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Abstract

This online survey of 248 dairy farms from all 4 UK nations identified areas to optimise calf health and welfare, with a particular focus on extended colostrum feeding (beyond the first 24 hours of life). Chi squared analysis, Cochran Armitage trend tests and logistic regression were used to investigate biologically plausible associations between variables. Thematic analysis was used to construct and refine thematic maps.

There was a significant linear trend between the frequency of blood sampling of calves to monitor serum IgG concentrations and testing of colostrum for IgG concentration ($p<0.01$). A number of farms (41.53%) pooled colostrum (without pasteurising), which may reduce overall IgG concentration and increase disease transmission risk. Timing of colostrum harvest (within 6 hours of calving) was suboptimal on some (23.39%) farms. Many of the perceived barriers to extended colostrum feeding were human and physical including tangible commodities such as storage and facilities, labour and procedural problems.

Key words: Colostrum management, survey, UK, dairy, extended colostrum

Introduction

The main pillars of colostrum management are that calves must receive 10-12% of their bodyweight in high quality (>50g/L IgG) colostrum as early as possible after birth (Bush and Staley 1980; Stott and Fellah, 1983; Morin et al., 1997; Chigerwe et al., 2008; Beam et al., 2009). Inadequate volume (<10% of the calf's bodyweight), timing (not fed in the first 0-12 h of life) and quality (<50g/L IgG) all reduce absorption of IgG from colostrum into the calf's blood; known as failure of passive transfer (FPT) or, more accurately, failure to transfer passive immunity (FTPI). Other colostrum management factors such as poor storage and unhygienic handling also result in FPT in calves (Godden et al., 2012; Gelsinger et al., 2015).

Research has focussed on reducing incidence of morbidity and mortality in dairy calves through optimal calf management strategies (Svensson et al., 2003; Johnson et al., 2011; Windeyer et al., 2014). Colostrum management is the single most important risk factor in determining calf health and survival (Godden et al., 2019) and colostrum management can be used as an all-encompassing term relating to risk factors affecting quality, quantity and timing of colostrum feeding as well as storage and preservation. Current UK literature has explored calf management practices focussing specifically on housing (Mahendran et al., 2021), but not on colostrum management in all 4 UK nations.

Colostrum is defined as first milking colostrum only (Quigley et al., 2013) and 'transition milk' is the first 2-10 milkings post calving (Davis and Drackley 1998). Anecdotally, there is some confusion amongst producers on the definition of 'colostrum', particularly since the first 96 hours of milkings post calving are withheld from supply due to differing composition which makes it unsuitable for processing. A recent UK survey found that only 32% of farms ensured that both the first and second feed were from the first milking, confirming two feeds of 'true' colostrum (Boulton et al., 2015). Extended colostrum feeding (Brix 22-28%) for up to 14 d has also been shown to have beneficial health effects such as improved growth rates and reduced morbidity due to diarrhoea and pneumonia in neonatal calves (Kargar et al., 2020). It is also recommended on the data sheet of vaccines which rely on passive protection via the mother's milk, such as commercially available multivalent diarrhoea vaccines.

Some UK literature has been published on colostrum management. In 2008, 19 English dairy farms recorded colostrum management practices as part of a wider study into dairy calf growth rates (Brickell et al., 2008). A larger scale 2020 investigation enrolled 38 farms in Scotland, but was more focussed on particular colostrum quality outcomes than wider management strategies (Haggerty et al., 2021). A total of 102 dairy farms in England, Scotland and Wales were surveyed in a face-to-face questionnaire focussing on cost of dairy heifer rearing (Boulton et al., 2015), however Northern Irish farms were not included in this survey. Furthermore, 21 grass based dairy farms in Northern Ireland provided some colostrum management information in 2017, but this is not reflective of the bulk of UK dairy farming systems (Dunn et al., 2017). A large scale survey including all countries in the UK and focussing on colostrum management and extended colostrum feeding is needed.

The objective of this survey was to gather some data on colostrum management practices on UK dairy farms. There was particular interest in extended colostrum feeding (feeding colostrum for more than 24 hours) in this survey as a preliminary exploration into farmers' views on the practice with an intention to design further research work on extended colostrum feeding.

Materials and methods

Dairy farmers were invited to participate on the social media platform of a large pharmaceutical company (MSD Animal Health). Data were collected under University of Glasgow ethics licence (number 200210018). A literature review on colostrum management and expert opinion (authors and clinical farm animal veterinarians) were used to create a questionnaire on colostrum management practices with a particular focus on extended colostrum feeding (beyond the first 24 h of life). The questionnaire was beta tested with four farm animal clinical veterinarians and four dairy farmers in person to 'sense check' questions and subsequently small modifications to the initial questions were made.

Farmers were asked to complete the questionnaire consisting of 23 ‘tick box’ and 2 ‘free text’ responses (see Appendix A for questionnaire) between 6th March 2022 and 19th April 2022. Farm size categories were calculated based on a dairy replacement rate of 25% and average UK farm size of 166 animals (AHDB 2021 figures). The survey was created on the software platform GetFeedback (Momentive Inc.) and data were later imported into Microsoft Excel (Microsoft, version 2203). Participation in the survey was voluntary, but participants were incentivised by small rewards such as headtorches and socks from the MSD Animal Health (study funder), data were anonymised prior to analysis.

Statistical methods

A sample size calculator (Ausvet Epitools, ACT 2617, Australia) was used to determine the required number of respondents. Assuming a prevalence of extended colostrum feeding of 0.2, to estimate the prevalence with a 95% confidence interval (95% CI) and a desired precision of 0.05, 246 respondents were required.

Data were checked for missing and incongruous values and imported into Stata (StataCorp LLC version 15) for analysis. Descriptive statistics were explored and frequency tables created for each variable. Chi squared analysis and the Cochran Armitage test for trend (to maximise power for multiple comparisons) were used to investigate biologically plausible associations between the variables (with significance declared at $p<0.05$). Biologically plausible associations were decided on by the authors based on their experience and published data, and included: pooling and pasteurisation of colostrum; method of feeding and volume of colostrum fed; farm size and calving pattern, farm size and extended colostrum feeding (and potential storage solutions to facilitate this); and number of calves reared and pooling colostrum. Logistic regression models were used to calculate odds ratios for the frequency of blood sampling with colostrum quality testing as the outcome of interest and to calculate the odds ratio for volume of colostrum fed with oesophageal tube feeding as the outcome of interest. Free text response to the question on transition to milk replacer from colostrum feeding were broadly categorised into 'abrupt transition to milk replacer'; 'whole milk feeding' and 'mix of whole milk and milk replacer feeding'.

For the two free text response questions ('If it were shown to be beneficial to feed colostrum for the first 5 days, could you practically fit this in your farm system?' and 'Would you need to change any processes on-farm to be able to do this, if so what?'), themes in the data were identified and verified by two of the authors independently. Thematic analysis (using methods described by Braun and Clarke (2006)) was used to construct and refine thematic maps. Briefly the authors familiarised themselves with the data; manually generated initial codes; searched for themes; reviewed themes through collaborative discussion, refined and named themes and produced diagrams.

Results

Three hundred and thirty individuals clicked on the survey link to start the survey and 248 online questionnaire responses were received (75.2% completion rate). Table 1 shows the frequency of responses for each question.

Respondent demographics

Only 207 of the 248 respondents recorded their country of origin. Figure 1 shows the country of origin of the respondents and demonstrates that geographically the entire UK was represented in the sample number (49.8% from England; 24.2% from Northern Ireland, 11.6% from Scotland and 14.5% from Wales). The majority of the farms that responded reared more than 81 calves annually (*n*=157/248; 63.3%), but there was no relationship (*P*=0.81) between number of calves reared and calving system (64.1% all-year-round).

Missing and incongruous values

There was one missing response on the frequency of calf blood sampling for FPT and seven missing responses for the volume of colostrum fed to newborn calves. Of the 180 responses indicating that colostrum was stored frozen, 178 responses were recorded on method of thawing. Twenty- eight respondents (*n*=28/248; 11.3%) recorded they did not store any colostrum, however in the 'volume stored' responses, *n*=44/248 (17.7%) of respondents recorded this as 'not- applicable'. This discrepancy may have partly been because a further *n*=17/248 (6.9%) of respondents only stored colostrum at room temperature and did not measure this volume. Other discrepancies in the data included only 10 respondents recording that the calf was left to suck the dam in the in 'time to harvest' (time from calving to first colostrum harvest) question and 22 respondents asserting that the calf was left to suck the dam in 'time to feeding' (time from colostrum harvest to feeding to newborn calves) question. Small numbers (*n*=20/248; 8.1%) of respondents left calves on their dams after birth for first colostrum feeding. All incongruous data was retained in the dataset.

Volume of colostrum fed and stored

Five of the seven respondents who left calves on their dams also cited not knowing the volume of colostrum their calves were ingesting at first feed (see Table 1). Some, *n*=36/248 respondents (14.5%) recorded feeding <2 L of colostrum at first feed, rather than the required 10-12% of bodyweight.

Approximately 40% of respondents reported that the volume of colostrum stored in each batch exceeded 2 L.

Extended colostrum feeding

The majority of respondents fed colostrum (first and second milking) for 48 h or more (*n*=151/248; 60.9%). Methods of colostrum storage to facilitate this are shown in Table 1. Of the 248 respondents, 189 (76.2%) said that if feeding extended colostrum for 5 d was shown to be beneficial that they would be able to practically do this in their farming system. A small majority of farmers (*n*=131/248; 52.8%) said they would not need to make any system changes to accommodate an extended colostrum feeding protocol if it were shown to be beneficial to do so. There was no relationship between farm size (*P*=0.1-0.3) and calving pattern (*P*=0.57) and whether or not farmers said they could feed colostrum for 5 d.

Thematic maps

Figure 2 shows the final thematic maps relating to required system changes necessary for extended colostrum feeding and Fig. 3 shows themes relating to extra information and support required and barriers to implementing these changes. Physical and animal themes were repeated for both questions, but there were additional human related subthemes for the second free text question as shown in Fig. 3. For the themes shown in Fig. 3, it was impossible to separate ‘additional information needed’ and ‘barriers to change’ responses because of the way in which the question was framed. Many of the perceived barriers to extended colostrum feeding were human and physical. Physical barriers included more tangible commodities such as storage and facilities, while human barriers included more intangible labour and standard operating procedure problems. There was some scepticism on purported advantages of extended colostrum feeding and the inconvenience which may result from implementing changes to management systems to allow for this.

Colostrum storage and supply

Storage and supply were cited as barriers to extended colostrum feeding. The majority of respondents used temperature (refrigeration or freezing) to store colostrum with only a very small minority using chemical colostrum preservatives. Low temperature preservation was commonly employed by respondents, (*n*=203/248; 81.9%); but many refrigerators and freezers in the current work were not kept cool enough (-20°C for freezing and 4°C for refrigeration). In this work, *n*=2/42 (4.8%) and *n*=7/46 (15.2%) of respondents who did record that they checked the temperature of their refrigerator or freezer did not know the temperature of the appliance. Water baths which were used most frequently (in 90.6% cases) to thaw colostrum. One farm reported using a microwave to thaw colostrum.

Whole milk or milk replacer feeding

Twenty four of the 248 respondents (9.7%) reported feeding whole milk to calves between colostrum and milk replacer feeding. A further 67 respondents (27.0%) fed a mixture of whole milk and milk replacer. Some free text responses cited feeding whole milk because milk replacer products are costly.

The majority of respondents abruptly transitioned calves from colostrum onto milk replacer (*n*=158/248; 63.7%), usually after the third feed or later (*n*=192/248; 77.4%).

Pooling and pasteurisation of colostrum

A substantial number of farms (*n*=103/248; 41.5%) pooled colostrum for calves. Chi squared analysis revealed that there was no significant ($\chi 2$ (1, n = 248) =<0.01, *P*=0.989) association between pooling and pasteurisation with only 10/103 (9.7%) respondents who pooled colostrum also pasteurised it. In total only 9.7% of respondents were pasteurising colostrum. There was also no significant association between pooling and number of calves reared (*P*=0.2-0.4).

Monitoring of calf health and colostrum quality

The majority (72.6%) of respondents stated that calves were never sampled to check immune status or were only sampled ‘in the event of a problem’ (referring to an outbreak of disease). Perhaps unsurprisingly, respondents were more likely to check colostrum quality if they checked their calf serum measurements. Table 2 shows the frequency of calf blood sampling in relation to colostrum quality monitoring. Compared with farms where calves were never blood sampled the odds of checking the quality of colostrum on farms where calves were blood sampled only in the event of a problem was 4.5 (95% CI=2.2-9.3); on farms where calves were blood sampled 1-4 times yearly was 8.0(95% CI=2.7-24.2) and on farms where calves were blood sampled >4 times per year was 21.7 (95% CI=2.8 -166.4). The Cochran Armitage test showed a significant trend (p<0.01)

Time to colostrum harvest and time to colostrum feeding

A substantial number of farmers (*n*=190/248; 76.6%) harvested colostrum in the first 6 h after calving (with *n*=58/248, 23.4% failing to do so). Many respondents (*n*=207/248 (83.5%)) also fed harvested colostrum promptly (within 60 min of birth).

Method of feeding

Oesophageal tube feeding of colostrum was commonplace either for every calf or for those who refused to drink (51.2%). Table 3 shows the relationship between oesophageal tube feeding and volume of colostrum fed at first feed. Compared with farmers feeding <2L of colostrum, the odds ratio for oesophageal tube feeding where farmers fed 2.5-4L and >4L were 1.7 (95% CI=0.8-3.6) and 4.2 (95% CI=1.3-13.3) respectively. The Cochran Armitage trend test was significant (P=0.01).

Discussion

Many colostrum management risk factors were explored from 248 farms from all 4 UK nations in the current study. While recommendations for colostrum management have not changed in recent years, several issues identified here demand industry attention and should be the focus of any renewed effort to improve UK calf health. In the current study 64.1% of farms were all year round calving, similar to other UK work where 72.7% of farms had an all-year-round calving pattern (Johnson et al., 2017).

In the current work 14.5% of respondents fed under 2L of colostrum at first feed and it was acknowledged by most (71.4%) of the farmers who left calves on their dams that the volume of colostrum consumed is unknown (as is inevitably the case). Low volumes of first feeding colostrum can prohibit passive transfer of IgG molecules and accelerate gut closure such that even if larger volumes are later fed, they may not be adequately absorbed (Stott et al., 1979). This is because even a small volume of colostrum will stimulate maturation of the neonatal enterocytes such that they become impermeable to large IgG molecules. In comparable work, the volume of first feed colostrum fed to calves was unknown on approximately half of enrolled farms; the rest gave their calves either ≤3 L (27%) or >3 L (27%) (Brickell et al., 2008). In further comparable studies, 54-56% of dairy farmers gave calves over 3 L of colostrum (Haggerty et al., 2020; Baxter-Smith and Simpson 2020).

Northern Irish work showed that around 80% of calves were fed >2 L of colostrum at their first feed (Dunn et al., 2017). In order to supply enough colostrum to the calf to meet passive transfer requirements, citing low volumes of 2-3 L is arbitrary and inadequate given the 10-12% bodyweight requirement. There is room for much improvement in terms of increasing volume of colostrum offered at the first feed (Besser et al., 1991; Chigerwe et al., 2008; Boulton et al., 2015;).

In other work 52% of farms employed oesophageal tubing for feeding colostrum to every newborn calves (Dunn et al., 2017), similar to the current work where oesophageal tube feeding of colostrum was commonplace either for every calf or for those who refused to drink (51.2%) Teat feeding on a bottle has also been well documented on UK farms, but with 83% of farmers (n = 85) employing an oesophageal tube if the calf failed to consume sufficient colostrum during the first feed (Boulton et al., 2015). The advantage of oesophageal tube feeding is that a known volume of colostrum can be delivered to the calf's abomasum in a timely fashion, however oesophageal groove closure may not be promoted (Tamate et al., 1962). Kaske et al., (2005) concluded that proper use of the oesophageal tube is a useful method to supply adequate colostrum and the failure of oesophageal groove closure appears to be of no clinical consequence. Likewise, (in a study using colostrum replacer) where adequate volumes of colostrum were fed, method of feeding was of little consequence, with the caveat that where inadequate volumes were fed, oesophageal tube feeding exacerbated FPT (possibly due to a relatively large proportion of colostrum being deposited into the reticulorumen resulting in delayed release into the abomasum, with consequent reduced apparent efficiency of absorption) (Godden et al., 2009). Chigerwe et al. (2012) found no difference in absorption efficiency and passive transfer prevalence between calves fed via a teat feeder or oesophageal tube. The trend observed between oesophageal tube feeding and volume of colostrum fed at first feed may be because it is more expedient to deliver larger volumes of colostrum by oesophageal tube than to wait for calves to suck. Published data indicates that colostrum may be supplied by tube or teat (depending on farmer convenience) (Godden et al. 2009), but farmers should perhaps be encouraged to use oesophageal tube feeding to deliver large volumes of colostrum quickly.

A substantial number of farms left more than 6 h between calving and first colostrum harvest (23.4%), but this was a better outcome than in Scottish work where approximately 40% of farmers left more than 6 h between calving and first colostrum harvest (Haggerty et al., 2021). Reschke et al., 2017 demonstrated that a lag time of greater than 6 h between parturition and first milking was a risk factor for poor colostrum quality. Other studies also found that colostrum collected 6, 10, and 14 h after calving had significantly lower IgG concentrations than colostrum collected 2 h after calving (Moore et al., 2005) and that IgG concentration in colostrum decreases by 3.7% for each subsequent hour after calving (Morin et al., 2010), so prompt harvesting after calving is paramount (Quigley et al., 2013). Further work could explore individual farm circumstances for delayed colostrum harvest including weekends, nights or times of staff shortages.

The majority of respondents fed first and second milking colostrum for 48 h or more and said they would not need to make any significant management changes to be able to feed colostrum in an extended fashion. In other work, the majority of farms (61%) fed calves colostrum for 1–4 d, but it is not clear whether this was purely first milking (Brickell et al., 2008). It has also been reported that UK calves were fed colostrum for 3.1 ± 1.8 d (range 0.5 to 10 d) (Boulton et al., 2015). Another study showed that 70% of dairy farmers fed colostrum for more than 24 h with 26% feeding it for more than 3 d (Baxter Smith and

Simpson 2020), but again first milking was not specified. As mentioned, strictly speaking colostrum is first milking only and mix of first and second milking colostrum will not be as high quality as first milking only colostrum (Quigley et al., 2013), however measuring colostrum quality was beyond the scope of this work.

Previous research has explored whether extended colostrum (EC) feeding is beneficial beyond the first 24 h of life. Neonatal enterocytes cease active pinocytosis (required to absorb IgG molecules from the gut lumen to calf serum) when the animal is 24 h old (Stott et al., 1979; Weaver et al., 2000); however IgG molecules continue to be of benefit in the gut lumen to provide local immunity (Besser et al., 1988). In addition, colostrum is an excellent energy source and provides other beneficial nutrients and proteins including cytokines and other immune modulating factors, many of which remain undiscovered or poorly understood (Kargar et al. 2020). A recent publication by Kargar et al. (2020) suggested that extended colostrum feeding may improve weight gain and decrease the incidence of diarrhoea and pneumonia in neonatal calves. Feeding of colostrum beyond the first 24 h of life may also improve growth and maturation of the gastrointestinal tract (Blum and Hammon, 2000; Hernandez-Castellano et al., 2015), as well as promoting establishment of beneficial bacteria (Malmuthuge et al., 2015; Malmuthuge and Guan, 2017); enhancing glucose uptake (Hammon et al., 2013) and reducing calf morbidity and mortality (Conneely et al., 2014). Other work has demonstrated that extended colostrum feeding did not improve weight gain but reduced disease occurrence and antibiotic therapy in dairy calves during the preweaning period (Chamorro et al., 2017). As mentioned, pooling colostrum for extended feeding should be approached with caution.

Very few farmers in this study used chemical preservatives to preserve colostrum. We hypothesise that if a better storage solution could be introduced in the UK, producers might feel encouraged to feed colostrum or transition milk (milkings 2-8 post calving) for longer. Colostrum supply issues were frequently cited in free text responses so it is hypothesised that farmers may not be able to feed first milking only colostrum for an extended period as production of adequate volumes of first milking colostrum by the dam may be problematic (Conneely et al., 2013; Gavin et al., 2018).

Colostrum may be preserved using low temperatures or chemical preservatives such as potassium sorbate (keeping IgG concentrations high and bacterial counts low). Chemical preservation is seldom used in the UK but can allow for colostrum to be preserved for up to 7 days even at ambient temperatures (Denholm et al., 2017). While the published recommended temperatures for preservation of colostrum are -20◦C for freezing and 4◦C for refrigeration (Stewart et al., 2005; Denholm et al., 2017; Denholm, 2022), and methods of temperature preservation were commonly employed by respondents; many refrigerators and freezers in the current work were not kept cool enough. This is similar to Irish and Scottish results which showed that around 75% of farmers used low temperatures to preserve their colostrum (Barry et al., 2017; Haggerty et al., 2020); but only 26.5% of farmers had a temperature gauge on their freezers and refrigerators and only about half of these respondents checked their temperature gauge regularly. Indeed, another UK based study on 20 farms showed much variability in refrigerator temperatures for storage of vaccines (Williams and Paixao, 2018). Again, there is much room for improvement in terms of education of farmers on preservation of colostrum and options for this.

Pooling colostrum is thought to be a more common phenomenon in seasonal calving systems (Denholm et al., 2017). In other UK work Brickell et al. (2008) observed 63% of farms fed calves supplemental colostrum (pooled or frozen colostrum) in addition to that from their own dam and Baxter Smith and Simpson (2020) observed that 19% of dairy farmers used pooled colostrum. The large number of respondents pooling colostrum may have been due to overrepresentation of large farms in the sample size (>81 calves reared) and to the convenience of feeding multiple calves by pooling colostrum; however it is important to note that pooling colostrum will reduce overall IgG concentration since low immunoglobulin, high volume colostrum will be overrepresented in the pool (Weaver et al. 2000). Disease transmission risk is also increased with pooled colostrum, particularly with pathogens such as Johnes disease and Salmonellosis (Nielsen et al., 2008; Mohler et al., 2009). Only a small proportion (10.75%) of respondents who were pooling colostrum also pasteurised it. Pasteurisation has been demonstrated to reduce the risk of transfer of pathogens to calves through colostrum feeding by reducing bacterial contamination (which may interfere with IgG absorption from the gut) (Donahue et al., 2012). Typically, colostrum can be heated to 60◦C for 60-120 min without changing viscosity or denaturing IgG molecules (McMartin et al., 2006).

Study limitations

Respondents were more likely to be proactive, engaged dairy farmers. Respondents also required access to internet in order to complete the survey; however the Office for National Statistics estimated, in 2018, 89% of adults in the UK used the internet at least weekly and this figure has likely increased since. The data may also have been subject to recall bias. In addition, it is possible that response bias may have led to inaccurate self-reporting in this survey, although there would be no motive for this. Many of the survey questions were ‘tick box’ to improve the quality of the data collected but this may also have introduced an element of bias.

Encouraging dairy farmers to become more proactive in monitoring calf health parameters such as serum IgG concentrations seems to be challenging for vets (Barrett et al., 2020) and it has been asserted that: “Although good progress has been made in the past 20 years, there remains a considerable opportunity for many dairy producers to improve their colostrum management practices, resulting in improved short-term and long-term health and performance of the animals” (Godden et al., 2019, p. 535). It has been corroborated by other literature that there is an opportunity for more veterinary involvement in on -farm monitoring, since no farms monitored either colostrum quality or passive transfer outside a study by Johnson et al., 2017, and the majority of farms surveyed (57-87%) by Boulton et al. (2015) and Barry et al. (2017) did not check the quality of the colostrum before feeding. Additionally, testing calves for successful passive transfer of immunoglobulins from colostrum via blood test was never performed in 53% of dairy farmers surveyed, (Baxter-Smith and Simpson 2020). The trend observed between calf blood sampling frequency and colostrum quality monitoring may be indicative of more frequent veterinary visits to the farms in question however this was not measured in the current survey.

Conclusions

This survey provides an insight into colostrum management practices on UK dairy farms, allowing for identification of gaps and areas for improvement to optimise dairy calf health and welfare. The responses indicate that there are missed opportunities for vets and other dairy professionals to monitor parameters such as calf serum and colostrum IgG concentration and to provide advice on how best to enhance these. Responses also showed that there are still some farmers not optimally managing colostrum in terms of storage (correct temperature) and timing of harvest post calving and making small changes to these management practices could be hugely beneficial. Most of the respondents to this survey said that if it were shown to be beneficial, extended colostrum feeding (for 5 d) could be implemented into their farming systems with adjustments to labour, equipment and facilities.

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Table 1. Responses from an online survey of dairy farmers in the UK (248 responses) on their colostrum management feeding practices.

Variable	Category	Frequency	Percentage
Number of calves reared annually	<20	13	5.24
	21-40	25	10.08
	41-60	27	10.89
	61-80	26	10.48
	>81	157	63.31
Calving pattern	All year round	159	64.11
	Spring block	31	12.50
	Autumn block	49	19.76
	Autumn and spring	5	2.02
	Other*	4	1.61
Volume of colostrum fed at first feed	<2 L	36	14.52
	2.5-4 L	183	73.79
	>4.5 L	22	8.87
	Unknown	7	2.82
Method of feeding of colostrum	Stomach tube (all calves)	71	28.63
	Stomach tube (if not feeding independently)	56	22.58
	Teat feeder	94	37.90
	Bucket	7	2.82
	Leave calf to suck dam	20	8.06
How long is colostrum from milkings 1 and 2 fed to newborn calves	24 h	97	39.11
	48 h	79	31.85
	3-5 d	68	27.42
	>5 d	4	1.61
Method of transition from colostrum to milk replacer	Abrupt transition	158	63.71
	Whole milk fed	21	8.47
	Mix of whole milk and milk replacer	67	27.02
	Whole milk on cows	2	0.81
When is milk replacer first introduced?	After first feed	13	5.24
	After second feed	43	17.34
	After third feed or later	192	77.42
Is colostrum quality checked using a colostrometer or Brix refractometer?	Yes	121	48.79
	No	64	25.81

	Sometimes	63	24.81
Are calves blood sampled to check for immune status?	Never	99	39.92
	Only in the event of a problem	81	32.66
	1-4 times per year	41	16.53
	>4 times per year	26	10.48
	Unknown	1	0.4
Is colostrum pooled for calves?	Yes	103	41.53
	No	145	58.47
Method of feeding in first week of life	Individual feeders	180	72.58
	Group feeders	60	24.19
	Automatic feeder	8	3.23
Could you feed colostrum for 5 d if it was shown to be beneficial?	Yes	189	76.21
	No	59	23.79
Time from calving to colostrum harvest	1-6 h	190	76.61
	6.5-12 h	40	16.13
	12.5-18 h	5	2.02
	18.5-24 h	2	0.81
	>24 h	1	0.40
	Calf suck from dam	10	4.03
Time from harvest to feeding	<30 min	151	60.89
	30-60 min	56	22.58
	61-120 min	11	4.44
	>120 min	8	3.23
	Calf suck from dam	22	8.87
Storage	Freezer	104	41.94
	Fridge	20	8.06
	Fridge and freezer	54	21.77
	Room temperature	17	6.85
	No storage	28	11.29
	Freezer and room temperature	19	7.66
	Fridge and room temperature	3	1.21
	Fridge and freezer and room temperature	3	1.21
Volume of batch of colostrum stored	<1 L	17	6.85
	1.5-2 L	86	34.68
	2.5-3 L	69	27.82

	>3.5 L	32	12.90
	Not applicable	44	17.74
Temperature of fridge checked at least once weekly	Yes	42	16.94
	No	37	14.92
Temperature of freezer checked at least once weekly	Yes	46	18.55
	No	134	54.03
Temperature of fridge (◦C)	≤4	29	69.05
	3-5	2	4.76
	>4	9	21.43
	Unknown	2	4.76
Temperature of freezer (◦C)	-2 to -19	37	80.43
	<-19	2	4.35
	Unknown	7	15.22
How do you thaw colostrum for feeding?	Microwave	1	0.56
	Water bath	163	90.56
	Room temperature	14	7.78
	Unknown	2	1.11
Pasteurise colostrum	Yes	23	9.27
	No	224	90.32
	Sometimes	1	0.40
Chemical preservatives for colostrum	Yes[Ŧ]	3	1.21
	No	245	98.79

[*]Summer and summer and winter calving herds

[Ŧ]Of these farmers 2 used formic acid and 1 used potassium sorbate

Table 2. Table showing the frequency of calf blood sampling on farms where colostrum quality was checked and where colostrum quality was not checked with a Brix refractometer or colostrometer.

		Frequency of calf blood sampling				
		Never	Only in event of problem	1-4 times/year	>4 times/year	Total
Quality of colostrum checked	No	46	13	4	1	64
	Yes	53	68	37	25	183
Total		99	81	41	26	247

Table 3. Table showing the volume of colostrum fed at first feed on farms where colostrum was fed by oesophageal tube and where it was fed in some other way.

		Volume of colostrum fed at first feed			
		<2 L	2.5-4 L	>4.5 L	Total
Stomach tube	No	22	87	6	115
	Yes	14	96	16	126
Total		36	183	22	241

Figure legends

Fig. 1. Total number of survey respondents from each region of the country (n=207).

Fig. 2. Final thematic map showing three main themes and eight subthemes for system changes needed to implement an extended colostrum feeding protocol on UK dairy farms. Farmers were asked: ‘If it were shown to be beneficial to feed colostrum for the first 5 d, could you practically fit this in your farm system?’ and ‘Would you need to change any processes on-farm to be able to do this, if so what?’ Farmer quotes are included underneath each of the categories to which they pertain.

Fig. 3. Final thematic map showing additional human associated subthemes for information and support needed (including any barriers to change) in order to implement an extended colostrum feeding protocol on UK dairy farms. Farmers were asked: ‘What information or support would you need to be able to do this on your farm? OR what barriers do you envisage to implementing it?’ Farmer quotes are included underneath each of the categories to which they pertain.