The influence of colostral immunoglobulin concentration in heifer calves' serum on their health and growth

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ABSTRACT

The aim of this study was to determine factors affecting passive transfer in heifer calves born within 1 yr and how passive transfer influences rearing to the period of first insemination under commercial dairy farm conditions. Calves were divided into 4 groups based on serum immunoglobulin concentrations at 30 to 60 h of life (<5, 5–10, 10–15, and >15 g/L, respectively in groups 1 to 4). Calving ease, dam parity, calf body weight at birth, calf vitality, quality of colostrum, time and volume of first colostrum fed, morbidity rate and intensity of illness, growth rate, and age and efficiency of first insemination service were recorded. Plasma fibrinogen, and serum γ -globulin, IgG₁, IgG₂, IgM, and haptoglobin were estimated at 30 to 60 h and again at 21 to 28 d of life. Additionally, the immunoglobulin index (I_{Ig3-4}) was calculated. The main cause of FPT and PFPT in the calves was poor vitality associated with dystocia and low volume of ingested colostrum. The calves born to primiparous cows were more endangered than those born to multiparous cows. The morbidity and intensity of disease course were lowest in heifer calves with serum Ig concentration exceeding 10 g/L at 30 to 60 h of life; these calves did not become ill before d 14 of life. Calves with >15 g/L γ -globulin in serum avoided respiratory tract infections. The immunoglobulin index was lowest (0.61) in calves from group 4 and highest in calves from groups 1 and 2 (1.44 and 0.88, respectively). The suitability of this index as well as haptoglobin determination was confirmed in prediction of morbidity risk and disease intensity in growing heifer calves. Heifers with serum γ -globulin levels >10 g/L at 30 to 60 h of life showed better health status and reached body weights allowing first insemination sooner.

Key words: calf, colostral immunity, dairy heifer, health status

INTRODUCTION

The reduction in survival of dairy cows and the need to maintain a herd's reproduction level are associated with the effects of rearing heifer calves and their health (Campbell et al., 2007). The exploitation of cows for milk under large-farm conditions causes the common early breaking of the natural cow-calf contact. Feeding colostrum to calves is done by hand and entails time restrictions and reliable supervision (Petrie, 1984; McGuirk and Collins, 2004; Jaster, 2005). Despite increasing knowledge about factors that may limit the efficiency of the passive transfer of immunity, failure of passive transfer (**FPT**) occurs in a considerable portion of newborn dairy calves in Poland and other countries (Furman-Fratczak et al., 2005; Swan et al., 2007; Beam et al., 2009). An insufficient level of colostral immunity increases the susceptibility of calves to alimentary and respiratory tract infections and the risk of death in the first weeks of life (Wells et al., 1996; Donovan et al., 1998). Diarrhea and perinatal mortality are the main causes of death of calves up to d 14 of age (Bunning-Fann and Kaneene, 1992; Sivula et al., 1996). Moreover, calves that survive diarrhea before d 14 of life were more susceptible to respiratory tract infections in the ensuing period (Curtis et al., 1988; Virtala et al., 1999; van der Fels-Klerx et al., 2001).

A high level of colostral immunoglobulins in the serum of calves improves not only their health and growth in the first weeks of life, but also their further use as cows (DeNise et al., 1989; Donovan et al., 1998; Jarmuz et al., 2001). The literature describes different levels of serum immunoglobulin concentrations in neonatal calves that protect against disease. At 24 h of life, a diagnosis of FPT in calves occurs when the serum Ig concentration is <10 g/L (Weaver et al., 2000; Swan et al., 2007; Beam et al., 2009). Higher Ig levels indicate proper maternal protection of calves. Moraes et al. (2000) estimated the level of passive transfer in calves using a turbidity test and established that FPT occurs in calves with a serum Ig concentration <5 g/L. In contrast to research in foals, partial failure of passive transfer (**PFPT**) is rarely described in calves and is

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likely underestimated in practice. Basoglu et al. (1999) and Güngör et al. (2004) stated that after the period of passive transfer, Ig levels <8 g/L indicate FPT in calves and concentrations between 8 and 16 g/L indicate PFPT. In properly protected calves, serum Ig levels exceeded 16 g/L. The level of risk differs in calves with FPT and PFPT and influences the efficiency of treatment. In our own study, the following classification of calves was made: FPT = serum Ig <5 g/L, PFPT = 5 to 10 g/L, good protection = 10–15 g/L, and very good protection = >15 g/L (Furman-Fratczak et al., 2005).

Early detection of health disturbances in calves on dairy farms is difficult because of the large number of individuals and the group-keeping system (Tourlomousis et al., 2004). An attractive diagnostic tool seems to be determining levels of acute phase proteins (APP), which increase in response to infectious and noninfectious inflammatory processes. Especially useful APP in cattle are haptoglobin (Hp), fibrinogen (Fb), and serum amyloid A (Horadagoda et al., 1999; Ganheim et al., 2003; Jawor et al., 2008). In healthy cattle, Hp is not detected in about 50% of individuals and in the remaining 50%, its serum level is <0.1 g/L. The normal plasma Fb concentration is stable in cattle and does not exceed 3 to 7 g/L (Eckersall and Conner, 1988).

The weight gain of calves and heifers should be maintained at a level that enables first insemination at around 15 mo. Optimal weight gain allows early calving and reduces the costs of rearing heifers (Hoffman and Funk, 1992; Macdonald et al., 2007).

The aim of this study was to determine factors affecting passive transfer in heifer calves and how it influences rearing to the period of first insemination under commercial dairy farm conditions.

MATERIALS AND METHODS

Animals and Treatments

The study was carried out on a dairy farm of 400 cows of the Polish Holstein-Friesian black and white breed. One hundred seventy-five heifer calves born during 1 yr were observed from birth to the confirmation of first pregnancy. Bull calves were sold within the first 2 wk of life. Immediately after birth, the calves were placed in individual straw-bedded boxes and kept there for 2 wk. Newborn calves were handled and hand-fed colostrum by staff according to the farm's own procedures. The dam's first colostrum was given by artificial nipple when the calf made its first efforts to stand. Subsequent colostrum feedings depended on the farm's milking times, which were at 0600 and 1500 h. Newborn calves were injected 2 times subcutaneously (at 2

and 14 d of life) with 100 mL of serum obtained from 10 cows of the same farm immunized with *Histophilus somni* vaccine (Pro Animal, Wrocław, Poland). The day after the last serum injection, the calves were moved to a calf barn into pens for 12 individuals. The calves were dehorned between wk 8 and 10 of life. In the fifth month of life, heifer calves were selected according to weight and moved to the next calf barn into pens for 20 individuals.

At the age of 6 mo and BW of 200 kg, the heifers were moved to the heifer barn. Before being moved, they were dewormed using ivermectin (Vetoquinol, Gorzów Wielkopolski, Poland) and vaccinated twice against dermatomycosis (Bovitrachovac, Biowet Pulawy, Poland). The heifer barn was divided into 3 parts: animals were kept in the first part until 11 mo of age and in the second until 15 mo of age and 380 kg of BW; in the third part they underwent AI. Insemination of the heifers was performed at the first detected estrus. Pregnancy was detected about 30 d after insemination.

Immediately after birth, the vitality of the calves was estimated on a scale of V_0 to V_3 according to Szenci (1982; V_0 = toneless, head drooping, limbs extended, cardiac activity absent; V_1 = toneless, head drooping, limbs extended, cardiac activity present; V_2 = low tonicity, abdominal recumbency with head requiring support, reduced number and intensity of reflectoric movements; V_3 = normal tonicity, head erected, normal reflectoric movements) and calves were weighed. Still-born calves (V_0) were excluded from the study. Data on cow age (primiparous or multiparous) and hour of birth were recorded. Calving ease was estimated on a scale of 1 to 3 (1 = natural, easy, 2 = pulled by farm staff, 3 = complicated, with veterinarian intervention).

The quality of the first colostrum was determined based on organoleptic characteristics (including color and smell) on a scale of 1 to 4 (1 = normal color and smell, 2 = normal colostrum with blood traces, 3 = colostrum with inflammatory changes, 4 = watery, pathological secretion). The density of the first colostrum was determined by a colostrometer (Pro Animal), and the immunoglobulin concentration was calculated based on a table relating colostrum density to Ig concentration. Based on colostrum density and Ig concentration, the colostrum was qualified as bad (<39 g of Ig/L), passing (42–77 g of Ig/L), good (80–118 g of Ig/L), or very good (>121 g of Ig/L). Calves were fed their mothers' colostrum until d 3 of life. The volume and hour of the first colostrum intake were recorded.

Jugular vein blood samples were taken from the calves twice: between 30 and 60 h of life (mean: 35.5 h) and between 21 and 28 d of life (mean: 25 d). Fibrinogen was measured in EDTA-containing blood samples. Blood serum was collected by centrifugation (2,000 ×

g for 10 min at room temperature) and frozen (-20°C) for subsequent analysis.

The calves were divided into 4 experimental groups based on serum γ -globulin concentration measured between 30 and 60 h of life: group 1 = <5 g/L, FPT ($n = 22$); group 2 = ≥ 5 to 10 g/L, PFPT ($n = 83$); group 3 = >10 to 15 g/L, good protection ($n = 55$); and group 4 = >15 g/L, very good protection ($n = 15$).

The number of veterinary treatments for diarrhea and respiratory tract infection was noted. Diarrhea cases were divided into (1) mild (lax feces); (2) moderate (multiple defecation of loose feces, signs of dehydration); and (3) severe (watery feces, strong dehydration, recumbency). Respiratory tract infections were divided into (1) mild (pathologic discharge from nostrils, sporadic cough); (2) moderate (pathological discharge from nostrils, frequent cough, poor disposition); and (3) severe (apparent dyspnea, recumbency, poor fettle).

During the rearing period, the heifers were weighed once a month. Their age and BW at the time of first insemination as well as the insemination index were determined. The criteria for allowing a heifer to the first insemination were age (minimum: 15 mo) and BW (minimum: 390 kg).

Analytical Procedures

Fibrinogen was measured in whole-blood samples according to Millar et al. (1971). Total serum protein was determined using the Biuret method and its fractions (albumin, α -, β -, γ -globulins) by paper electrophoresis. Haptoglobin concentration was determined by the guaiacol method according to Jones and Mould (1984). The concentrations of IgG₁, IgG₂, and IgM were measured by radial immunodiffusion (Mancini et al., 1964, modified by Gasowska and Stefaniak, 2003) in 10 randomly selected calves from each group. The index of total immunoglobulins ($I_{\text{Ig3-4}}$) was calculated according to Nikolajczuk et al. (1994; the $I_{\text{Ig3-4}}$ was calculated as the quotient of the serum Ig values in the third to fourth week of calves' lives divided by the Ig concentration in the forty-eighth hour of living; this index is a good measure of the adequacy of the calves' humoral postcolostral immunity against the present microbial threat).

Statistical Analysis

Treatment comparisons were made by ANOVA for a completely randomized design using the Statistica 8 statistical package (StatSoft Inc., Tulsa, OK). Differences between means were determined by the Duncan test when 3 groups were analyzed and by the Tukey

test when 2 groups were analyzed. Pearson correlation coefficients for selected factors were calculated.

RESULTS AND DISCUSSION

Delivery Course

Under the conditions of the examined farm, the majority (56%) of the cows calved in the afternoon and at night. Cows calved without human assistance in only 38% of cases. The proportion of multiparous cows in the respective experimental groups increased from 50% in group 1 to 80% in group 4 (Table 1). Moreover, the percentage of delivery courses of score 1 (natural, easy) increased from 27% in group 1 to 53% in group 4. Most of the multiparous cows calved between 1200 and 1800 h (27.88% of deliveries), and primiparous cows calved mainly between 2100 and 0300 h (34.37%). Because cows calved primarily during the day, the care routine of the staff was more efficient for multiparous cows than for primiparous cows. Because of the presence of all staff during the day, the supervision of delivery, early intervention, and the colostrum feedings were easier during the day than at night.

Colostrum Quality

The worst colostrum quality (score 4) was observed in groups 1 and 2 (9.1 and 1.2% of cases, respectively). The rate of blood presence in colostrum samples (score 2) was 4.5% in group 1. In group 2, colostrum with inflammatory signs (score 3) was found in 6% of the samples. In groups 3 and 4, normal colostrum with a pleasant smell and proper color was found in 80% of the examined samples. In groups 3 and 4, no colostrum samples had scores 3 and 4. It seems highly probable, therefore, that the poor passive transfer in the calves of groups 1 and 2 was caused in some cases by the colostrum used, which should generally be excluded from their feeding.

The mean colostrum Ig concentration was lowest in calves of group 2 (63.2 g/L) and highest in calves of group 4 (104.8 g/L). A common opinion is that colostrum appropriate for calves should contain at least 50 g of Ig/L (Vasseur et al., 2009). Therefore, the mean colostrum Ig concentration in this herd (79.48 g/L) could be considered good compared with that in other studies in Poland (65.5 g/L in Kinal et al., 2004; 63.0 g/L in Zachwieja, 1995), as well as in other countries (59.0 g/L in Abel Francisco and Quigley, 1993; 48.8 g/L in Kaske et al., 2005; 34.9 g/L in Kehoe et al., 2007; and 48.2 g/L in Pritchett et al., 1991). In groups 1 to 3, the rates of colostrum evaluated as very good were

Table 1. Origin, vitality, amounts of colostrum consumed, and BW of the calves (mean $\pm$ SD for last 3 traits)

Trait	Group ¹			
	1	2	3	4
No. of cows (primiparous/multiparous)	11/11	33/50	19/36	3/12
Vitality score ² 1 (%)	4.54	1.2	0.00	0.00
Vitality score 2 (%)	31.82	10.84	3.64	6.66
Vitality score 3 (%)	63.64	87.95	96.36	93.33
Volume of first colostrum consumed (L)	1.36 $\pm$ 0.52	1.74 $\pm$ 0.40	1.85 $\pm$ 0.38	1.83 $\pm$ 0.36
BW at birth (kg)	39.7 $\pm$ 5.9	39.9 $\pm$ 5.7	39.9 $\pm$ 6.3	38.8 $\pm$ 6.0
Colostrum consumed (% of BW)	3.5 $\pm$ 1.25	4.4 $\pm$ 1.05	4.7 $\pm$ 1.08	4.8 $\pm$ 1.09

¹Groups 1, 2, 3, and 4 had serum immunoglobulin concentrations at birth of <5, 5–10, 10–15, and >15 g/L, respectively.

²Vitality score: V₀ = stillborn, V₁ = very poor disposition, V₂ = poor disposition, and V₃ = good disposition.

similar (about 9%). In groups 1 and 2, in which the calves showed worse passive transfer, the rates of bad colostrum were higher (22.7 and 19.3%, respectively). Although the rate of bad colostrum was higher in group 1 than in group 2, the rate of good colostrum was also higher in group 1. Therefore, we identify dystocia and the high percentage of calves showing poor vitality at birth as the main causes of FPT in the calves of group 1.

Colostrum Administration and Ig Course

Despite the relatively high colostrum Ig concentration, over 90% of the calves had serum Ig concentrations <15 g/L at 30 to 60 h of life. A considerable number of the calves (69.7%) were fed the first colostrum within 2 h after birth. In group 1, 59.1% of the calves were given the first colostrum within 2 h of life, of which most were fed within 30 min after birth. In group 2, a slightly higher percentage (69.9%) of calves were fed colostrum within 2 h of life. In the same group, the lowest percentage of calves (33.7%) obtained colostrum within 30 min. In group 3, the highest percentage of calves (12.7%) obtained first colostrum after 6 h of life. In group 4, 60.0% of the calves obtained the first colostrum within 30 min of life, 86.7% before 2 h, and only 13.3% between 2 and 6 h of life. The ability of the calves to ingest colostrum early was associated with a vitality score of 3 in 63.6 to 96.4% of the calves in the respective groups (Table 1). Moreover, 88% of the newborn calves showed the highest degree of vitality. Immunoglobulin absorption is most efficient in the first few hours of life and declines rapidly after 12 h of life (Weaver et al., 2000) and it is recommended that calves be fed colostrum before 4 h of life (Beam et al., 2009).

At the first colostrum feeding, the calf should intake at least 2 L (about 5% of BW), but that was

not achieved in this herd (Table 1). In this study, the calves were fed 1.7 L of the first colostrum, which is more than that observed by Blaszkowska and Twardon (2005), where the calves consumed, on average, 1.3 L and individuals with FPT only 1.0 L. Vasseur et al. (2009) obtained different results: the calves ingested 3.3 L, and in that study only 22% of them consumed less than 2 L. The greatest individual differences in the volume of first colostrum fed occurred in the calves of group 1 (Table 1). Because the volume of voluntarily ingested colostrum depends on the willingness to suck (Vasseur et al., 2009), the relatively low amount observed in some calves was associated mostly with poor vitality. Early separation of calves from their dams and feeding an increased volume of colostrum within 6 h of birth is significantly associated with a reduced risk of FPT (Trotz-Williams et al., 2008).

The birth weights of the calves were very similar (mean: 39.8 kg; Table 1), but significantly lower than in the study by Vasseur et al. (2009), where the mean birth weight of calves was 47.7 $\pm$ 7.1 kg.

At 30 to 60 h of life, highly significant differences were observed among the groups in γ -globulin serum concentration, upon which the grouping of the calves was based. Mean γ -globulin at 21 to 28 d of life decreased by 1.9 g/L compared with the level at 30 to 60 h of life. In 10 calves that had γ -globulin concentrations <5 g/L (group 1), the sum of IgG₁, IgG₂, and IgM, determined using radial immunodiffusion, was 8 g/L. In groups 2, 3, and 4, the sum of IgG₁, IgG₂, and IgM was 10.4, 13.6, and 14.9 g/L, respectively. In group 1, increases in IgG₁ and IgG₂ were observed between the 2 sampling periods, but the IgM level remained almost unchanged. In group 2, we observed slight decreases in IgG₁ and IgM but an increase in IgG₂ (Table 2). The increase in IgG₂ before wk 5 of life is a consequence of the immune reaction to early infection caused by inappropriate protection by colostrum immunoglobulins.

Table 2. Average γ -globulin and IgG₁, IgG₂, and IgM levels (mean $\pm$ SD; g/L) in calves' serum and immunoglobulin index (I_{Ig3-4})¹ value

Parameter	Group ²			
	1	2	3	4
IgG ₁ at 30–60 h of life	6.92 $\pm$ 3.71 ^A	9.01 $\pm$ 2.75 ^a	11.42 $\pm$ 1.51 ^B	12.36 $\pm$ 2.63 ^{b,B}
IgG ₂ at 48 h of life	0.46 $\pm$ 0.70 ^{ac,A}	0.52 $\pm$ 0.38 ^{c,A}	1.18 $\pm$ 0.49 ^b	1.51 $\pm$ 0.66 ^{b,B}
IgM at 48 h of life	0.61 $\pm$ 0.30 ^{a,A}	0.81 $\pm$ 0.23	0.99 $\pm$ 0.06 ^B	0.87 $\pm$ 0.20 ^b
IgG ₁ at 21–28 d of life	7.21 $\pm$ 2.11 ^A	7.90 $\pm$ 2.08 ^A	10.37 $\pm$ 1.27 ^B	11.11 $\pm$ 1.97 ^B
IgG ₂ at 21–28 d of life	0.67 $\pm$ 0.46 ^a	0.61 $\pm$ 0.29 ^A	1.01 $\pm$ 0.27	1.39 $\pm$ 0.72 ^{b,B}
IgM (g/L) 21–28 d of life	0.62 $\pm$ 0.13	0.74 $\pm$ 0.11	0.69 $\pm$ 0.14	0.65 $\pm$ 0.14
Total γ -globulin Ig at 48 h	3.70 $\pm$ 0.71 ^A	7.44 $\pm$ 1.29 ^B	12.03 $\pm$ 1.41 ^C	16.96 $\pm$ 2.30 ^D
Total γ -globulin at 21–28 d	5.84 $\pm$ 1.58 ^{a,A}	6.45 $\pm$ 2.13 ^{a,A}	8.32 $\pm$ 2.75 ^{b,B}	10.35 $\pm$ 2.70 ^{bc,BC}
I_{Ig3-4}	1.54	0.88	0.70	0.61

^{a-c}Means within a row with different superscripts differ $P \leq 0.05$.

^{A-D}Means within a row with different superscripts differ $P \leq 0.01$.

¹The I_{Ig3-4} was calculated as the quotient of the serum Ig values in the third to fourth week of calves' lives divided by the Ig concentration in the forty-eighth hour of living. This index is a good measure of the adequacy of the calves' humoral postcolostral immunity against the present microbial threat.

²Groups 1, 2, 3, and 4 had serum immunoglobulin concentrations at birth of <5, 5–10, 10–15, and >15 g/L, respectively.

In groups 3 and 4, decreases in all the examined immunoglobulins classes were found, and this may be considered a desirable result, indicating appropriate passive protection of the calves (Nikolajczuk et al., 1994).

The immunoglobulin index (I_{Ig3-4}) may be an interesting index for predicting the health of calves in future rearing stages and for evaluating the farm's prophylactic program (Table 2). The calculated mean I_{Ig3-4} was 0.9 for all the calves examined. According to the increase of colostrum protection in the respective groups, the I_{Ig3-4} value decreased from 1.54 (group 1) to 0.61 (group 4). This result must be considered disappointing compared with the optimum value of 0.4 proposed by Nikolajczuk et al. (1994). This high value may be a consequence of the fact that 60% of the calves (groups 1 and 2) were poorly protected by colostral immunity. The I_{Ig3-4} value calculated for the calves of group 4 (0.6) may be considered as only satisfactory. Similar results were described by Kinal et al. (2004). Based on I_{Ig3-4} values, as well as on immunoglobulin class changes, we conclude that most of the calves born in this herd were influenced by FPT or PFPT of immunity and therefore started an active immune response too early.

Some important correlations between the calves' passive immunity and selected rearing parameters were found (Table 3). Serum Ig concentration at 30 to 60 h of life was highly significantly correlated with that at d 21–28 of life. It is noteworthy that a highly significant negative correlation was found between the γ -globulin concentration at 30 to 60 h and I_{Ig3-4} . The correlation coefficient between I_{Ig3-4} and gastrointestinal tract morbidity was statistically significant and indicates its high application value.

APP Levels and Health Status

The mean Fb concentration in the calves' blood plasma was initially 4.0 g/L and increased to 4.8 g/L at the second sampling (Table 4). At 30 to 60 h of life, all the calves of group 4 showed normal Fb concentrations and, in the other groups, only a few individuals had elevated levels (Ganheim et al., 2003). At 21 to 28 d of life, mean Fb levels were normal in all examined groups, and the rates of individuals showing elevated Fb levels were 18, 12, 3, and 13% in groups 1, 2, 3, and 4, respectively.

Table 3. Correlation coefficients between selected parameters

	Group	Neonatal diarrhea	Diarrhea in calf barn	Pneumonia	Ig 30–60 h	Ig 21–28 d	Ig index	Colostrum Ig
Group	1							
Neonatal diarrhea	−0.350	1						
Diarrhea in calf barn	−0.160	0.000	1					
Pneumonia	0.075	0.577	0.000	1				
Ig 30–60 h	0.908**	−0.293	−0.173	−0.311	1			
Ig 21–28 d	0.433**	0.000	−0.011	−0.103	0.471*	1		
Ig index	−0.607**	0.866	0.332*	0.279	−0.705**	0.208	1	
Colostrum Ig	0.165	0.865*	−0.138	0.158	0.296**	0.314**	−0.046	1

* $P \leq 0.05$; ** $P \leq 0.01$.

Table 4. Mean fibrinogen and haptoglobin levels (mean $\pm$ SD; g/L) in the groups of calves

Parameter	Group ¹			
	1	2	3	4
Fibrinogen				
30–60 h of life	4.32 $\pm$ 1.56	3.91 $\pm$ 1.03	4.24 $\pm$ 1.29	4.10 $\pm$ 0.89
21–28 d of life	5.47 $\pm$ 1.80 ^b	4.79 $\pm$ 1.78	4.53 $\pm$ 1.32 ^a	5.59 $\pm$ 1.65 ^b
Haptoglobin				
30–60 h of life	0.45 $\pm$ 0.96	0.21 $\pm$ 0.38	0.28 $\pm$ 0.71	0.26 $\pm$ 0.41
21–28 d of life	1.65 $\pm$ 3.53 ^b	1.04 $\pm$ 2.43	0.39 $\pm$ 1.42 ^a	0.34 $\pm$ 0.89
Haptoglobin ²				
30–60 h of life	1.08 $\pm$ 1.30	0.61 $\pm$ 0.45	0.75 $\pm$ 1.00	0.56 $\pm$ 0.44
21–28 d of life	3.67 $\pm$ 4.61	3.18 $\pm$ 3.38	1.38 $\pm$ 2.49	0.95 $\pm$ 1.37

^{a,b}Means within a row with different superscripts differ $P \leq 0.05$.

¹Groups 1, 2, 3, and 4 had serum immunoglobulin concentrations at birth of <5, 5–10, 10–15, and >15 g/L, respectively.

²Only in calves showing elevated Hp concentration (>0.1 g/L).

Increased Hp concentration (>0.1 g/L) was found in the serum of 32% of the calves at 30 to 60 h of life. Because Hp is not commonly detected in healthy cattle (Eckersall and Conner, 1988; Jawor et al., 2008), it was confusing that such a high percentage of calves showed elevated Hp levels at both 30 to 60 h and at 21 to 28 d. This indicates a very unfavorable health status of the calves on the farm. The calves were in danger of inflammation from the first hours of life because it is known that about 10 h elapses between induction of inflammation and an Hp level >0.1 g/L (Hiss et al., 2004). The highest Hp levels, as well as the highest individual differences, occurred in the calves of group 1 (Table 4). At 21 to 28 d of life, 31% of the calves showed elevated Hp levels. In groups 1 and 2, the Hp levels increased by 28 and 4%, respectively, and in groups 3 and 4, they decreased by 21 and 16%, respectively. An increase in Hp concentration is commonly related to the intensity of an inflammatory reaction (Heegaard et al., 2000). In the groups less protected by colostral immunity, higher mean Hp levels and a higher rate of individuals showing elevated Hp concentration were detected. This observation agrees with the higher intensity and frequency of respiratory and gastrointestinal tract morbidity in the calves of groups 1 and 2 (Figure 1). In the calves better protected by colostrum, elevated levels of APP occurred rarely at 30 to 60 h and 21 to 28 d of life. The concentrations of Hp, Fb, γ -globulin, and Ig classes (IgG₁, IgG₂, and IgM) at 30 to 60 h and 21 to 28 d of life may be used as prediction indices of calf health during rearing.

During the observation period, gastrointestinal or respiratory tract disease occurred in more than half of the calves. Diarrhea occurred in 36.6% of calves and respiratory tract infections were observed less frequently (13.7%). This is consistent with the results of Brun-

ning-Fann and Kaneene (1992), who found respiratory tract infections in 7 to 15% of calves. The incidence of disease differed among the groups, from 81.8% in group 1 to 26.7% in group 4. Before moving calves to the calf barn, neonatal diarrhea was observed only in the calves of groups 1 (18.2%) and 2 (6.0%). No severe course was observed. After moving the calves to group pens in the calf barn, diarrhea cases occurred in calves of all groups (Figure 1). No mild course of respiratory tract infections was observed, but, surprisingly, no cases were detected in group 4 (with Ig level >15 g/L at 30–60 h of life).

Growth Rate During Observations

No significant differences in growth rate were found in the calves during the first 6 mo of life. The average growth rate in this period was 640 g/d. In the youngest group of heifers, statistically significant differences in growth rate occurred only in mo 8 between calves in groups 2, 3, 4 and group 1 ($P \leq 0.01$), which showed the lowest rate.

Between 12 and 15 mo of life, the heifers of group 4 showed the highest growth rate. Statistically significant differences were found between groups 3 and 4 at mo 14 and between groups 1 and 4 at mo 15 of life. The heifers of group 1 showed the lowest growth rate (463 g/d) in mo 17 of life. It is noteworthy that the first heifer of group 1 was inseminated as late as age 18 mo. The mean age of the heifers at insemination was the lowest in group 4 (454 d), whereas the mean age on the farm was 471 d. The difference between the heifers of groups 4 and 1 was 30 d ($P \leq 0.01$), that between groups 4 and 2 was 14 d, and that between groups 4 and 3 was 21 d ($P \leq 0.05$). The average BW at first insemination (407 kg) was similar in all groups.

Figure 1. Rate and intensity of diseases in the groups of calves. Groups 1, 2, 3, and 4 had serum immunoglobulin concentrations at birth of <5, 5–10, 10–15, and >15 g/L, respectively.

CONCLUSIONS

The main cause of FPT and PFPT in the calves was poor vitality associated with dystocia and a low volume of ingested colostrum. The calves born to primiparous cows were more endangered than those born to multiparous cows. The morbidity and intensity of disease course were the lowest in heifer calves with serum Ig concentration exceeding 10 g/L at 30 to 60 h of life; these calves did not become ill before d 14 of life. Calves with serum γ -globulin >15 g/L avoided respiratory tract infections. Low risk of disease was confirmed by I_{Ig3-4} and APP values. Heifers with serum γ -globulin levels >10 g/L after passive transfer showed better health status and achieved BW allowing first insemination sooner.

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