Implementation of hypocalcaemia prevention programmes in commercial dairy herds: From theory to practice

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ABSTRACT

Hypocalcaemia prevention programmes have been widely studied in experimental settings, but their feasibility has not been assessed under field conditions. The main objective of this study was to evaluate, in the context of small dairy farms in western France, whether and how dairy farmers implement prevention programmes and manage the feeding of dry cows to prevent hypocalcaemia. Seventy-nine commercial Holstein dairy farms in Brittany (France) were enrolled in a qualitative study in 2019. We conducted in-person interviews with the farmers to 1) understand the rationale behind the type and seasonality of prevention programmes they implemented and 2) assess how closely they followed common recommendations when implementing them. Most farmers (80 %) used at least one prevention programme, especially supplying a mineral mix formulated to meet the needs of dry cows in late gestation (53 %), acidifying the diet in late gestation (37 %), and supplying calcium at calving (oral or injectable form, 37 %). The use of programmes depended on whether the diet composition varied throughout the year. Among farmers who provided an acidified diet, 25 % did not supply a specific mineral mix to dry cows to ensure an adequate amount of P, Ca, and Mg, which could decrease the effectiveness of the acidification programme. A lack of reliability in feeding practices, such as not weighing feed or not delivering feed frequently enough, was identified for 61 % of contributing farms. Management practices could result in supplying an unsuitable amount of P, Ca, or Mg immediately before calving; for example, inappropriate batching practices around calving were identified for 22 % (cows) to 32 % (heifers) of farms. In addition, nearly all contributing farmers had no processes in place to monitor the effectiveness of the programmes implemented. Reasons for this overall lack of compliance should be explored.

Implications

Milk fever and subclinical hypocalcaemia are common in dairy cattle. Prevention programmes exist, some of which include feeding strategies in late gestation or peripartum treatments. This study of 79 commercial dairy farms shows that, despite the common use of prevention programmes, their implementation leads to frequent imprecisions in feeding, management, and monitoring practices. Our findings highlight the need to strengthen advice to dairy farmers and understand the reasons for this lack of compliance.

Introduction

Hypocalcaemia is a major health issue of dairy cattle that occurs around calving. Clinical hypocalcaemia, also known as milk fever, concerns 1.8–7.1 % of dairy cows (Saborío-Montero et al., 2017; Venjakob et al., 2017) and is associated with a greater risk of culling in early lactation (Probo et al., 2018). Subclinical hypocalcaemia (serum concentration < 2 mM/l) is far more frequent, as it concerns 25–54 % of dairy cows, depending on the cows' parity (Reinhardt et al., 2011). It has detrimental effects on immunity, as it reduces the percentage of neutrophils involved in phagocytosis and reduces their oxidative burst response (Martinez et al., 2014; Leno et al., 2017). It thus increases the incidence of disease during the postpartum period (McArt and Neves, 2019), especially metritis (Venjakob et al., 2019). Several prevention strategies have been developed, of which the most common are diet acidification in late gestation and supplying calcium (**Ca**) at calving (Goff,

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2008; Wilkens et al., 2020). These strategies have been widely tested in experimental studies over the past three decades, as reported in a recent meta-analysis (Lean et al., 2019). However, the incidence of milk fever and subclinical hypocalcaemia remains high in dairy herds despite scientific knowledge provided by experimental studies (Reinhardt et al., 2011; Venjakob et al., 2017). Only a few studies quantified the influence of hypocalcaemia prevention strategies under field conditions (Venjakob et al., 2017; Roberts and McDougall, 2019). As a consequence, the relevance, feasibility, and effectiveness of these strategies in a wide variety of contexts remain uncertain. Recent studies highlight the difficulty for advisers (i.e. nutritionists and veterinarians) and farmers to collaborate on managing dairy cow health during the dry period, suggesting that barriers to adopting and implementing good practices exist (Mills et al., 2020; Redfern et al., 2021). Based on a few surveys, the use of prevention strategies seems to be common in commercial dairy herds worldwide, although their types and frequencies vary by geographical area (Hansen et al., 2007; USDA, 2014; Venjakob et al., 2017). One reason for the persistently high incidence of milk fever could be how farmers implement these strategies in practice. For instance, in temperate regions, forage availability varies by season. Changes in forage or variations in the percentage of grazed herbage in the diet could thus lead to difficulties in adapting the mineral supply or acidifying the diet. In experimental studies, the preventive effects of acidified diets have been assessed mainly using a close-up approach (i.e. fed only during the last 3 weeks before calving). In several European countries, small farms (<200 cows) with mixed crop-livestock farming systems predominate (Institut de l'Elevage, 2019). In this context, feeding a close-up diet could be difficult as it is labour-intensive: it involves mixing small amounts of feed for a few cows and allocating a few dry cows to the close-up group. To illustrate this idea, the USDA (USDA, 2016) reported that anionic salts were used more frequently for large herds (≥500 cows, 55 %) than for medium (100–499 cows, 32 %) or small herds (<100 cows, 21 %). To our knowledge, no study has evaluated how farmers implement hypocalcaemia prevention strategies to feeding and management practices, especially in the context of small-to-medium farms. While experimental studies accurately measure feed delivery and strictly monitor management practices, on-farm studies are frequently based on farmers' reports. This challenges the validity of field studies that assess the effectiveness of prevention strategies.

The main objective of this study was to evaluate, in the context of small commercial dairy farms in western France, how dairy farmers implement prevention strategies and manage feeding of dry cows to prevent the risk of hypocalcaemia. Specifically, we aimed to understand the rationale behind the type of prevention strategies they implemented and how closely they followed common recommendations.

Material and methods

Study sample

The study was conducted from January to June 2019 in the Brittany region, which is a typical western European plain and the main milk production area in France. We selected a study population of dairy farms from a database provided by the private animal health company GDS Bretagne (France) that contains all dairy farms in Brittany (n = 9 525). Only dairy farms with at least 60 cows were selected, in order to ensure that the dairy herd was the main production and thus that farmers were followed by advisory companies and aware of common hypocalcaemia prevention strategies. Additionally, we included only dairy farms with at least 90 % Holstein cows, as Holstein is the main breed in the area and could be considered as high risk for hypocalcaemia because of its high milk yield potential (N = 4 238). From this population, we set the target sample size at 80 farms as a compromise between ensuring a sufficient diversity of farmers' practices and putative prevention strategies and being feasible within a 6-month period for practical reasons. Farms were thus randomly selected using successive random samplings (without replacement) of 80 farms. To obtain herd variability in hypocalcaemia risk and thus in the types of prevention programmes, the random selection was stratified by the median milk yield in the region (7 500 kg/cow/year). Farmers who owned the farms selected were called to ask for their consent to participate in the study, and the random sampling was repeated until 80 farms were obtained.

Data collection

The data collection consisted of a 90 min in-person interview with each farmer that was conducted by one of two investigators (the first author and a veterinary student) using a highly structured interview guide. We followed general recommendations to design the interview guide (Dohoo et al., 2009) based on the literature on strategies for preventing hypocalcaemia (Thilsing-Hansen et al., 2002; Goff, 2008; Wilkens et al., 2020), which we then adapted to correspond to local feeding practices. Before finalising the interview guide, the two investigators tested the feasibility, reproducibility, and time required to complete the interview on four farms.

The questions concerned the year prior to the date of the study. The interview guide included five core sections (Table 1, Supplementary Material S1):

- Main farm characteristics
- Diet: the type and quantity of diets fed to dry cows and pregnant heifers, especially forage combinations. When available, forage-analysis reports and composition sheets for commercial mixes (i.e. concentrates and minerals) were collected. Emphasis was placed on identifying potential seasonal variations in diet and periods of calcium deficit for milk fever prevention.

Table 1
Details of the topics included in the structured interview guide on dairy cow farmers' practices.

Topic	Criteria
Main farm characteristics	• Number of cows, culling rate, milk yield.
Prevention programmes	• Description of programmes used: supply of a specific mineral mix, diet acidification, vitamin D injection before calving, calcium supply around calving. Description of seasonal fluctuations.
Diet	• Description of forage, concentrates, and minerals fed to dry cows and pregnant heifers. Description of seasonal fluctuations. Commercial mix amounts and contents of Ca, K, Na, Cl, S, and results of DCAD[1] calculations and forage analysis.
Feeding practices	• Method used to estimate amounts of fed forage, concentrates, and mineral supplies. Frequencies of diet mixing, diet delivery, and refusal removal.
Management practices	• Dry-period duration, close-up diet duration, Time of allocation of dry cows and pregnant heifers. Description of seasonal fluctuations. Description of monitoring practices: body condition score and urinary pH measurements.

[1] Dietary cation–anion difference.

- Prevention programmes: the type of programmes implemented by farmers to prevent hypocalcaemia. When used, nutritional programmes based on specific mineral mix or acidified diet are commonly fed to a specific group during the close-up period, which differs from the diet fed to far-off dry cows (i.e. 9–3 weeks before calving). Thus, if present, the existence of a close-up group was noted. Emphasis was placed on describing potential seasonal variations in programmes.
- Feeding practices, especially method for feed amount estimation, whether ingredients are mixed together or delivered separately, rhythm of feed delivery and of refusal removal
- Management practices, in particular the duration of prevention programme, criteria and rhythm for allocating cows to the close-up group, timing for allocating cows to the lactation group

Seasons were defined astronomically based on equinoxes and solstices.

Analysis strategy

After a description of the study sample (number of cows, percentage of primiparous cows, milk yield), the presence or absence of prevention programmes during the close-up period were noted. Following recommendations from literature on the prevention of hypocalcaemia (NASEM, 2021), prevention programmes provided by feed/advisor companies in the area of study can be classified as follows: (i) supplying a mineral mix adapted to dry-cow needs (i.e. in comparison to mineral mix adapted to cows in lactation, low Ca and phosphorus (**P**) concentrations, a high magnesium (**Mg**) concentration, a high vitamin D concentration and potentially containing zeolite to reduce the absorbed Ca, **MM**), (ii) acidifying the diet (**AcD**) by adding anionic salts directly to the ration or incorporated in a specific premix, (iii) supplying Ca around calving with injectable or oral form (**CaS**), and (iv) injecting vitamin D a week before calving (**VitD**). The first author conducted the classification of prevention programmes after reading of commercial sheet from commercial mixes. MM and AcD were then categorised as nutritional programmes, and CaS and VitD as therapeutic programmes.

We hypothesised that the implementation of nutritional programmes would depend on the variability in diet composition over seasons. Thus, the use of a programme was categorised as either part of the year (i.e. used for 1–3 seasons) or the entire year. In addition, the forage type of the diet on each farm was categorised as either constant (i.e. the same throughout the year) or variable (i.e. changed at least once during the year). We assumed that the use of a prevention programme and its nature depend on the variability of forage types over the year.

Feeding and management practices were described to assess how well the prevention programmes were implemented, especially for farmers who used a programme based on specific nutrition during the close-up period (MM and/or AcD). The reliability of the amounts of feed delivered was considered key to the quality of the nutritional programmes implemented. Feed reliability was categorised as ‘good, ‘fair’, or ‘poor’ as a function of feed-weighing practices, diet-mixing practices (total mixed ration or feed delivered separately), rhythm of delivering feed (daily, every-2 days or less frequently), and rhythm of removing refusals (daily, every-2 days or less frequently) (Supplementary Table S1). Feed-weighing practices were categorised as weighing (scale) or benchmarking (volumetric calibration) 1) all feed, 2) some feed, or 3) no feed. Management practices for the close-up group were evaluated for farms that used close-up at least part of the year. The reliability of management practices was assessed for AcD, as implementing it requires monitoring several management practices. Management reliability was categorised as ‘good’, ‘fair’, or ‘poor’ as a function of the duration of the programme, criteria for allocating cows to the close-up group, and timing of allocating cows to the lactation group. The categorisation was performed by the first author according to responses of farmers and to its field expertise in cow nutrition advisory (Supplementary Table S2).

Dietary cation–anion difference (**DCAD**) values of commercial mixes were estimated to assess whether AcD users supplied sufficient anionic salts to induce metabolic acidosis. The Ca supply in the commercial mix were estimated to assess whether farmers who used MM but not AcD adapted the mineral supply to obtain a diet with less than 20 g of Ca/cow/day. Supplies from the commercial mix were calculated based on the declared amounts fed and the composition provided by feed manufacturers, or from French tables of nutritional values for raw feedstuffs (INRA, 2018). To strengthen the comparison, we have estimated whole diet DCAD and whole diet Ca amounts by adding amounts from commercial mixes to those coming from forage as described in Supplementary Material S2.

Quantitative data were calculated as the mean ± standard deviation (SD). Qualitative data were described by the number and corresponding percentage of farmers who provided a particular response.

Results

A total of 79 farmers agreed to participate in the study (one farmer declined just before the time of interview). Main characteristics of farms from the study sample were similar to those of the target population (100 ± 59 and 99 ± 37 cows per herd, respectively; 34 % ± 6 % and 33 % ± 7 % of primiparous cows, respectively; 8 798 ± 1 122 and 8 789 ± 1 171 kg/cow/year, respectively) (data for the target population in 2019 came from databases of France Conseil Elevage and GDS Bretagne).

Most of the contributing farmers (80 %) used at least one prevention programme at least part of the year (Table 2). Nutritional programmes were the most used (n = 50, 63 %). The MM programme was used on most of the farms (n = 42, 53 %). Among farmers using MM programme, no one used a mineral mix containing zeolite in order to decrease calcium absorption. The AcD programme (n = 32, 37 %) was used during close-up (n = 17) or throughout the dry period (n = 15). Both nutritional programmes were used throughout the entire year on most farms (33/42 for MM and 30/32 for AcD). Therapeutic programmes were less used (n = 31, 41 %). CaS, which was used on 29 (37 %) farms, was restricted to cows in their third lactation or higher. The use of multiple programmes was frequent (n = 38, 48 %). The combination of

Table 2
Farmers’ responses to interviews regarding prevention programmes for dry cows and pregnant heifers, for the 79 dairy farms included in the study.

Prevention programme	Farms (%)
Nutritional	50 (63 %)
Specific mineral mix during late gestation (MM)	42 (53 %)
Part of the year	9 (11 %)
Entire year	33 (42 %)
Acidified diet (AcD)	32 (41 %)
Part of the year	2 (3 %)
Entire year	30 (38 %)
During close-up	17 (22 %)
During the entire dry period	15 (19 %)
Therapeutic	32 (41 %)
Calcium supply at calving (CaS)[1]	29 (37 %)
Prepartum injection of vitamin D (Vitamin D)[1]	11 (14 %)
Combined (nutritional + therapeutic)	38 (48 %)
None	16 (20 %)

[1] All farmers who used this programme did so for the entire year.

AcD and MM programmes, with or without CaS and VitD, was the most frequent (24/38 farms) (Fig. 1). Nutritional and therapeutic programmes were combined on 35 (44 %) farms (Fig. 1).

Forage composition of the diets remained constant throughout the year for most of the farms (n = 51, 65 %) (Fig. 2). On these farms, the main forage compositions were maize silage with straw or hay. When the diet composition varied over seasons, pasture and grass silage were frequently fed. The type of prevention programme that farmers used differed between farms with a constant diet composition (i.e. mostly nutritional programmes) and farms with a variable diet composition (i.e. mostly therapeutic programmes) (Fig. 3). For instance, AcD was used on 53 % of farms with a constant diet composition (n = 27) but on 18 % of farms with a variable diet composition (n = 5). In contrast, CaS was used on 29 % of farms with a constant diet composition (n = 15) but on 50 % of farms with a variable diet composition (n = 14). A large percentage of farmers used the MM programme for only a part of the year when the diet composition varied over seasons.

To assess how well the farmers implemented the prevention programmes, we examined results for feeding practices (Table 3 and Fig. 4a) and management practices (Table 4 and Fig. 4b). The reliability of feeding practices was considered good for 12 % of farms that used a nutritional programme. Poor and fair reliabilities (58 % and 30 %, respectively) were associated mainly with the lack of weighing or benchmarking at least some of the feed delivered (54 % of farms) and with a low rhythm of removing refusals (less than once every-3 days on 66 % of farms). Only 28 % of farms with a nutritional programme combined all feed (total mixed ration, TMR), which ensures that minerals are distributed homogeneously in the diet. When farmers used a volumetric benchmark, the measurement error (absolute value) was 25 % ± 40 % of the target weight. Only 8 % (mineral concentration) and 12 % (DCAD measurement) of farms that used a nutritional programme used a laboratory forage analysis to estimate the amounts of mineral supplements to be provided. Thus, calcium and DCAD supplied from the commercial mix could not be measured for every farm that used a nutritional programme, usually because the ingredient list for the commercial mix was not available or was incomplete at the time of study. Ca supplies from the commercial mix were similar for acidified and unacidified diets (47 ± 40 g/day, n = 19, and 48 ± 26 g/day, n = 16). For acidified diets, the DCAD supply from commercial mix was −633 ± 421 mEq/day (n = 19).

The reported dry-period duration was 57 ± 6 days on farms that used a nutritional programme, and the dry-off date was recorded for each cow on 74 % of the farms (Table 4). The reported close-up duration was 22 ± 7 days, but none of the 31 farmers who used close-up recorded the date when cows were allocated to the close-up group. Most farmers (n = 21, 68 %) who used close-up allocated cows to the close-up group via batching, with a batching frequency of 8 ± 3 days. When close-up was not used, pregnant heifers were allocated as far-off dry cows on 68 % of farms, and the reported timing of allocation was 75 ± 53 days before expected calving. Farmers did not record the dates when pregnant heifers were allocated to the far-off dry-cow group. Pregnant heifers were allocated to the close-up group on 84 % of the farms that used close-up. The reported timing of allocation was 27 ± 13 days before expected calving, but again farmers did not record the date of allocation.

Most farmers who used a nutritional programme allocated dry cows and pregnant heifers to the group of lactating cows (lactating diet) on the day of calving (76 % and 60 %, respectively). A few (10 % for dry cows, 20 % for pregnant heifers) allocated them to the group of lactating cows before calving, for which the reported timing of allocation was 7 ± 5 days and 11 ± 6 days before expected calving, respectively. A few farmers (12 % for both dry cows and pregnant heifers) allocated them to the group of lactating cows after calving, with a reported timing of allocation of 2 ± 1 days after calving for both. Ultimately, the reliability of management practices was considered poor for 47 % of farms that used an AcD programme.

Few farmers who used a nutritional programme monitored feeding, as only one farmer monitored urinary pH during the dry period (3 % of farmers who used AcD) and only four farmers measured body condition score at dry-off (8 % of farmers who used a nutritional programme). Values for feeding and management practices were quantitatively similar for farms that used a nutritional programme and those without a nutritional programme (Tables 3 and 4).

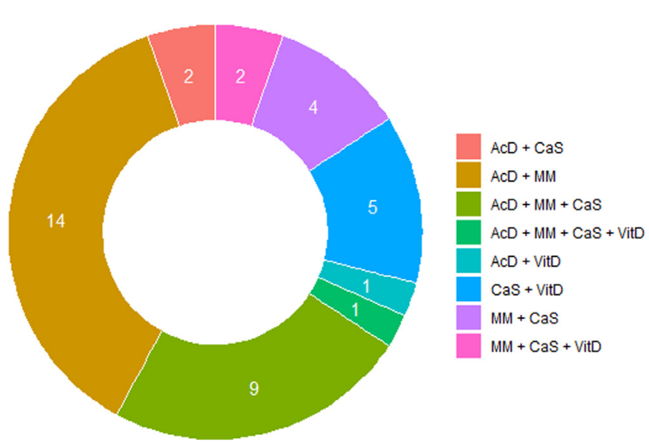

Fig. 1. Combinations of prevention programmes used on dairy cows and pregnant heifers for the 38 dairy farms subject to combinations. AcD = Acidified diet during late gestation, MM = specific mineral mix during late gestation, CaS = Calcium supply at calving, VitD = prepartum injection of Vitamin D.

Discussion

Our study revealed that prevention programmes are commonly used in Brittany but also highlighted great variability and some paradoxes in how they are implemented. We considered the use of a specific mineral mix for cows in late gestation as a prevention strategy, which is not considered in other studies (Venjakob et al., 2017). Unsuitable amounts of Ca, P, and Mg could increase the risk of hypocalcaemia and negate the effects of acidified diets. Only 53 % of contributing farmers reported using an MM programme for cows in late gestation, and only 42 % used it throughout the year. We could not find published data to compare to our results, but we expected a higher frequency, as feeding a mineral mix adapted to dry-cow needs seems a common and basic recommendation in Brittany. As a consequence, Ca, Mg, and P supplies were likely unsuitable for preventing the risk of hypocalcaemia on ca. 50 % of the farms. Using an AcD programme without also using an MM programme, which concerned 8 of 32 farmers who used AcD, could reduce the effectiveness of diet acidification due to high supply of P (Keanthao et al., 2021) or Ca (Goff, 2014), or low supply of Mg (Lean et al., 2006). The frequency of feeding an acidified diet in late gestation (41 % of farmers from our study) is in agreement with the 28 % frequency highlighted in the USA in the most recent USDA survey of dairy cattle management practices (USDA, 2016), but higher than the 9 % frequency that Venjakob et al. (2017) recently described for German herds. In our study, 37 % of farmers supplied Ca at calving, which is less frequent than the 69 % of farmers surveyed in the USA (USDA, 2014) or the 67 % (51/76) of farmers surveyed in New Zealand (Roberts and McDougall, 2019). Besides differences in study design, future studies should explore why the types and frequencies of prevention programmes or strategies differ among studies. The dominant feeding system, herd size, farmers' goals, and the relation between farmers and stake-

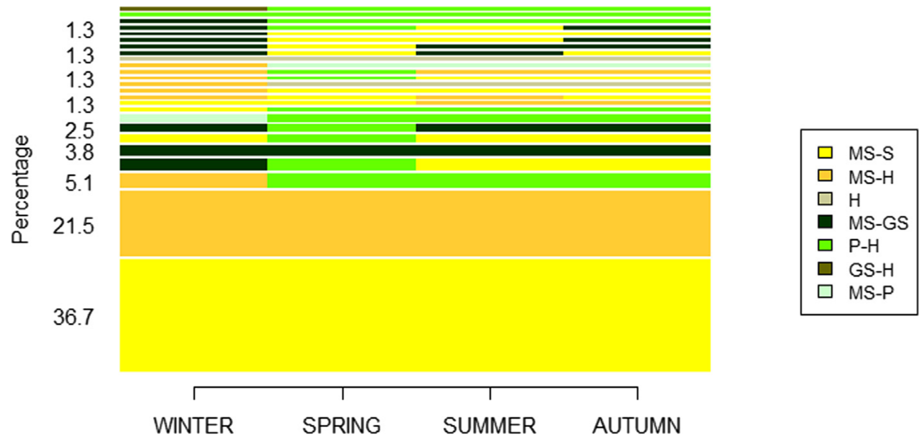

Fig. 2. Forage composition of diets for cows in late gestation as a function of season for the 79 dairy farms included in the study. MS = maize silage, S = straw, H = hay, GS = grass silage, P = pasture.

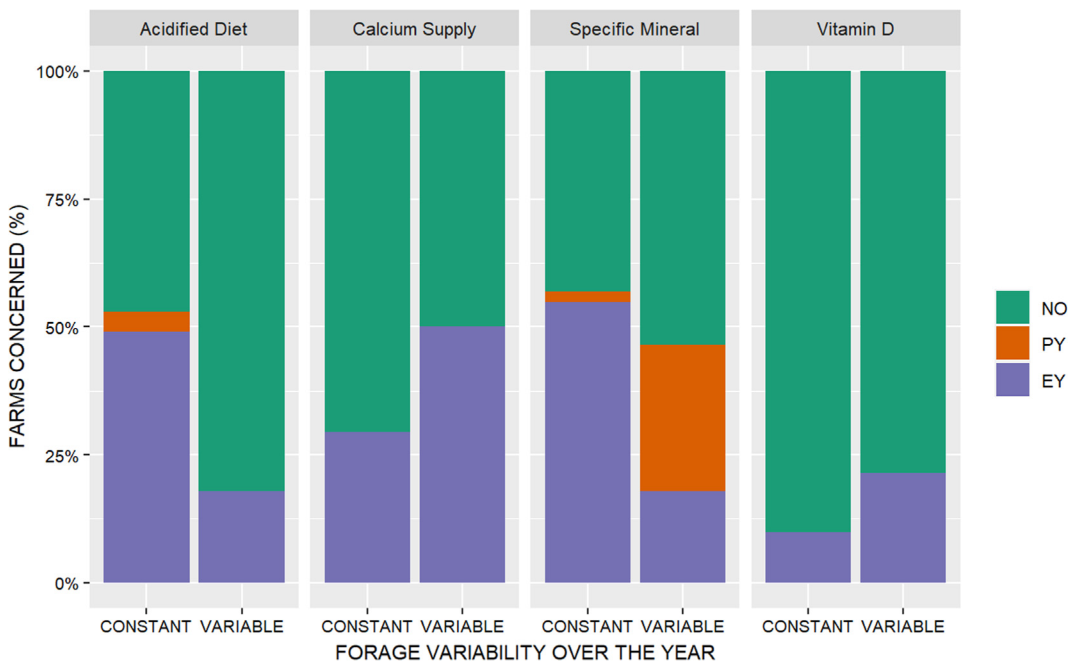

Fig. 3. Frequency and seasonality of prevention programmes as a function of whether the forage fed to cows in late gestation was constant or variable over the year, for the 79 dairy farms included in the study. Prevention programmes were used for the entire year (EY), part of the year (PY), or were not used (NO).

holders can vary among regions worldwide and thus influence farmers' use of programmes.

Our study illustrates that the type of prevention programme chosen depends on seasonal variation in diet composition. Among farms with a variable diet composition, the large percentage of farmers who used an MM programme for only a part of the year and the small percentage who used an AcD programme (i.e. ca. 20 %) may reflect farmers' difficulty in adapting the mineral supply to each change in forage composition throughout the year. Variation in diet composition throughout the year was related to the use of grass-based forage. Because grass-based forage has higher DCAD than maize silage and straw, it is more difficult to acidify, which may represent an additional challenge. These difficulties could prompt farmers to use more therapeutics, as illustrated in our study by the large percentage of therapeutic programmes used on farms with a variable diet composition. In contrast, although the percentage of farmers who used an AcD programme was higher among farms with a constant diet composition (i.e. ca. 50 %), the remaining issue is why AcD is not generalised in this context. Redfern et al. (2021) highlighted that the relationship between farmers and their advisers (e.g. nutritionists, veterinarians) could be a key factor for implementing such a nutritional programme. They indicated that some barriers could hinder studies of nutrition in this area, such as the risk of not meeting performance targets and lack of measurable benefits when implementing a nutritional programme. Collaboration between farmers and advisers presupposes that advisers have methods to assess the effects of programmes on the farm (Krogh and Enevoldsen, 2012).

Our study revealed a lack of accurate estimates of the amount of feed offered to cows and a gap between feeding practices and recommendations, which could decrease the effectiveness of nutrition programmes. The poor reliability of feeding practices, which concerned most of the contributing farms, was associated mainly with the lack of weighing feed. This, plus the large measurement errors when calibrating the quantity of commercial mix, and not analysing the mineral concentrations in forage were frequent factors that reduced the effectiveness of nutritional programmes on most of the concerned farms. Certain good practices are difficult

Table 3
Farmers' responses to interviews regarding feeding practices and mineral supply for dry cows and pregnant heifers, for the 79 dairy farms included in the study.

Feeding practices	All sample (%)	Farms with a nutritional programme sample (%)
Feed weighing	n = 79	n = 50
All feed weighed or benchmarked (volumetric)	22 (27 %)	15 (30 %)
Feed partly weighed or benchmarked	40 (51 %)	27 (54 %)
No feed weighed	17 (22 %)	8 (16 %)
Error in commercial mix estimates (volumetric benchmarking)	28 ± 39 %	25 ± 40 %
Diet mixing		
Total mixed ration	21 (27 %)	14 (28 %)
Feed delivered separately	58 (73 %)	36 (72 %)
Frequency of feed delivery		
Every day	54 (68 %)	34 (68 %)
Every-two days	8 (10 %)	6 (12 %)
Less frequently	17 (22 %)	10 (20 %)
Frequency of refusal removal		
Every day	17 (22 %)	10 (20 %)
Every-two days	12 (15 %)	7 (14 %)
Less frequently	50 (63 %)	33 (66 %)
Reliability of reported estimates of feed quantity		
Good	10 (13 %)	6 (12 %)
Fair	20 (25 %)	15 (30 %)
Poor	49 (62 %)	29 (58 %)
Quantitative analysis of at least one forage	55 (70 %)	50 (67 %)
Analysis of mineral concentrations (Ca, P, Mg)	9 (11 %)	4 (8 %)
Analysis of DCAD	8 (10 %)	6 (12 %)
Reported commercial mix supplied during the last 3 weeks before calving		
Standard diet, measurable Ca supply	18	16
Ca (g/cow/day)	47 ± 25	48 ± 26
Acidified diet, measurable Ca supply	19	19
Ca (g/cow/day)	47 ± 40	47 ± 40
Acidified diet, measurable DCAD supply	16	16
DCAD (mEq/cow/day)	−633 ± 421	−633 ± 421

Abbreviations: DCAD = Dietary cation–anion difference = ([K +] + [Na +]) – ([Cl-] + [S2-]).

to implement on small farms, such as those in our study, as weighing forage implies using a TMR mixer-wagon, which small farms rarely have. However, other practices, such as weighing concentrates and minerals, are simple to implement because a standard scale is sufficient. When data on the commercial mix were available, the Ca supply was not adapted to the absence of diet acidification, as it did not differ between farms with or without an AcD programme (47 ± 40 and 48 ± 26 g/cow/day, respectively). Thus, it is likely that on farms without an AcD programme, the Ca supply cannot result in a dietary concentration less than 20 g of Ca/cow/day, as recommended by Goff (2008). In addition, no farmers indicated that they used zeolite to decrease calcium absorption, while this can be effective for high dietary calcium concentrations. Similarly, diet acidification using a commercial mix on farms with an AcD programme (DCAD = -633 ± 421 mEq/cow/day) differs greatly from the −2 000 mEq tested by Goff and Horst (1998) to induce metabolic acidosis in a diet with maize silage as the main forage. In addition, the analysis of our local database on forage mineral content supports the hypothesis that diet acidification was insufficient in a majority of farms (Supplementary Material S2). However, recent experimental studies indicated that a mildly acidified diet had positive effects (i.e. DCAD of −20 to −10 mEq/kg DM) on postpartum serum Ca (Goff and Koszewski, 2018; Diehl et al., 2018). These uncertainties could make it difficult for advisers to provide clear recommendations to farmers.

Certain frequent management practices, such as feeding an acidified diet throughout the dry period (46 % of farms with an AcD programme), can jeopardise the preventative effect of this programme. Feeding an acidified diet for more than 3 weeks could dysregulate the secretion of parathyroid hormone (PTH) (DeGaris et al., 2010) or increase insulin resistance (Vieira-Neto et al., 2021), which could increase the risk of milk fever (Lean et al., 2006). Allocating cows and heifers in late gestation to the group of lactating cows before calving, which concerned a relatively large percentage of farms (10 % for cows and 20 % for heifers), can be an alternative strategy to close-up for preventing ketosis or an adaptation of the milking system for heifers. However, it could also increase the risk of hypocalcaemia because diets for lactating cows usually contain more Ca and have a higher DCAD. In our study, the timing of allocation to the group of lactating cows before calving was sufficiently long (7 ± 5 days for cows and 11 ± 6 days for heifers) to decrease PTH secretion and its regulating effects on serum Ca (Goff et al., 1986). Similarly, allocat-

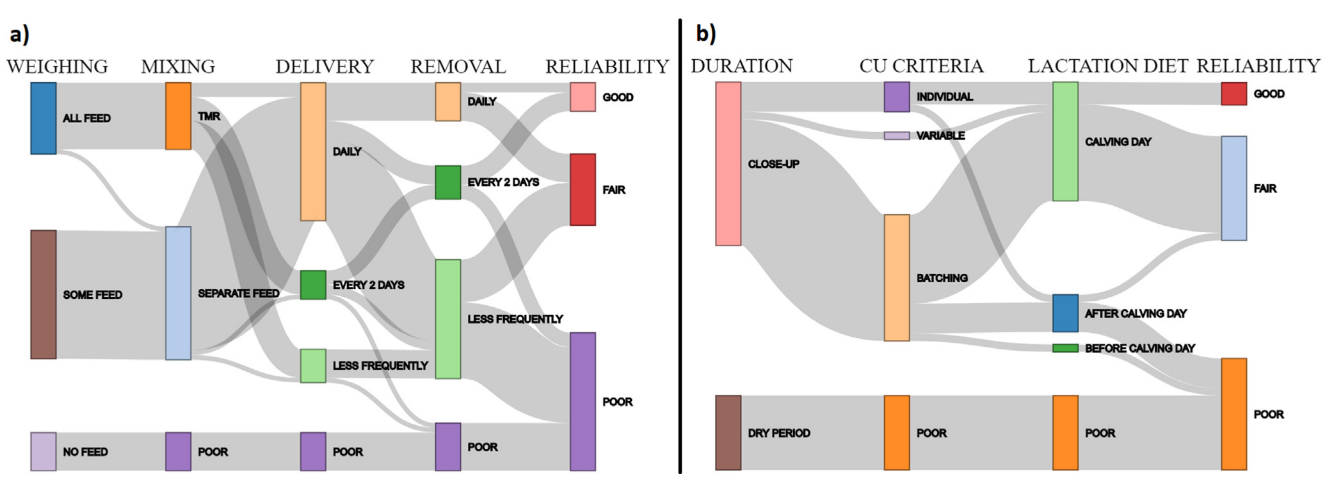

Fig. 4. Flow diagrams of a) feeding practices on dry cows and pregnant heifers for 50 contributing farmers who used a nutritional programme and b) management practices on dry cows and pregnant heifers for 32 contributing farmers who used an acidified diet. These practices determined the RELIABILITY category of each farm. WEIGHING = proportion of feed that is weighed, MIXING = all feed is mixed (total mixed ration (TMR)) or delivered separately (SEPARATE FEED), DELIVERY = frequency of feed delivery, REMOVAL = frequency of refusal removal, DURATION = acidified diet duration, CU CRITERIA = criteria for allocation to the close-up group, LACTATION DIET = day of allocation to the lactation group.

Table 4
Farmers' responses regarding management of dry cows and heifers in late gestation and reported durations of dietary phases from dry-off to calving, for the 79 dairy farms included in the study.

Management practices	All sample	Farms with a nutritional programme sample
Dry-period duration	n = 79	n = 50
Duration, in days	56 ± 7	57 ± 5
Farms with recorded data (date of allocation)	61 (77 %)	37 (74 %)
Close-up diet duration	n = 48	n = 31
Duration, in days	21 ± 6	22 ± 7
Farms with recorded data (date of allocation)	0 (0 %)	0 (0 %)
Individual allocation to the close-up group	17 (35 %)	7 (22 %)
Batch allocation to the close-up group	28 (58 %)	21 (68 %)
Undetermined or variable	3 (6 %)	3 (10 %)
Allocation frequency, in days	9 ± 4	8 ± 3
Pregnant heifer allocation to the far-off dry-cow group (if no close-up)	n = 31	n = 19
Pregnant heifers allocated to far-off dry-cow group	16 (52 %)	12 (68 %)
Timing of allocation before calving, in days	76 ± 58	75 ± 53
Farms with recorded data (date of allocation)	0 (0 %)	0 (0 %)
Pregnant heifer allocation to the close-up group (if close-up)	n = 48	n = 31
Pregnant heifers allocated to the close-up group	40 (83 %)	26 (84 %)
Reported timing of allocation before calving, in days	24 ± 12	27 ± 13
Farms with recorded data (date of allocation)	0 (0 %)	0 (0 %)
Dry-cow allocation to the lactating cows group	n = 79	n = 50
Before the day of calving	11 (14 %)	5 (10 %)
Timing of allocation before calving, in days	10 ± 6	7 ± 5
The day of calving	53 (67 %)	38 (76 %)
After the day of calving	12 (15 %)	6 (12 %)
Timing of allocation after calving, in days	4 ± 6	2 ± 1
Undetermined or variable	3 (4 %)	1 (2 %)
Pregnant heifer allocation to the lactating cows group	n = 79	n = 50
Before the day of calving	21 (27 %)	10 (20 %)
Timing of allocation before calving, in days	13 ± 7	11 ± 6
The day of calving	41 (52 %)	30 (60 %)
After the day of calving	12 (15 %)	6 (12 %)
Timing of allocation after calving, in days	2 ± 2	2 ± 1
Undetermined or variable	5 (6 %)	4 (8 %)
Reliability of reported management practices for acidified diet users		n = 32
Good		3 (9 %)
Fair		14 (44 %)
Poor		15 (47 %)
Cow monitoring		
Urinary pH measurement during dry period (if acidified diet, n = 32)		1 (3 %)
Body condition score measured at dry-off	6 (8 %)	4 (8 %)

ing cows and heifers in late gestation to the group of lactating cows several days after calving instead of the day of calving could increase the risk of hypocalcaemia. The diet of dry cows usually contains insufficient Ca concentrations for cows in early lactation, which were allocated to the group of lactating cows (2 ± 1 days after calving for both cows and heifers) after the period with the highest risk of hypocalcaemia (Moore et al., 2015). Even if the poor reliability of management practices observed can be explained in part by difficulties involved in managing small groups of cows, future studies should explore other reasons.

The frequent errors and inaccuracies, which are sometimes cumulative (as highlighted by the poor reliability of feeding and management practices), could also be associated with the lack of farmers' knowledge, and thus a lack of communication between farmers and their advisers, as highlighted by recent social studies on managing cows during the transition period (Mills et al., 2020; Redfern et al., 2021). In particular, Mills et al. (2020) recommended that advisers pay attention to farmers' goals and be trained "in how to communicate scientific knowledge". This implies that advisers consider scientific results and be able to adapt them to individual farms.

Most of the farmers who used a nutritional programme did not have a process in place to monitor its effectiveness. However, monitoring (measuring output) is crucial to assess the effectiveness of prevention programmes, especially given the poor reliability of practices (poor quality of input data). For instance, measurement of urinary pH enables farmers to control that metabolic acidosis is effectively induced when the absence of analysis of forage mineral content avoid estimating precisely diet DCAD. In this context, the effects of prevention programmes observed in experimental studies are difficult to achieve under field conditions. To partly address this problem, field studies should be designed to include the reliability of practices as confounding factors, even though this would likely be insufficient. The difficulty in collecting higher-quality data on commercial farms could be critical in the context of alternative research methods based on on-farm experiments, such as the EVOP (EVolutionary OPeration) concept implemented on dairy farms by Østergaard et al. (2020). As hypocalcaemia is mainly a subclinical disease, developing diagnostic tests to determine its within-herd incidence could help researchers and farmers. The latter could become more aware of the risk and thus become more receptive to the need for improvement. Thus, research that includes tests that can be used in routine practice and that allow for continuous measurement of within-herd incidence is of great interest.

Conclusion

Characteristics of hypocalcaemia prevention programmes vary among farms in the Brittany region (France) and could depend in part on the variability in diet throughout the year. In some cases, prevention programmes were not followed according to recommendations. Major issues remain in implementing good feeding and management practices in order to maximise the effectiveness of prevention programmes and to improve the validity of field studies. Doing so requires educational efforts and thus better collaboration among farmers, advisers, and researchers. Future research could focus on developing easy-to-use monitoring processes for farmers to assess the effectiveness of prevention programmes under field conditions.

Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.animal.2022.100639.

Ethics approval

Not applicable.

Data and model availability statement

None of the data were deposited in an official repository. Data are available upon request.

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Declaration of interest

None.

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