EFFECTS OF DIETARY ELECTROLYTE BALANCE ON SOW AND LITTER PERFORMANCE, BLOOD CHEMISTRY, AND URINE CHEMISTRY IN LACTATING SOWS[1]

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Summary

Decreasing the dietary electrolyte balance (dEB) in diets for lactating sows from 500 to 100 mEq/kg increased piglet survivability but had no effect on litter weight gain. Decreased dEB reduced pH and bacteria in the sows urine and, thus, could influence the health status of the reproductive tract.

(Key Words: Sows, Dietary Electrolyte Balance, Acid-Base Balance.)

Introduction

Dietary electrolyte balance is calculated as the sum of Na and K minus Cl and is expressed in mEq/kg of diet. The manipulation of dietary electrolyte balance (dEB) to enhance lactation and reproductive performance in dairy cattle and laying hens is not a new concept. However, the effects of dEB on reproduction and lactation in sows have not been elucidated. Thus, our objective for the experiments reported herein was to determine the impact of dEB on performance of lactating sows and their litters.

Procedures

Treatment Determination. On d 109 of gestation, 30 sows (Line C 22; PIC, Franklin, KY) were assigned to lactation treatments and moved to a farrowing facility. Diets were corn-soybean meal-based (Table 1) and fed in meal form. The dEB treatments of -150, -100, 0, 100, and 200 were selected based on previous research in growing pigs. The sows were allowed ad libitum consumption of feed (four feedings per d) and water (via a nipple waterer). Orts were collected and weighed on d 7 and at weaning to allow calculation of ADFI. Litter size was standardized within 24 h postfarrowing, and all sows had at least 10 pigs after cross-fostering. Sow and piglet weights were recorded at farrowing and weaning.

Lactation Experiment. On d 110 of gestation, 153 sows (Line C 22; PIC, Franklin, KY) were assigned to lactation treatments and moved to a farrowing facility. There were six farrowing groups, with parity ranging from 1 to 4. We were careful to ensure that parity number was comparable among all treatments. Treatments were corn-soybean meal-based diets (Table 2) with dEBs of 0, 100, 200, 350, and 500 mEq/kg. All diets were formulated to constant Ca, P, and K concentrations, and Cl and Na were changed to achieve the desired dEB treatments. The lowest dEB (0) was achieved by mixing 1.08% $CaCl_2$ and 1.8% HCl (6 N) into the diet. The dEB treatment of 100 had 1.0% $CaCl_2$. The diets with dEBs of 200, 350, and 500 mEq/kg required additions of .08, 1.5, and 2.5% sodium bicarbonate, respectively. A typical lactation diet that is formulated to a similar nutrient profile as used in this experiment would contain a dEB of approximately 185 mEq/kg. The sows were allowed ad libitum consumption of feed (four feedings per d) and water (via a nipple waterer). Each farrowing crate was equipped with a water meter, so water disappearance could be determined. Orts were collected and weighed on

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d 10 and at weaning to allow calculation of ADFI.

The sows were weighed and scanned ultrasonically at the first rib, last rib, last lumbar vertebra, and off midline at the last rib (both sides) to determine weight and backfat at farrowing, d 10, and at weaning. Litter size was standardized within 24 h post-farrowing, and piglet weights were recorded at farrowing, d 10, and weaning. All sows used in the experiment had at least 10 pigs after cross fostering.

Between d 10 and 12 of lactation, approximately 75 mL of urine (midstream) was collected at 6:00 a.m. from each sow. The samples immediately were analyzed for pH and total bacteria. At d 10 to 12 of lactation (2 h after the first morning feeding), the sows were restrained with a nose snare and given .5 mL of oxytocin (via ear vein) to enhance milk letdown. A sample of about 100 mL of milk was collected from the first three productive mammary glands on each side. Milk lactose, fat, protein, and pH were determined. Finally, blood samples were collected from the sows; placed on ice; and within 20 min, were analyzed for pH, pCO_2, pO_2, Na, K, Cl, and Ca.

Statistical analyses were performed with sow as the experimental unit. Polynomial regression was used to describe the shape of the response to changes in dEB. Lactation length, parity, and initial litter size after cross-fostering were used as covariates for analyses of weaning weight; litter weight gain; survivability of the pigs; ADFI, backfat, and BW changes; percentage return to estrus; and days to estrus for the sows. Parity and lactation length were used as covariates for number born alive in the subsequent litter. Also, parity was used as a covariate for analyses of milk chemistry.

Results and Discussion

Treatment Determination. At d 7, ADFIs were similar (10 to 11 lb/d) among sows fed the dEB treatments of 0, 100, and 200 mEq/kg. However, sows fed the lowest dEB treatments (-100 and -150 mEq/kg) had an ADFI of only of 5.3 lb/d (linear effect, P<.03). Thus, those two treatments were dropped from the experiment. The other sows were continued on their treatment diets until weaning at d 21.

Sow weight change (P>.39), litter weight gain (P>.28), and ADFI (P>.45) were not affected by the dEB treatments of 0, 100, and 200 mEq/kg. Thus, we concluded from this pilot project that to avoid depressing feed intake, the lowest dEB to use for the larger-scale lactation experiment should be 0 mEq/kg.

Lactation Experiment. Sow weight and backfat loss during lactation were not affected (P>.11) by dEB (Table 3). Also, ADFI and water usage were not affected by dEB at d 10 (P > .06) and overall (P>.17).

Number of pigs (P<.04) and survivability (P<.05) of the piglets during the first 10 d of lactation increased as dEB was decreased. Similarly, number weaned (P<.01) and overall survivability (P<.02) increased with decreased dEB. The greater survivability could have been a function of greater milk output and(or) health status of the pigs as dEB was decreased. This hypothesis was supported by the slight numerical increase in litter weight gain with decreased dEB, but differences were not significant at d 10 (P>.15) or overall (P>.41). Finally, percentage of sows returning to estrus (P>.41), d to estrus (P>.15), and number born in the subsequent litter (P>.39) were not affected by dEB of the lactating diet.

Milk pH (P>.13), fat (P>.32), lactose (P>.36), and CP (P>.44) were not altered by dEB (Table 4). Thus, it seems unlikely that the composition and, thus, nutritional value of sow's milk can be manipulated by changing the dEB of the diet. However, blood pH (quadratic effect, P<.001), pCO_2 (linear effect, P<.001), and bicarbonate (quartic effect, P<.003) were decreased as dEB was decreased showing a direct metabolic response to differences in diet acidity.

As for blood electrolytes, Na concentrations decreased (quartic effect, P<.07) and K and Cl concentrations increased (quadratic effect, P<.04) with decreased dEB. Both ionized (quadratic effect, P<.001) and normalized (linear effect, P<.005) Ca in blood were increased with decreased dEB. This indicates greater bone mobilization with a more acidic diet. In dairy cattle, early lactation diets are formulated to low dEB to increase Ca concentrations in the blood, which helps suppress the incidence of milk fever. However, milk fever is not a known concern in lactating sows, and our data indicate no advantage in lactation performance from increased circulating concentrations of Ca.

The pH of urine (quartic effect, P<.001) and total bacterial counts were decreased with decreased dEB (linear effects, P<.03). Urinary tract disease is caused by bacteria in the reproductive tract. and acidic diets are used extensively in the pet food industry to prevent this disease. Thus, it seems plausible that acidic diets could be used to decrease urinary tract disease in afflicted sow herds.

In summary, the acid-base balance in lactating sows was influenced by dietary electrolyte balance. Decreasing dietary electrolyte balance below that of a simple-corn-soybean meal-based diet decreased urine pH and bacterial counts and increased piglet survivability and the number of pigs weaned.

Table 1. Compositions of Diets for Treatment Determination[a]

	Electrolyte Balance, mEq/kg[b]				
Item	-150	-100	0	100	200
Ingredient, %					
Corn	59.93	60.51	61.80	62.58	62.78
Soybean meal (46.5% CP)	27.10	27.08	27.03	26.94	26.88
Corn gluten meal	3.34	3.27	3.11	3.03	2.95
Soy oil	3.00	3.00	3.00	3.00	3.00
Sodium bicarbonate	---	---	---	---	.04
Calcium chloride	1.98	1.98	1.98	1.00	---
HCl (6 *N*)	1.54	1.05	---	---	---
H_3PO_4	1.86	1.86	1.84	---	---
Monocalcium phosphate	---	---	---	2.13	2.12
Limestone	---	---	---	.11	1.24
Salt	.50	.50	.50	.50	.50
Vitamin premix	.50	.50	.50	.50	.50
Trace mineral premix	.15	.15	.15	.15	.15
Antibiotic[c]	.10	.10	.10	.10	.10

[a]Diets were formulated to 1.0% lysine, 1.0% valine, .95% Ca, and .8% P.

[b]Calculated as mEq/kg of Na + K – Cl.

[c]Provided 100 g of chlortetracycline per ton of complete diet.

Table 2. Compositions of Diets for Lactation Experiment[a]

Item	Electrolyte Balance, mEq/kg 0	100	200	350	500
Ingredient, %					
Corn	59.33	59.33	59.33	59.33	59.33
Soybean meal (46.5% CP)	27.13	27.13	27.13	27.13	27.13
Corn gluten meal	3.42	3.42	3.42	3.42	3.41
Soy oil	3.00	3.00	3.00	3.00	3.00
Sodium bicarbonate	---	---	.04	1.29	2.54
Calcium chloride	1.06	1.00	---	---	---
HCl (6 *N*)	1.80	---	---	---	---
Cellulose[b]	.90	2.67	2.50	1.25	---
Monocalcium phosphate	2.11	2.11	2.11	2.11	2.11
Limestone	---	.09	1.22	1.22	1.22
Salt	.50	.50	.50	.50	.50
Vitamin premix	.50	.50	.50	.50	.50
Trace mineral premix	.15	.15	.15	.15	.15
Antibiotic[c]	.10	.10	.10	.10	.10
Analyzed composition, %					
DM	88.5	89.0	89.0	88.9	88.9
Ash	5.0	5.5	5.3	5.7	5.8
CP	19.6	19.6	19.8	19.6	19.6
Ether extract	5.2	5.1	5.2	5.4	5.3
pH	4.01	5.21	6.12	6.82	6.98
Ca	.95	.97	.93	.94	.96
P	.80	.78	.78	.81	.83
Na	.21	.18	.22	.56	.85
K	.78	.76	.77	.75	.78
Cl	.97	.59	.32	.30	.31
Electrolyte balance, mEq/kg[d]	15	107	203	351	482

[a]Diets were formulated to 1.0% lysine, 1.0% valine, .95% Ca, and .8% P.

[b]Solka floc (Fiber Sales, Urbana, OH).

[c]Provided 100 g of chlortetracycline per ton of complete diet.

[d]Calculated as mEq/kg of Na + K – Cl from analyzed values.

Table 3. Effects of Dietary Electrolyte Balance on Performance of Sows and Litters[a]

	Electrolyte Balance, mEq/kg						Probability			
Item	0	100	200	350	500	SE	Linear	Quadratic	Cubic	Quartic
No. of observations	27	33	34	28	31					
Mean parity	2.1	2.4	2.2	2.1	2.2	.2	---[d]	---	---	---
Mean lactation length, d	20.6	21.2	21.0	21.0	20.9	.3	---	---	---	---
Sow BW postfarrowing, lb	478.3	478.0	488.0	493.7	485.8	3.6	---	---	---	---
Fat depth postfarrowing, in	.63	.67	.69	.69	.44	.7	---	.15	---	---
Initial pigs/litter	11.4	11.3	11.4	11.4	11.2	.2	---	---	—	---
Initial litter BW, lb	37.3	39.2	38.8	39.2	38.8	.5	---	---	---	---
d 10									---	
BW change, lb	-17.2	-9.0	-9.7	-16.5	-18.5	1.6	---	.11	---	---
Fat change, in	-.01	-.01	-.01	-.01	-.01	.01	---	---	.06	---
ADFI, lb	9.7	11.2	10.6	10.4	10.6	.2	---	---	---	---
Water usage, gal/d	14.0	13.2	13.3	11.6	14.2	5.4	.04	---	---	---
Pigs/litter	10.7	10.5	10.5	10.3	10.3	.2	.05	---	---	---
Survivability, %	94.7	93.0	92.9	91.5	91.2	1.3	---	---	---	---
Litter wt, lb	79.4	78.1	80.0	78.3	76.3	1.1	.15	---	---	---
Litter wt gain, lb	42.1	38.9	41.2	39.1	37.5	.9		---		---
Weaning							---		---	
BW change, lb	-31.3	-24.5	-23.4	-32.2	-36.4	2.1	.14	.11	---	---
Fat change, in	-.02	-.01	-.01	-.01	-.02	.01	---	---	---	---
ADFI, lb	11.4	12.3	12.7	11.9	12.3	.2	—	---	---	---
Water usage, gal/d	12.9	12.6	12.1	11.8	14.6	5.0	.01	---	---	---
Pigs/litter	10.5	10.3	10.1	10.0	9.9	.2	.02	---	---	---
Survivability, %	92.9	91.1	89.3	88.6	87.8	1.6	---	---	---	---
Litter wt, lb	135.0	133.4	134.1	133.2	131.9	1.9	---	---	---	---
Litter wt gain, lb	97.7	94.2	95.3	94.0	93.1	1.7	---	---	---	---
Return to estrus, %[b]	91.6	91.4	94.2	96.1	93.2	4.4	---	---	.15	---
Days to estrus[c]	4.6	5.5	4.9	4.3	4.3	.4		---		---
Subsequent no.							---		--	
Born alive	11.1	10.3	11.2	10.7	11.1	.3		---		---

[a]A total of 153 sows.
[b]Percentage sows returning to estrus within 30 d of weaning.
[c]For sows returning to estrus within 30 d of weaning.
[d]Dashes indicate P>.15.

Table 4. Effects of Dietary Electrolyte Balance on Milk, Blood, and Urine Chemistry in Lactating Sows[a]

	Electrolyte Balance, mEq/kg						Probability			
Item	0	100	200	350	500	SE	Linear	Quadratic	Cubic	Quartic
Milk Composition										
pH[b]	6.97	6.96	6.99	7.03	6.99	.02	---[d]	---	.13	---
Fat, %	6.0	6.1	6.3	6.2	6.3	.2	---	---	---	---
Lactose, %	5.5	5.5	5.4	5.5	5.5	.1	---	---	---	---
CP, %	4.6	4.7	4.7	4.7	4.7	.1		---	---	---
Whole blood							.001			
pH[b]	7.33	7.36	7.39	7.41	7.43	.01	.001	.001	---	---
pCO_2, mmHg	46.3	46.5	49.0	49.9	50.8	.7	—	---	---	.15
pO_2, mmHg	43.6	42.9	44.8	43.4	40.1	1.5	.001	.12	---	---
HCO_3^-, mmol/L	19.0	21.4	25.1	25.5	28.8	.3	—	.001	---	.003
Na^+, mmol/L	145.0	145.5	144.7	145.0	145.3	.3	.007	—	---	.07
K^+, mmol/L	5.0	4.9	4.7	4.7	4.7	.1	.001	.04	---	---
Cl^-, mmol/L	109.8	108.0	104.0	102.4	101.4	.3	.001	.001	---	.007
Electrolyte balance[c]	40.2	42.4	45.4	47.3	48.6	.4		.002	---	.13
Ca^{++}, mg/dL							.001		---	
Ionized	5.5	5.3	5.2	5.1	5.0	.03	.005	.001		---
Normalized	5.3	5.3	5.2	5.2	5.2	.03		---	---	---
Urine							.001		---	
pH[b]	4.87	5.01	6.64	7.00	7.70	.2	.03	.001	---	.001
Bacteria, log	3.86	4.00	4.15	4.27	4.19	.12		---		---

[a]A total of 153 sows.

[b]Converted to $[H^+]$ before statistical analysis was conducted.

[c]Calculated as Na + K – Cl from analyzed values.

[d]Dashes indicate $P > .15$.