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EFFECTS OF INORGANIC AND ORGANIC ACIDS ON URINE pH IN LACTATING SOWS[1]

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Summary

Some swine practitioners are advocating the use of dietary acidifiers to reduce urine pH and, thereby, reduce the incidence of urinary tract infections. In our experiment, sows fed an inorganic (phosphoric) acid had lower urine pH than sows fed diets with organic (fumaric, lactic, formic, propionic, and citric) acids. Indeed, the organic acids at 1.5% and 3.0% of the diet increased blood pH and decreased pCO_2, indicating that these sows were in a more alkalotic (not acidotic) state.

(Key Words: Sows, Urine pH, Acidification.)

Introduction

Acidification of nursery diets can enhance piglet growth and efficiency by changing the pH of the intestinal contents. This change in pH of the digesta is thought to inhibit proliferation of pathogenic organisms. In a similar manner, use of acidifiers in gestation and lactation diets has been suggested as a means to lower urine pH, thereby reducing the occurrence of urinary tract disease. This effect has not been well documented, however, and the effects of different types and concentrations of acids in sow diets have not been demonstrated.

Procedures

On d 110 of gestation, 44 sows were assigned randomly to a corn-soybean meal-based diet (Table 1). Dietary treatments were the basal diet or the basal diet with acid as 1.5 or 3.0% of the formulation. Treatments were phosphoric acid (Kem Gest®); a mixture of fumaric, lactic, propionic, formic, and citric acids (Acid Lac®); and citric acid. Sow and piglet weights were recorded at weaning (d 21), and litter size was standardized by d 2 of lactation. The sows were allowed ad libitium access to feed and water. Venous blood samples were taken from the brachial region on d 10 and analyzed (within 20 minutes) for blood gases and electrolytes. Urine samples (midstream) were collected on d 10 to 12 to determine pH. Response criteria included sow and litter performance and blood and urine chemistry. All data were analyzed with sow as the experimental unit, and orthogonal contrasts were used to separate treatment means.

Results and Discussion

Sow weights, daily feed intake, and litter performance (Table 2) were similar among the treatments (P>.24). We should note, however, that this experiment was designed to determine the effects of treatments on blood and urine chemistry, especially urine pH. Thus, the number of sows used was too small to draw meaningful conclusions about treatment effects on sow and litter performance.

Sows fed the acid treatments had higher blood pH (P<.10) than sows fed the control (Table 3). Blood pH is controlled by the concentrations of CO_2 (carbon dioxide) and

[1]Appreciation is expressed to Dr. Richard Odgaard and Kemin Industries for the acid products (Kem Gest®, Acid Lac®, and citrate) and funding of this project.

HCO_3^- (bicarbonate), which are the main buffering agents in blood. In an alkalotic state, the pCO_2 is lowered, and HCO_3^- is raised. In our experiment, the pCO_2 (carbon dioxide in the gas phase of blood) tended to be lower (P<.15) for sows fed the acid treatments versus the control, but the amount of HCO_3^- was not affected by treatment (P>.78). Nonetheless, the differences in extracellular pCO_2 indicates a shift to intracellular formation of carbonic acid (H_2CO_3) from HCO_3^- and H^+. This decreases the extracellular H^+, thus increasing extracellular pH. This process reduces the amount of free H^+, also raising pH of the blood.

Urine pH of sows fed the acidified diets was not different than that of sows fed the control diet (P>.20). However, this was caused by greater urine pH for sows fed the organic acids and lower urine pH of sows fed the inorganic acid (P<.001). This response raises questions about the efficacy of organic acids for acidification of urinary tracts in sows.

The pO_2 (mmHg) and O_2 saturation (%) are the amount of oxygen in the gas state in blood and the amount of oxygen that is bound to available hemoglobin, respectively. In our experiment, both were in the normal range for lactating sows, and no treatment effect occurred (P>.29).

The amounts of Na^+ (P< .12) and Cl^- (P<.05) were increased when acid concentration in the diet was increased, especially for the phosphoric acid and acid mixture treatments (acid mixture vs citric acid x concentration interaction, P<.08). The mechanism for this response was unclear, but an electrolyte balance must be maintained within the blood and explains why Na^+ and Cl^- moved together. Concentration of K^+ decreased (P<.02) when the concentration of citric acid was increased from 1.5 to 3.0%. Those sows given the 3.0% treatments may have been in a more alkalotic state, because they had the highest urine and blood pHs. A shift of K^+ into cells is associated with this condition, thereby lowering its concentration in the blood.

The concentration of Ca^{++} in the blood is a predictor of demineralization in the bones. Normalized Ca^{++} is the concentration that has been adjusted to a blood pH of 7.40, and ionized Ca^{++} concentration is the value at the animal's current blood pH. Ionized Ca^{++} tended to be lower for sows fed inorganic versus organic acids (P<.11) and decreased as acid addition was increased (P<.07). Also, normalized Ca^{++} decreased (P<.07) as acid addition was increased and with acid mixture versus citric acid × concentration (P<.08). These responses indicated less demineralization of bone during lactation when the diet contained inorganic acid and greater concentrations of acid.

Base excess in blood is the number of millimoles of strong acid or base needed to adjust 1 L of blood to pH 7.40. The base excess in extracellular fluid is a value calculated (from base excess in the blood) to estimate base excess in the whole body. No differences were detected among treatments (P>.37) for base excess, and all treatment means were in normal ranges.

In conclusion, the inorganic acid used in our experiment reduced urine pH of sows, whereas the organic acids increased pH.

Table 1. Basal Diet[a]

Ingredient	%
Corn	62.95
Soybean meal (46.5% CP)	26.98
Corn gluten meal	2.96
Soy oil	1.00
Monocalcium phosphate	2.08
Limestone	1.24
Acidifier[b]	--
Salt	.50
Vitamin premix	.25
Sow vitamin premix	.25
Trace mineral premix	.15
Antibiotic[c]	.10
Total	100.00

[a]Formulated to 1.0% lysine, 1.0% valine, .95% Ca, .80% P, and 1,462 kcal/lb of ME.
[b]For the other treatments, 1.5% or 3.0% acid product (phosphoric acid was Kem Gest®); the mixture of fumaric, lactic, propionic, formic, and citric acids was Acid Lac®; and citric acid) was added.
[c]Provided 100 g/ton of chlortetracycline.

Table 2. Inorganic and Organic Acids and Sow and Litter Performance[ab]

		Phosphoric Acid		Acid Mixture[d]		Citric Acid		
Item[c]	Control	1.5%	3.0%	1.5%	3.0%	1.5%	3.0%	SE[d]
No. of sows	9	5	3	9	9	5	4	
Sow wt at farrowing, lb	488	497	471	515	460	498	463	23
Sow wt at weaning, lb	472	463	450	493	448	466	430	7
ADFI, lb	14.8	15.0	15.5	14.2	14.0	15.2	13.7	.7
Initial pigs/litter	11.6	12.0	12.3	10.8	12.0	11.4	11.5	.5
Pigs weaned/litter[b]	10.8	10.8	10.7	9.8	10.8	9.8	10.3	.5
Initial litter wt, lb[b]	37	37	37	41	39	41	41	2
Litter wt gain, lb[b]	115	111	118	121	119	128	127	7

[a]A total of 44 sows (PIC C-22 parities 1 to 4).
[b]Least-square means with initial pigs / litter used as a covariate.
[c]No treatment effect (P>.15).
[d]Mixture of fumaric, lactic, formic, propionic, and citric acid.

Table 3. Physiological Effects of Inorganic and Organic Acids on Lactating Sows[ab]

		Phosphoric Acid		Acid Mixture[c]		Citric Acid		
Item	Control	1.5%	3.0%	1.5%	3.0%	1.5%	3.0%	SE
Body fluid pH								
Blood	7.36	7.39	7.37	7.37	7.36	7.39	7.39	.01
Urine	6.92	6.05	6.01	6.88	7.18	7.17	7.35	.10
Blood gases								
pO_2, mmHg	50.5	48.2	41.5	44.6	44.2	40.6	41.0	2.9
O_2 saturation, %	74.0	77.3	68.0	70.3	69.4	71.5	72.2	2.7
pCO_2, mmHg	54.9	50.0	51.6	52.8	53.0	50.6	51.4	1.6
tCO_2, mmol/L	31.6	31.4	30.7	31.5	31.1	31.2	31.9	.7
HCO_3^-, mmol/L	30.1	30.0	29.2	30.1	29.6	29.8	30.5	.7
BE-ECF, mmol/L[d]	4.9	5.4	4.2	5.2	4.6	5.1	5.8	.8
BE-BLD, mmol/L[e]	4.8	5.5	4.3	5.2	4.6	5.1	5.8	.7
Blood electrolytes								
Na^+, mmol/L	145.3	144.8	145.3	145.7	146.8	145.0	145.8	.5
K^+, mmol/L	4.6	4.9	5.1	4.8	4.8	5.1	4.3	.2
Cl^-, mmol/L	103.2	103.4	105.0	103.3	105.1	103.8	103.5	.1
Electrolyte balance	46.7	46.3	45.4	47.2	46.5	46.3	46.6	--
Ca++, mg/dL								
ionized	5.2	4.4	5.0	5.2	5.2	5.1	4.9	.2
normalized	5.2	5.1	5.0	5.2	5.2	5.2	5.0	.1

[a]A total of 44 (PIC-22 parities 1 to 4).
[b]Urine collected on d 10 to 12; Blood collected on d 10.
[c]Mixture of fumaric, lactic, formic, propionic, and citric acids.
[d]Base excess in extracellular fluid.
[e]Base excess in blood.

Table 4. Physiological Effects of Inorganic and Organic Acids on Lactating Sows[a]

	Contrasts, P <[b]					
Item	Control vs others	Inorganic vs organic	Acid mixture[c] vs citric acid	1.5% vs 3.0% acid concentration	Inorganic vs organic acid × concentration	Acid mixture vs citric acid × concentration
Body fluid pH						
Blood	.10	--	--	--	--	--
Urine	--	.001	.07	.15	--	--
Blood gases	--	--	--	--	--	--
pO_2, mmHg	--	.14	--	--	--	--
O_2 saturation, %						
pCO_2, mmHg	.15	--	--	--	--	--
tCO_2, mmol/L	--	.05	--	--	.09	--
HCO_3^-, mmol/L	--	--	--	--	--	--
BE-ECF, mmol/L[d]	--	--	--	--	--	--
BE-BLD, mmol/L[e]	--	--	--	--	--	--
Blood electrolytes						
Na^+, mmol/L	--	--	--	.12	--	--
K^+, mmol/L	--	--	--	--	.15	.02
Cl^-, mmol/L	--	--	.08	.05	--	.08
Ca++, mg/dL						
ionized	--	.11	--	--	.07	--
normalized	--	--	--	.07	--	.10

[a]A total of 44 (PIC C-22 parities 1 to 4).
[b]Dashes indicate P>.15.
[c]Mixture of fumaric, lactic, formic, propionic, and citric acids.
[d]Base excess in extracellular fluid.
[e]Base excess in blood.