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DO DIETARY BUFFERS IMPROVE GROWTH PERFORMANCE OR NUTRIENT DIGESTIBILITY OR DECREASE STOMACH ULCERS IN FINISHING PIGS?

K. J. Wondra, J. D. Hancock,
K. C. Behnke[1], and R. H. Hines

Summary

The effects of supplemental buffers in finely ground diets were determined in two experiments. In Exp. 1, 128 pigs (123 lb average initial body wt) were fed a corn-soybean meal-based diet (488 µm mean particle size for corn) for 66 d. Treatments were a control and 1, 2, or 3% added sodium bicarbonate ($NaHCO_3$). Average daily gain, dressing percentage, and plasma urea N concentration decreased as the concentration of $NaHCO_3$ in the diet was increased. However, the reduction in average daily gain occurred only at the 2 and 3% additions. Feed intake, feed/gain, backfat thickness, stomach ulceration score, stomach keratinization score, and blood gases (pH and HCO_3^-) were not affected by treatment. In Exp. 2, 120 pigs (121 lb average initial body wt) were fed a pelleted wheat-soybean meal-based diet (355 µm mean particle size for the wheat) during a 64-d growth assay. Treatments were: 1) control; 2) 1% added $NaHCO_3$; and 3) 1% added potassium bicarbonate ($KHCO_3$). Average daily gain, feed intake, feed/gain, backfat thickness, stomach keratinization score, plasma urea N concentration, and digestibilities of dry matter and nitrogen were not affected by treatment. However, addition of $NaHCO_3$ and $KHCO_3$ tended to decrease the incidence of ulcers and increased the digestibility of gross energy. These data indicate that a 1% addition of either $NaHCO_3$ or $KHCO_3$ may help to reduce the severity of gastric ulcers in finishing pigs without adversely affecting growth performance or nutrient digestibility.

(Key Words: Finishing, Stomach, Buffers, Particle Size.)

Introduction

The effects of buffers, such as sodium ($NaHCO_3$) or potassium ($KHCO_3$) bicarbonate, on growth performance and nutrient digestibility in pigs are not fully understood. Some researchers have reported increased average daily gain (ADG) and nutrient digestibility in pigs fed lysine-deficient diets supplemented with $NaHCO_3$ or $KHCO_3$. However, others have reported no improvement in rate of gain or nutrient digestibility with supplementation of these buffers. Some researchers have suggested that a relationship exists between decreased pH in the esophageal region of the stomach and increased ulcerations; thus, buffers could help to neutralize the acidity of the stomach and decrease the incidence of ulcers. The experiments reported herein were conducted to determine the effects of dietary buffers ($NaHCO_3$ and $KHCO_3$) on growth performance, carcass characteristics, stomach morphology, nutrient digestibilities, and blood components in finishing pigs.

Procedures

Experiment 1. One-hundred twenty-eight crossbred finishing pigs (123 lb initial body wt) were used to determine differences in growth performance, stomach mor-

[1]Department of Grain Science and Industry.

phology, and blood chemistry with diets having various concentrations of $NaHCO_3$. The pigs were housed in a modified open-front building (four barrows and four gilts per pen), with 50% solid concrete and 50% concrete slat flooring. Each pen (6 ft x 16 ft) had a two-hole self-feeder and a nipple waterer to allow ad libitum consumption of feed and water. There were four pens per treatment. Treatments were a control with no buffer, and 1, 2, or 3% added $NaHCO_3$ in a randomized complete block design, with initial body wt as the blocking criterion. The diets (Table 1) were corn-soybean meal-based; formulated to .65% lysine, .65% Ca, and .55% P; and met or exceeded National Research Council recommendations for all nutrients. The corn was finely ground (488 µm) in a hammermill with screen openings of 1/16 in.

Pigs and feeders were weighed at initiation and conclusion of the growth assay to determine growth rate (ADG), feed intake (ADFI), and feed/gain (F/G). Two blood samples were collected from each barrow on d 50. One sample was immediately analyzed for pH and HCO_3^- using an automated blood pH-gas analyzer, and plasma from the other sample was analyzed for urea N concentrations.

When pigs in a weight block averaged 250 lb, the entire group was removed from the growth assay. Two blocks reached the end weight on d 63 and two on d 69 of the experiment. The barrows were slaughtered at a commercial slaughter facility, and hot carcass weight was recorded for calculation of dressing percentage. Last rib backfat thickness was measured with a ruler on each half of the split carcass at the midline. Stomachs were collected and scored for severity of ulcers and keratinization. The scoring system used for ulcers was 1 = normal stomach, 2 = erosion, 3 = ulcer, and 4 = severe ulcer. The scoring system used for keratinization was 1 = normal, 2 = mild parakeratosis, 3 = moderate parakeratosis, and 4 = severe parakeratosis.

Experiment 2. One-hundred twenty crossbred finishing pigs (121 lb initial body wt) were fed diets with different buffers in an attempt to determine further the effects of buffering agents on growth performance, carcass characteristics, stomach morphology, nutrient digestibilities, and blood chemistry. Housing and management were the same as described for Exp. 1, with the exception that each pen in Exp. 2 had five barrows and three gilts. Treatments were a control with no buffers added, 1% added $NaHCO_3$, or 1% added $KHCO_3$. The diets (Table 1) were wheat-soybean meal-based; formulated to .65% lysine, .65% Ca, and .55% P; and met or exceeded National Research Council recommendations for all nutrients. Wheat was used because it is more ulcerogenic than corn; thus, the effects of buffers on the incidence of gastric lesions could be defined more clearly. The wheat was ground to a mean particle size of 355 µm, and the diets were pelleted.

Growth rate, ADFI, and F/G were determined as described in Exp. 1. From d 28 to 33, pigs were fed a diet with .20% chromic oxide. Grab samples of feces were collected from three barrows and two gilts in each pen on d 33. The fecal samples were dried, and digestibilities of dry matter (DM), nitrogen (N), and gross energy (GE) were determined using the indirect ratio method with chromic oxide as the indigestible marker. Blood samples were collected and analyzed as described in Exp. 1.

Termination of the growth assay (56 d for one weight block, 62 d for two weight blocks, and 69 d for two weight blocks) and collection of stomach tissues were as described in Exp. 1. The carcasses were skinned prior to weighing; therefore, the carcass weights were adjusted to skin-on hot carcass weights using the Farmland Foods (Crete, NE) adjustment factor (HCW ÷ .91). Tenth rib fat thickness was measured 2 in from the midline using a Fat-O-Meter® probe and adjusted to skin-on fat thickness by adding .1 in to the probe reading. In addition, a 2 in-thick loin chop (10th rib) was removed from the chilled carcasses of two pigs per pen, and water holding capacity of the longissimus muscle was determined at 48 h postmortem.

Results and Discussion

Experiment 1. Growth rate decreased (linear effect, $P<.01$) and ADFI tended to decrease with increasing levels of $NaHCO_3$ in the diet, but only with the 2 and 3% additions (Table 2). Efficiency of gain was not affected by addition of $NaHCO_3$. The decreased growth performance of pigs given the 2% and 3% $NaHCO_3$ treatments (140 and 181 meq/lb of diet, respectively) indicated that the pigs may have been in an alkalotic state.

Last rib backfat thickness was not affected by treatment, but a linear decrease in dressing percentage resulted from increased concentrations of $NaHCO_3$ ($P<.05$). Two more pigs had normal stomachs in the 1% $NaHCO_3$ treatment group (10 of 16) compared to the control group (8 of 16), but no differences were observed for the mean ulceration or keratinization scores.

No differences in pH and HCO_3^- concentrations of blood were observed. However, plasma urea N concentrations decreased (linear effect, $P<.01$) as supplemental $NaHCO_3$ was increased. The factors regulating acid-base balance and amino acid metabolism are complex, and whether the differing urea N concentrations were a result of changes in amino acid metabolism or differing feed intakes is unclear.

Experiment 2. Average daily gain, ADFI, F/G, tenth rib fat depth, dressing percentage, and water holding capacity of the longissimus were not affected by 1% additions of either $NaHCO_3$ or $KHCO_3$ (Table 3). Thus, as in Exp. 1, inclusion of 1% alkaline salts did not decrease growth performance or carcass merit. However, pigs fed the bicarbonate sources showed a trend for reduced stomach ulcer scores ($P<.10$). This difference resulted from fewer pigs developing ulcers (four vs seven for the buffered and control treatments, respectively) and agrees with the lower number of ulcers in pigs fed the 1% $NaHCO_3$ treatment in Exp. 1.

Apparent tract digestibilities of DM and N were unaffected by treatment. However, energy digestibility was increased ($P<.05$) by addition of the bicarbonates, and more so by $KHCO_3$ than $NaHCO_3$ ($P<.10$).

Blood HCO_3^- increased ($P<.05$) with the addition of the alkaline salts; however, blood pH and plasma urea N concentrations were unaffected. Other researchers have reported increased blood HCO_3^- in pigs and chicks when alkaline salts were added to their diets. However, the lack of effects by the treatments on other blood measurements in our experiment indicated that the pigs maintained acid-base homeostasis with 1% addition of $NaHCO_3$ and $KHCO_3$.

In conclusion, esophagogastric ulcers are becoming of more concern with advances in grain processing techniques such as fine-grinding and extrusion. Implementation of these techniques improves feed efficiency, but is limited because of their ulcerogenic effects. A diet supplement that would allow swine producers to capitalize on feed efficiency improvements without compromising growth performance and health status of pigs would be beneficial. Alkaline salts may ameliorate the ulcerogenic effects of finely ground diets, but our data indicated minimal benefits to growth performance. Further research is warranted, especially in swine herds with frequent incidence of gastric lesions.

Table 1. Composition of Diets[a]

Item	Experiment 1 ($NaHCO_3$, %)				Experiment 2		
	Control	1	2	3	Control	$NaHCO_3$	$KHCO_3$
Ingredients, %							
Corn	82.95	81.87	80.79	79.69	—	—	—
Wheat (hard red winter)	—	—	—	—	88.39	88.39	88.39
Soybean meal (48% CP)	14.20	14.28	14.35	14.44	8.03	8.03	8.03
Monocalcium phosphate	1.08	1.08	1.09	1.10	.82	.82	.82
Limestone	1.02	1.02	1.02	1.02	1.10	1.10	1.10
Salt	.25	.25	.25	.25	.25	.25	.25
Vitamins and minerals[b]	.40	.40	.40	.40	.25	.25	.25
Antibiotic[c]	.10	.10	.10	.10	.10	.10	.10
Lysine HCl	—	—	—	—	.06	.06	.06
$NaHCO_3$	—	1.00	2.00	3.00	—	1.00	—
$KHCO_3$	—	—	—	—	—	—	1.00
Solka floc	—	—	—	—	1.00	—	—
Electrolyte balance, meq/lb[d]	80	108	140	181	61	101	105

[a]Diets were formulated to .65% lysine, .65% Ca, and .55% P.
[b]Exp. 1: old KSU vitamin mix (.25%), old KSU mineral mix (.10%), and old KSU selenium mix (.05%); Exp. 2: KSU vitamin mix (.15%), and KSU mineral mix (.10%).
[c]Antibiotic supplied 100 g/ton chlortetracycline.
[d]Electrolyte balance calculated as meq Na + meq K - meq Cl.

Table 2. Effects of Sodium Bicarbonate on Growth Performance, Stomach Morphology, and Blood Chemistry in Finishing Pigs (Exp. 1)[a]

		$NaHCO_3$, %			
Item	Control	1	2	3	CV
ADG, lb[c]	1.99	2.01	1.92	1.85	3.2
ADFI, lb	6.51	6.51	6.49	6.18	4.0
F/G	3.27	3.24	3.38	3.34	3.4
Fat thickness, in	1.26	1.30	1.23	1.27	6.4
Dressing percentage, %[b]	75.1	74.4	74.7	74.3	.5
Stomach ulcers[d]	2.00	1.75	2.06	2.02	21.1
Stomach keratinization[e]	3.44	3.50	3.27	3.80	4.1
Whole blood					
pH	7.32	7.34	7.31	7.36	.4
HCO_3^-, mmol/L	35.4	36.2	36.5	34.3	4.7
Plasma urea N, mg/100 mL[c]	15.6	14.5	12.6	12.5	9.7

[a]A total of 128 pigs (eight pigs/pen and four pens/treatment) with an avg initial body wt of 123 lb and an avg final body wt of 250 lb.
[bc]Linear effect of $NaHCO_3$ addition ($P<.05$ and $P<.01$, respectively).
[d]Scoring system: 1 = normal, 2 = erosion, 3 = ulcer, and 4 = severe ulcer.
[e]Scoring system: 1 = normal, 2 = mild, 3 = moderate, and 4 = severe.

Table 3. Effects of Sodium Bicarbonate and Potassium Bicarbonate on Growth Performance, Stomach Morphology, Digestibility of Nutrients, and Blood Chemistry in Finishing Pigs (Exp. 2)[a]

Item	Control	1% $NaHCO_3$	1% $KHCO_3$	CV
ADG, lb	2.03	2.00	2.00	2.7
ADFI, lb	6.44	6.50	6.42	3.4
F/G	3.17	3.25	3.21	3.0
Fat thickness, in	.98	1.01	.94	7.0
Dressing percentage, %	70.6	71.3	70.8	1.2
Water holding capacity[b]	.468	.473	.474	6.2
Stomach ulcers[ce]	2.24	1.89	1.96	11.2
Stomach keratinization[d]	2.64	2.52	2.42	8.6
Apparent nutrient digestibility, %				
DM	85.2	85.6	85.8	.8
N	85.3	85.2	85.6	1.2
GE[fg]	85.6	86.3	86.4	.7
Whole blood				
pH	7.32	7.33	7.34	.4
HCO_3^-, mmol/L[f]	34.6	35.7	35.6	1.6
Plasma urea N, mg/100 mL	20.9	23.3	21.7	8.2

[a]A total of 120 pigs (eight pigs/pen and five pens/treatment) with an avg initial body wt of 121 lb and an avg final body wt of 250 lb.
[b]Expressed as a ratio of meat film area to total area [i.e., muscle area ÷ (fluid + muscle area)], with a smaller value representing greater water holding capacity.
[c]Scoring system: 1 = normal, 2 = erosion, 3 = ulcer, and 4 = severe ulcer.
[d]Scoring system: 1 = normal, 2 = mild, 3 = moderate, and 4 = severe.
[ef]Buffer vs no buffer ($P<.10$ and $P<.05$, respectively).
[g]$NaHCO_3$ vs $KHCO_3$ ($P<.10$).