Strategies for keeping dairy cows and calves together – a cross-sectional survey study

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ABSTRACT

Although it is still most common to rear dairy calves separately from adult cattle, the interest in prolonged contact between dairy calves and lactating cows during early life is increasing. Previous research has documented positive effects of cow-calf contact (**CCC**) on for example early calf growth and udder health of suckled cows, but also negative effects such as increased separation distress and reduced weight gains after weaning. The aim of this study was to use information from European farms with prolonged cow-calf contact to identify innovative solutions to common challenges for CCC farms. Commercial dairy farms that kept calves with adult lactating cows for seven days or more after birth were invited to participate, and interviews were performed with 104 farmers from six countries. During interviews, information about farm management, calf rearing, farmers' perception of animal health on their farm, and farmers' drivers and barriers for implementing CCC were collected. We found that CCC was practised in a large variety of housing and management systems, and that calves could be reared together with their dam, with foster cows, or using a combination of the two. The contact period varied considerably (7–305 days) between farms and about 25% of the farms manually milk fed the calves during parts of the milk feeding period. Daily contact time varied between farms, from 30 minutes per day to permanent contact except at milking. Behaviours indicative of separation distress, most commonly vocalisation in cows and calves, were reported by 87% of the farmers. Strategies to alleviate separation distress, for example simultaneous gradual weaning and separation, were used on some farms. Building constraints were most often mentioned as a barrier for implementing CCC. Our findings suggest that CCC is practised in a variety of commonly used husbandry systems. Reported challenges were primarily related to weaning and separation, and to building constraints; these aspects should be areas of future research.

Implications

Dairy calves are often removed from the dam shortly after birth, but the interest in prolonged cow-calf contact is increasing. In this study, we identified practices that are used on European farms with cow-calf contact, and what challenges these farmers face. Cow-calf contact was practised in a large variety of husbandry systems, with calves being reared with the dam, with foster cows, or using a combination of the two. Daily contact time varied substantially between farms. Primary challenges for the farmers were weaning distress and building constraints; further research into these aspects would support farmers using cow-calf contact.

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Introduction

Within the dairy sector, it is routine practice on many farms to separate cow and calf within 24 h after birth. Proposed benefits of separating cows and calves shortly after birth are increased amount of saleable milk (Neave et al., 2022), decreased stress at separation (Flower and Weary, 2001), and health benefits (for example Muskens et al., 2003). However, there is an increasing interest among consumers and dairy farmers in systems allowing prolonged contact between cow and calf during early life. These so-called cow-calf contact (**CCC)** systems were recently defined as any type of housing or management system allowing calves contact with their dam or with foster cows (Sirovnik et al., 2020). Multiple surveys conducted in North America (Ventura et al., 2013), the US and Germany (Busch et al., 2017), and Brazil (Cardoso et al., 2017) reported that most participants with no involvement in the dairy industry do not favour early separation of cow and calf. The study of Ventura et al. (2013) also included people working within the dairy sector, and the authors reported that 8 of the 29 American farmers included in their study disagreed with early separation. To meet consumer demands, products from CCC farms are now marketed under labels specifying prolonged ($\geq$12 weeks) cow-calf contact in Germany (Interessengemeinschaft kuhgebundene Kälberaufzucht, 2021).

Beaver et al. (2019) and Meagher et al. (2019) systematically evaluated scientific literature contrasting early separation with prolonged cow-calf contact. For calves, the results for many health outcomes (for example mortality, diarrhoea, and respiratory health) were inconsistent (Beaver et al., 2019). However, the majority of studies reported a reduced risk of intramammary infections in suckled cows (Beaver et al., 2019). Meagher et al. (2019) reported that most studies found that calves allowed to suckle had better daily weight gain during the milk feeding period than manually milk-fed calves. Prolonged cow-calf contact was also related to a reduced risk of abnormal behaviours in the calves, including cross-sucking (Meagher et al., 2019).

However, potential challenges have been reported with CCC systems. Two of the most consistent findings are increased acute behavioural responses, such as vocalisation, when separation occurs >24 h postpartum and reduced growth rate after weaning for suckling calves (Meagher et al., 2019). Control of transmissible diseases has also been suggested as a potential challenge when cattle are housed in mixed age groups (Johnsen et al., 2016), although this belief has been challenged in a recent systematic review (Beaver et al., 2019).

Farmers pioneering CCC systems are difficult to identify, as many European countries do not register this type of information in centralised databases. As such, there is a need to describe the range of practices that are used on CCC farms in Europe. More information on which type of practices that are used on CCC farms, and what aspects the farmers perceive as challenging with these systems is crucial for identifying what questions that remain to be answered on how to best manage dairy cows and calves together. The experiences of pioneer farms may help finding innovative solutions for common challenges in CCC systems, which will be important moving forward as the number of CCC farms is predicted to increase.

In the current study, researchers from seven European countries [Austria, France, Germany, Italy, Poland, Sweden, and Switzerland] conducted quantitative surveys with dairy farmers using CCC systems, with the aims of identifying and describing calf rearing strategies that allow cow-calf contact after calving in the European dairy sector.

Material and methods

For this study, we used a standardised quantitative questionnaire including both open questions to record continuous numerical data, and multiple-choice or checklist questions to record data related to factor variables and categorised numerical variables. Most multiple-choice questions were semi-open, providing an option "Other, please specify", to allow identification of important factors or themes not originally included in the questionnaire. Recurring "other" responses were recoded to allow for quantification; for example, some farmers mentioned building constraints, which was not included in the original questionnaire, as an important barrier when they were going to implement CCC on their farms. Farmers could choose which questions to respond to; therefore, the number of answers differs between questions.

Questionnaire development

The questionnaire (Supplementary Material S1) was developed in 2018 and consisted of 55 questions in seven subsections: administrative data, farm description, rearing system, suckling practices, performance testing, farmer perception of animal health, and drivers and barriers for implementing CCC systems. As it was assumed that the male calves were sold off farm within a few weeks after calving, rearing practices for the female calves were the main focus. For inquiries related specifically to the female calves, the gender was therefore explicitly mentioned in the questions. The development process included discussion and agreement between all project partners regarding linguistic clarity and interpretation of the included questions. An external person with expertise in data collection from structured interviews facilitated the discussion, provided additional feedback on the written material and trained representatives from the different countries to ensure consistency in how the interviews were carried out. The questionnaire was then translated into the different national languages, and 1–6 persons per country performed the interviews. Depending on the country, some or all interviewers participated in the development of the questionnaire. In respective country, persons involved in questionnaire development instructed the other interviewers on how to conduct the survey. The interviews were carried out either by telephone or in person. Most interviews (79%) took place between 28 August 2018 and 21 March 2019; data collection was completed on 25 June 2019.

Participant recruitment

As cow-calf rearing was believed to be an uncommon practice in all participating countries, our intention was not to collect a random or representative sample of farmers using CCC systems, but rather to include a diverse range of farm types and management practices (for example, geographical region, farm size, years of experience with cow-calf rearing, and rearing practices). Only dairy farms keeping calves together with adult lactating cows (either the dam or foster cows) for at least seven days were eligible for inclusion. This cut-off was chosen so that farms needed to keep cows and calves together for longer than the colostrum period to be enrolled. A higher cut-off would have limited the number of farms we could include from some countries, as there were regional differences in the number of farms that transferred calves to manual milk feeding after an initial period with the dam. The goal was to identify at least 20 organic or conventional dairy farms meeting this criterion in each country. Depending on the country, farms were identified through a combination of existing farm and advisor contacts, outreach to other research groups, advertisement

in social media, and contact with farmer, dairy and organic organisations. To further increase the sample size, farmers enrolled in the study were asked whether they knew other farmers using CCC systems [described by Goodman (1961) as snowball sampling].

Research groups from three countries (Germany, Italy and Switzerland) had an active collaboration with CCC farms, and could recruit farms through their existing networks, while three countries (Austria, Poland and Sweden) had not previously collaborated with CCC farms and therefore partly relied on snowball referral for identification of potential farms. The French research group had recently (March 2018) performed a similar questionnaire on 102 farms that allowed at least two days of cow-calf contact (Le Cozler et al., 2018). To avoid a low response rate from French farmers in the current study, data from the previous questionnaire were included for the 26 farms meeting our enrolment criterion. Questions in the two questionnaires were largely, but not fully, overlapping, leading to missing data for some questions. A version of the French questionnaire translated to English is available as Supplementary Material S2.

Data handling

Data were entered, verified and processed by representatives from each country, using the Netigate platform (Netigate AB, Stockholm, Sweden). When entering the data, responses were translated to English. Data entries were reviewed, erroneous entries were corrected, and farms that did not meet the inclusion criteria were removed from the data set. Finally, the complete data set was downloaded as a csv-file for further analyses in R version 4.0.0 (Wickham, 2016; R Core Team, 2020; RStudio Team, 2020) and as a xlsx-file for further analyses in Stata SE version 14 (Stata Corp LP, College Station, TX, USA). Scripts are available as Supplementary Material S3.

Data were then analysed descriptively regarding possible differences between (1) countries, (2) conventional and organic herds, and (3) small and large herds, as well as (4) different CCC durations. For comparisons related to herd size, the median herd size per country was calculated from the farms enrolled in the study. The farms were subsequently categorised as small (<median herd size), or large (≥median herd size). Responses to open and semi-open questions were used to classify the daily amount of cow-calf contact. Daily contact allowance was classified as either permanent contact (female calves had access to the cows except during milking), half-day contact (female calves could access the cows either between morning and evening milking or vice versa), restricted contact around milking (female calves could suckle for a limited amount of time either before, during or after milking), or use of more than one of these strategies (most often depending on the age of the female calves). Regarding comparisons related to CCC duration, the data set was split into short (7–28 days), moderate (29–90 days) and long contact (>90 days). The reported number of calves dying before three months of age per year (stillbirths not included) was divided by the reported number of calves born the last 12 months, to obtain an approximate mortality rate for young calves. Inconsistent answers (for example, more female calves weaned than the total number of calves born) to specific questions were removed when analysing the data, while responses from the same farmer to other questions were retained in the data set.

Results

Farms using CCC systems were identified in all consortium countries except Poland. Of 121 identified farms fulfilling the enrolment criteria (≥7 days CCC after birth), data were obtained from 117 farms as four Swedish farms declined to participate in the study. Thirteen of these 117 farms were removed from the data set during data cleaning. Ten of the 13 removed farms either did not milk the cows or only milked for subsistence, two farms did not let the calves suckle but kept them with adult animals from three weeks of age, and one farm had only one dairy cow (which was used as a foster cow for beef calves).

Enrolled farms

Farm characteristics of the 104 dairy farms included in the final analyses are presented in Table 1, while breeds used are presented in Table 2. In general, the number of adult dairy cows per farm was centred around the average herd size in each country, except for Italy and Sweden (Fig. 1). Most farms, except in Italy, had implemented CCC systems after the year 2010 (Table 3). Of the 19 Italian farms, 15 had started with CCC before the year 1990, and many had used CCC systems for generations. Most farms used open pack or free-stall housing, while tie-stall housing was rare in all countries. Farms that kept dairy cattle outside during all four seasons were only reported in Italy. Parlour milking was the most common milking system in Austria, France, Germany and Switzerland, while this system was uncommon in Italy and Sweden (Table 1). Of farmers responding to the question, 91 of 94 raised recruitment heifers on their own farm.

In Austria, Germany and Sweden, large farms generally earned a larger proportion of household income from dairy production compared to small farms, while in Switzerland and Italy, no clear relationship between herd size and income from milk production was discernible (Table 1). Fattening female calves for slaughter was relatively common in Switzerland (7 of 11 farms), Germany (12 of 21 farms), Italy (8 of 19 farms) and Austria (6 of 15 farms), but occurred infrequently in Sweden (1 of 12 farms) and France (1 of 26 farms).

Rearing systems

Various calf rearing strategies were used on the enrolled farms. Of the 104 farms, most either kept the calves with their dams until weaning (n = 37) or used a mix of dams and foster cows (n = 30). Mix of dam and foster rearing is here defined as either keeping the calves with their dams >7 days and then transferring them to foster cows, or alternatively housing dams and foster cows together and letting calves suckle all cows in the group until weaning. An additional 11 farms raised calves in systems only using foster cows (here defined as keeping the calves with their dams for ≤7 days after calving, followed by foster rearing). Farms using only foster cow rearing most commonly kept all female calves with the foster cows until weaning, except one farm that kept half of the female calves in group boxes without contact with adult cows. The strategy to first manually feed the calves with milk followed by foster rearing was only used in Sweden (n = 3). One of the farmers mentioned that this system was used to reduce the risk of diarrhoea among the calves. There were also 23 farms that initially kept calves together with the dam (23 ± 13 days; mean ± SD), and then manually fed the calves milk or used automatic milk feeding systems after separation. The relative frequencies of different rearing systems per country are illustrated in Fig. 2.

Median herd size for farms that used dam rearing was 30 adult cows [Interquartile range (**IQR**) 18–40], while it was 50 cows (IQR 43–99) for farms with only foster rearing, and 50 cows (IQR 37–68) for farms using mixed rearing. Farms that transferred calves to manual milk feeding after the suckling period had a median herd size of 40 cows (IQR 33–60), while the median herd size for farms that transferred the calves from manual milk feeding to foster rearing was 210 cows (IQR 155–355).

Table 1
Farm characteristics of 104 European dairy farms with ≥7 days of cow-calf contact after calving, per country.

Item	Austria	France[1]	Germany	Italy[2]	Sweden	Switzerland
Number of farms	15	26	21	19	12	11
Herd size (median)[3]	25	50	55	40	85	30
Herd size (range)[3]	7–40	25–210	20–160	19–100	9–500	15–45
Housing system (%)						
Tie-stall	2 (13)	3 (12)	0 (0)	3 (16)	3 (25)	1 (9)
Cubicles	7 (47)	11 (42)	13 (62)	0 (0)	6 (50)	7 (64)
Open pack	5 (33)	12 (46)	8 (38)	9 (47)	2 (17)	2 (18)
Other	1 (7)[4]	0 (0)	0 (0)	7 (37)[5]	1 (8)[6]	1 (9)[4]
Milking system (%)						
Pipeline	2 (13)	3 (12)	0 (0)	2 (11)	4 (33)	1 (9)
Parlour	11 (73)	21 (81)	19 (90)	2 (11)	1 (8)	7 (64)
AMS	0 (0)	0 (0)	2 (10)	0 (0)	4 (33)	1 (9)
Bucket	2 (13)	0 (0)	0 (0)	10 (53)	2 (17)	1 (9)
Other	0 (0)	2 (8)[7]	0 (0)	5 (26)[8]	1 (8)[9]	1 (9)[10]
Income from milk (%)[11]						
0-25%	1 (7)	–	1 (5)	3 (16)	2 (17)	1 (9)
26-50%	6 (40)	–	8 (38)	12 (63)	2 (17)	2 (18)
51-75%	4 (27)	–	5 (24)	2 (11)	4 (33)	6 (54)
76-100%	4 (27)	15 (58)	7 (33)	2 (11)	4 (33)	1 (9)
Calving practice (%)						
Continuous	7 (47)	21 (81)	18 (86)	13 (68)	9 (75)	5 (45)
Seasonal	8 (53)	5 (19)	2 (10)	6 (32)	2 (17)	6 (54)
Other	0 (0)	0 (0)	1 (5)[12]	0 (0)	1 (8)[13]	0 (0)
Hectare crop land[14]	36 ± 20	141 ± 120	156 ± 101	54 ± 67	186 ± 12	29 ± 10
Hectare pasture[14]	16 ± 14	110 ± 91	56 ± 41	33 ± 32	115 ± 143	27 ± 11
Proportion of pasture in ration (%)[15]						
0%	2 (13)	0 (0)	1 (5)	2 (11)	0 (0)	0 (0)
1–25%	0 (0)	0 (0)	0 (0)	1 (5)	2 (17)	0 (0)
26–50%	1 (7)	0 (0)	5 (24)	2 (11)	3 (25)	1 (9)
51–75%	1 (7)	0 (0)	8 (38)	7 (37)	0 (0)	1 (9)
76–100%	11 (73)	26 (100)	7 (33)	7 (37)	7 (58)	9 (82)
Certified organic (%)	15 (100)	15 (58)	20 (95)	4 (21)	5 (42)	11 (100)

Abbreviations: AMS = Automatic Milking System.
[1] All farms were located in two semi-mountainous regions (Grand-Est and Massif Central).
[2] All farms were located in Sicily.
[3] Total number of adult cows, including dry cows but excluding pregnant heifers.
[4] One farm that used both cubicle and open pack systems.
[5] Seven farms that kept their dairy cattle outside during all seasons.
[6] One farm that used both tie-stalls and a cubicle loose housing system.
[7] One farm with pipeline milking in a free-stall system and one farm using a mobile milking parlour.
[8] Five farms that hand-milked the cows for commercial purposes.
[9] One farm with a rotary milking system.
[10] One farm using a mobile milking parlour system on pasture.
[11] Some information for French (n = 11) and Swiss (n = 1) farmers is missing.
[12] The farmer avoids calvings in February and March.
[13] The farmer avoids calvings during winter.
[14] Mean ± SD; cropland = arable land with crops, pasture = both permanent pasture (land not ploughed for many years) and temporary pasture (leys occasionally ploughed).
[15] Proportion of pasture included in the total feed ration during pasture season.

Foster cows were used on 44 farms for at least part of the milk feeding period (either only foster cow rearing, a mix of dam and foster cow rearing or manual milk feeding followed by foster cow rearing). The number of calves per foster cow differed between countries (Table 3) but was similar in organic (2.6 ± 0.7 calves; n = 32) and conventional farms (2.6 ± 1.1 calves; n = 12). The age when calves were moved to foster cows differed between farms (range 0–90 days), although foster cow rearing began within three weeks after calving on 35 of the 42 farms responding to this question. Criteria for selecting early-lactation foster cows were reported by 39 farmers. The most frequently stated criteria were high somatic cell count (n = 15), good maternal behaviour (n = 13), and difficulties to milk the cow (n = 9). Four farmers specifically stated that they did not use cows with high somatic cell count as foster cows, and one farmer never used *Staphylococcus aureus* positive cows for female calves but occasionally for male calves. Thirty farmers reported their criteria for selecting late-lactation foster cows, which were similar to reasons for choosing early-lactation foster cows. The most frequently stated criteria were high somatic cell count (n = 18), difficulties to milk the cow (n = 9) and that the cow had been selected for culling (n = 7).

Daily cow-calf contact allowance

For all enrolled farms, it was most common to allow permanent cow-calf contact (n = 48 farms), followed by contact around milking (n = 37), using more than one strategy (n = 14) and half-day contact (n = 5; day-time contact: two farms, night-time contact: three farms). The daily contact allowance differed between countries (Table 3), between calf rearing strategies (Fig. 3A), and between types of milking system (Fig. 3B).

On farms with parlour milking (n = 62), permanent cow-calf contact was most common (n = 34). Sixteen of these 34 farms initially let the calves suckle their dams (median 21 days; range 8–56 days) and then manually fed milk to the calves for the rest of the milk feeding period (median 16 weeks; range 9–26 weeks). Although six out of seven farms with automatic milking systems (**AMSs**) used permanent contact, no farm kept the calves in the milking herd. For farms that milked with milking buckets connected to an air compressor (n = 15) or hand-milked the cows for commercial purposes (n = 5), it was instead most common to let the calves suckle around milking (n = 16; Fig. 3B). In these systems, most farmers let the calves suckle during the full milk

Table 2
Dairy breeds used on 104 European dairy farms with ≥7 days of cow-calf contact after calving, per country.

Country	Dairy breeds[1]	
Austria	Fleckvieh (n = 6)	Holstein (n = 4)
	Tyrolian Grey[2] (n = 3)	Dairy-type Brown Swiss (n = 1)
	Murbodner[2] (n = 1)	Dual-purpose Braunvieh[2] (n = 1)
France	Montbéliarde (n = 24)	Crossbreed (n = 5)
	Abondance (n = 3)	Holstein (n = 2)
	Simmental (n = 1)	Tarentaise (n = 1)
	Vosgienne[2] (n = 1)	
Germany	German Black Pied[2] (n = 9)	Holstein (n = 9)
	Fleckvieh (n = 6)	Crossbreed (n = 4)
	Dual-purpose Braunvieh[2] (n = 3)	German Red Pied[2] (n = 2)
	Dairy-type Brown Swiss (n = 1)	Angler Red[2] (n = 1)
Italy	Modicana[2] (n = 9)	Crossbreed (n = 5)
	Pezzata Rossa[2] (n = 2)	Dairy-type Brown Swiss (n = 1)
	Cinisara[2] (n = 1)	Holstein (n = 1)
	Siciliana[2] (n = 1)	
Sweden	Swedish Red (n = 9)	Holstein (n = 8)
	Swedish Polled[2] (n = 5)	Jersey (n = 3)
	Fleckvieh (n = 1)	
Switzerland	Fleckvieh (n = 7)	Dairy-type Brown Swiss (n = 5)
	Crossbreed (n = 4)	Dual-purpose Braunvieh[2] (n = 2)
	Holstein (n = 2)	Red Holstein (n = 1)

[1] Multiple answers possible per farm.
[2] Endangered breeds with state-supported breeding programmes.

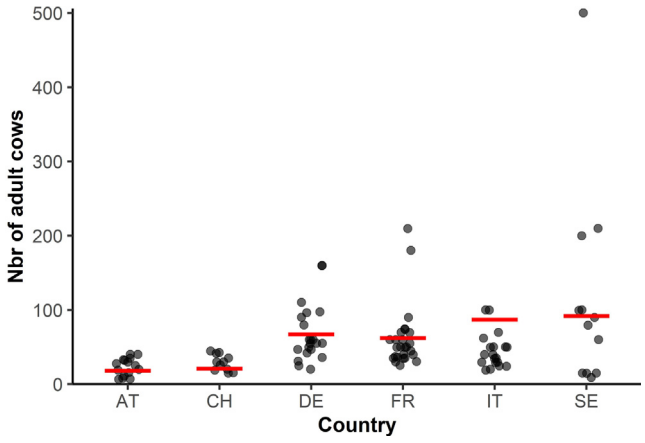

Fig. 1. Number of adult dairy cows, including dry cows, on European dairy farms (n = 104) with ≥7 days of cow-calf contact after calving, depending on country. Red crossbars illustrate the average number of adult cows per dairy farm in each country during the data collection period, based on information obtained from official sources (Austria (AT): ZAR Cattle breeding in Austria 2018, Switzerland (CH): Federal Statistical Office, Germany (DE): Milchindustrie-Verband e.V., France (FR): Centre national interprofessionnel de l'économie laitière, Italy (IT): Italian Animal Breeders Association, Sweden (SE): Swedish Board of Agriculture).

feeding period (18 of 20 farms), most often from their own dam (14 of 20 farms).

All farms with half-day contact (n = 5) kept cows and calves together once per day, with the contact duration varying between 5.5 and 14 h per day. On farms where contact was restricted to the period before, after or at milking (n = 37), it was uncommon that the calves had access to cows on other occasions (one farm let the female calves suckle between milking events, but only during the first three weeks of life). Contact duration around each milking varied between 10 min and 2 hours between farms.

The milk-fed calf - feeding practices

On 96 of the enrolled 104 farms, colostrum was normally fed through suckling. On four of these 96 farms, the farmer mentioned that some of the calves additionally were manually fed to ensure colostrum intake, particularly lethargic calves. On the other eight farms, all calves were manually fed colostrum, either by teat bucket (n = 6), bottle (n = 1) or by drenching (n = 1).

On 94 of the 104 enrolled farms, all calves of both genders had contact with lactating cows (either their dam or foster cows or both). On two farms either all female (n = 1), or all male (n = 1) calves were allowed to suckle, while a lower proportion of the other gender had contact with lactating cows (90 and 50%, respectively). On the remaining eight farms, the proportion of female and male calves that could suckle varied between 30–90% and 50–90%, respectively.

The duration of the suckling period for female calves varied more within than between countries. In most countries, the suckling period varied between 20 and 200 days, with no major differences between conventional and organic farms (Fig. 4A). It was uncommon to provide supplemental milk to female calves during the suckling period. Only one farm supplied *ad libitum* extra whole milk to all female calves during the full suckling period. An additional three farms either gave extra milk to some of the calves (n = 1), to calves that were learning to suckle from foster cows (n = 1), or to calves that were learning to drink from teat buckets (n = 1; this farm sold all calves to a rearing farm). One additional farm provided supplemental milk feeding to calves with diarrhoea.

Weaning age was reported by 97 farmers, the other seven farms either mistook weaning age for age at separation or did not know when the calves were weaned (i.e., all calves were sold to a rearing farm during the milk feeding period). Of the 97 farms, 70 let female calves suckle from birth until weaning. The age at weaning varied somewhat between countries (Fig. 4B), and between conventional [median 12.5 (IQR 9.3–24.0) weeks] and organic farms [17.0 (IQR 13.0–21.4) weeks]. While the end of the milk feeding period and the separation from adult lactating animals coincided on many farms (n = 71), some farms used strategies to achieve a gradual reduction of milk allowance, often combined with a gradual reduction in CCC. For calves that were group housed together with multiple lactating cows, a gradual reduction of milk allowance was achieved by reducing the number of cows kept in the pen (n = 2) over time, or by gradually reducing the daily duration that calves

Table 3
Description of cow-calf production systems used in 104 European dairy farms with ≥7 days of cow-calf contact after calving, per country. Numerals indicate the number of farms unless otherwise stated.

Item	Austria	France	Germany	Italy	Sweden	Switzerland
Number of farms	15	26	21	19	12	11
Started with CCC (%)						
<1990	1 (7)	1 (4)	0 (0)	15 (79)	0 (0)	0 (0)
1990–1999	2 (13)	1 (4)	4 (19)	0 (0)	2 (17)	0 (0)
2000–2009	2 (13)	5 (19)	3 (14)	2 (11)	5 (42)	2 (18)
≥2010	10 (67)	19 (73)	14 (67)	2 (11)	5 (42)	9 (82)
Rearing system (%)						
Dam	8 (53)	6 (23)	4 (19)	11 (58)	5 (42)	3 (27)
Foster	1 (7)	0 (0)	5 (24)	2 (11)	2 (17)	1 (9)
Mix[1]	1 (7)	7 (27)	12 (57)	3 (16)	2 (17)	5 (45)
Dam + Manual[2]	5 (33)	13 (50)	0 (0)	3 (16)	0 (0)	2 (18)
Manual + Foster[3]	0 (0)	0 (0)	0 (0)	0 (0)	3 (25)	0 (0)
Contact allowance (%)						
Permanent[4]	7 (47)	17 (65)	10 (48)	3 (16)	8 (67)	3 (27)
Half-day[5]	2 (13)	0 (0)	1 (5)	0 (0)	1 (8)	1 (9)
Around milking[6]	3 (20)	7 (27)	7 (33)	15 (79)	1 (8)	4 (37)
Multiple[7]	3 (20)	2 (8)	3 (14)	1 (5)	2 (17)	3 (27)
Median (IQR) number of calves per foster cow[8]	2.0 (2.0–2.0)	2.0 (2.0–2.8)	2.5 (2.5–3.0)	1.0 (1.0–3.0)	3.0 (3.0–3.5)	3.0 (2.8–3.4)
Median (IQR) age at weaning (weeks)[9]	15 (12-16)	19 (13-26)	16 (13-17)	25 (24-30)	12 (10-12)	20 (17-21)
Calf ration (%)						
Forage access	15 (100)	26 (100)	21 (100)	19 (100)	12 (100)	11 (100)
Starter access	8 (53)	21 (81)	13 (62)	17 (89)	12 (100)	1 (9)
Age in weeks at first forage access[10,11]	1.3 ± 0.8	0.8 ± 0.4	1.0 ± 0.0	2.9 ± 1.8	1.1 ± 0.3	1.0 ± 0.0
Age in weeks at first starter access[10,12]	4.5 ± 3.3	–	2.5 ± 4.7	3.9 ± 3.4	0.7 ± 0.5	0

Abbreviations: CCC = Cow-calf contact, IQR = Interquartile range.
[1] The calves suckled both the dam and foster cows, either simultaneously when housed in a mixed group or first the dam for at least one week and then foster cows.
[2] The calves initially suckled the dams and were then manually milk fed.
[3] The calves were first manually milk fed and then housed only with foster cows.
[4] The calves were housed with the cows except during milking.
[5] The calves were housed with the cows either between morning and evening milking, or vice versa.
[6] The calves could suckle either directly before, during or directly after milking, but were otherwise housed separately from the cows.
[7] Two or more types of cow-calf contact were used depending on calf age, most often first permanent contact with dam, followed by restricted contact with the dam (n = 4 farms) or contact only with foster cows (n = 6).
[8] Calculated for all farms that used foster cows during any part of the milk feeding period (i.e. Foster, Mix and Manual + Foster; n = 44).
[9] Some information for Austrian (n = 1), Italian (n = 4) and Swiss (n = 2) farmers is missing.
[10] Mean ± SD.
[11] Some information for French (n = 21) and Swiss (n = 1) farmers is missing.
[12] Some information for French (n = 21) farmers is missing.

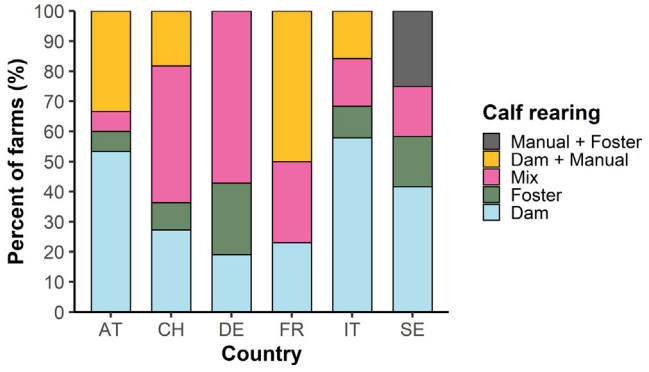

Fig. 2. Rearing systems for female calves on European dairy farms (n = 104) with ≥7 days of cow-calf contact after calving, depending on country (Austria (AT) = 15, Switzerland (CH) = 11, Germany (DE) = 21, France (FR) = 26, Italy (IT) = 19, Sweden (SE) = 12 farms, respectively). Farms most often let calves suckle the dams (Dam) or only foster cows (Foster) or used a combination of dams and foster cows (either chronologically or by group housing calves with both dams and foster cows; Mix) until weaning. Allowing the calves to suckle their dams for some weeks followed by separation and manual milk feeding (Dam + Manual) was practised in several countries. In addition, three Swedish farms manually milk fed the calves for 1–4 weeks after birth, followed by foster cow rearing.

were kept together with the cows (n = 2). Strategies to gradually reduce milk allowance on farms with restricted CCC included reducing the number of times per day the calves could suckle (n = 3), letting younger calves suckle the cows before older calves were given access (n = 2), or starting to milk the suckled cows as the calves got older (n = 2). On some farms, weaning was performed after separation, either by manually milk feeding the calves after separation (n = 3) or by transferring the calves to cows already bonded with younger calves (n = 3).

Weaning and separation distress

Of the 104 farmers, 90 reported problems in connection with permanent separation of cows and calves, while 14 did not observe any difficulties. Of the 90 farmers that observed signs of separation distress, they most often reported increased vocalisation among the cows (n = 76), followed by increased vocalisation among the calves (n = 56). Less common observations included difficulties to milk the cow after separation (n = 17) and calves losing weight after separation (n = 9).

The most frequent strategies to solve distress at separation were stepwise separation of cows and calves (n = 16) and treatment with herbal remedies or homeopathy (n = 11). In addition, a low number of farmers put nose-flaps on the calves for some time before separation (n = 3), used medical treatment of cows and calves at separation (n = 3) or supplied attractive feed to divert cows' and calves' attention (n = 4) after separation. Strategies could differ substantially between farms; for example, while some

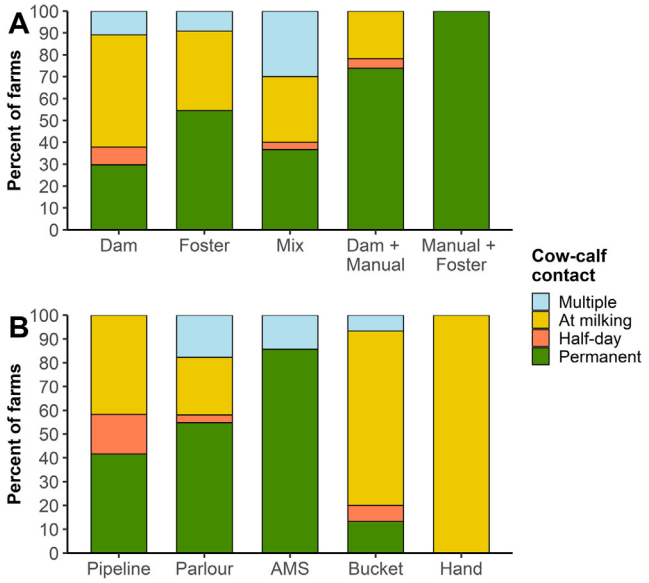

Fig. 3. Type of cow-calf contact for female calves used on European dairy farms (n = 104) with ≥7 days of cow-calf contact after calving, depending on calf rearing strategy and milking system. Female calves were either continuously housed with the cows (Permanent), housed with cows between the morning and evening milking (or vice versa; Half-day), or could suckle the cows around milking (At milking). Some farms used more than one type of cow-calf contact depending on for example calf age (Multiple). (A) Calf rearing strategies used at the farms included dam rearing until weaning (n = 36; Dam), only foster rearing from ≤7 of age until weaning (n = 11; Foster), combination of dam and foster cow rearing (n = 30; Mix), initial suckling of the dam followed by manual milk feeding (n = 24; Dam + Manual), and manual milk feeding followed by foster rearing (n = 3, Manual + Foster). (B) Milking systems used at the farms included pipeline (n = 12), parlour (all types of indoor parlours; n = 61), automatic (n = 7), milking bucket (n = 15), and hand (n = 5) milking systems. Four farms used unique milking systems, contact allowance for these farms are not shown.

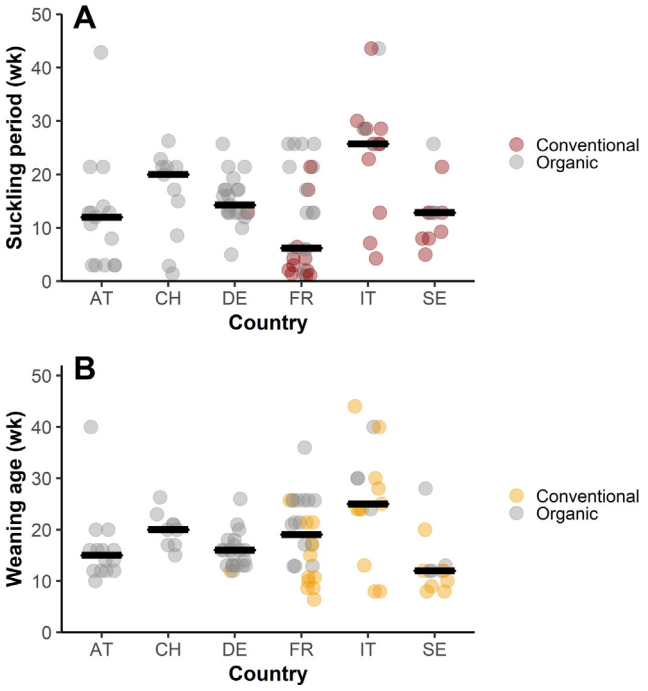

Fig. 4. The milk feeding period on European dairy farms with ≥7 days of cow-calf contact after calving, depending on country and farming method. The number of farms that responded differed between questions. (A) Duration of suckling period in weeks for female calves (n = 102); (B) weaning age in weeks for female calves (n = 97). Crossbars represent the median. The original questions asked about suckling duration in days and weaning age in weeks, which likely led to small systematic rounding errors [i.e., calves 'weaned' at 12 weeks (84 days) could *de facto* suckle until 90 days (12.9 weeks)].

farmers kept cows and calves so they could not hear each other after separation (n = 5) to reduce stress, others ensured visual and auditory contact between cows and calves for some days after separation (n = 2) for the same reason. In addition, while three farms separated small groups of calves simultaneously for company, this practice was avoided on one farm to reduce the risk that vocalisation from multiple calves would trigger further stress responses. Of the 45 farmers that used any kind of management strategy to reduce separation distress, 40 (89%) still reported acute animal responses at separation, compared to 50 (85%) of the 59 farmers that did not use any particular strategy. Of the 44 farms that used foster cows for at least a part of the milk feeding period, five ensured that the foster cows got access to young calves immediately after separation from the older calves to reduce stress responses among the cows.

Perception of health

Farmers were asked about their opinion on whether health outcomes differ between CCC animals and animals that are conventionally managed, both for cow (fertility and udder health) and for calf (general health, daily weight gain, diarrhoea, respiratory disease) outcomes. The questions were closed multiple-choice questions with the following possible responses: "Yes, better", "Yes, worse", "No difference" and "I don't know".

Cows

Of the 104 farms, 54 farmers perceived that the fertility of cows suckled by calves was the same as for cows that were only milked, while 20 and 10 thought that fertility was better and worse, respectively. Twenty farmers stated that they did not know whether there was any difference in fertility. The perceptions of CCC's effect on fertility differed between countries (Fig. 5A), but the length of the suckling period was similar for farms that thought fertility was better (104 ± 74 days; mean ± SD), the same (104 ± 62 days) or worse (112 ± 84 days). Udder health was perceived as the same in cows that were suckled and in cows that were only milked by 42 farmers, better by 40 farmers and worse by five farmers, while 17 farmers did not know (Fig. 5B). Again, there was no obvious relation to the duration of the suckling period (better udder health: 124 ± 74 days; same: 78 ± 55 days; worse: 96 ± 54 days).

Calves

General calf health was perceived as better in suckling calves compared to manually milk-fed calves by 82 of 104 farmers, while 11 farmers thought calf health was the same, two farmers thought it was worse, and nine farmers did not know (Fig. 5C). Of 102 responding farms, 86 farmers found suckling calves to have higher weight gain compared to conventionally managed calves, seven farmers perceived no difference and two farmers thought the weight gain was reduced, while seven farmers did not know (Fig. 5D). When asked about more specific health issues, a larger proportion of farmers was uncertain about the effect of CCC on calf diarrhoea (Fig. 5E) and respiratory disease (Fig. 5F).

Sufficient information to calculate an approximate annual mortality rate for calves 0–3 months of age was reported for farms from Austria (n = 14), Germany (n = 21), Italy (n = 18) and Switzerland (n = 11). Although most farms stated that no or very few calves died annually, the approximate mortality rate was ≥10% for nine of the 64 farms included in this analysis (Fig. 6). Farms with mortality ≥10% had on average smaller herd size (29 vs 48

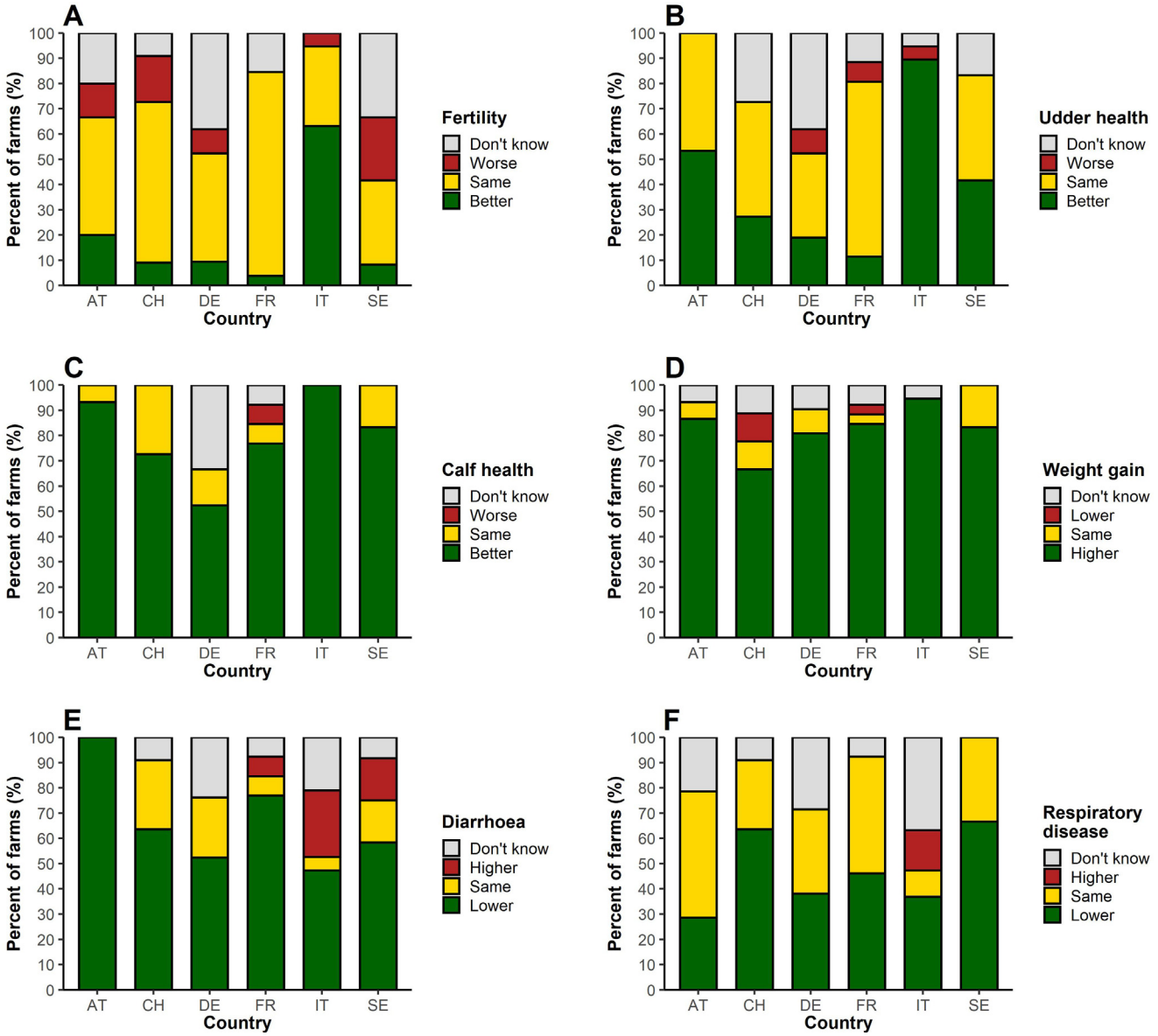

Fig. 5. Perception of health on European dairy farms with ≥7 days of cow-calf contact after calving, depending on country (Austria (AT) = 15, Switzerland (CH) = 11, Germany (DE) = 21, France (FR) = 26, Italy (IT) = 19, Sweden (SE) = 12 farms, respectively). The number of farms that responded differed between questions: The perceived effect on (A) fertility of suckled cows, n = 104; (B) udder health of suckled cows, n = 104; (C) general calf health, n = 104; (D) calf weight gain, n = 102; (E) frequency of calf diarrhoea with impaired general condition, n = 104; (F) frequency of respiratory disease in calves, n = 103.

Fig. 6. Estimated annual 0–3 months calf mortality rate on European dairy farms (n = 64) with ≥7 days of cow-calf contact after calving (Austria (AT) = 14, Switzerland (CH) = 11, Germany (DE) = 21, Italy (IT) = 18 farms, respectively).

cows) and lower acreage (41 vs 128 hectares), less often earned income only from milk (0 vs 24% of farms), and more often hand- (22 vs 4% of farms) or pipeline (22 vs 5% of farms) milked the cows, compared to farms with lower mortality. Despite their relatively high mortality, these farmers all perceived general calf health to be better in suckling calves than in calves from conventional calf rearing. However, it was more common for these farmers to believe that respiratory disease (11 vs 4% of farmers) and particularly diarrhoea (33 vs 4% of farmers) occurred more often in suckling calves than in conventionally raised calves, compared to CCC farmers from low mortality farms.

Drivers and barriers

Of 100 responding farmers, 77 stated that their CCC system was not more time consuming than an artificial rearing system where

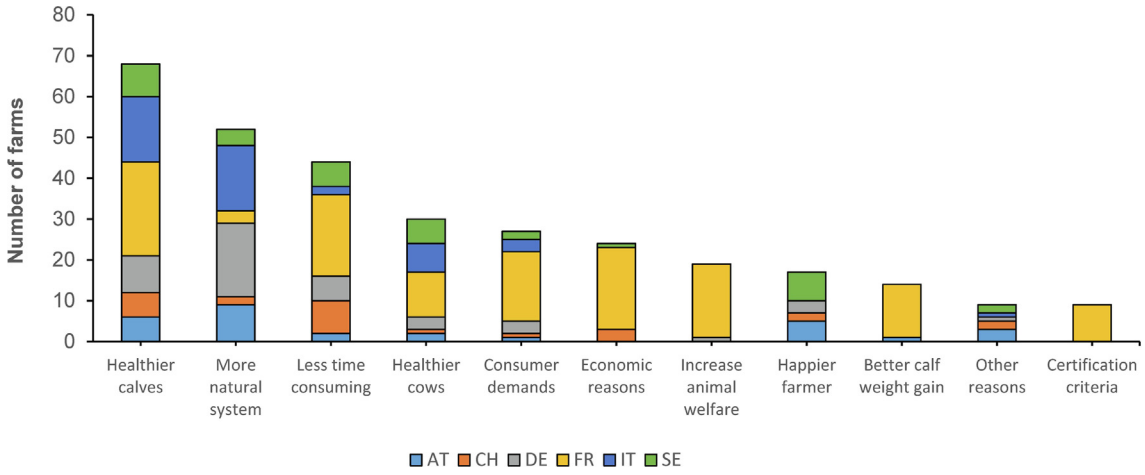

Fig. 7. Drivers for implementing cow-calf contact on European dairy farms (n = 104). The category 'Other reasons' included "a place to put 'trouble cows' with poor legs", "dislike against plastic bottles", "cows that are difficult to milk usually work better in cow-calf contact systems" and "wanted to give the system a try".

cows and calves are separated directly after birth, with 20 farmers commenting that CCC systems are less time consuming. Conversely, 22 farmers thought CCC took more time. Thirteen of these 22 farmers did not comment on their answer. Of those who did, labour needed to move cows and calves (n = 6) was the most frequently mentioned reason.

The main drivers for using CCC systems were improved calf health (n = 68), more natural calf rearing (n = 52), and less time-consuming management (n = 44; Fig. 7). The most common barriers before the farmers started with CCC were improper barn construction (n = 14), CCC systems being too complicated (n = 7) or too time consuming (n = 5), lacking knowledge about CCC (n = 3) and avoiding late separation (n = 1). Forty-three of 104 farmers did not think of any barriers before starting with CCC. Open-ended answers on how the farmers wanted to modify their CCC systems revealed that 46 of the 104 farmers were planning to alter some aspects of their production system. Rebuilding animal facilities was most often mentioned (n = 17), primarily to improve indoor calf rearing (n = 13), but also to enable CCC at pasture (n = 1), reduce workload (n = 1), increase farm size (n = 1), and improve housing for adult cows (n = 1). Some farmers also wanted to change some aspects of their management, and seven farmers specifically mentioned reducing stress at separation as important. Six of the 46 farmers wanted to change CCC allowance, of which two planned to increase daily cow-calf contact, two planned to reduce daily cow-calf contact and two planned to stop CCC and manually milk feed the calves in the future. An additional three farmers planned to stop with dairy farming in general.

Calf rearing vs contact duration

Within the data set, there was a large variation in the duration that calves were kept with adult cows (range 7–305 days). To explore if the contact duration was associated with the type of CCC system used at the farm, or with perceived health, behaviours indicating separation distress and drivers and barriers for CCC implementation, the data set was split into farms with short (n = 16), moderate (n = 40), and long contact (n = 48) period. Results for calf rearing strategies, perception of health and separation distress are presented in Table 4.

Natural rearing was selected as an important driver by a somewhat higher number of farmers with long contact (30 of 48 farms), compared to farmers with short (6 of 16 farms) and moderate contact duration (16 of 40 farms). Within each group, calf health was more frequently selected as an important driver than was cow health (by a factor of 1.5–3.0). Reduced workload was important for around 40% of farmers in each group, while consumer demands and profit were selected by a higher proportion of farmers with short contact duration (short: 38 and 50%, moderate: 23 and 13%, long: 25 and 21%, respectively). Work satisfaction was considered important by a somewhat higher proportion of farmers with moderate contact duration (8 of 40 farms), compared to farms with short (2 of 16 farms) and long (4 of 48 farms) contact. Although few farmers reported barriers for CCC implementation, barn construction was most commonly mentioned as a challenge in all three groups (10–20% of responding farmers in each group).

Discussion

Enrolled farms

Our study showed that CCC is practised under variable conditions on European farms, from farms that house and hand milk their cows outdoors to farms with technology-intensive systems such as AMS barns. This result suggests that CCC can be successfully implemented in different management systems. Even though CCC was practised on very different types of farms, 80% of the farms in our sample used either indoor open bedded pack systems or cubicle barns. It is unclear if CCC is easier to implement in these housing systems, or if this finding is simply due to loose-housed indoor systems being more common than other housing systems in Europe. Similarly, the type of milking systems present on the CCC farms in our sample could reflect what is commonly used in the different countries. For example, bucket milking was surprisingly the second most used milking method, primarily because it was a common practice among the enrolled Italian farms. This is likely explained by all Italian farms being recruited on Sicily, as traditional, small-scale milk production on low-input farms is more common in Sicily compared to mainland Italy. In contrast, a third of the Swedish CCC farms used AMS, which may mirror the high proportion of dairy herds with AMS in this country (39% in 2020, van Dijk, 2022).

Most farmers (57%) had started with CCC in the year 2010 or later, suggesting a rapid increase in farms with CCC in Europe over the last 10 years. In contrast, most Italian farmers had practised CCC for several generations. This was likely due to almost half of

Table 4
Description of calf rearing and cow-calf allowance practised on European dairy farms, depending on how long the calves were kept with adult cows. Proportion of farmers reporting behaviours indicative of separation distress, and the farmers' perceptions on health and fertility in cows and calves when the calves could suckle, as compared to cows and calves that are separated shortly after birth are also reported. All outcomes are reported as the proportion of responding farmers per contact duration category.

Contact duration	7–28 days	29–90 days	>90 days
Number of farms	16	40	48
Rearing system			
Dam	6%[1]	40%	42%
Foster	0%	13%	13%
Mix[2]	0%	20%	46%
Dam + Manual[3]	94%	20%	0%
Manual + Foster[4]	0%	8%	0%
Type of cow-calf contact			
Permanent[5]	69%	53%	33%
Half-day[6]	13%	5%	2%
Around milking[7]	19%	33%	44%
Multiple[8]	0%	10%	21%
Separation distress			
Vocalisation cow	94%	68%	71%
Vocalisation calf	50%	55%	54%
Milking difficulties	13%	13%	21%
Weight loss calf	6%	15%	4%
Cow health			
Mastitis			
Better	25%	35%	46%
Same	69%	45%	27%
Worse	0%	10%	2%
Uncertain	6%	10%	25%
Fertility			
Better	31%	10%	23%
Same	44%	58%	50%
Worse	6%	15%	6%
Uncertain	19%	18%	21%
Calf health			
Diarrhoea			
Better	75%	63%	67%
Same	6%	18%	10%
Worse	13%	10%	6%
Uncertain	6%	10%	17%
Respiratory disease[9]			
Better	40%	43%	48%
Same	47%	40%	25%
Worse	7%	5%	0%
Uncertain	7%	13%	27%

[1] One farm that sold all calves to a rearing farm at 21 days of age.
[2] The calves suckled both the dam and foster cows, either simultaneously when housed in a mixed group or first suckling the dam for at least one week and then transferred to foster cows.
[3] The calves initially suckled the dams and were then manually milk fed.
[4] The calves were first manually milk fed and then housed with foster cows.
[5] The calves were housed with the cows except during milking.
[6] The calves were housed with the cows either between morning and evening milking, or vice versa.
[7] The calves could suckle either directly before, during or directly after milking, but were otherwise housed separately from the cows.
[8] Two or more types of cow-calf contact were used depending on calf age, most often first permanent contact with dam followed by restricted contact with the dam (n = 4 farms) or contact only with foster cows (n = 6).
[9] Information for one farm with 7–28 days contact duration is missing.

the farms keeping Modicana cattle for traditional cheese production. Modicana cattle is an indigenous Sicilian cattle breed that needs the presence of the calf for milk let-down, making CCC rearing a necessity. The use of the Modicana breed in Sicily also likely explains why letting calves suckle only during milking was more common, and the median suckling period was longer for the Italian farms, compared to the other countries. Cattle breeds used on the enrolled CCC farms differed between countries, and varied from dual-purpose breeds to specialised dairy breeds. Endangered breeds were used on some of the farms in all countries.

Rearing systems

The enrolled farms used a variety of strategies for rearing calves together with adult cows, either together with the dams or with foster cows (or both), which aligns with previous research (Vaarst et al., 2020; Neave et al., 2022). Although multiple types of CCC rearing were used in all countries, the systems used and their relative frequency differed. Reasons for these regional differences have not been explored in the current study, but it is possible that differences in certification requirements, public interest in animal welfare issues and regional customs could have influenced these results. For example, in Sweden, foster cows have been used by a low number of farmers for more than two decades (Norrbom, 2001).

Initial manual milk feeding followed by foster rearing was only reported in three large (100+ adult cows) Swedish farms. As a larger group size (Svensson and Liberg, 2006; Buczinski et al., 2018) has been reported to increase disease occurrence in dairy calves, it is possible that this rearing practice was used as a way to reduce disease spread among young calves in these large herds. However, Marcé et al. (2010) reported that almost all group-housed calves on conventional farms were initially kept in individual pens for about 2 weeks in Sweden, before being moved to larger boxes. This practice has been recommended by Swedish calf health experts (Svensson and Liberg, 2006), and it is possible that initial manual milk feeding followed by foster rearing was a regional adaptation of this practice for the CCC setting.

Other types of CCC rearing were also related to herd size, with farms using dam rearing for the full suckling period generally being smaller compared to all other systems. Farms with dam rearing also had the highest proportion of farms earning ≤50% of household income from milk, and the highest proportion of farmers reporting natural rearing and work satisfaction as important drivers for using CCC. It is possible that, at least in the sample used in this study, dam rearing was perceived as more attractive for farmers interested in CCC from an ethical standpoint, while other systems allowed for a larger profit margin. It is important to note that the current study only provides indirect support for this notion; further qualitative research is needed to better understand CCC farmers' perspectives on calf rearing practices. For example, Neave et al. (2022) reported that while many of the 63 conventional farmers interviewed in their study were concerned that the colostrum intake would be impaired in CCC systems, the CCC farmers (n = 4) did not bring this up as an issue during semi-structured interviews.

Cow-calf contact allowance

Contact allowance differed depending on what calf rearing practice and what milking system were used on the farms. This finding suggests that CCC is possible in a wide variety of dairy systems, but that factors such as barn construction and herd management influence which type of CCC is most feasible. For example, many farmers using only foster rearing mentioned that the foster cows and calves were housed away from the milking herd, likely explaining why permanent contact was used on more than half of foster farms. Similarly, a number of farmers with permanent contact followed by manual milk feeding mentioned that the dam-calf pair was housed together in the calving box for an extended period until separation. Allowing suckling only around milking was the second most common strategy for CCC among the enrolled farms, which may be because this practice is possible to implement without extensive reconstruction of the barn. Another possibility is that CCC allowance was restricted to increase the amount of saleable milk, although a recent study described that cows with a restricted suckling contact just before milking had

lower machine milk yields than cows with half- and full-day contact (Barth, 2020).

Few farms used half-day CCC, despite previous research showing satisfactory calf growth both before (Johnsen et al., 2015a) and after (Veissier et al., 2013) separation. The half-day system also allows for more social interactions between cows and calves compared to restricted contact around milking, and affiliative behaviours have been observed for dam-calf pairs even when suckling was prevented with udder nets (Johnsen et al., 2015b). It is possible that the labour needed for separating cows and calves make this system less attractive for farmers, but this was not evaluated in this study.

Although research on public views on different types of CCC rearing is largely lacking, it is possible that very short daily CCC allowance would be perceived less favourably than half- and full-day contact. This potential critique could be addressed by increasing the amount of time cows and calves meet around milking. In the current study, some farmers kept the animals together for up to two hours around milking, which allowed daily social interactions between cows and calves. Even if the management of male calves was not systematically evaluated in the current study, we identified some other potentially contentious practices among the farms in our sample, such as selling and transportation of male and unwanted female calves before one month of age and slaughter of suckling calves less than 4 months old. Ritter et al. (2022) showed a low acceptability for early transportation and slaughter of surplus calves. In addition, Sirovica et al. (2022) reported that foster rearing is perceived as bad as rearing calves in single hutches by the public.

The potential of discrepancies between what calf rearing practices are used on CCC farms and expectations from the public may be a concern. To better inform farmers, and to maintain social acceptance of CCC, the European public's acceptance for calf rearing practices identified in the current study should be further evaluated.

Weaning and separation distress

Although behavioural responses after separation were commonly observed, the end of the milk feeding period coincided with separation from adult cows on 85% of the farms. Abrupt weaning from milk has been shown to reduce postweaning growth, possibly due to insufficient adaptation of the gastrointestinal tract preweaning (Steele et al., 2017). In addition, gradual weaning may reduce the behavioural responses to separation, as abruptly weaned calves were reported to vocalise more than gradually weaned calves (Bittar et al., 2020; Budzynska & Weary, 2008; Jasper et al., 2008). The reasons for farmers in this sample choosing simultaneous weaning and separation were not explored but could possibly have been due to farm management and building configuration.

Methods varied considerably among the farms that did use gradual weaning and separation. These discrepancies suggest that separation methods must be tailored to the situation on the individual farm, or alternatively that low-stress strategies for weaning and separation of suckling dairy calves have not yet been identified. Johnsen et al. (2018) reported that suckling dairy calves that knew how to drink milk from an automated milk feeder when they were separated at six weeks of age showed less separation distress, compared to dairy calves separated at the same age but with no previous experience with the feeder. Their results suggest that nutritional independence from the dam decreased behavioural responses to separation in calves, although this practice likely does not reduce separation distress in the cows. Loberg et al. (2008) used a two-stage weaning and separation approach, where dairy calves were prevented to suckle from foster cows by nose-flaps, to separate these stressful events in time. The intervention reduced both behavioural and physiological stress reactions in the calves. Using nose-flaps to prevent calves from suckling before separation has also been reported to reduce distress in beef calves (Haley et al., 2005). Only three out of 104 farmers in the current study used nose-flaps at weaning, but the reasons for the low acceptance of nose-flaps among the farmers in our study has not been investigated.

Perception of health

Most farmers were of the opinion that suckling calves have better general health and higher weight gains than calves that are separated early. It is important to note that no independent assessment of these outcomes was performed, making the results susceptible to recall and social desirability bias. Similarly, farmers were asked to estimate early life mortality, with no requirement that they based this estimate on farm records. However, our results align with the findings of recent studies (Neave et al., 2022) and systematic reviews (Beaver et al., 2019; Meagher et al., 2019).

As only one farm used both CCC and artificial rearing of female calves, almost no farmers were able to directly compare the two rearing strategies. This may explain the relatively large proportion of farmers that were uncertain about the effects of CCC on health, particularly when asked about more specific disease symptoms such as diarrhoea. Roth et al. (2009) observed diarrhoea more frequently in suckling dairy calves compared to manually milk-fed calves, but the suckling calves did not need to be treated against diarrhoea more often. The authors suggested that the loose faecal consistency was due to the amount of consumed milk (osmotic diarrhoea). A higher number of days with loose stool but no concurrent increase in the number of medicated calves has been reported for single-housed calves on intensive milk feeding (high-protein milk replacer at 2.1% BW), compared to calves with restrictive milk feeding (regular milk replacer at 1.2% BW; Davis Rincker et al., 2011), supporting this notion.

Self-reported mean 0–3 months mortality rate was relatively low (4.5%) compared to national numbers (for example 3.7–7.4% 0–3 months mortality rate for female calves in Germany, depending on region; PraeRi, 2020), which aligns with farmers' perceptions reported in another CCC study (Vaarst et al., 2020). However, some farmers self-reported high mortality rate during early life, and a proportion of farmers thought diarrhoea and respiratory disease occurred more frequently on their farms than on farms with manual milk feeding. These results suggest that infectious diseases still play a key role for calf health and welfare on CCC farms, and that CCC rearing is no substitute for other management practices aiming to reduce disease risks.

Drivers and barriers

A large variability was seen in the drivers for the enrolled farmers, with reported drivers largely aligning with those reported by Vaarst et al. (2020) and Neave et al. (2022). There were regional differences in which drivers were considered important. These regional differences were most often due to a deviant response pattern for French farmers, possibly because of slight differences in how the questions were phrased in the two questionnaires. A large proportion of farmers did not perceive any barriers for implementing CCC on their farms, likely because only farms that already practised CCC were included in the sample. Of the important barriers that were brought up, inappropriate barn design was mentioned twice as often as any other factor. Similar to what was reported by Vaarst et al. (2020), the main concern for farmers in this study was to ensure proper calf housing when keeping cows and calves together. Specific building aspects that limited CCC rear-

ing were not explored in this study, but for example, slatted floors have been raised as a concern by farmers in an earlier study (Vaarst et al., 2020).

Calf rearing versus contact duration

Unsurprisingly, dam rearing followed by manual milk feeding was most common among farms with short contact duration, while dam and mixed rearing were more often practised on farms with moderate to long CCC. Cow vocalisation after separation was observed by a higher proportion of farmers with short contact duration, suggesting that separation when the calves are young is more stressful for the cows. This aligns with Pérez-Torres et al. (2016), who reported that a higher proportion of Brahman cows were vocalising and that the adult animals vocalised more frequently when temporarily separated from their calves 25 days after calving, compared to temporary separation when the calves were 45 days old.

In the current study, calf vocalisation was reported by approximately the same proportion of farmers regardless of contact duration, perhaps because calves' vocal responses to separation are more tied to hunger (Johnsen et al., 2018). These findings conform to Stěhulová et al. (2017), who reported that beef calves of all ages (age span 5–9 months) vocalised approximately the same amount after abrupt weaning and separation. Although uncommon, calf weight loss at separation was observed by a somewhat higher proportion of farmers with moderate (29–90 days) contact duration. It is possible that calves in this age group were still not nutritionally independent from the adult cows, while being more difficult to transfer to supplemental milk than calves <1 month of age.

With increasing contact duration, it was more common for the farmers to perceive udder health as better, and less common to perceive it as the same as in farms without CCC. This result aligns with the findings of a recent systematic review (Beaver et al., 2019), which reported that contact duration >60 days was more common in studies finding a positive effect of CCC on udder health compared to studies reporting no effect. In contrast, most farms perceived fertility as being the same as in farms without CCC, regardless of contact duration. Perceptions of calf health differed little depending on contact duration, with most farmers in each group considering CCC as beneficial for diarrhoea.

Study limitations

It is currently unknown how many farms use CCC systems in Europe. Due to the difficulties in identifying farms that practise CCC, farms were recruited through outreach activities and farm collaboration networks. However, even if snowball referral was used as a mean to recruit more farms, few farms were actually enrolled through other farmers. We also included French farmers that had participated in a recent, largely overlapping survey in our data set to reduce the risk of non-response bias due to respondent fatigue in this consortium country. This choice resulted in missing data for questions that were not included in the French questionnaire. The enrolled farms should not be considered a representative sample of all CCC farms in the consortium countries, and inferences should be limited to our sample. However, the current research still constitutes the most comprehensive study evaluating calf rearing practices on European CCC farms to date.

The questionnaire developed during the study was not piloted before data collection, but linguistic clarity and interpretation of the included questions were evaluated during joint training sessions. Despite these training sessions, issues distinguishing between for example weaning and separation were identified during data analysis. One possible explanation for these misconceptions is that the original English questions were translated to several different languages, potentially inducing slight differences in their meaning. Not all interviewers participated in the joint practice sessions, which could have compounded this issue. Back translation of the translated questionnaires would have increased the likelihood of identifying misconceptions before data collection, and this step should be included in future surveys conducted in multiple countries.

Although the herd size in our sample generally corresponded to the average herd size in the respective country, other countries with intensive milk production often have larger farms. As such, care should be taken when interpreting the results outside the European context.

Conclusion

The current study showed that CCC is used in a large variety of housing systems in Europe today, suggesting that it is possible to rear dairy calves together with lactating cows in most commonly used housing systems as long as farm management is otherwise satisfactory. A large variation in calf rearing strategies and daily contact duration was observed. In general, CCC farmers considered calf health and calf growth to be better in suckling calves, compared to calves that are separated shortly after birth. Weaning and separation distress was commonly observed by farmers, and building constraints were most often mentioned as a barrier for implementing CCC.

Ethics approval

The study was conducted in accordance with the Declaration of Helsinki and followed relevant international standards and guidelines for research. All respondents gave their informed consent before participating in the study, and they were informed that all data would be treated confidentially and presented in such a way that their farm identities would not be revealed. No ethical approval was required for this study as no sensitive data was collected.

Data and model availability statement

The data presented in this study are available on request at the SLU e-repository, through the Swedish National Data Service (https://archive-harvest.slu.se:8443/jspui/handle/20.500.12703/3988); reference number SND-ID: 2022-37.

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Declaration of interest

The authors declare no known competing financial interest in the work reported. The funding bodies had no role in the design, execution, interpretation, or writing of the study.

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Appendix A. Supplementary material

Supplementary material to this article can be found online at https://doi.org/10.1016/j.animal.2022.100624.

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