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Influence of rearing conditions and birth season on calf welfare in the first month of life

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Abstract: The aim of this study was to analyze the influence of farm conditions and season of birth on body mass, respiratory system diseases and diarrhea occurrence, and mortality during the first month of calves' life. The study was conducted on two tie-stall–system farms with intensive milk production and similar nutrition of dairy cows, but with differences in rearing conditions of calves in the first week of life. The calves were tied on lying area with straw as bedding material (farm A) or free in individual boxes with straw bedding (farm B). In the first consumption, they take 1–2 L of colostrum produced by their mother or by another cow (farm A), or 2.5–3 L of colostrum produced by their mother or by another cow or frozen colostrum (farm B). According to the results, average body mass of calves was significantly higher on farm B than of those on farm A at all ages (on birth, at 8 days, and 30 days). Mortality rate and diarrhea occurrence in calves were higher on farm B, while respiratory system diseases incidence was higher on farm A. All observed welfare indicators were very significantly ($P < 0.01$) influenced by farm conditions and birth season.

Key words: Calves, rearing conditions, birth season, body mass, welfare

1. Introduction

During the first month of life, calves are very vulnerable and demand quality care, since they are threatened by numerous risks factors influencing their welfare, growth, body mass gain and condition. All these issues matter or are very important for in production efficacy and consumers' attitude, which makes research in this field highly interesting and therefore financed in Europe in the last few decades (1–3).

It is a well-known fact that rearing conditions (microclimate, hygiene regime, nutrition, and farm management) may have a high influence on calves' welfare (4–8). If rearing conditions are not good, welfare problems may arise, such as negative emotions (pain, fear, frustration, etc.), behavior disorders, health problems of skin, digestive, respiratory and locomotor systems diseases, injuries, and mortality. Besides these farm influences, the birth season may also have significance through climate and microclimate conditions (9,10).

The aim of this study was to analyze the impact of the established practices on farms for the well-being of calves, such as the influence of birth season and farm conditions on body mass, respiratory system diseases and diarrhea occurrence, and the mortality of calves, as major animal-based welfare indicators of calves on two farms with the intensive system of rearing, in the first thirty days of life.

2. Materials and methods

In this study, 596 male and female Holstein Friesian calves (171 during autumn, 150 in winter and spring, and 125 in summer) of farm A, and 572 (by seasons: 173, 131, 140 and 125, respectively) of farm B, from the birth to day 30 were used. During a season, the calves were selected randomly. Farms A and B are located in the same geographical region about 15 km west of Belgrade and from each other. The calves' mothers were aged 4 to 6 years.

Investigations were performed on two dairy farms (A and B) for one year, starting in autumn (September 23rd to December 22nd), through winter (23rd December to March 22nd), spring (March 23rd to June 22nd) and summer (June 23rd to September 22nd).

The calves on both farms are separated from their mothers in 2 h after birth. They were then kept individually in the same tie-stall, tied (farm A) or free in the box (farm B). They were fed 1–2 L of colostrum (farm A) and 2.5–3 L of colostrum (farm B) by bucket, two times a day for the first 4 days of life. Colostrum was collected from their own mothers, but in the absence of their mother, the calves were

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fed other cows' fresh colostrum (farms A and B) and also frozen colostrum (farm B). The first colostrum feeding took place 2 h after birth on both farms. From day 5 until day 15, the calves were fed 3 L of milk two times a day and after day 15, the same quantity of milk replacers. Different amounts of colostrum results from the differences in the established practices in the technological process of production on farms A and B. These differences were the starting point for examining the amount of colostrum as a risk factor and their reflection on animal-based welfare indicators. From day 8, the calves were allowed to consume water ad libitum, as well as quality hay and granulate concentrate (PKB "Inshra", Serbia). At the age of 7 days, the calves were moved into the group boxes: 10 in the farm A group and 5 in the farm B group. IgG and TP concentrations were measured regularly by colostrometer, their values ranged within the reference levels and in general no significant differences were identified between the farms. It has been a common production practice in years in both farms since the 1960s.

During our investigations, the following welfare indicators were recorded: (a) body mass of calves at birth and at the ages of 8 and 30 days using the appropriate scale; b) respiratory system diseases and diarrhea occurrence data among calves were collected from structured veterinary evidence on the farms, as well as (c) calves' mortality data during the first 30 days of life, at 0, 8, 15, 22, and 30 days, respectively. In addition, microclimate in the stalls where the calves were kept was measured (air temperature and relative humidity on five spots on the altitude of calves heads, using digital handheld anemometer "TESTO 410-2" and light intensity by luxmeter "TESTO 540" (Testo Inc., West Chester, PA, USA), and hygiene conditions in stalls (bedding material, lying surfaces and boxes) were assessed as it was described in (5).

2.1. Statistical analysis

The obtained data were processed by statistical package SPSS v. 21 (SPSS Inc, USA). Testing of differences of body masses of calves regarding seasons was performed with analysis of variance with repetitive measuring Wilks' lambda and multivariate tests.

In the post hoc analysis, the Duncan test was used for 5% and 1% thresholds (11). Individual impacts of the examined factors and their interactions were measured with partial eta-squared coefficient (Partial Eta Squared), classified according to Cohens' gradation (12). In order to establish the impact of farm condition and birth season on respiratory system diseases and diarrhea occurrence, logistic regression analysis was applied.

3. Results

3.1. Environmental conditions

During the first 30 days of life, the calves were kept on clean and dry straw over firm laying space. Situations when laying area were slippery and the bedding was moist occurred occasionally, but the calves' exposure to them was short-term. Hygiene in the stalls was good, but there were a lot of possibilities to improve it.

During the study, the average air temperature was between 10 and 26 °C. During the summer, the temperatures were higher than 26 °C, even over 32 °C in several cases on farm B. The lowest temperatures during winter were in the interval of 0–10 °C. The relative humidity on farm A was in the interval of 50%–80%, being more favorable than on farm B, where it exceeded 85% during the summer. This indicates poor ventilation and therefore possibility for heat stress. The airflow and air quality were estimated to be very good, varying from excellent to satisfying, but on both farms, lack of efficient ventilation was evident. The worst estimated indicator was lighting. More than one-third of the calves were exposed to the light intensity under 50 lx.

3.2. Body masses of calves

The average body masses of the calves from farms A and B during different seasons were presented in Table 1.

Duncan's test analysis of average body masses of the calves on both farms by seasons were presented in Table 2. This test revealed significantly higher body masses on farm B than on farm A in calves of all ages ($P < 0.01$).

In order to find the differences in calves' body masses on both farms by seasons, method of two-factor analysis of variance with repeated measures was used as it is presented in Table 3.

Analysis of body masses of calves revealed significant differences, not only between farms A and B but also between seasons, which confirms the hypothesis that farm conditions and season of birth may influence calves' welfare during the first month of life. In addition, the interaction of these two welfare indicators revealed significance regarding the calves' body masses, as it is presented in Table 3. From the data in this table, it can be seen that the impact of examined factors (the rearing conditions and birth season) on body mass changes expressed through partial eta square coefficient was not high, regarding the season and interaction of farm × season, which were 1.82% and 4.32%, respectively, while farm conditions impact was much higher –22.24% (0.01, small effect; 0.06, moderate effect; 0.14, high effect) (12).

Season was revealed to have significant effect ($P < 0.05$) on body mass changes at birth of calves during winter and autumn (39.371 kg and 38.905 kg, respectively) and very significant effect ($P < 0.01$) compared to spring (38.744 kg) and summer (38.787 kg).

At the age of 8 days, the highest average body mass of calves was noted during the winter (41.057 kg), although it was significantly higher only in relation to the average body mass in spring ($P < 0.01$), with no difference from those in the autumn and summer ($P > 0.05$).

Table 1. Average mass of calves on farms A and B during seasons.

Farm	Season	Age of calves		
		Day 0	Day 8	Day 30
		Calves body mass (kg)		
		($\Sigma x \pm S_{\bar{x}}$)	($\Sigma x \pm S_{\bar{x}}$)	($\Sigma x \pm S_{\bar{x}}$)
A	Autumn	38.64 ± 0.16	40.38 ± 0.17	51.70 ± 0.21
	Winter	38.75 ± 0.18	40.21 ± 0.20	51.36 ± 0.24
	Spring	37.29 ± 0.21	39.04 ± 0.23	50.94 ± 0.27
	Summer	36.94 ± 0.10	38.92 ± 0.14	49.75 ± 0.20
	Σ	37.95^{a} ± 0.09	39.68^{a} ± 0.10	51.01^{a} ± 0.12
B	Autumn	39.17 ± 0.22	40.92 ± 0.23	51.85 ± 0.26
	Winter	40.03 ± 0.14	41.95 ± 0.14	52.45 ± 0.45
	Spring	40.42 ± 0.19	42.02 ± 0.22	53.12 ± 0.24
	Summer	40.65 ± 0.19	42.62 ± 0.20	53.31 ± 0.21
	Σ	39.99^{b} ± 0.10	41.80^{b} ± 0.11	52.62^{b} ± 0.15

Σx –Average body mass of the calves;
$S_{\bar{x}}$–Standard error;
a, b – significant differences ($P < 0.05$) between values marked with different letters in the same column.
There are no significant differences ($P > 0.05$) between the values marked with the same letters.

Table 2. Post hoc analysis for season of birth of calves for both farms (Duncan's test).

Season	Age of calves		
	Day 0	Day 8	Day 30
	Average body mass of calves (kg)		
Autumn	38.905^{b}	40.649^{ab}	51.777^{a}
Winter	39.371^{a}	41.057^{a}	51.890^{a}
Spring	38.744^{b}	40.425^{b}	51.952^{a}
Summer	38.787^{b}	40.763^{ab}	51.522^{a}

a, b – significant differences ($P < 0.05$) between values marked with different letters in the same column.
There are no significant differences ($P > 0.05$) between the values marked with the same letters.

There were no significant differences of average body masses of calves between seasons (in autumn 51.777 kg, winter 51.890 kg, spring 51.952 kg, and summer 51.522 kg, respectively) at the age of 30 days ($P > 0.05$).

3.3. Mortality

Calves' mortality at birth and before weaning are relevant welfare indicators because they point out failures in calves rearing technology and management. In Table 4, the mortality rate on both farms regarding calves age and season of birth is presented.

On farm A, 22 (3.7%) calves died in total; in autumn 3 calves (1.75%), in winter 14 calves (9.3%), and in spring 5 calves (3.33%), whereas in summer there was no mortality. On farm B, 29 (5.1%) calves died in total; in autumn, winter, spring, and summer 9 calves (5.2%), 4 calves (3.05%), 15 calves (10.71%), and 1 calf (0.8%), respectively. The highest mortality rate on farm A was observed at the age of 22 days (13 calves, 2.18%), while on farm B, it was observed at the first few days of life (10 calves, 1.75%).

Farm conditions and birth season significantly influenced calf mortality ($P < 0.01$), while it was not the case with the age of calves ($P > 0.05$). The mentioned significance confirms the initial hypothesis about farm conditions and the effect of birth season on calves' welfare level.

Season, independent of age, significantly influenced calf mortality. Regarding the assessed coefficients of regression for the introduced simulated variables related to the birth season, it could be noticed that rates of mortality in autumn, winter, and spring were higher than in summer ($e^{0.609} = 1.838$, $e^{1.149} = 3.155$, and $e^{1.229} = 3.418$ times more, respectively, compared to the last season), meaning that rates of calf mortality were 83% higher in autumn, more than three times higher in winter, and 3.4 times higher in spring than in summer.

Table 3. Wilks' lambda test values.

Source of variation	Value	df	F	Significance	Partial eta square
Farm	0.7776	3	106.0	0.000	0.2224
Season	0.9562	9	5.6	0.000	0.0182
Farm × Season	0.8980	9	13.6	0.000	0.0432

Table 4. Calf mortality rate on farms A and B regarding calf age and season of birth.

Farm	Season	Age of calves					
		Day 0	Day 8	Day 15	Day 22	Day 30	Σ
		Mortality rate (%)					
A	Autumn	0.58	0.00	0.58	0.00	0.58	1.75
	Winter	0.00	0.00	0.67	8.00	0.67	9.33
	Spring	1.33	0.00	0.67	0.67	0.67	3.33
	Summer	0.00	0.00	0.00	0.00	0.00	0.00
	Σ	0.50	0.00	0.50	2.18	0.50	3.68
B	Autumn	0.58	0.00	1.74	1.16	1.74	5.20
	Winter	0.76	0.00	1.53	0.76	0.00	3.05
	Spring	5.00	0.00	2.14	2.86	0.71	10.71
	Summer	0.80	0.00	0.00	0.00	0.00	0.80
	Σ	1.75	0.00	1.40	1.22	0.70	5.07

Logistic regression			
Parameter	Estimate	Std. error	Sig
D1	0.609	0.589	0.343
D2	1.149	0.567	0.045
D3	1.229	0.530	0.034
Age	–0.001	0.015	0.957
Farm A	–5.857	0.570	0.000
Farm B	–5.604	0.560	0.000

D1 – autumn, D2 – winter, D3 – spring.

3.4. Respiratory system diseases

Respiratory system disease incidence at different ages of calves regarding season of birth on farms A and B are presented in Table 5.

In all seasons, on farm A there were more calves with respiratory system diseases (300 or 50.3%) than on farm B (119 or 20.8%). The highest disease rate on farm A was noted in winter, while on farm B it was in autumn. Both farm conditions and season had significant effect ($P < 0.01$), which is in accordance with the initial hypothesis. The difference between farms was very significant ($c^2 = 63.947$, $P = 0.000$), meaning that the number of sick calves on farm B was significantly lower than that on farm A ($P < 0.01$). In addition, it may be noted that the season influenced the number of the diseased calves independently of the calves' age.

The highest risk of respiratory system disease occurrence was established for autumn, winter, and spring, since the risks of disease occurrence were higher in autumn, winter, and spring than in summer ($e^{0.053} = 1.054$, $e^{1.092} = 2.980$ and $e^{-0.046} = 0.955$, respectively).

3.5. Diarrhea

Diarrhea occurrence was similar on both farms A and B (338 and 333 calves, 56.71% and 58.22%, respectively) and varied related to the birth season and calf age, as it is presented in Table 6.

On farm A, the highest occurrence of diarrhea was in winter (141 calves or 94.0%) and the smallest was in

Table 5. Respiratory diseases occurrence rates of calves regarding age and season of birth

Farm	Season	Age					
		Day 0	Day 8	Day 15	Day 22	Day 30	Σ day 0
		Respiratory diseases occurrence rate, %					
A	Autumn	4.09	4.68	9.94	4.68	5.26	28.65
	Winter	16.67	21.33	32.00	26.00	18.67	114.67
	Spring	7.33	5.33	10.67	4.00	2.67	30.00
	Summer	9.60	4.80	6.40	3.20	3.20	27.20
	Σ	9.23	9.06	14.93	9.56	7.55	50.33
B	Autumn	2.89	4.05	5.20	7.51	4.62	24.28
	Winter	1.53	2.29	3.05	5.34	4.58	16.79
	Spring	3.57	4.29	7.14	3.57	0.00	18.57
	Summer	2.40	1.60	5.60	6.40	7.20	23.20
	Σ	2.62	3.15	5.24	5.77	4.02	20.80

Logistic regression			
Parameter	Estimate	Std. error	Sig
D1	0.053	0.170	0.774
D2	1.092	0.153	0.000
D3	–0.046	0.179	0.797
Age	–0.003	0.005	0.609
Farm A	–2.602	0.154	0.000
Farm B	–3.538	0.170	0.000

D1 – autumn, D2 – winter, D3 – spring.

summer (27 calves or 21.6%), while on farm B the highest number of the diseased calves was recorded during spring (105 calves or 74.5%) and the smallest in summer (44 calves or 35.2%). Most of the calves on farm A were ill at the age of 8 days, while on farm B at the age of 15 days. Significances of impacts of age, farm conditions, and birth season on diarrhea occurrence in calves on both farms were presented through logistic regression. The probability for diarrhea to occur was higher in autumn ($e^{0.612} = 1.844$), winter ($e^{1.195} = 3.303$), and spring ($e^{0.972} = 2.643$) than in summer, meaning that it was higher for more than 84%, three times, and two and half times, respectively. The influence of season on diarrhea was significant, and the highest prevalence of diarrhea was noted in winter on farm A and in spring on farm B.

4. Discussion

The effect of birth season on the body mass of calves was much lower (1.82%) than that of farm conditions (22.24%), while the interaction of both farm conditions and the birth season was 4.32%. It could be noted that average body mass of calves on farms A and B were similar to (13,14) or lower than (15) the values that are characteristic for the Holstein Friesian breed as it was indicated in the literature .

The mortality rate of calves in the 22-day-old calves was high on Farm A in winter. The reason for this was poor microclimatic conditions on the farm, since the calves were kept tied individually in the same tie-stall on the opposite side to dams of feeding corridor in inadequate conditions, such as low temperature, high humidity, draft, insufficient bedding, etc. (farm A). A detailed investigation is necessary to identify the reason why more farm B calves kept in individual boxes died compared to the tied calves on farm A in the first days. This could be partly due to the vitality of calves at birth, but the adaptation to the confined comfort in the boxes cannot be excluded.

Nevertheless, it could be emphasized that the average body masses of calves on farm B were significantly higher than those on farm A, confirming the initial hypothesis that rearing conditions and nutrition of calves influence their welfare in the first 30 days of life. These results are in accordance with research results regarding rearing conditions (16), nutrition (17), and man's attitude towards calves (18). Besides the significant impact of the farm

Table 6. Diarrhea occurrence rates of calves regarding age and season of birth.

Farm	Season	Age of calves					
		Day 0	Day 8	Day 15	Day 22	Day 30	Σ
		Diarrhea occurrence rate, %					
A	Autumn	2.92	22.81	14.04	2.92	2.34	45.03
	Winter	11.33	37.33	32.00	6.00	7.33	94.00
	Spring	7.33	19.33	20.00	12.67	2.67	62.00
	Summer	7.20	2.40	10.40	1.60	0.00	21.60
	Σ	7.05	21.31	19.30	5.87	3.19	56.71
B	Autumn	10.98	15.03	18.50	6.94	4.05	55.49
	Winter	8.34	17.56	21.37	16.03	3.82	67.18
	Spring	10.71	20.00	29.29	11.35	3.55	74.47
	Summer	2.40	8.00	15.20	3.20	6.40	35.20
	Σ	8.39	15.21	20.98	9.27	4.37	58.22

Logistic regression			
Parameter	Estimate	Std. Error	Sig
D1	0.612	0.146	0.000
D2	1.195	0.142	0.000
D3	0.972	0.145	0.000
Age	–0.024	0.004	0.000
Farm A	–2.498	0.139	0.000
Farm B	–2.455	0.139	0.000

D1 – autumn, D2 – winter, D3 – spring.

conditions on body masses of the calves, there was significant influence of birth season, through climate factors on feed consumption and body mass gain, which is in accordance with the initial hypothesis and the literature data (19,20). In addition, many authors state that farm conditions are one of the key factors influencing early calf mortality rate, through herd size, system of rearing, preparation of cows for partus during the dry period, organization of calving (use of individual boxes, partus assistance, etc.), feeding the calves with colostrum, separation from the mother, as well as stress reduction and exposure to pathogens. As one of the risk factors, the authors considered that the amount of colostrum directly contributed to a higher incidence of neonatal period of illnesses (21). Birth season of the calves influences through climate and microclimate conditions (22), as well as dystocia, twin calving, diseases, calf's sex, cows' parity, etc.

Both respiratory system diseases and diarrhea were treated with broad spectrum antibiotics without delay after clinical signs of disease were noticed. Specific pathogens are being actively monitored on yearly bases with noted bovine viral diarrhea and infectious bovine rhinotracheitis occurrence. Also, some rapid diagnostic tests for rota and corona viruses, *E. coli*, *Clostridium perfrigens*, etc., were in use on both farms.

Vaccination of both farm populations was performed according to the yearly National Program for Animal Health Protection; against lumpy skin disease and blue tongue vaccination is mandatory, and against anthrax, depending on the epidemiological situation.

The respiratory system disease occurrences on farms A and B were influenced not only by rearing conditions but also by the presence of specific pathogens. Discussing the rearing conditions in calf stalls; air quality (temperature, humidity, presence of dust and ammonia), poor ventilation, stocking density, and the presence of different cattle categories and other species (dogs, cats, birds, rodents, etc.), as well as certain pathogens, such as bovine viral diarrhea virus and infectious bovine rhinotracheitis virus (23) stand out.

In many studies (24–28), respiratory system diseases is referred to as one of the most common calf diseases and one of the most important causes of early calf mortality. In addition, respiratory system diseases lead to other health disorders, as well as body mass gain and consequently poor calf welfare. The risk of respiratory system diseases

is higher in calves older than 30 days (29). The measures that can help in reducing the incidence of the respiratory system diseases in calves may be divided as general and specific. General measures include improving sanitation and air quality in buildings and providing adequate housing for calves. Specific measures include reduction of infective pressure in the herd, adequate and timely medical treatment, and vaccination against diseases if possible, etc.

The significant impact of farm conditions and birth season on diarrhea occurrence on both farms was proved in this study. Diarrhea may have numerous specific and nonspecific causes. Nonspecific causes are related to the calving hygiene and accommodation of newborns, quantity and quality of colostrum, as well as quality and temperature of feeding colostrum, whole milk, and milk replacers (30), hygiene of rearing (8), groups forming in boxes, etc. Specific causes include the presence of specific pathogens that lead to disorders in the digestive tract and diarrhea. The occurrence rate of diarrhea confirms that not only it is one of most common diseases of dairy calves, but one of the main causes of early calf mortality as well (23,25,27–29). In addition, the occurrence of diarrhea reduces body mass gain in calves (24), with the highest rate of occurrence at the age of 2–3 weeks, which is in accordance with the literature data (29). Measures for suppression of diarrhea consist of raising the general immunity of the calves, proper nutrition, and maintaining high-quality general hygiene, and preventing the spread of disease, etc.

All observed animal-based indicators of calf welfare (the body mass, respiratory system diseases, diarrhea, and mortality) may be affected by microclimate factors, especially the air temperature, relative humidity, and draft (5,7,10), whose nature and effect on the calves' body are complex, mutually intertwined in the action, and when deviate, may adversely affect the calf welfare. In this study, they were closely related to seasonal changes during the winter and summer periods. According to the analysis of the results, they expressed correlation to all tested animal-based welfare indicators. Regarding housing conditions, providing dry bedding and permanent appropriate clean surface for lying for calves is important (2,5). Proper colostrum feeding has a crucial role in calf welfare (2).

According to the presented and analyzed results of the investigations on farms A and B, it may be concluded that welfare of the calves in the first 30 days of life were significantly influenced by rearing conditions on the farm and birth season, which was particularly expressed through direct welfare indicators of the calves, such as average body mass and mortality and disease occurrence rates. Besides this, it can be concluded that all observed animal-based indicators of calf welfare (body mass, respiratory system diseases, diarrhea, and mortality) may be affected by microclimate factors (especially air temperature, relative humidity, and drafts) and the first colostrum intake. In respect of housing conditions, providing dry bedding and permanent appropriate clean surface for lying for calves is important.

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