Impact of feeding and housing systems on disease incidence in dairy calves

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Contentious issues in calf rearing include milk feeding level and single versus group housing. The current study was performed on a high-producing 170 Holstein cow dairy farm to investigate the impact of nutrition and housing on disease incidence. Calves (n=100) were allocated in birth order to one of two commonly used feeding strategies. Group A calves were group housed from birth and ad libitum milk replacer (MR) via a computerised machine using a single teat, with weaning commencing at 63 days. Group R calves were initially housed in individual pens receiving 2.5 litres of MR twice daily via a bucket until three weeks of age when they were group housed and fed 3 litres of MR twice daily via a group trough with weaning commencing at 56 days. In total, 80 (80 per cent) calves suffered from at least one incident of disease during the period from birth to 12 weeks. Group A calves had a greater risk of disease than group R calves (diarrhoea: OR 3.86 (95 per cent CI 1.67 to 8.9); pneumonia: OR 5.80 (95 per cent CI 2.33 to 14.44)). There was a 5.1 per cent incidence of failure of passive transfer of Ig assessed via measurement of plasma total protein concentrations at 48 hours of age. It is hypothesised that the increased diarrhoea risk in group A calves was most likely associated with group housing, while the increased pneumonia risk was associated with the use of a single teat allowing increased transmission of pathogens from calf to calf.

Increased milk feeding of dairy calves is associated with improved growth rates during the preweaning period and improved production and health in adult life (Soberon and others 2012, Soberon and Van Amburgh 2013). However, there is controversy regarding group housing of young dairy calves due to the greater potential for disease transmission compared with single-housing (Cobb and others 2014). Furthermore, individual penning of dairy calves and restricted milk or milk replacer (MR) feeding before weaning may present potential welfare problems (Stull and Reynolds, 2008). The chief diseases seen in preweaned dairy calves are diarrhoea during the first three weeks of life, and pneumonia, associated with viral and bacterial agents, generally occurring in calves over four weeks old (Lorenz and others 2011).

Various means of increasing milk or MR intakes in calves have been used, including increased concentrations and/or volume of MR fed twice daily, ad libitum acidified milk feeding, computerised feeding whether regulated or ad libitum (Appleby and others 2001, Drackley and others 2007, Borderas and others 2009, Anderson 2011, Hill and others 2013). The use of computerised feeding systems necessitates group housing of calves, a recognised risk factor for disease transmission (Svensson and Liberg 2006, Cobb and others 2014). A further issue is that on many farms assembling groups of 25–30 calves as recommended by manufacturers of these systems involves a wide range of age-mixing, thereby increasing the risk of pneumonia due to the likely range of immune competencies in large age groups.

The following study investigates the null hypothesis that disease risk among calves group housed from birth and fed via a computerised feeding system to receive ad libitum MR, was no different to that among calves initially individually housed than group housed, which received a fixed amount of MR twice daily, via either a single bucket or a group milk trough.

Materials and methods

This study was performed in compliance with Home Office (Animal (Scientific Procedures) Act) legislation and was approved by the University of Liverpool Animal Welfare Committee. The study was performed between January 2011 and January 2013 at the University of Liverpool’s Wood Park Dairy Farm, Neston, Wirral, UK (53°N). The farm milked approximately 170 Holstein Friesian cows, calving all year round, with an annual lactation yield of 10,500 litres on a three times daily milking regimen. All lactating cows were housed in freestalls all year round apart from cows in the final 100 days of lactation during the summer months that would graze outside. All non-lactating pregnant cows were housed throughout the eight-week dry period, initially in freestalls for five weeks then in a straw yard accommodating 5–15 cows. All calves were born in this straw yard. Calves born between 08:00 and 12:00 were removed from their mothers within four hours of birth and taken directly to the calf foster pens, animals born from 12:00–16:00 were fostered within four hours of birth. The following study investigates the null hypothesis that disease risk among calves group housed from birth and fed via a computerised feeding system to receive ad libitum MR, was no different to that among calves initially individually housed than group housed, which received a fixed amount of MR twice daily, via either a single bucket or a group milk trough.
All calves were examined twice daily for signs of illness by the researchers. Diarrhoea was diagnosed on the basis of a faecal score >2 (McGuirk 2008). Pneumonia was diagnosed on the basis of the presence of one or more of the following signs, accompanied by a rectal temperature >39.4°C: nasal discharge, ocular discharge, coughing and increased respiratory rate. Cases of diarrhoea received 2 litres twice daily of oral rehydration solution (Effydral, Zoetis) by bucket and teat or oesophageal feeder if no suck reflex was present. Rehydration therapy was continued for at least three days. Diarrhoeic calves were not removed from their accommodation and continued being fed MR at the same rate as their healthy counterparts. Cases of pneumonia were treated once with subcutaneous injections of tulathromycin (Draxxin, Zoetis) at a dose rate of 2.5 mg/kg and meloxicam (Metacam, Boehringer Ingelheim) at a dose rate of 0.5 mg/kg.

Data were collated in an Excel (Microsoft) spreadsheet and transferred to Stata V.13 (StatCorp) for analysis. Student’s t and Fisher’s exact chi-square tests were used to investigate any group differences in birth weight, colostrum quality, FPT concentrations and associations between colostrum quality, FPT and disease occurrence. Following exploratory univariable logistic regression analysis, two multivariable logistic regression models were fitted with the binary outcome variables being occurrence of a case of diarrhoea (model 1) or pneumonia (model 2). To account for clustering of calves at group pen level, robust standard errors (se) and 95 per cent CIs were estimated. Only primary incident cases were considered in the analyses. All potential explanatory variables, namely feeding regimen (ad libitum vs restricted), dam parity, colostrum quality, FPT, birth weight and group size, were offered to the initial models. Selection of variables for the final multivariable models was by backwards stepwise removal taking a P value <0.15 (log-likelihood test) for retention of a variable. Kaplan-Meier survival plots were fitted for age at pneumonia diagnosis. A log-rank test was used to compare survival plots. Where appropriate, standard deviations (sd) or 95 per cent CIs were estimated and presented. P values ≤0.05 were taken as indicating statistical significance.

Results

Brix refractometry was performed on 90/100 peripartum colostrum samples. Mean (sd) specific gravity was 25.5 per cent (4.6). Using a cut-off of 22 per cent (Chigerwe and Hagey 2014) to indicate ‘good quality’ colostrum, 54 (57.8 per cent) samples failed to be classified as good quality. Colostrum quality was not associated with dam parity (P=0.32) or dietary group (P=0.52). FPT concentrations were measured in 97/100 calves at 48 hours of age. Mean FPT (sd) concentration was 68.9 g/l (0.81) with no dietary group (P=0.76) nor dam parity-associated (P=0.91) differences. Taking a FPT cut-off of 56.0 g/l as indicative of adequate passive transfer, five (5.1 per cent) calves were classified as having FPT. There were no associations between occurrence of FPT and calf group (P=1.00) or dam parity (P=0.65). There was a significant association between colostrum quality, based on a 22 per cent cut-off, and occurrence of FPT (P=0.045). There was no association between occurrence of FPT and occurrence of diarrhoea (P=0.59) or pneumonia (P=0.38). Median number of calves per group pen was 3 (range 2–6) for group R and 4 (range 2–6) for group A (P=0.15). There were a total of 54 groups of calves during the study.

Voluntary daily MR intakes in group A calves increased rapidly to reach 7.6 litres/day (95 per cent CI 6.5 to 8.7) by day 5. Thereafter, overall, mean daily MR intake increased linearly to reach 15.5 litres (95 per cent CI 12.4 to 14.2) by day 26 before the rate of increase slowed to peak at 15.3 litres/day (95 per cent CI 14.2 to 16.4) near the onset of gradual weaning on day 64. The maximum daily MR intake recorded for any calf was 25.5 litres. Over the three-week course of MR withdrawal, intakes declined at an overall average rate of 0.7 litres daily (Fig 1).

All calves presenting with clinical signs of disease were treated appropriately and the mortality rate was zero. In total,
80 (80 per cent) calves suffered from at least one incident of disease during the period from birth to 12 weeks. Calves in group R had an overall lower incidence of disease (n=53, 66 per cent, 95 per cent CI 52 to 80) than group A (n=47, 94 per cent, 95 per cent CI 87 to 100, P=0.001). There were 57 cases of diarrhoea affecting 56 calves (one calf in group A had two separate incidents) equating to an overall primary case incidence of 56 per cent (95 per cent CI 46.1 to 66). There were significantly more primary cases of diarrhoea in group A (n=36, 72 per cent, 95 per cent CI 57.5 to 83.3) compared with group R (n=20, 40 per cent, 95 per cent CI 26.4 to 54.8, P=0.001). Rotavirus was isolated from 3/3 diarrhoeic faecal samples (two from group A and one from group R), suggesting that it was the most likely causal agent.

There were 42 cases of pneumonia affecting 37 calves (five calves [four calves: group R, one calf]) suffered a second incidence of disease defined as occurring at least 14 days after the first treatment and requiring treatment, equating to an overall primary case incidence of 57 per cent (95 per cent CI 27.4 to 46.6). There were significantly more primary cases of pneumonia in group A (n=28, 56 per cent, 95 per cent CI 41.2 to 70) compared with group R (n=9, 18 per cent, 95 per cent CI 8.6 to 31.4, P=0.001).

Group A calves had a significantly higher risk of exhibiting symptoms of both diarrhoea and pneumonia, with unadjusted ORs of 3.86 (95 per cent CI 1.45 to 10.28) and 5.80 (95 per cent CI 1.35 to 24.86), respectively, compared with their group R counterparts. There was no association between dam parity, colostrum quality, FTP or birth weight and the likelihood of an offspring surviving the first weeks of life. There was no evidence of any increased risk of disease in calves born to first-time dams, compared with those born to multiparous cows. There was no association (P=0.94) between death and calf sex.

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There was considerable variation in the incidence of both diarrhoea and pneumonia throughout the study, although no clear trends were apparent. Diarrhoea was seen throughout most of the study period with only the final two months of the study being totally free from diarrhoea (Fig 3). The minimum and maximum temperatures and humidity’s of the calf house were recorded daily (Fig 4) using a maximum and minimum temperature and humidity recording device placed in the middle of the house at a height of 1.5 m. Visual appraisal of Fig 3 suggests that the ambient temperature within the calf house was below the lower critical temperature (20°C: National Research Council (NRC) 2001) for a calf of up to three weeks of age for prolonged periods during the winter months. The relative humidity within the calf house fluctuated greatly and was above the optimum range for a young calf (65–75 per cent) throughout the study period with minor exceptions.

**Table 1:** ORs (robust 95% CI) derived from univariable logistic regression models, including explanatory variables associated with the probability of a calf suffering an episode of either diarrhoea or pneumonia

| Explanatory variable | OR   | 95% CI          | P    |
|----------------------|------|-----------------|------|
| Outcome variable: episode of diarrhoea |      |                 |      |
| Feeding group (ad libitum v restricted milk replacer) | 3.86 | 1.45–10.28 | 0.007 |
| Dam parity (primiparous v multiparous) | 1.41 | 0.64–3.12 | 0.40  |
| Colostrum quality (%) | 1.08 | 0.90–1.21 | 0.94  |
| Plasma total protein (g/l) | 1.35 | 0.83–2.20 | 0.26  |
| Birth weight (kg) | 0.98 | 0.91–1.05 | 0.55  |
| Outcome variable: episode of pneumonia |      |                 |      |
| Feeding group (ad libitum v restricted milk replacer) | 5.8  | 1.35–24.86 | 0.018 |
| Dam parity (primiparous v multiparous) | 1.40 | 0.61–3.24 | 0.13  |
| Colostrum quality (%) | 1.02 | 0.95–1.10 | 0.55  |
| Plasma total protein (g/l) | 1.01 | 0.68–1.50 | 0.94  |
| Birth weight (kg) | 0.98 | 0.91–1.06 | 0.62  |
| Group size (per one calf increase in group size) | 1.18 | 0.72–1.92 | 0.51  |

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**FIG 2:** Kaplan-Meier survival plot of age in days of diagnosis of pneumonia

1–21 days). Mean age of diagnosis of pneumonia was significantly higher (P=0.005) in the ad libitum-fed calves compared with their restricted-fed counterparts (54 days 95 per cent CI 48.8 to 59.0 v 36 days 95 per cent CI 22.0 to 50.0) (Fig 2: log-rank test, P=0.0004). There was no association (P=0.81) between occurrence of a second case of pneumonia in an individual calf and feeding group. There was no association between occurrence of a case of diarrhoea and subsequent occurrence of a case of pneumonia in an individual calf (P=0.26).

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**Discussion**

The results presented are nested within a larger study with the overall objective of comparing growth and performance between calves group housed with ad libitum feeding with calves kept under regimens currently commonly practised in the UK, namely individual housing for a period followed by group housing with restricted feeding of MR. Results from a concurrent questionnaire survey of 723 UK farmers (in preparation) suggested that such systems are commonplace although varying in precise timing, group size, etc.

The present study provides valuable information regarding impact of feeding and housing systems on disease incidence, despite there being implicit study limitations that must be acknowledged. First, calves were not randomly allocated to intervention arm. This was dictated by the farm size and calving rate, coupled with the requirement to produce groups of up to six calves with no more than 14 days age difference between them. Second, due to the standard farm policy for housing calves group housed with ad libitum feeding with calves kept under regimens currently commonly practised in the UK, namely individual housing for a period followed by group housing with restricted feeding of MR. Results from a concurrent questionnaire survey of 723 UK farmers (in preparation) suggested that such systems are commonplace although varying in precise timing, group size, etc.

**Diarrhoea and pneumonia are recognised as the key disease challenges facing the preweaned dairy calf and have major economic impacts, both in terms of mortality and reduced performance in later life (Roy and Tennouth 1972).** While FTP of Ig is
feeding system employed. This is apparent from the high disease incidence experienced in the calf house used in the present study. The calf house was adapted for group housing, though the number of calves per group varied from one to four. Since this was an experiment, the number of calves per group was determined by a pre-defined treatment. From three weeks of age, all calves were housed under identical conditions in groups containing up to six calves with no more than 14 days age difference. These limits on group size were responsible for beds that were often wet despite regular additional of straw. Throughout the study period, the relative humidity in the calf house fluctuated, being outside the recommended range of 65–75 per cent for much of the time. During the winter months, the house temperature was often below 20°C (NRC 2001), the lower critical temperature for calves under the age range were in place specifically to minimise disease risk. The overall high pneumonia incidence (37 per cent) is likely a reflection of the suboptimal environmental conditions coupled with group housing of calves (Cobb and others 2014). The pneumonia risk was further increased in the ad libitum-fed calves both at pen level (OR 5.40) and at individual calf level (OR 5.80), suggesting that the practice of group feeding via a single shared teat compared with a trough represents an additional risk. In addition, bed wetness was accentuated by the increased amounts of urine produced consequent on the greater fluid intakes of the ad libitum-fed calves. The association between use of computerised feeding systems and increased incidence of pneumonia has been reported (Hepola 2003), although since use of such systems necessitates group housing, a known risk factor for pneumonia, it is unclear whether the increased risk is associated with use of a shared teat per se or associated with group housing. The present study would suggest that use of a shared teat is a risk factor in its own right, increasing the risk of pneumonia over and above the risk associated with group housing. It may be hypothesised that this is associated with transfer of respiratory pathogens in saliva and nasal secretions from calf to calf via the teat. This is supported by studies demonstrating oral infection with Mycoplasma species (Maunsell and others 2012) and by a report of

Diarrhoea was observed chiefly in the first three weeks of life and was likely associated with rotavirus infection, as determined by faecal sampling of three calves. Since no other calves were sampled, the role of other pathogens cannot be discounted. The diarrhoea incidence risk was considerably greater in the group housed, ad libitum-fed calves compared with the individually penned (for the first three weeks of life) restricted milk-fed calves (OR 3.86). Two hypotheses may be generated to explain this observation; first, feeding increased volumes of MR is a risk factor for diarrhoea. However, peer reviewed studies (Appleby and others 2001, Jasper and Weary 2002) do not support this hypothesis. The alternative hypothesis, supported by numerous studies, for example, Klein-Jobstl and others (2014), is that group housing of the ad libitum-fed calves facilitated transmission of infectious agents via direct contact and increased environmental contamination.

Thirty-seven calves suffered from one incident of pneumonia with five calves suffering from a second incident. Mean age of first occurrence was significantly higher in the ad libitum-fed calves compared with their restricted-fed counterparts (52.1 v 36 days). Diagnosis was made on clinical grounds and no laboratory investigations were performed. The high treatment success rate (100 per cent) was likely due to prompt recognition and treatment. From three weeks of age, all calves were housed under identical conditions in groups containing up to six calves with no more than 14 days age difference. These limits on group size and age range were in place specifically to minimise disease risk. The overall high pneumonia incidence (37 per cent) is likely a reflection of the suboptimal environmental conditions coupled with group housing of calves (Cobb and others 2014). The pneumonia risk was further increased in the ad libitum-fed calves both at pen level (OR 5.40) and at individual calf level (OR 5.80), suggesting that the practice of group feeding via a single shared teat compared with a trough represents an additional risk. In addition, bed wetness was accentuated by the increased amounts of urine produced consequent on the greater fluid intakes of the ad libitum-fed calves. The association between use of computerised feeding systems and increased incidence of pneumonia has been reported (Hepola 2003), although since use of such systems necessitates group housing, a known risk factor for pneumonia, it is unclear whether the increased risk is associated with use of a shared teat per se or associated with group housing. The present study would suggest that use of a shared teat is a risk factor in its own right, increasing the risk of pneumonia over and above the risk associated with group housing. It may be hypothesised that this is associated with transfer of respiratory pathogens in saliva and nasal secretions from calf to calf via the teat. This is supported by studies demonstrating oral infection with Mycoplasma species (Maunsell and others 2012) and by a report of
isolating pathogenic Mycoplasma species from a shared teat on a farm with high levels of Mycoplasma species-associated pneumonia (J. Oultram, personal communication).

Despite the pneumonia risk being lower in the trough-fed calves compared with the teat-fed calves, they succumbed at an earlier age (36 v 52 days) than the ad libitum-fed calves. It is recognised that the decline in maternally derived antibodies is associated with increasing disease risk with the rate of decline depending, in part, on the amount of Ig consumed initially, as reflected by FTP concentrations measured in the first few days of life. In the current study, there was no difference in mean calf group FTP concentrations suggesting no association with the observed age-related disease susceptibility. There is increasing evidence of positive associations between nutrition status and immune response (Pollock and others 1994, Obeidat and others 2015) with improved nutritional status reducing the impact of clinical disease (Ollivett and others 2012). It is hypothesised that the increased nutrition provided to the ad libitum-fed calves resulted in increased resilience to respiratory pathogens such that clinical disease only occurred when calves were older despite the increased infectious risk associated with use of a single teat.

Conclusions

Two main broad conclusions may be arrived at from the present study. First, group housing of calves during the first three weeks of life in suboptimal conditions may significantly increase diarrhoeal disease risk, likely due to increased transmission of enteric pathogens. Second, while automated feeder systems allow delivery of increased volumes of milk, facilitating improved growth, they appear to very significantly increase the risk of pneumonia if used in a suboptimal environment as in the present study. It would be prudent to avoid using automated feeding systems under such environmental conditions, that is, they should only be used in suitable housing systems that minimise the risk of pneumonia. In addition, there is an urgent need for manufacturers of such systems to develop teat sanitation protocols between individual calves to further minimise transmission.

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