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First-calving age and first-lactation milk production on Dutch dairy farms

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ABSTRACT

Farmers attempting to reduce first-calving age (FCA) need to understand which rearing management factors influence FCA and first-lactation milk production (FLP). Reduced FCA might be associated with lower FLP. This study describes the association between herd FCA, FLP, and several herd-level health and rearing management variables and describes the association between FCA and FLP at the cow level. It uses data from a 2010 survey of 100 Dutch dairy farms about general management, colostrum and milk feeding, housing, cleanliness, healthcare, disease, and breeding. It also used available data on FCA and 305-d FLP at both cow and herd level. The associations between median FCA and median FLP of the herd and herd-level health and rearing management variables were determined using multivariate regression analysis. The median FCA was associated with minimum age of first insemination, feeding of waste milk, and the amount of milk given preweaning. The median FLP was associated with median FCA and vaccination status for bovine respiratory syncytial virus. The association between FCA and FLP (based on 8,454 heifers) was analyzed with a single-effect linear mixed model, where the dependent variable was either FCA or relative FCA (defined as the difference between FCA of the heifer and median FCA of the herd to which they belonged). Heifers having an FCA of 24 mo produced, on average, 7,164 kg of milk per 305 d, and calving 1 mo earlier gave 143 kg less milk per 305 d. When FCA did not deviate from the median herd FCA, heifers produced, on average, 7,272 kg of milk per 305 d. From the median FCA of the herd, heifers calving 1 mo earlier produced 90 kg of milk per 305 d less, and heifers calving 1 mo later produced 86 kg per 305 d more. This is the first study that explained FLP using relative FCA. It assumes that heifers raised within the same farm have similar development because they are similarly managed. Similar management is reflected by the median FCA of the herd, with a deviation of the heifer's FCA from median FCA reflecting the heifer's development relative to the herd's average. The advantage of using relative FCA was that it accounts for between-farm differences in rearing management. It showed that earlier insemination without adjusting management to ensure sufficient development lowers FLP. An economic optimum exists between rearing costs, FCA, and FLP and, as a consequence, decisions with regard to young stock management should be made with care.
Key words: first-calving age, milk production at first lactation, dairy heifer, rearing management

INTRODUCTION

Young stock rearing requires a large economic investment from dairy farmers (Gabler et al., 2000; Tozer and Heinrichs, 2001), with, for example, on Dutch farms, the total costs of rearing varying between $1,800 and $2,200 per heifer (Mohd Nor et al., 2012). Per heifer, reducing first-calving age (**FCA**) by a month reduces the costs of rearing by $51 to $116 (Gabler et al., 2000; Mohd Nor et al., 2012). However, a reduced FCA might be associated with lower first-lactation milk production (**FLP**). This possible negative effect must be considered when making decisions on reducing FCA.

First-calving age, growth rate, and BW at first calving are generally correlated (Le Cozler et al., 2008), making it difficult to ascertain independently the effects of each variable on FLP (Mourits et al., 1997). In rearing experiments, 2 experimental variations will always exist, as growth rate will affect BW at first calving unless the FCA is changed accordingly (Mourits et al., 1997). The advantage of rearing experiments is the possibility of having detailed insights into growth and the time of insemination and time of calving. For instance, lowering the FCA with an accelerated daily gain during the prepubertal period is known to have a negative effect on FLP (Sejrsen et al., 2000; Le Cozler et al., 2008). According to a study by Dobos et al. (2001), this lowering can be offset by increasing the BW at calving. The disadvantage of such experimental studies is the relatively low numbers of animals and

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farms that were studied, which make generalization more difficult.

In contrast, analyses of field data generally involve heifers with the same growth strategies but with different ages and BW at first calving (Mourits et al., 1997). Such studies have high numbers of animals and farms, but lack information about growth and BW at calving (e.g., Ettema and Santos, 2004; Haworth et al., 2008; Berry and Cromie, 2009). As previous field studies have shown, lowering FCA by a month can reduce FLP by 56 to 60 kg (Pirlo et al., 2000; Dobos et al., 2001; Berry and Cromie, 2009), lowering FCA under 700 d with an equal daily gain among heifers can create total yield losses of more than 310 kg (Ettema and Santos, 2004) and lowering FCA below 2 yr of age can lower FLP by up to 0.6 L per day (Haworth et al., 2008). Under practical farm circumstances, however, the correlation with BW at calving makes studying the association between FCA and FLP difficult.

As findings from previous studies have indicated, specific management factors have an influence on both FCA and FLP. For example, FCA increases with a higher number of days of antibiotic treatment in the first 16 wk of life, maximum milk intake, maximum humidity, and daily temperature and with increased ammonia levels in calf housing areas (Heinrichs et al., 2005; Hultgren et al., 2008). First-calving age decreases with a high-energy and -protein diet during rearing (Davis Rincker et al., 2011). First-lactation milk production has been shown to increase with number of days of antibiotic treatment before 4 mo of age, increases in DMI during weaning, and increases in the amount of concentrate fed around calving (Svensson and Hultgren, 2008; Heinrichs and Heinrichs, 2011). First-lactation milk production decreases with morbidity due to calf diarrhea (Svensson and Hultgren, 2008) and with a higher number of days of illness before 4 mo of age (Heinrichs and Heinrichs, 2011).

Farmers attempting to make decisions that will reduce rearing costs need to understand which rearing management factors influence FCA and FLP. Yet, studies to support such decisions within intensive dairy farming are scarce (Mourits et al., 1999). Particularly useful in this regard are studies that evaluate the association between FCA and FLP with management factors during rearing such as calf diseases, healthcare, preweaning feeding, housing, and breeding, as well as those that examine the association between FCA and FLP under practical farm circumstances.

The first objective of this study was to describe the association between FCA and FLP with health and management rearing factors derived from a questionnaire that queried Dutch dairy farmers on general management, healthcare, calf diseases incidence, preweaned colostrum and milk feeding, housing, cleanliness, and breeding. The second objective of this study was to describe the association between FCA and FLP at the cow level.

MATERIALS AND METHODS

Data Collection

Data were collected at 100 farms in the western part of the Netherlands. These farms were chosen to participate because they were regular clients of the University Large Animal Veterinary Practice (Utrecht University, Utrecht, the Netherlands). Each farm was visited once by a trained veterinary student in September or October 2010 for a survey including both the student's observations (e.g., on factors such as the cleanliness of the barns) and a questionnaire about young stock rearing management. The questionnaire included 98 questions related to young stock rearing management, with open-ended (n = 33), closed (n = 44), and semi-closed (n = 20) types of questions. They covered general information about the farm, colostrum, and milk feeding, breeding, diseases, healthcare, and housing. The questions about feeding, diseases, healthcare, housing, and cleanliness were carried out for 3 different age groups: from birth to weaning, from weaning to 1 yr of age, and from 1 to 2 yr of age. Some questions (e.g., on the cleanliness of the barn during inspection) used a 5-point scale. An outline of the questionnaire design is given in Appendix Table A1. The full questionnaire (in Dutch) is available upon request from the authors. For this study, the University Large Animal Veterinary Practice also provided the average number of animals on the farms in 2010 and the average age of first insemination (mo). The average number of animals on the farm was provided for different age groups: less than 1 yr of age young stock, between 1 and 2 yr of age, and more than 2 yr of age. For all heifers on these 100 farms from July 2003 to June 2010, the cooperative cattle improvement organization CRV BV (Arnhem, the Netherlands) provided milk production records and calving dates.

Data Preparation

Herd-Level Data Set. For analysis of the association between FCA and FLP with health and management rearing, 13 farms were excluded because they did not rear their own young stock (n = 11) or they had no young stock below 1 yr of age (n = 2). The final data set thus covered 87 farms.

For these 87 farms, the median FCA and median 305-d FLP were determined using data of individual heifers. The median was used instead of the average to exclude extreme heifers that may have unduly influenced the results. To determine the median FCA and median 305-d FLP, only heifers calved after January 2008 were used. This guaranteed that the heifers experienced the rearing conditions that were reported in the survey (autumn 2010). For 2 farms that indicated their rearing management changed dramatically since 2008, only heifers calved after January 1, 2010, were included. In one of the farms, data on FCA of the heifer was unavailable and further, in those 2 farms, data on FLP of the heifer was unavailable. Consequently, median FCA was determined for 86 farms and median FLP for 85 farms. The median FCA of the herd was categorized into 3 groups: ≤24 mo of age, >24 to <27 mo of age, and ≥27 mo of age.

From the survey, a total of 115 herd-level rearing management variables were available, representing general management, colostrum and milk feeding, housing, cleanliness, healthcare, disease, and breeding during rearing. Certain variables were excluded (e.g., treatment variables) because more than 50% of values were missing, combined with each other (e.g., hygiene score and barn cleaning frequency), categorized (e.g., housing variables), or newly produced (e.g., estimated number of sick animals) during data editing. In this way, meaningful variables were defined and the power of the statistical analysis was improved. Examples of variables produced from the raw data included disease incidence due to calf scours and bovine respiratory disease (**BRD**). These were based on the farmer's own estimation of the number of sick animals and not from records, divided by the average number of young stock (age <1 yr) on the farm, to yield the disease incidence of these diseases in calves younger than 1 yr of age. The waste milk variable used in this study was defined as milk taken from dairy cows treated with antibiotics, which cannot be sold for human consumption. A complete overview of the edited variables appears in Appendix Table A2.

Cow-Level Data Set. For the analysis of the association between FCA and 305-d FLP, information on 8,454 individual heifers was available from the 100 herds. These heifers had an FCA >18 mo of age, a first-lactation duration >250 d, and had calved between July 3, 2003, and June 10, 2010. Subtracting the heifer's birth dates from their first-calving dates produced the absolute FCA. To account for differences in rearing management among herds, the relative FCA was calculated. This was done by first determining the median FCA for every herd and then calculating relative FCA by subtracting the absolute FCA of every individual heifer from the median FCA of the herd to which they belonged. Data preparation was performed using SAS (version 9.2; SAS Institute Inc., Cary, NC).

Data Analysis

Herd-Level Analysis. For the analysis of the association between median FCA of the herd and rearing management, the data were analyzed with a multinomial logistic regression model with a logit link using PROC LOGISTIC in SAS (version 9.2). As a first step, univariate chi-squared analyses were performed, testing (one at a time) the independent variable possibly associated with median FCA of the herd and selecting those independent variables with a type 3 $P \leq 0.25$ based on the F-test. Thereafter, the selected independent variables were used in the multivariate model, which was built using a backward selection procedure. In each step, the least statistically significant independent variable was excluded until all independent variables in the final multivariate model had a type 3 $P \leq 0.05$.

For the analysis of the association between median FLP of the herd and rearing management, analysis of the data was performed with a linear regression model using PROC GLM in SAS (version 9.2), assuming normality of residuals. Univariate analyses were performed to select independent variables possibly associated with median FLP of the herd with a type 3 $P \leq 0.25$ based on the F-test. The selected independent variables and an interaction term [amount of first colostrum (L) after birth with the time after birth to give the first colostrum (min)] were included in the multivariate model. The final multivariate model was built using a backward selection procedure. In each step, the least statistically significant independent variable was excluded until all independent variables in the final multivariate model had a type 3 $P \leq 0.05$. The overall model fit was assessed by graphical examination of residuals, the Shapiro-Wilk test, looking for outliers, and by checking for homoscedasticity.

Cow-Level Analysis. For the analysis on the association between FCA and 305-d FLP, the data of 8,454 heifers were analyzed with a single-effect linear mixed model using PROC MIXED in SAS (version 9.2). The dependent variable was the heifer's 305-d FLP, and the independent variable was absolute FCA. The variables season, herd (random variable), and year (random variable) were forced in the model. The absolute FCA was categorized by monthly age groups and the model was analyzed with an absolute FCA of 24 as the reference category. In addition, a similar model using relative FCA as independent variable was analyzed. The relative FCA was categorized by monthly age groups and the model was analyzed with the category 0 (not deviating from the median FCA of the herd) as the reference category. The overall model fit was assessed by graphical examination of the residuals and by the Kolmogorov-Smirnov test, looking for outliers and checking for homoscedasticity.

RESULTS

General Herd Characteristics

The average number of dairy cows on the 87 Dutch farms ranged between 26 and 170 cows, with an average of 73 (SD ± 26) cows. The average number of dairy heifers (1 to 2 yr of age) and the average number of heifer calves (<1 yr of age) present on these farms were 20 (SD ± 8; range 1 to 43) heifers and 24 (SD ± 10; range 7 to 56) heifer calves. The predominant breed was Holstein-Friesian (91%).

The median FCA of the herd on the 86 farms was 25.4 mo (SD ± 1.45, range 23 to 30). The median 305-d FLP of the herd on the 85 farms was 7,518 kg per 305 d (SD ± 835, range 5,803 to 10,364 kg per 305 d).

Young Stock Rearing Management Characteristics

The average time in providing the first colostrum to heifer calves was 93 min (SD ± 77; range 1 to 480 min), with an average first amount of 2 L (SD ± 0.74; range 0.75 to 4 L). Within the first 24 h, the total amount of colostrum given was, on average, 5.4 L/d and decreased to 4.3 L/d on the second day. During the first day, the average frequency of feeding the colostrum was 3 times per day (SD ± 0.78, with a range of 1 to 5 times per day). On about 44% of the farms, the heifer calves were given the waste milk. The weaning age was, on average, 74 d (SD ± 24.81; range 24 to 200 d).

The minimum heifer age farmers were willing to start the first insemination was, on average, 14.9 mo (SD ± 1.02; range 13 to 18 mo). The average heifer age farmers actually started with insemination was 15.9 mo (SD ± 1.44; range 13.9 to 19.6 mo). The majority of the farmers (60%) indicated that they used age to determine the moment of first insemination.

No disease problems in unweaned heifer calves were reported by 34% of the farms, whereas 44% of farms had either calf scours or BRD and 22% indicated that they had both calf scours and BRD. Using the farmers' estimates for the number of sick animals, calf scours incidence in heifer calves averaged 29% (SD ± 0.26; range 0 to 0.96) from birth to 1 yr of age, which was especially concentrated in the time before weaning (on average, 9 d of age). BRD incidence averaged 11% (SD ± 0.20) from birth to 1 yr of age, and ranged from 0 to 87%. Deworming was practiced by 63% of the farms, especially in grazing heifers. Vaccination of heifer calves was done by less than half of the farms, using lung worm vaccine (43%), bovine respiratory syncytial virus (**BRSV**) vaccine (34%), bluetongue vaccine (26%), infectious bovine rhinotracheitis vaccine (11%), bovine viral diarrhea vaccine (10%), rotavirus and coronavirus vaccine (5%), and *Escherichia coli* vaccine (1%).

Associations Between Median FCA and Median 305-d FLP of the Herd with Rearing Management

The results of the univariate analysis on the association between rearing management and median FCA of the herd are presented in Tables 1 and 2. The final multivariate model included the variables minimum age to first insemination, giving calves waste milk, and the amount of milk given to a calf (Table 3). Increasing the minimum age to first insemination by 1 mo resulted in higher odds of having a higher median FCA of the herd. Not giving waste milk and increasing the amount of milk by 1 L resulted in higher odds of having a lower median FCA of the herd.

The results of the univariate analysis on the association between median FLP of the herd and rearing management are presented in Tables 1 and 4. The final multivariate model included the variables vaccination status for BRSV and median FCA of the herd (Table 5). Not vaccinating heifers against BRSV lowered the farm's 305-d FLP by 493 kg ($P = 0.063$). Compared with median herd FCA of >24 to <27 mo, a median herd FCA of ≤24 mo was correlated to a higher median herd FLP (+573 kg per 305 d; $P = 0.037$).

Associations Between FCA and 305-d FLP

Heifers that calved at 24 mo of age produced, on average, 7,164 kg per 305 d (Table 6). Heifers that calved a month earlier (absolute FCA = 23 mo) had an FLP of 143 kg per 305 d less, a significantly lower amount. Heifers that calved a month later (absolute FCA = 25 mo) had an FLP of 48 kg more per 305 d. Heifers that calved 2 mo later (absolute FCA = 26 mo), had an FLP of 144 kg more per 305 d, a significantly higher amount.

Heifers with a relative FCA of 0 (not deviating from the median FCA of the herd) had, on average, an FLP of 7,272 kg per 305 d (Table 6). Heifers calving 1 mo earlier than this (relative FCA = −1) had an FLP of 90 kg per 305 d less, a significant difference, whereas those calving 2 mo earlier (relative FCA = −2) produced 174 kg less than the median. Heifers calving a month later than their farm's median FCA (relative FCA = +1) had an extra FLP of 86 kg of milk per 305 d, and

Table 1. Effect of management factors (continuous) during rearing on the median 305-d milk production of the herd during first lactation (n = 85) and the median first-calving age of the herd (n = 86)[1]

	Median first-calving age of the herd				Median milk production of the herd at first lactation		
Management factor	Months	n	Mean (SD)	*P*-value	n	Mean (SD)	*P*-value
Breeding							
Minimum age at first insemination	≤24	22	14.2 (0.61)	0.001	—	—	—
	>24 to <27[2]	46	15.0 (0.73)	—			
	≥27	14	15.9 (1.38)	0.004			
Colostrum management							
First colostrum amount (L)	—	—	—	—	81	2 (0.68)	0.16
Total colostrum amount first day (L)	≤24	22	5.9 (1.91)	0.17	80	5 (1.60)	0.11
	>24 to <27[2]	46	5.3 (1.36)	—			
	≥27	12	4.6 (1.62)	0.099			
Time after birth farmers give colostrum (min)	—	—	—	—	81	93 (77.4)	0.20
Milk feeding							
Weaning age (d)	—	—	—	—	78	73 (24.6)	0.05
Amount of milk (L/d)	≤24	23	5.3 (1.43)	0.37	85	5 (1.23)	0.16
	>24 to <27[2]	47	5.1 (0.99)	—			
	≥27	15	4.2 (1.15)	0.02			
Disease							
Calf scours incidence (%)	—	—	—	—	80	29 (0.26)	0.23
BRD incidence[3] (%)	—	—	—	—	85	11 (0.20)	0.22

[1]All estimates are based on univariate analyses and only management factors with $P < 0.25$ are reported.

[2]Farm with first-calving age of >24 to <27 mo was the outcome reference group.

[3]BRD = bovine respiratory disease.

Table 2. Effect of management factors (categorical) during rearing on median first-calving age of the herd (n = 86) by univariate analyses, with $P < 0.25$ reported

		Median first-calving age of the herd (mo)			
Management factor	Category	≤24 (n)	>24 to <27[1] (n)	≥27 (n)	*P*-value
Preweaning feeding					
Milk type	Cow	6	22	11	0.012
	Artificial	16	16	3	—
	Both	2	9	1	—
Waste milk given to calf	No	18	24	6	0.057
	Yes	6	23	9	—
Healthcare					
Lung worm vaccination	No	11	24	12	0.073
	Yes	13	23	3	—
Deworming	No	11	15	8	0.25
	Yes	13	32	7	—
BRSV[2] vaccination	No	15	27	13	0.091
	Yes	9	20	2	—
Housing					
Keeping young stock					
Age group = 1 to 2 yr	With cows	12	25	3	0.062
	Separate barn	12	22	12	—
Type of bedding					
Age group = before weaning (individually)	Straw	10	29	4	0.082
	Grid	12	17	9	—
Age group = before weaning (in group)	Straw	21	38	10	0.14
	Others	2	3	4	—
Type of ventilation					
Age group = before weaning (in group)	Passive	8	11	7	0.22
	Natural	10	32	4	—
	Fan	3	1	1	—
Housed with dairy cows					
Age group = 1 to 2 yr	No	12	24	3	0.080
	Yes	12	23	12	—

[1]Farm with first calving age of >24 to <27 mo was the outcome reference group.

[2]Bovine respiratory syncytial virus.

Table 3. Results of the final multivariate model on the association between rearing management factors and median first-calving age of the herd in 86 Dutch dairy farms that reared own young stock

Variable	Odds ratio	95% Wald confidence limits	P-value
Waste milk not given			
≤24 mo	3.656	0.953–14.034	0.059
>24 to <27 mo	Ref[1]	—	—
≥27 mo	0.499	0.119–2.091	0.34
Amount of milk (L/d)			
≤24 mo	1.776	0.932–3.384	0.081
>24 to <27 mo	Ref	—	—
≥27 mo	0.582	0.319–1.062	0.078
Minimum age at first insemination (mo)			
≤24	0.201	0.076–0.530	0.001
>24 to <27	Ref	—	—
≥27	2.834	1.316–6.103	0.008

[1]Ref = reference group.

for those calving 2 mo later than their farm's median FCA (relative FCA = +2), the yield difference was 163 kg. The 305-d FLP of heifers calving in winter was the highest (on average, 7,652 kg, SD ± 1,280). Heifers calving in the summer had the lowest 305-d FLP (on average, 7,312 kg, SD ± 1,282; $P < 0.05$).

DISCUSSION

This study used data from farms in the western part of the Netherlands. Although this geographical distribution indicates that they were not randomly selected from the Dutch population of farms, the number of dairy cows and heifers, average FCA, and 305-d FLP are comparable with Dutch dairy heifer population averages (CRV, 2010). Incidences for both calf scours and BRD in this study were higher than earlier reports both for Norway and the Netherlands (Perez et al., 1990; Gulliksen et al., 2009). This could be related to the fact that the number of sick animals in the current study was based on the farmers' own estimations and not based on actual farm records. At the same time, as Dutch farmers are more known to underestimate disease incidences than to overestimate disease incidences (Huijps et al., 2008), it could very well be that the incidence of diseases has increased over time. Other young stock rearing management factors, such as weaning age and breeding moment, are comparable with the results of other previous Dutch study (Mourits et al., 2000b).

As our results show, the median FCA of the herd was associated with only a few rearing management factors. These management factors are the amount of milk given to unweaned calves, whether waste milk is given to calves, and the minimum age at first insemination (Table 3). Further, only a few rearing management factors were associated with a herd's median FLP. These management factors were the median FCA of the herd and whether calves were vaccinated against BRSV (Table 5). The near absence of management factors associated with the median FCA and FLP of the herd can be explained by several interconnected factors. First, the median FCA of the herd and the age of the heifers when farmers started first insemination were strongly associated. As rearing management on each farm can influence both growth and BW, farmers expect their heifers to be sufficiently developed at a certain minimum age. They, therefore, prefer to use age and not BW to determine the start of insemination. This risk-avoiding behavior may have masked the effect on median FCA and FLP of other management factors during rearing (such as colostrum management and disease incidences). Second, measuring the farmer's management is difficult and, with a relatively small number of farms (n = 86), could have resulted in the low number of statistically significant relations between young stock rearing management and FCA and FLP. In addition, data on several factors that can be seen as links between management and FCA/FLP (e.g., nutrition, feed intake, energy density and protein level, calving weight, and growth) were unavailable and, therefore, were not included in the model.

Still, as these results indicate, a lower median FCA of the herd (Table 3) was associated with a greater amount of milk given during the first months of life. Similar results have been shown in previous studies, which have indicated that a greater amount of milk is related to better growth and earlier insemination (Le Cozler et al., 2008; Svensson and Hultgren, 2008), which can result in a lower FCA. In our study, a lower FCA for the herd was also associated with not giving waste milk (Table 3). This finding may be explained by the fact that farms that did not giving waste milk were the farms that practiced good animal welfare (Vasseur et al., 2010) and good rearing management. This is

Table 4. Effect of management factors (categorical) during rearing on median 305-d milk production of the herd (kg; n = 85) at first lactation by univariate analyses, with $P < 0.25$ reported

Management factor	Category	Median milk production of the herd at first lactation		
		n	Mean (SD)	*P*-value
Median herd first-calving age	≤24 mo	24	7,830 (978)	0.077
	>24 to <27mo	46	7,356 (764)	—
	≥27 mo	15	7,515 (693)	—
Feeding				
Water ad libitum	No	20	7,331 (1,055)	0.16
	Yes	65	7,568 (729)	—
Vaccination				
BRSV[1] vaccination	No	55	7,403 (845)	0.084
	Yes	30	7,730 (786)	—
Housing				
Intention to adapt barn				
Age group = weaning to 1 yr	No	48	7,423 (857)	0.23
	Yes	37	7,641 (801)	—
Age group = 1 to 2 yr	No	35	7,379 (837)	0.20
	Yes	50	7,615 (828)	—
Type of floor				
Age group before weaning (in group)	Solid floor	49	7,598 (780)	0.20
	Grid floor	29	7,356 (837)	—
Age group = after weaning to 1 yr	Solid floor	13	7,234 (682)	0.20
	Grid floor	71	7,559 (855)	—
Type of ventilation				
Age group = before weaning (in group)	Passive	34	7,344 (672)	0.21
	Natural	28	7,711 (932)	—
	Fan	7	7,597 (928)	—
Housed with dairy cows				
Age group = before weaning (individually)	No	81	7,547 (842)	0.15
	Yes	4	6,929 (365)	—
Pregnant heifers kept with dairy cows	No	34	7,353 (785)	0.14
	Yes	51	7,628 (857)	—

[1]Bovine respiratory syncytial virus.

supported by previous findings indicating that giving waste milk did not affect a heifer's growth during preweaning (Jamaluddin et al., 1996).

Interestingly, an association was found between median FLP of the herd and BRSV vaccination status. Bovine respiratory syncytial virus is one of the causes for BRD, which from previous studies is known to reduce growth in heifers (Van der Fels-Klerx et al., 2002). As growth and BW at calving are related to milk production (Le Cozler et al., 2008), growth reduction due to not vaccinating against BRSV may explain the found reduction of median FLP of the herd. In addition, in a previous study, a reduction in milk production was found after an outbreak of BRSV on a farm (Beaudeau et al., 2010).

In this study, the association between FCA and FLP was studied by using both absolute FCA and relative FCA (Table 6). In previous studies using field data, FLP was explained by absolute FCA. For instance, in an Italian study, a change in absolute FCA from 29 to

Table 5. Results of the final multivariate model on the association between rearing management factors and median 305-d milk production of the herd (kg) at first lactation in 85 Dutch dairy farms that reared own young stock

Variable	Category	β	SE (β)	df	*P*-value
Intercept		7,369	619	1	<0.0001
Vaccinated with BRSV[1]	Yes	Ref[2]	—	—	—
	No	−493	258	1	0.063
Median herd first-calving age (mo)	≤24	573	266	1	0.037
	>24 to <27	Ref	—	—	—
	≥27	696	390	1	0.082

[1]Bovine respiratory syncytial virus.

[2]Ref = reference group.

Table 6. The association between 305-d milk production (kg) at first lactation with first-calving age of 8,454 heifers[1]

Item	Absolute first-calving age (mo)												
	≤20	21	22	23	24[2]	25	26	27	28	29	30	31	≥32
n	19	30	180	825	1,756	1,733	1,372	854	610	391	257	149	323
305-d milk production at first lactation (kg)													
β^3	6,295***	6,697*	6,876***	7,021***	7,164	7,212	7,308***	7,454***	7,489***	7,545***	7,540***	7,760***	7,816***
SE (β)	244	199	112	89	85	85	86	88	91	96	102	115	99
	Relative first-calving age (mo)												
	≤−6	−5	−4	−3	−2	−1	0[2]	+1	+2	+3	+4	+5	≥+6
n	23	18	44	210	856	1,957	2,063	1,253	772	476	282	181	319
305-d milk production at first lactation (kg)													
β^3	6,274***	7,125	6,738***	6,952***	7,098***	7,182**	7,272	7,358*	7,435***	7,542***	7,591***	7,643***	7,779***
SE (β)	231	251	171	105	85	81	81	83	86	90	187	107	96

[1]Heifers that calved at absolute first-calving age of 24 mo were the reference group because this group contained the largest number of heifers. Heifers that calved at relative first-calving age = 0 reflected heifers within the same farm and imposed with similar management. A deviation from this reflected heifers that were less developed (− sign) or more developed (+ sign). The effect of calving at different absolute first-calving ages and the effect of deviations in relative first-calving age are shown in 305-d milk production at first lactation.

[2]The reference group.

[3]*P*-value using linear mixed effects.

*$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

24 mo reduced the 305-d FLP by 255 kg (Pirlo et al., 2000), whereas in the current study, this would be a reduction of 391 kg. To our knowledge, ours is the first study that explained 305-d FLP using relative FCA to reflect the development of each heifer relative to the management of the herd in which the heifer was raised. This required the assumption that within the same farm, heifers will have similar development because they were similarly managed. Rearing management can be reflected by median FCA of the herd and, therefore, a deviation in the heifer's FCA from the median FCA is thought to reflect the heifer's development relative to the herd's average. The advantage of using relative FCA was that it took into account that each farm in this study had a different rearing management strategy and, therefore, it was suitable to be used in a field situation. Lowering the relative FCA on a farm will reduce the rearing costs (Mohd Nor et al., 2012). However, when the FCA is lowered by earlier insemination without adjusting the management to ensure sufficient development, it will also lower the milk production at first lactation (Table 6). At the cow level, although a month lower relative FCA is expected to reduce the total cost of rearing by, on average, \$77 per heifer (Mohd Nor et al., 2012), it creates additional loss in revenues by reducing milk yield by 90 kg in the first lactation. This means that with a net benefit per kilogram of milk of \$0.32 (LEI, 2012), the reduced rearing costs from a month lower FCA should be adjusted to an estimated \$48 per heifer. This was estimated to be 1.7% of the gross margin per cow per year (LEI, 2012). At the herd level, lowering the FCA will produce additional savings by reducing the number of replacement heifers needed (Mourits et al., 2000a). As our results also indicate, a higher relative FCA resulted in higher milk production (Table 6), but these higher benefits from milk production were associated with higher rearing costs. These results show that an economic optimum exists between rearing costs, FCA, and FLP, and, as a consequence, that decisions with regard to young stock management should be made with care.

In our study, the majority of the farmers (60%) indicated that age determined the moment of first insemination. The minimum age the farmers would like to start inseminating was, on average, 15 mo, varying between 14 to 16 mo (5–95% percentiles). This would indicate that the desired FCA would be 24 mo, varying between 23 to 25 mo (5–95% percentiles). The age at first insemination should be the result of a proactive goal in combination with (feeding) management that enables reaching the goal. However, it is our impression that the answers of the farmers reflected knowledge rather than a well-thought-out proactive goal. This impression is supported by the findings that young stock rearing is the least important element on Dutch dairy farms (Derks et al., 2012) and that the majority of Dutch farmers relate their rearing performance primarily to chronological target values instead of physiological target values (Mourits et al., 2000b). The lack of a proactive goal for insemination/FCA would mean that achieving a higher FLP at a lower FCA would be difficult because farmers would not actively work on adjusting the management and nutrition to ensure sufficient BW at calving. Previous studies have already stressed the importance of proactive FCA and BW at calving as the primary factors that influence FLP (Van Amburgh et al., 1998; Fox et al., 1999; Bach and Kertz, 2010). Unfortunately, in our study, as in other studies (Ettema and Santos, 2004; Le Cozler et al., 2010), that information was not available. Due to the lack of information on BW, nutrition, and growth, it was not possible to do a complete investigation on which factors influence the FLP.

CONCLUSIONS

First-calving age was found to be associated with several management factors during the rearing period: the amount of milk fed to the calves, waste milk feeding, and the minimum age the farmer used for starting the first insemination. First-lactation milk production was associated with FCA and BRSV vaccination status. To reduce the total costs of rearing, farmers can lower their heifers' FCA by earlier inseminations. However, earlier inseminations without adjustment of the rearing management to ensure sufficient development will cause lower FLP. These findings indicate that with regard to young stock rearing, an economic optimum exists between rearing costs and FCA.

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APPENDIX

Table A1. Detailed outline of the questionnaire design, which consisted of sections of topics containing information about management variables (only main management variables were counted; n = 98)

		Type of question		
Section	Management variable	Open ended (n)	Closed ended (n)	Semi-closed (n)
Farm information	Name, address, location, farm number (UBN)	5	—	—
Farm general description	Breed, number (milking cows, dry cows, unweaned calf, weaned to 1 yr of age heifer, 1 to 2 yr of age heifer), milk quota, farm size (ha), specialization (e.g., cheese making, organic, among others)	7	2	1
Young stock description	Rear own young stock, outsourcing options, selection criteria, heifer calf kept on the farm, minimum age at first insemination	1	3	1
Housing				
Age = unweaned				
Individual	Housing status, days kept individually, type of bedding, barn cleaning frequency per year, type of ventilation, hygiene score	1	3	3
Group	Housing status, automatic drinking machine, days kept in group, housing type, floor type, type of bedding, barn cleaning frequency per year, type of ventilation, grazing status, hygiene score	1	7	4
Age = weaned to 1 yr	Housing status, housing type, floor type, type of bedding, barn cleaning frequency per year, type of ventilation, grazing status, hygiene score	1	7	2
Age = 1 to 2 yr	Housing status, housing type, floor type, type of bedding, barn cleaning frequency per year, type of ventilation, grazing status, practicing using milking parlor, hygiene score	2	8	3
Feeding				
Age = unweaned	Colostrum amount, type of colostrum, type of milk, amount of milk, waste milk status, water ad libitum, type of concentrate, weaning age, weaning criteria	5	6	2
Health				
Birth to 1 yr	Calf scours status and treatment, bovine respiratory disease status and treatment	4	—	4
Age = 1 to 2 yr	Health problem during grazing season and in barn, vet visits per year, reason for vet visit	6	—	—
Vaccinations	Vaccinations performed for infectious bovine rhinotracheitis, bovine viral diarrhea, rotavirus/coronavirus, *Escherichia coli*, bovine respiratory syncytial virus, lung worm and deworming	—	8	—

Table A2. The edited management variables with descriptions and categories (the continuous variables that were categorized were not included)

Management factor	Description	Category
Housing		
Type of barn	The types of group barn for unweaned calf (in group); others include igloo, cubicles, and ligbox (a small area that is fenced off with steel bars)	Deep litter Other
Type flooring in group	The type of flooring for unweaned calf (in groups)	Grid Solid floor
Type of bedding	The types of bedding in group barn for unweaned calves (in groups); the category includes saw dust, rubber, and concrete	Straw Other
Type of ventilation	The type of ventilation of individual housing for unweaned calves (individual)	Wall and ridge Natural and open front Fan
Barn cleanliness		
Average barn cleaning frequency per year	Assuming 1 to 12 times per year was not frequent and disinfection every time before receiving new animal was frequent; the farm average barn cleaning frequency was averaged across different age groups in the farm	Less frequent Moderate Frequent
Average farm hygiene score	The average hygiene score of the barn in the farm was calculated by averaging the hygiene score of the barn from different age groups in the farm	Clean Moderate Dirty
Disease incidence		
Incidence of calf scours	The incidence of calf scours in young stock <1 yr of age; it was calculated from the estimated number of young stock <1 yr of age infected with calf scours divided by the average number of young stock <1 yr of age	
Incidence of bovine respiratory disease (BRD)	The incidence of BRD in young stock <1 yr of age; it was calculated from the estimated number of young stock <1 yr of age infected with BRD divided by the average number of young stock <1 yr of age	