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# Performance of Pre-Weaned Dairy Calves under Hot Arid Environment: Effects of Immunoglobulins and Age on Diseases and Mortality

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**Abstract: Problem statement:** A high mortality rate (crude mortality 43.6%) of pre-weaned dairy calves resulted in unavailability of replacement heifers in Kuwait. Dairy producers resorted to import pregnant heifers for herd replacement. This study was undertaken to investigate the effects of dam vaccination and age, serum Immunoglobulin (Ig) on disease syndromes and mortality in pre-weaned calves. **Approach:** Late pregnant Holstein Friesian dairy cows and heifers of five commercial dairy operations were divided into two herds: Treatment (T) vaccinated using Lactovac against *Rotavirus*, *Coronavirus* and *Escherichia coli* and Control (C) unvaccinated herds. Total of 1,088 newborn calves of above herds were also divided as T and C for studies from their birth to weaning at 90 days. Calves weighed at birth, fed colostrum, serum proteins and Ig (IgG, IgM and IgA) were determined; disease syndromes, morbidity and mortality rates were investigated. **Results:** Mean birth weight (34.25±SE 0.21 kg) of calves did not differ significantly ($p<0.01$) between treatments. Crude mortality rates differed significantly ($p<0.01$) ranging from 2.83-22.83% in calves among herds. Highly significant differences were observed in Ig classes of blood serum of calves: IgG (F 3.47 $p<0.010$), IgM (F 3.52 $p<0.009$) and IgA (F 3.66 $p<0.008$). The effects of Ig levels on calf morbidity rates were significant ($p<0.05$) on three disease syndromes: pneumonia, diarrhea and pneumo-enteritis. Vaccination of pregnant dams and oral administration of antibodies to newborn calves reduced calf morbidity and mortality rates. Major disease syndromes were pneumo-enteritis (34.6%) and pneumonia (33.8%). Younger calves were greatly affected by these diseases. **Conclusion:** Inadequate levels of passive immunity of young calves were commonly found in Kuwait's farms. This study demonstrated the importance of passive immunity of calves by ensuring adequate levels of serum Ig and protein levels.

**Key words:** Dairy calves, mortality, morbidity, colostrum, immunoglobulin

## INTRODUCTION

Kuwait's total dairy cattle of 27,000 in 33 commercial farms are managed under intensive system (zero grazing). Crude mortality rate of pre-weaned calves ranged from 10-90% (mean 43.6%) in some of the dairy farms of Kuwait due to acute diarrhea, dehydration, septicemia, enteritis and pneumonia[19] in arid environment of Kuwait.

Updated data of the magnitude of calf losses due to morbidity and mortality of commercial operations for many countries are scarce, yet these statistics are vital for viable dairy enterprises. Recently, Ortiz-Pelaez *et al.*[15] assessed calf mortality rates in Great Britain and found regional differences with a mean of 12%. Earlier, United States National Dairy Heifer Evaluation Project reported a mean death loss of 8.4±SD 0.4% of pre-weaned heifers[29]. Silva *et al*.[25] found that mortality rate in twin birth was higher (28.2%) than single birth (7.2%) in USA. They reported that prenatal early embryonic loss was up to 40%, later embryo loss up to 20% and abortion 5%. The most common cause of disease and death of calves in Kuwait's dairy herds was diarrhea followed by pneumonia[21]. Losinger and Heinrichs[11] found that pre-weaned calf death loss was 9.4%. Previously, a number of researchers had found that management, feeding and environmental factors were associated with calf mortality[3,4].

The beneficial effects of dam vaccination for passive transfer of antibodies to the newborn calves through the colostrum feeding were observed[24]. The effectiveness of the passive transfer of Ig depends on the volume of

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colostrum given to the calves and concentration of Ig in the colostrum[31]. Timing of colostrum administration and immune status of calves were found to be closely related to morbidity and mortality rates in young calves[23,28]. Suh *et al*.[26] observed that serum levels of Ig classes (IgG, IgM and IgA) reached its peak 24 h after birth in calves and remained constant till 8 d of age. Orro *et al*.[14] found that there was a dynamic change of serum protein in new born calves that could reflect the passive immunity status. The objectives of this study were to examine the effects of dam vaccination, dam related factors and serum Ig levels on mortality and morbidity of pre-weaned calves.

## MATERIALS AND METHODS

**Study location and climate:** The dairy farms were located in Sulaibiya, a Government assigned area, 25 km northwest of Kuwait city. Summer months are June, July, August and part of September. Summer season is mostly dry, Relative Humidity (RH) not exceeding 30%, with extremely hot temperatures exceeding 48°C. After last part of July, temperature reaches 50°C for 1-2 weeks with dry air. RH increases after mid August and September reaching over 90%. Temperatures start to decrease by the end of August reaching 40-43°C during the first half of September. Autumn season extends over October to November and temperature decreases to 30°C throughout October and 20°C in November. Winter season extends from December to February and part of March. In this season temperature reaches as low as -4°C and high temperatures 10-19°C at night and day respectively. Spring season covers part of March, April and May with temperatures reaching 20-30°C[18].

**Calving area:** Separate maternity facilities were provided to cows which were due for calving, allowing 5 cows with space of 20 $m^2$ of area/cow. Clean desert sands were used as bedding materials.

**Experimental calves:** Five commercial dairy herds representing 2 large, 2 medium and 3 small farms were used. A total of 1,150 late pregnant Holstein Friesian dairy cows and heifers were divided into two groups in each of the five farms. Treatment (T) herd was vaccinated using Lactovac against *Rotavirus*, *Coronavirus* and *Escherichia coli* and Control herds (C) remained unvaccinated. Total 1,088 newborn calves obtained from both T and C of ages from birth to weaning at 90 day were under investigation. Calves received colostrum at a level of 10-15% of their body weight within the first eight hrs of birth, not beyond 24 h and transferred to the clean calf rearing units. Details of dam information, sex of calves and treatment provided were recorded[20].

**Age group of calves:** Five age groups included were 0-7, 8-14, 15-30, 31-60 and 61-90 day for examining the disease occurrences. Only one occurrence of a specified syndrome in a defined time period was considered for calculation of an incidence rate; any second or further occurrences of the same syndrome in a time period were ignored. Total number of calves at risk was derived from the following: Calf-day totals (with one calf-day representing the presence of a calf for 1 day). A calf no longer contributed to calf days when it left the calf group-either through death or by attaining the age of 90 day (no calves were recorded as having been sold during the study). The mean number of calves present, being the average of the number present at the beginning of an age period and the number present at the end of the age period[12,27].In calculating risk rates the denominators were taken as the number of calves that either died or survived for the entire 90 day period.

**Biochemical studies:** About 10 mL blood samples were collected from 24-36 h old calves into tubes, allowed to coagulate, clear serum was obtained by centrifugation at $1,500 \times$ g for 15 min and stored at -70°C. Total serum protein concentration was determined by refractometer (Serum Protein Refractometer SPR-NE for a scale of 0-12 g/100 mL and reflective index scale of 1.33-1.360 from Atago Co. Ltd., Japan). Serum IgG, IgM and IgA concentrations were determined by the Radial Immuno Diffusion (RID) method[8,23].

**Disease diagnosis:** The calves found to be off feed, coughing, elevated temperatures, diarrhea and other ailments were identified, isolated and administered intravenous electrolytes[6]. Data of disease occurrence, clinical symptoms, disease suspicion, recoveries, deaths and post-mortem findings were collected.

**Calf management criteria:** Criteria for scoring the calf management and housing, hygiene, feeding data to assess the overall performance of the calves on the surveyed farms were developed[30].

**Data analysis:** Data were analyzed according to Ross and Payne[16]. Chi-square was used to test for differences in proportions of calves that died or were clinically affected by a specified syndrome.

## RESULTS

**Mortality rates:** The true mortality rates for calves ranged from 2.83 and 15.87% (Table 1). Herd 3 had exceptionally low mortality rates showing high quality management of young calves. A total of 961 calves were weaned representing 88.32% of the total calves born in both sexes. It is quite clear (Fig. 1) that the calving rate increased sharply in August, reaching a peak in October thereafter, declined quite sharply in November. Overall ratio of male-to-female calves was 1:1 (Table 2). However, herd-wise ratios were slightly different than the overall ratio, as was expected.

**Effect of dam vaccination:** Selected factors affecting the mortality of calves were investigated by dichotomizing these factors, using the chi-square test. Birth weights of calves and dam parity had no significant effect on calf mortality (Table 3). Vaccination of pregnant dams and administration of Ig to newborn calves resulted in a significant reduction ($p<0.05$) of calf morbidity and mortality rates.

**Serum proteins and immunoglobulin of calf serum deleted:** A farm-wise distribution of the concentration of total serum proteins of 776 samples are shown in Table 4. Mean total serum protein concentration ranged between 4.47 and 5.26 g $dL^{-1}$. However, serum protein concentration was as low as 2.4 g $dL^{-1}$ and as high as 9.2 g $dL^{-1}$. Relatively low values of all classes of Ig were observed indicating fairly low passive immunity status in young calves. Ig classes of five farms are given in Table 5 showing the herd differences were quite clear and had statistical significance ($p<0.05$).

**Immunoglobulin and morbidity:** Significant effects of Ig levels ($p<0.05$) on morbidity rates were observed for three disease syndromes: Pneumonia, diarrhea and pneumo-enteritis and five age groups 0-7, 8-14, 15-30, 31-60 and 61-90 day of calves (Table 6). The results indicate significantly high incidences of pneumonia and pneumo-enteritis at the age of 1-7 day compared to other age groups due to low serum concentrations of all classes of Ig.

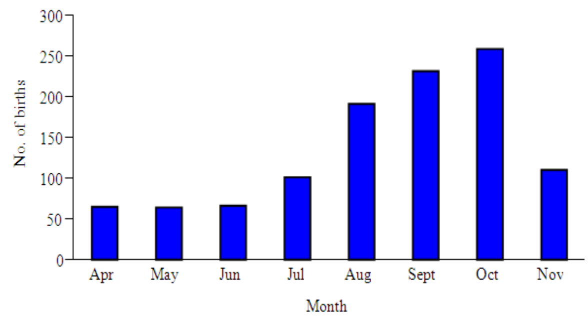


Fig. 1: Seasonality of calving

Table 1: Numbers of births, deaths and calves weaned by herds

| Parameter | Herd No. 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| [a]herd size | Small | Large | Small | Large | Medium | Total |
| At start of period | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Births | 52.00 | 363.00 | 120.00 | 323.00 | 230.00 | 1088.00 |
| Deaths | 7.00 | 35.00 | 3.00 | 60.00 | 22.00 | 127.00 |
| Weaned at end of period | 45.00 | 328.00 | 117.00 | 263.00 | 208.00 | 961.00 |
| Calf-days | 3,969.00 | 25,307.00 | 9,527.00 | 23,649.00 | 15,848.00 | 78,300.00 |
| 90 day mortality rate (%) | 15.87 | 12.44 | 2.83 | 22.83 | 12.49 | 14.59 |

[a]: Total Herd size (No. of cattle of all categories in the herds No. 1-5); 1: Small: 215, 2: Large: 600, 3: Small: 250, 4: Large: 550, 5: Medium: 450

Table 2: Distribution of calves by sex and parity of dam by herd

| Sex | Herd No. 1 | 2 | 3 | 4 | 5 | Total |
|---|---|---|---|---|---|---|
| Male | 25 | 185 | 59 | 158 | 117 | 544 |
| Female | 27 | 178 | 61 | 165 | 113 | 544 |
| Total | 52 | 363 | 120 | 323 | 230 | 1088 |
| **Dam parity** | | | | | | |
| No data[a] | 0 | 11 | 1 | 0 | 96 | 108 |
| 1 | 50 | 321 | 118 | 305 | 134 | 928 |
| 2 | 0 | 5 | 1 | 5 | 0 | 11 |
| 3 | 2 | 26 | 0 | 13 | 0 | 41 |
| Total | 52 | 363 | 120 | 323 | 230 | 1088 |

[a]: Complete records of dam parity were unavailable

Table 3: Effects of dam parity and vaccination on birth weight of calves

| Fate | Dam parity 1 | >1 | Total | Dam vaccinated No | Yes | Birth weight Total 133 | category ≤Mean 43.24 Kg | >mean 34.25 Kg | Total |
|---|---|---|---|---|---|---|---|---|---|
| Died | 110.0 | 8.0 | 118.0 | 46.0 | 87.0 | 133.0 | 61.0 | 66.0 | 127 |
| Survived | 816.0 | 44.0 | 860.0 | 311.0 | 633.0 | 944.0 | 445.0 | 469.0 | 914 |
| Total | 926.0 | 52.0 | 978.0 | 357.0 | 720.0 | 1077.0 | 506.0 | 535.0 | 1041 |
| Proportions | 11.9[a] | 15.4[a] | 12.1[a] | 12.8[a] | 12.1[a] | 12.3[a] | 11.9[a] | 12.3[a] | |

[a]: No significant difference

Table 4: Summary of serum Ig (mg $dL^{-1}$) and total protein concentrations

| Antibody class all farms | No. of observations | Range | Mean | SE |
|---|---|---|---|---|
| **Overall serum Ig classes** | | | | |
| IgG | 123 | 390-10,000 | 2,897.3 | 199.2 |
| IgM | 193 | 44-940 | 163.1 | 8.9 |
| IgA | 116 | 30-540 | 87.1 | 7.2 |
| **Farm wise serum protein concentrations (mg $dL^{-1}$)** | | | | |
| Farm no. | | | | |
| 1 | 15 | 3.0-7.0 | 4.78 | 0.27 |
| 2 | 284 | 3.4-9.2 | 5.26 | 0.06 |
| 3 | 84 | 2.6-4.5 | 4.54 | 0.11 |
| 4 | 278 | 3.0-8.2 | 5.03 | 0.54 |
| 5 | 115 | 2.4-6.4 | 4.47 | 0.07 |
| Total | 776 | 2.4-9.2 | 4.97 | 0.03 |

Table 5: Serum immunoglobulin concentrations (mg $dL^{-1}$) of calves by dairy herd (Mean ± SE)

| Antibody | Dairy herd number | | | | | | |
|---|---|---|---|---|---|---|---|
| class | 1 | 2 | 3 | 4 | 5 | Total | Total (%) |
| IgG | 1,310.0±311.0 (5) | 3,385.9±354.9 (49) | 4,094.7±1,012.9 (13) | 2,477.6±217.0 (36) | 2,074.2±199.9 (20) | 2,897.3±199.2 (123) | 92.06 |
| IgM | 110.7±9.0 (35) | 172.3±12.9 (79) | 227.9±43.2 (20) | 166.1±18.1 (52) | 110.7±9.0 (35) | 163.1±8.9 (193) | 5.18 |
| IgA | 52.4±7.2 (5) | 94.4±12.2 (47) | 159.4±47.1 (10) | 78.8±8.3 (36) | 54.2±4.0 (18) | 87.0±7.2 (116) | 2.76 |
| Total | 1473.1 | 3,652.60 | 4,482 | 2722.5 | 2,239.1 | 3147.4 | 100.00 |

SE: Standard Error, ( ) in parentheses: Number of observations. Means with different superscript (a, b, c, d) of each row are significantly different. IgG at p≤0.01, IgM at p≤0.09 and IgA p≤0.08

Table 6: Statistically significant differences between morbidity rates by immunoglobulin class and age group

| Immunoglobulin class | Syndrome | Age group (d) | $P_1$-incidence (%) at low Ig levels | $P_2$-incidence (%) at high Ig levels | Significance level (%) | $P_1$-$P_2$ risk difference |
|---|---|---|---|---|---|---|
| IgM | Pneumonia | 61-90 | 12.60 | 4.9 | 1.9 | 7.700 |
| | Pneumo-enteritis | 1-7 | 34.30 | 12.9 | 0.2 | 21.400 |
| | Pneumo-enteritis | 61-90 | 9.14 | 1.0 | 0.1 | 8.140 |
| IgA | Pneumonia | 61-90 | 23.10 | 2.7 | 0.0 | 20.400 |
| | Pneumo-enteritis | 1-7 | 36.10 | 13.3 | 3.5 | 22.800 |
| | Pneumo-enteritis | 61-90 | 13.50 | 1.0 | 0.0 | 12.500 |
| IgG | Pneumonia | 15-30 | 31.10 | 11.9 | 2.5 | 19.200 |
| | Pneumo-enteritis | 1-7 | 50.00 | 7.8 | 0.0 | 42.200 |
| | Pneumo-enteritis | 61-90 | 9.00 | 2.1 | 4.1 | 6.900 |

## DISCUSSION

Herd Size and Housing. The number of calves born in different farms were in the order of farm numbers 2 = 363>4 = 323>5 = 230>2 = 120>1 = 52, the corresponding total dairy herd sizes were 600, 550, 450, 250 and 215 respectively. Dairy herd sizes had no significant effect on calf mortality rates. Low feeding and housing scores were associated with a high mortality rate in calves. (Sqi-squared statistics for feeding 11.15, p = 0.0008 and for housing 19.16, p = 0.0000) (Table not presented). Recently, it was observed that mortality rates in pre-weaned calves were reduced and daily live weight gain of Holstein Friesian calves increased significantly when they were housed in open environment with well ventilated calf hutches compared to confinement crate housing[22]. Quigley *et al*.[2,7,17] found that timely colostrum feeding and naturally ventilated calf housing had a significant positive impact on feed intake, growth rate and survivals of young calves. Our present studies confirmed above findings. Pre-weaned calves exposed to an extremely hot (45-48°C) weather in summer and cool (-4°C) night in winter in Kuwait, were found to have performed significantly better in hutches than conventional confined housing[22].

**Calving pattern:** Uniform patterns of the calving rates were not applicable to all farms of Kuwait (Fig. 1) because of the differences in the introduction of pregnant heifers to the herds by importation from abroad. However, the findings are very valuable for the selection process of heifers for breeding and rearing purposes. These findings are consistent with the previous studies carried from the years 1998-2000[19].

**Sex of calves and dam parity:** The vast majority of calves (85%) in the study were the first parity heifer dams (Table 2). The present findings are consistent with several studies carried out by Roy[9,19,23]. This was presumably a function of the very short productive life of dairy cows (average 2.3 lactations) in Kuwait. Introduction of new pregnant heifers to the herds from abroad is a general practice in Kuwait; therefore, these dam parity results were expected.

**Serum immunoglobulins and proteins:** In our studies, three types of antibodies that identify and destroy disease causing organisms in calves were determined (Table 4). Lang[10] found that major Ig classes IgG, IgM and IgA represented 85-90, 5-10 and 5-10% of the total Ig in the colostrum. Our studies showed that 92.18, 5.18 and 2.76% of the total Ig were represented by IgG, IgM and IgA respectively (Table 5) in serum. In our study, the calves which had not received any colostrum within 12 h of birth, it was unlikely that they would be able to absorb antibodies for achieving adequate passive immunity[10].

Present study showed that variations between dairy farms in passive immunity status of calves were quite large (Table 5). On average, 50% of the total calves had an acceptable levels of IgG in serum. Twenty five percent of the total calves had Partial Failure of Passive Transfer (PFPT) of IgG and the remaining 25% had Failure of Passive Transfer (FPT) of IgG in calves (Table not presented). In earlier publications, surveys conducted by several researchers correlated the percentage of sick and dying calves with their IgG concentrations and indicated amounts below 800 mg/100 mL were Failure of Passive Transfer (FPT) and 800-1600 mg/100 mL were partial failure of passive transfer of antibodies (PFPT)[13]. Recommended concentration of total IgG in calf serum was above 1600 mg $dL^{-1}$[13].

Due to uncertainty in intake of maternal colostrum naturally and risk of transmission of diseases from the dams to calves, collection and hand feeding of either fresh or stored (frozen) colostrum was highly recommended by USDA's National Animal Health Monitoring System (NAHMS) as the cow colostrum is the only source of antibodies for newborn calves[1]. In our studies new born calves were separated from their dams immediately and fed colostrum by hand. However, in case of night delivery of cows, delay in feeding colostrum to calves might have resulted in inadequate passive immunity status as revealed from lower levels of IgG in serum. Farm 3 calves had high concentration of all classes of Ig and lower mortality rate in calves (Table 1 and 5). Serum protein levels below 5 g $dL^{-1}$ are considered to be an indicative of inadequate immunity status of calves[5,8].

**Immunoglobulin and morbidity:** It was found that a low concentration of IgG in serum was shown to be a good indicator of the immunity status of calves. However, other classes of Ig i.e., IgM and IgA also served as indicators of the rates of entero-pneumonia and pneumonia in calves. Similar findings were reported by Roy[23].

## CONCLUSION

Vaccination of dams and administration of colostrum to calves resulted in reduction of calf morbidity and mortality rates. This study demonstrated significance of ensuring on time colostrum feeding to newborn calves for obtaining adequate levels of all Ig classes (IgG, IgM and IgA) in their serum.

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