Electrolyte Status and Fecal Consistency in Newborn Calves

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ABSTRACT : In order to evaluate the change in plasma and fecal mineral content of calves to 6 days of age, and to clarify the relationship between electrolyte status and fecal consistency in calves at 6 days of age, data were collected from 52 Holstein calves. Fecal DM and Na of calves decreased at 6 days of age, but fecal Ca, P, Mg, K, Fe and Zn increased. Plasma Ca, inorganic P, Mg, Na, and Fe as well as blood hematocrit and hemoglobin of calves decreased at 6 days of age, but plasma alkaline phosphatase increased. Colostral Ca, P, Mg, Fe and Zn decreased with time postpartum, but colostral Na and K were not affected. The high plasma Na and K of calves at 6 days of age were influenced by the values at birth. There were negative correlations between fecal DM and fecal Na, and fecal K, of calves at 6 days of age, negative correlations between fecal DM and plasma Na, with plasma K. Plasma and fecal Na as well as plasma and fecal K of calves at 6 days of age were increased by the occurrence of diarrhea. These results suggest that the electrolyte status of calves at 6 days of age is adversely affected by the occurrence of diarrhea, and high plasma K and Na of calves at 6 days of age may be partly due to the electolyte status of calves at birth. ***(Asian-Aust. J. Anim. Sci. 2001. Vol. 14, No. 5 : 640-645)***

Key Words : Diarrhea, Electrolyte, Newborn Calves

INTRODUCTION

Mortality and morbidity of newborn calves continue to be major problems in dairy farms, and the most common disease among the calves is a diarrhea. The four major abnormalities or disturbances that can usually be identified in diarrhetic calves are dehydration, acidemia, electrolyte abnormalities, and negative energy balance or hypoglycemia (Roussel and Kasari, 1990). Fluid and electrolyte therapy in diarrhetic calves is one of the most rewarding and successful treatments available to veterinarians. Typical electrolyte disturbances in diarrhetic calves include a total body deficit of Na, Cl and K, and these electrolytes are lost primarily through the feces (Roussel and Kasari, 1990).

Successful calf health depends on many factors related to the management and nutrition, and the importance of consumption of an adequate amount of colostrum on acquisition of passive immunity is widely recognized (Quigley and Drewry, 1998). However, the disease resistance acquired from colostrum Ig is only temporary, and the newborn calves must become immunocompetent before passive maternal immunity wanes (Rajala and Castren, 1995). In addition to the colostral Ig, colostrum is a source of immune components and nutrients to the neonates and contains more protein, fat, vitamins and minerals than does milk. Kume and Toharmat (2001) reported that β-carotene status of calves at 6 days of age is dependent on colostrum concentrations of β-carotene and affects the occurrence of diarrhea.

Mineral status of newborn calves depends not only on mineral intake from colostrum but also on placental mineral transfer from the dam during gestation (Kume and Tanabe, 1993). Fecal score is commonly used as an indicator of diarrhea, but fecal composition of diarrhetic calves has not been well clarified. Kume et al. (1998) reported that mineral concentrations in plasma and meconium may be indicators of mineral status of newborn calves and the assessment for the relationship between mineral status and fecal mineral of newborn calves is necessary to maintain the health status of calves immediately after birth. The present study was conducted to evaluate the change in plasma and fecal mineral contents in calves to 6 days of age and to clarify the relationship between electrolyte status and fecal consistency in newborn calves.

MATERIALS AND METHODS

Data from 31 Holstein female and 21 male calves were collected at the National Institute of Animal Industry (Tsukuba, Japan) from March 1995 to March 1997. Calves consisted of 5 pairs of twins and 42 single calves. The BW at birth of calves was 41.7± 6.4 kg (mean±SD). The dams were given 3 to 4 kg/d of concentrate and appropriate amounts of silage and hay from Italian ryegrass on a fixed basis in individual tie stalls to meet recommendations (Agriculture, Forestry, and Fisheries Research Council Secretariat, 1994) for TDN, protein and minerals. The concentrate mix was barley, corn, milo and wheat bran. Calves were separated from the dams at birth and housed in individual pens. Each calf received

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approximately 1 kg of colostrum at parturition and, thereafter, 2.5 kg of colostrum at 0900 and 1600 h daily from its dam's fresh colostrum for 1 wk postpartum.

Blood samples from calves were collected at birth and at 0830 h at 6 days of age. At birth, blood samples were taken within 12 h after birth. Blood was sampled via jugular vein puncture into heparinized vacuum tubes. Fecal grab samples of calves were taken from rectum within 12 h after birth and at 6 days of age. Rectal temperature of the calves was measured by a clinical thermometer at birth and at 0830 h at 6 days of age. Colostrum samples from dams were collected at parturition and 96 h after parturition.

Blood hematocrit (Hct) and hemoglobin (Hb) were determined by centrifugation of heparinized blood in Hct tubes and sodium lauryl sulfate method, respectively (Kume and Tanabe, 1993). Plasma Ca, Mg, Na, K, Fe and Zn concentrations were determined by atomic absorption spectrophotometry, and plasma inorganic P (Pi) and alkaline phosphatase were determined colorimetrically (Kume and Tanabe, 1993, 1996). Fecal samples were dried and ground in a stainless steel mill. After fecal and colostrum samples were digested in nitric and perchloric acid, Ca, Mg, Na, K, Fe and Zn concentrations in samples were determined by atomic absorption spectrophotometry and P was determined colorimetrically (Kume and Tanabe, 1993; Kume et al., 1998).

The general linear models procedure of SAS (1988) was used to analyze the effect of time or the occurrence of diarrhea on fecal and plasma composition of calves and colostrum composition of dams. An ANOVA was performed, and the differences were tested by least significant difference. Relationships between fecal DM and other components in feces and plasma were determined by regression analysis, because fecal DM was not affected by calf sex and twinning. Significance was declared at $p<0.05$.

RESULTS AND DISCUSSION

Changes in fecal and plasma composition of calves

Fecal and plasma composition of calves varied with days of age (table 1). Rectal temperatures ($p<0.001$) increased at 6 days of age. Fecal DM ($p<0.001$) and Na ($p<0.001$) decreased at 6 days of age, but fecal Ca ($p<0.001$), P ($p<0.001$), Mg ($p<0.001$), K ($p<0.001$), Fe ($p<0.001$) and Zn ($p<0.05$) increased. In the fecal composition, there was a positive correlation between fecal P at birth and 6

Table 1. Least squares means and SD of fecal and blood minerals of 52 calves at birth and 6 days of age

	Age (d)				Age effect
	0		6		
	X	SD	X	SD	
Rectal temperatures, ℃	38.6	0.8	39.2	0.5	***
Feces[1]					
DM, %	34.8	5.6	24.1	6.1	***
Ca, mg/100 g	317	148	808	343	***
P, mg/100 g	45	22	349	159	***
Mg, mg/100 g	4	2	125	111	***
Na, mg/100 g	681	165	497	319	***
K, mg/100 g	167	137	515	231	***
Fe, ppm	14	14	296	174	***
Zn, ppm	158	46	215	156	*
Blood					
Hct, %	38.9	6.9	31.4	5.9	***
Hb, g/dl	11.5	2.2	9.8	2.0	***
Plasma					
Ca, mg/dl	12.2	1.0	11.8	0.7	*
Inorganic P, mg/dl	9.3	1.7	8.6	0.8	*
Mg, mg/dl	2.14	0.30	1.89	0.17	***
Na, mg/dl	334	24	324	24	*
K, mg/dl	20.6	2.3	20.6	2.2	NS
Fe, ppm	1.54	0.61	0.85	0.80	***
Zn, ppm	1.02	0.38	1.14	0.31	NS
Alkaline phosphatase, IU	148	72	189	71	**

* $p<0.05$. ** $p<0.01$ *** $p<0.001$.

[1] DM basis.

Table 2. Least squares means and SD of milk composition of 46 cows at parturition and 96 h postpartum

	Hours postpartum				Time effect
	0		96		
	X	SD	X	SD	
Milk yield, kg	1.7	0.9	12.5	2.9	***
Composition					
Ca, mg/100 g	216	51	132	13	***
P, mg /100 g	194	41	116	11	***
Mg, mg/ 100 g	38.1	11.4	11.6	1.4	***
Na, mg/100 g	52	15	46	12	NS
K, mg/100 g	168	26	172	20	NS
Fe, ppm	2.0	0.9	0.9	0.4	***
Zn, ppm	22.6	6.4	5.3	1.1	***

*** $p<0.001$.

days of age ($r=0.417$; $p<0.01$).

Blood Hct ($p<0.001$) and Hb ($p<0.001$) of calves decreased at 6 days of age, and there were positive correlations between the values for blood Hct ($r=0.827$; $p<0.001$) and for Hb ($r=0.810$; $p<0.001$) at birth and those at 6 days of age. Plasma Ca ($p<0.05$) and Pi ($p<0.05$) decreased at 6 days of age, and positive correlations were observed between the values for plasma Ca ($r=0.423$; $p<0.01$) and Pi ($r=0.412$; $p<0.01$) at birth and those at 6 days of age. Plasma Mg ($p<0.001$) decreased at 6 days of age, and there was positive correlation between plasma Mg at birth and 6 days of age ($r=0.417$; $p<0.01$). Plasma Na ($p<0.05$) and Fe ($p<0.001$) decreased at 6 days of age, and positive correlations were observed between the values for plasma Na ($r=0.749$; $p<0.001$) and Fe ($r=0.461$; $p<0.001$) at birth and those at 6 days of age. There were positive correlations between the values for plasma K ($r=0.606$; $p<0.001$) and Zn ($r=0.380$; $p<0.01$) at birth and at 6 days of age. Plasma alkaline phosphatase ($p<0.01$) increased at 6 days of age. Colostral Ca ($p<0.001$), P ($p<0.001$), Mg ($p<0.001$), Fe ($p<0.001$) and Zn ($p<0.001$) decreased with time postpartum, but there were no significant differences between sampling days in colostral Na and K (table 2).

Storage of minerals in fetal tissue reflects fetal demands for growth and the ability of the dam to transfer minerals (Abdelrahman and Kinkaid, 1993), and mineral excretion into meconium is the endogenous loss in fetal mineral at birth (Kume et al., 1998). In the present study, fecal Mg, Fe and P of calves were low at birth and increased greatly at 6 days of age. Kume and Tanabe (1996) reported that Fe-deficiency anemia often developed in calves at birth and normal development of erythropoiesis was needed to prevent high mortality in anemic newborn calves. The extremely low value of meconium Fe at birth was due to the efficient shift in the Fe storage of dams to blood Hb of newborn calves (Kume and Toharmat, 2001). Thus, fetal P and Mg as well as Fe may be efficiently utilized for the maintenance of calf health immediately after birth.

Adequate mineral intakes from colostrum and placental mineral transfer from the dam during gestation are important for newborn calves to maintain the optimum mineral status after birth (Kume and Tanabe, 1993). The low plasma Ca, Pi, Mg, Na, K, Fe and Zn of calves at 6 days of age were influenced by the low values at birth in the present study. Although colostrum is the main source of minerals for newborn calves after birth, the low concentrations of plasma minerals may be partly defined as the mineral status at birth. However, the availability or metabolism of minerals may vary due to the needs of the calves after birth, because the changes of meconium and plasma mineral concentrations of calves differed. Further study is needed to evaluate the role of minerals for proper calf nutrition and health.

Relationship between electrolyte status and fecal consistency in calves

Negative correlations were observed between fecal DM and fecal Na ($r=-0.689$; $p<0.001$), and with fecal K ($r=-0.655$; $p<0.001$), of calves at 6 days of age (figure 1). Negative correlations were observed between fecal DM and plasma Na ($r=-0.287$; $p<0.05$), and plasma K ($r=-0.424$; $p<0.01$), of calves at 6 days of age (figure 2). Also, plasma Na and K at birth were highly correlated ($p<0.001$) with those at 6 days of age (figure 3).

The measurement of serum electrolyte concentrations provides an accurate assessment of the ionic composition of the extracellular fluid, and electrolyte status of calves is a factor for the incidence of diarrhea (Roussel and Kasari, 1990). Scours of calves are common at 5 days to 3 weeks of age and then the incidence declines (Nocek et al., 1984; Quigley et

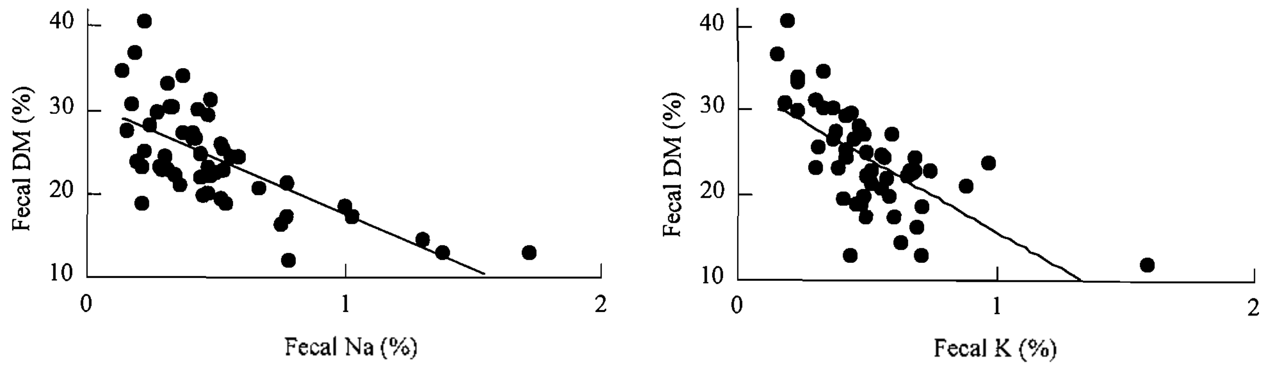

Figure 1. Relationships between fecal Na and K and the fecal DM of calves at 6 days of age. Regression equations of fecal DM (Y) on fecal Na (Xna) or K (Xk) were as follows:
$Y=-13.2^{***}Xna+30.7^{***}$; $Y=-17.2^{***}Xk+33.0^{***}$ (*** $p<0.001$).

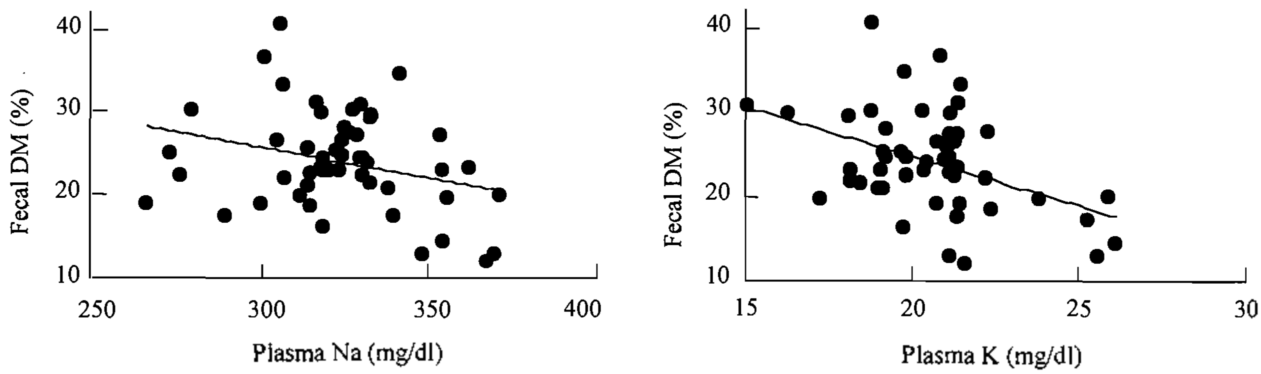

Figure 2. Relationships between plasma Na and K and the fecal DM of calves at 6 days of age. Regression equations of fecal DM (Y) on plasma Na (Xna) or K (Xk) were as follows:
$Y=-0.073^{*}Xna+47.5^{***}$; $Y=-1.166^{**}Xk+48.0^{***}$ (* $p<0.05$, ** $p<0.01$, *** $p<0.001$)

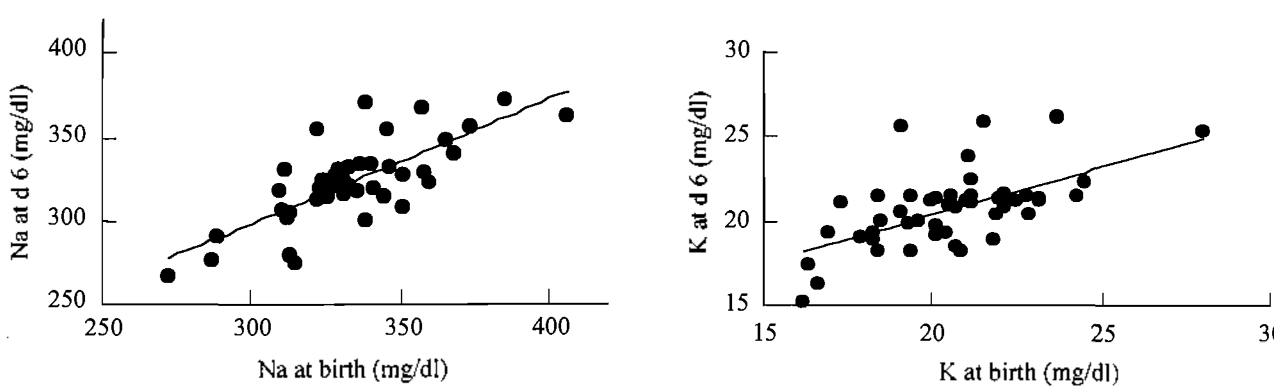

Figure 3. Relationships between plasma Na and K of calves at birth with those at 6 days of age. Regression equations of plasma Na (Yna6) or K (Yk6) at d 6 of age on plasma Na (XnaO) or K (XkO) at birth were as follows: $Yna6=0.74^{***}XnaO+75.0^{*}$; $Yk6=0.58^{***}XkO+8.8^{***}$ (* $p<0.05$, *** $p<0.001$).

al., 1995; Quigley and Drewry, 1998). Severe diarrhetic feces of calves contain more than 85% moisture, and feces that contain less than 80% moisture appear to be normal (Abe et al., 1999). In the present study, feces of the calves that contained more than 20% DM, from 20 to 15% DM and less than 15% DM 6 days of age were termed normal (n=39), subclinical diarrhea (n=9), and diarrhea (n=4), respectively. However, 51 calves had more than 20% of fecal DM and only one calf was termed subclinical diarrhea at birth.

Fecal Na concentration of calves at 6 days of age increased ($p<0.05$) with decreasing fecal DM, and fecal Na of the diarrhetic calves was 3.4 times higher than that of the normal calves (table 3). Fecal K concentration of the diarrhetic calves was higher ($p<0.05$) than that of the normal and subclinical diarrhetic calves. Plasma Na concentration of the diarrhetic calves was higher ($p<0.05$) than that of the normal and subclinical diarrhetic calves. Plasma K concentration of the diarrhetic and subclinical diarrhetic calves was higher ($p<0.05$) than that of the normal calves.

Sodium and Cl are mainly present in the extracellular fluid, and K is in the intracellular fluid. Calves with diarrhea are often treated with electrolytes and metabolic acidosis occurs frequently in diarrhetic calves because of the loss of bicarbonate in the feces (Garthwaite et al., 1994; Roussel and Kasari, 1990). Garthwaite et al. (1994) reported that diarrhetic calves have an increase in serum K concentration due to the acidosis, but low serum Na was attributed to the effects of fluid loss. Potassium ions diffuse into the extracellular fluid space in order to maintain electroneutrality, and intracellular fluid K and total body K contents are decreased because of fecal loss and renal excretion (Roussel and Kasari, 1990). In the present study, the increases in plasma K were reflected by the rapid loss of K in feces, because plasma and fecal K of the diarrhetic calves were higher than those of the normal calves. Also, the high plasma Na in the diarrhetic calves at 6 days of age may be due to the large loss of Na in feces. Additionally, the high plasma K and Na of calves at 6 days of age reflected the high values at birth. Thus, the electrolyte status of calves at 6 days of age is adversely affected by the occurrence of diarrhea, and high plasma K and Na of calves at 6 days of age may be partly due to the electolyte status of calves at birth, although the diarrhea did not occur in calves at birth.

Table 3. Least squares means (SE) of fecal and plasma electrolyte of 52 calves at 6 days of age

	Calves		
	Normal[1]	Subclinical diarrhea[2]	Diarrhea[3]
n	39	9	4
Feces (DM basis)			
DM, %	26.6 (0.7)[a]	18.4 (1.4)[b]	12.9 (2.1)[c]
Na, mg/100 g	0.38 (0.03)[c]	0.64 (0.06)[b]	1.30 (0.10)[a]
K, mg/100 g	0.47 (0.03)[b]	0.55 (0.07)[b]	0.85 (0.11)[a]
Plasma			
Na, mg/dl	321.3 (3.5)[b]	318.7 (7.1)[b]	360.0 (10.7)[a]
K, mg/dl	20.0 (0.3)[b]	22.0 (0.6)[a]	23.6(0.9)[a]

[1] Calves contained more than 20 % of fecal DM.

[2] Calves contained from 20 to 15% of fecal DM.

[3] Calves contained lessb than 15% of fecal DM.

[a,b,c] Means within same row with different superscript letters differ ($p<0.05$).

The responses of rectal temperatures should reflect the influence of invading pathogens, but not all diarrhea-causing organisms elicit an elevated rectal temperature (Garthwaite et al., 1994). Packed cell volumes are easily accessible data that can be used to estimate the relative state of hydration of most animals, but the packed cell volume of healthy one-week-old calves is highly variable, ranging from 22 to 45 % (Roussel and Kasari, 1990). In the present study, there were no significant correlations between fecal DM and rectal temperature or blood Hct of calves at 6 days of age.

Plasma and fecal Na as well as plasma and fecal K of calves are increased by the occurrence of diarrhea, but it is not clear whether the electrolyte status of dams affects the diarrhea of calves. The assessment of the relationship between the incidence of diarrhea and nutritional status of newborn calves and their dams is necessary to maintain the calf health after birth.

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REFERENCES

Abe, M., M. Matsunaga, T. Iriki, M. Funaba, T. Honjo and Y. Wada. 1999. Water balance and fecal moisture content in suckling calves as influenced by free access to dry feed. J. Dairy Sci. 82:320-332.

Abdelrahman, M. M. and R. L. Kinkaid. 1993. Deposition of copper, manganese, zinc, and selenium in bovine fetal tissue at different stages of gestation. J. Dairy Sci. 76:3588.

Agriculture, Forestry, and Fisheries Research Council Secretariat. 1994. Japanese Feeding Standard for Dairy Cattle. Chuouchikusankai, Tokyo, Japan.

Garthwaite, B. D., J. K. Drackley, G. C. McCoy and E. H. Jaster. 1994. Whole milk and oral rehydration solution for calves with diarrhea of spontaneous origin. J. Dairy Sci. 77:835-843.

Kume, S. and S. Tanabe. 1993. Effect of parity on colostral mineral concentrations of Holstein cows and value of colostrum as a mineral source for newborn calves. J. Dairy Sci. 76:1654-1660.

Kume, S. and S. Tanabe. 1996. Effect of supplemental lactoferrin with ferrous iron on iron status of newborn calves. J. Dairy Sci. 79:459-464.

Kume, S., T. Toharmat and K. Kobayashi. 1998. Effect of restricted feed intake of dams and heat stress on mineral status of newborn calves. J. Dairy Sci. 81:1581-1590.

Kume, S. and T. Toharmat. 2001. Effect of colostral β

-carotene and vitamin A on vitamin and health status of newborn calves. Livest. Prod. Sci. 68:61-65.

Nocek, J. E., D. G. Braund and R. G. Warner. 1984. Influence of neonatal colostrum administration, immunoglobulin, and continued feeding of colostrum on calf gain, health, and serum protein. J. Dairy Sci. 67:319-333.

Quigley, III J. D., V. and J. J. Drewry. 1998. Nutrient and immunity transfer from cow to calf pre- and postcalving. J. Dairy Sci. 81:2779-2790.

Quigley, III J. D., V., K. R. Martin, D. A. Bemis, L. N. D. Potgieter, C. R. Reinemeyer, B. W. Rohrbach, H. H. Dowlen and K. C. Lamar. 1995. Effects of housing and colostrum feeding on serum immunoglobul-ins, growth, and fecal scores of Jersey calves. J. Dairy Sci. 78:893-901.

Rajala, P. and H. Castren. 1995. Serum immunoglobulin concentrations and health of calves in two management systems from birth to 12 weeks of age. J. Dairy Sci. 78:2737-2744.

Roussel, A. J. and T. R. Kasari. 1990. Using fluid and electrolyte therapy to help diarrheic calves. Vet. Med. 85:303-311.

SAS User's Guide: Statistics, Version 6.03 Edition. 1988. SAS Inst., Inc., Cary, NC.