dairy calves aged 0–90 days. *Preventive Veterinary Medicine* **68**: 123–143.

McEwan, A.D., Fisher, E.W., Selman, I.E. and Penhale, W.J. 1970. A turbidity test for the estimation of immune globulin levels in neonatal calf serum. *Clinica Chimica Acta* **27**: 155–163.

McGuirk, S.M. and Peek, S.F. 2014. Timely diagnosis of dairy calf respiratory disease using a standardized scoring system. *Animal Health Research Reviews* **15**: 145–147.

Murray, C.F., Windeyer, M.C., Duffield, T.F., Haley, D.B., Pearl, D.L., Waalderbos, K.M. and Leslie, K. E. 2014. Associations of serum haptoglobin in newborn dairy calves with health, growth, and mortality up to 4 months of age. *Journal of Dairy Science* **97**: 7844–7855.

NRC. 2001. *National Research Council. Nutrient Requirements of dairy cattle*, 7th ed., Washington, DC, USA: National Academy of Sciences.

Obeidat, B.S., Cobb, C.J., Sellers, M.D., Pepper-Yowell, A.R., Earleywine, T.J. and Ballou, M.A. 2013. Plane of nutrition during the preweaning period but not the grower phase influences the neutrophil activity of Holstein calves. *Journal of Dairy Science* **96**: 1–12.

Peña, G., Risco, C., Kunihiro, E., Thatcher, M.J. and Pinedo, P.J. 2016. Effect of housing type on health and performance of preweaned dairy calves during summer in Florida. *Journal of Dairy Science* **99**: 1655–1662.

Raboisson, D., Delor, F., Cahuzac, E., Gendre, C., Sans, P. and Allaire, G. 2013. Perinatal, neonatal, and rearing period mortality of dairy calves and replacement heifers in France. *Journal of Dairy Science* **96**: 2913–2924.

Roth, B.A., Keil, N.M., Gygax, L. and Hillmann, E. 2009. Influence of weaning method on health status and rumen development in dairy calves. *Journal of Dairy Science* **92**: 645–656.

Schaefer, A.L., Cook, N.J., Church, J.S., Basarab, J., Perry, B., Miller, C. and Tong, A. K. W. 2007. The use of infrared thermography as an early indicator of bovine respiratory disease complex in calves. *Research in Veterinary Science* **83**: 376–384.

Sivula, N.J., Ames, T. and Marsh, W. 1996a. Management practices and risk factors for morbidity and mortality in Minnesota dairy heifer calves. *Preventive Veterinary Medicine* **27**: 173–182.

Sivula, N.J., Ames, T.R., Marsh, W.E. and Werdin, R.E. 1996b. Descriptive epidemiology of morbidity and mortality in Minnesota dairy heifer calves. *Preventive Veterinary Medicine* **27**: 155–171.

Svensson, C. and Jensen, M.B. 2007. Short Communication: identification of diseased calves by use of data from automatic milk feeders. *Journal of Dairy Science* **90**: 994–997.

Svensson, C., Linder, A. and Olsson, S.O. 2006. Mortality in Swedish dairy calves and replacement heifers. *Journal of Dairy Science* **89**: 4769–4777.

Svensson, C., Lundborg, K., Emanuelson, U. and Olsson, S.-O. 2003. Morbidity in Swedish dairy calves from birth to 90 days of age and individual calf-level risk factors for infectious diseases. *Preventive Veterinary Medicine* **58**: 179–197.

Tennant, B., Harrold, D., Reina-Guerra, M. and Laben, R.C. 1969. Neonatal alterations in serum gamma globulin levels of Jersey and Holstein-Friesian calves. *American Journal of Veterinary Research* **30**: 345–354.

Thompson, P.N., Stone, A. and Schultheiss, W.A. 2006. Use of treatment records and lung lesion scoring to estimate the effect of respiratory disease on growth during early and late finishing periods in South African feedlot cattle. *Journal of Animal Science* **84**: 488–498.

Torsein, M., Lindberg, A., Sandgren, C.H., Waller, K.P., Törnquist, M. and Svensson, C. 2011. Risk factors for calf mortality in large Swedish dairy herds. *Preventive Veterinary Medicine* **99**: 136–147.

Villarroel, A., Miller, T.B., Johnson, E.D., Noyes, K.R. and Ward, J.K. 2013. Factors affecting serum total protein and immunoglobulin G concentration in replacement dairy calves. *Advances in Dairy Research* **1**: 106.

Virtala, A.M., Mechor, G.D., Grohn, Y.T., Erb, H.N. and Dubovi, E.J. 1996. Epidemiologic and pathologic characteristics of respiratory tract disease in dairy heifers during the first three months of life. *Journal of the American Veterinary Medical Association* **208**: 2035–2042.

Vogels, Z., Chuck, G.M. and Morton, J.M. 2013. Failure of transfer of passive immunity and agammaglobulinaemia in calves in south-west Victorian dairy herds: prevalence and risk factors. *Australian Veterinary Journal* **91**: 150–158.

Waltner-Toews, D., Martin, S. and Meek, A. 1986. The effect of early calfhood health status on survivorship and age at first calving. *Canadian Journal of Veterinary Research* **50**: 314.

White, B.J. and Renter, D.G. 2009. Bayesian estimation of the performance of using clinical observations and harvest lung lesions for diagnosing bovine respiratory disease in post-weaned beef calves. *Journal of Veterinary Diagnostic Investigation* **21**: 446–453.

Wray, C. and Sojka, W.J. 1978. Experimental Salmonella typhimurium infection in calves. *Research in Veterinary Science* **25**: 139–143.