January 2000

The Investigation of Betaine as a Growth Promotor and/or Carcass Modifier and the Efficacy of Betaine to Replace Methionine in Finishing Diets

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Summary and Implications

Dietary betaine's effect on growth performance and carcass composition of finishing barrows was investigated. Two experiments were conducted to assess whether betaine improves growth and/or carcass characteristics. In the first experiment, barrows were fed either a control diet or a diet supplemented with betaine and were either crowded or not crowded. Shoulder weight was increased in pigs fed betaine. Generally, betaine had no effect on growth performance and carcass characteristics. The second experiment attempted to assess whether betaine can replace methionine in finishing diets. Betaine tended to be associated with increased fat-free lean gain. This experiment failed to show that betaine increases lean tissue deposition in situations where feed intake is decreased. Additionally, this research suggests that the current methionine recommendations may be greater than required for maximal growth. Because of the variability of responses to betaine in the literature, it is advised that betaine's efficacy and cost effectiveness be assessed on a farm-to-farm basis.

Introduction

Betaine is a byproduct of molasses production from sugar beets. During the past several years, the efficacy of betaine as a growth promotant and/or carcass modifier has been investigated. However, the conditions in which betaine improves performance and/or carcass composition have yet to be completely defined. Some researchers have shown that betaine improves growth performance in limit-fed pigs. Several management conditions are associated with reduced feed intake of growing pigs. The objective of Experiment 1 was to determine whether dietary betaine improves growth performance and/or carcass characteristics of pigs that have reduced feed intake (feed intake reduced by decreased pen space per pig). Because betaine is known to share some biological functions with methionine, the objective of Experiment 2 was to assess whether betaine can partially replace methionine in finishing pig diets.

Procedures

Experiment 1

One hundred-twenty crossbred barrows with an initial weight of 100 lb were allotted to treatments in a randomized complete block design experiment. Treatments were 0% betaine + 13 ft^2/pig (Control-UC), .125% betaine + 13 ft^2/pig (Betaine-UC), 0% betaine + 6.5 ft^2/pig (Control-C), and .125% betaine + 6.5 ft^2/pig (Betaine-C). The UC treatments had five pigs per pen, and the C treatments had 10 pigs per pen. Pigs had ad libitum access to feed and water. Pigs were housed in a mechanically ventilated building. Pigs were from lines that we characterize as having medium to high lean gain potential and were fed accordingly. Corn-soybean meal diets (Table 1) were fed in three phases. Phase 1 diets were fed from 100 to 130 lb, Phase 2 diets were fed from 130 to 190 lb, and Phase 3 diets were fed from 190 to 262 lb.

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The experiment lasted 82 days. Pigs and feeders were weighed every 14 days (denoted as periods) to determine average daily gain (ADG), average daily feed intake (ADFI), and gain:feed ratio (ADG/ADFI). Blood samples were collected every 14 days, and plasma was analyzed for urea concentration. Tenth-rib longissimus muscle area (LMA) and backfat depth (BF) were measured by real-time ultrasound on days 2 and 82 and used to calculate lean tissue gain (fat-free lean gain/day; FFLG; see "FFLG Calculations"). On day 82, all pigs were removed from the experiment and transported to a commercial slaughter facility. Total body electro-conductivity (TOBEC) was used to determine carcass lean percentage and primal cut weights.

Experiment 2

Sixty-four crossbred barrows with an initial body weight of 100 lb were allotted to a randomized complete block experiment. Treatments were two dietary concentrations of betaine (0 or .125%) and four concentrations of methionine (Tables 2 and 3). The diets were formulated to include one methionine deficient diet, one diet adequate (NRC requirements) in methionine, and two diets with methionine concentrations greater than NRC requirements. Pigs were individually penned, given ad libitum access to feed and water, and housed in a mechanically ventilated building.

These pigs also were characterized as being medium to high lean gain potential and were fed accordingly (Table 3), except for the methionine concentration. Diets containing corn, corn starch, feather meal, and blood meal were fed in three phases. Phase 1 was from 100 to 130 lb, Phase 2 was from 130 to 190 lb, and Phase 3 was from 190 to 247 lb (Table 2).

The trial lasted 77 days. Pigs and feeders were weighed every 14 days to determine ADG, ADFI, and ADG/ADFI. Blood samples were collected on the last day of each phase and analyzed for plasma urea concentra-

Table 1. Composition of experiment 1 diets, % (as-fed basis).

	Phase 1		Phase 2		Phase 3	
Ingredient	Control	Betaine	Control	Betaine	Control	Betaine
Corn	76.61	76.47	79.60	79.46	84.50	84.36
Soybean meal, 46.5% CP	20.18	20.18	17.50	17.50	12.75	12.75
Dicalcium phosphate	1.25	1.25	1.00	1.00	.85	.85
Limestone	.77	.77	.80	.80	.80	.80
L-Lysine•HCl	.10	.10	0	0	0	0
Salt	.30	.30	.30	.30	.30	.30
Vitamin premix[a]	.70	.70	.70	.70	.70	.70
Mineral premix[b]	.10	.10	.10	.10	.10	.10
BETAFIN S6→[c]	0	.14	0	.14	0	.14
Calculated Composition:						
ME[d], Mcal/lb	1.50		1.50		1.50	
Crude protein, %		15.73		14.74		12.93
Lysine, %		.88		.73		.60
Calcium, %		.65		.60		.55
Phosphorus, %		.57		.51		.46
Phosphorus, Available, %		.30		.25		.21
Supplemental choline, ppm		77.09		77.09		77.09
Total choline, ppm		1,102		1,048		949

[a]Supplied per kg of diet: retinyl acetate, 3,086 IU; cholecalciferol, 386 IU; α-tocopherol acetate, 15.4 IU; menadione sodium bisulfite, 2.3 mg; riboflavin, 3.86 mg; d-pantothenic acid, 15.4 mg; niacin, 23.1 mg; choline, 77.2 mg; vitamin B_{12}, 15.0 ug.
[b]Supplied per kg of diet: Zn (as ZnO), 110 mg; Fe (as $FeSO_4 \cdot H_2O$), 110 mg; Mn (as MnO), 22 mg; Cu (as $CuSO_4 \cdot 5H_2O$), 11 mg; I (as $Ca(IO_3) \cdot H_2O$, .02 mg; Se (as Na_2SeO_3), .3 mg.
[c]BETAFIN S6 was donated by FinnSugar BioProducts, Inc. and supplied .125% betaine in the diets.
[d]Metabolizable energy.

Table 2. Composition of experiment 2 diets, % (as-fed basis).

	Phase 1		Phase 2		Phase 3	
Ingredient	Basal	Betaine	Basal	Betaine	Basal	Betaine
Corn	67.50	67.50	67.50	67.50	66.00	66.00
Corn starch	15.51	15.37	19.29	19.15	24.20	24.06
Blood meal	3.25	3.25	1.85	1.85	.35	.35
Feather meal	7.20	7.20	5.00	5.00	3.25	3.25
Tallow	2.50	2.50	2.50	2.50	2.50	2.50
L-Lysine•HCl	.36	.36	.38	.38	.39	.39
L-Tryptophan	.06	.06	.06	.06	.07	.07
L-Threonine	.08	.08	.08	.08	.10	.10
DL-Methionine[a]	0	0	0	0	0	0
Dicalcium phosphate	1.50	1.50	1.25	1.25	1.00	1.00
Limestone	.75	.75	.80	.80	.85	.85
Salt	.30	.30	.30	.30	.30	.30
Vitamin premix[b]	.70	.70	.70	.70	.70	.70
Mineral premix[c]	.10	.10	.10	.10	.10	.10
BETAFIN S6®[d]	0	.14	0	.14	0	.14
Commercial pellet binder	.20	.20	.20	.20	.20	.20
Calculated Composition:						
ME[e], Mcal/lb.		1.54		1.56		1.59
Crude protein, %		14.00		11.10		8.30
Lysine, %		.85		.72		.58
Methionine, %		.17		.15		.12
Calcium, %		.66		.61		.57
Phosphorus, %		.48		.43		.37
Phosphorus, available, %		.30		.26		.21
Supplemental choline, ppm		77.09		77.09		77.09
Total choline, ppm	587		556		518	

[a]DL-Methionine was added at 0%, .025%, .05%, and .075% in the diets.
[b]Supplied per kg of diet: retinyl acetate, 3,086 IU/lb; cholecalciferol, 386 IU; α-tocopherol acetate, 15.4 IU; menadione sodium bisulfite, 2.30 mg; riboflavin, 3.86 mg; d-pantothenic acid, 15.4 mg; niacin, 23.1 mg; choline, 77.2 mg; vitamin B_{12}, 15.0 ug.
[c]Supplied per kg of diet: Zn (as ZnO), 110 mg; Fe (as $FeSO_4 \cdot H_2O$), 110 mg; Mn (as MnO), 22 mg; Cu (as $CuSO_4 \cdot 5H_2O$), 11 mg; I (as $Ca(IO_3) \cdot H_2O$, .02 mg; Se (as Na_2SeO_3), .3 mg.
[d]BETAFIN S6 was donated by FinnSugar BioProducts, Inc. and supplied .125% betaine in the diets.
[e]Metabolizable energy.

Table 3. Comparison of methionine requirements (NRC) to experiment 2 diets on a true ileal digestible basis (% of diet).

	NRC Requirement	Phase 1 Diets			
		Methionine 1	Methionine 2	Methionine 3	Methionine 4
Lysine	.70	.75	.75	.75	.75
Methionine	.19	.15	.18	.20	.23
Methionine + cystine	.41	.50	.53	.55	.58
Tryptophan	.13	.16	.16	.16	.16
Threonine	.45	.53	.53	.53	.53
	NRC Requirement	Phase 2 Diets			
		Methionine 1	Methionine 2	Methionine 3	Methionine 4
Lysine	.58	.64	.64	.64	.64
Methionine	.16	.13	.16	.18	.21
Methionine + cystine	.34	.42	.44	.47	.49
Tryptophan	.11	.13	.13	.13	.13
Threonine	.38	.43	.43	.43	.43
	NRC Requirement	Phase 3 Diets			
		Methionine 1	Methionine 2	Methionine 3	Methionine 4
Lysine	.48	.52	.52	.52	.52
Methionine	.13	.11	.13	.16	.18
Methionine + cystine	.29	.34	.36	.39	.41
Tryptophan	.09	.12	.12	.12	.12
Threonine	.32	.36	.36	.36	.36

Table 4. Effects of dietary betaine and crowding on growth performance, carcass characteristics, and plasma urea concentration (Experiment 1).

	Treatment				Space	Diet	Space× Diet
	Control UC[a]	Betaine UC[a]	Control C[a]	Betaine C[a]	P-value		
Period I (day 1-14)							
ADG[b], lb	2.20	2.15	1.92	1.97	<.005	NS	NS
ADFI, lb	5.26	5.03	4.69	4.90	<.05	NS	<.10
ADG/ADFI		.42	.43	.41	.40	<.10	NS
PU, mg/100 mL	30.05	29.61	30.26	32.63	<.05	NS	<.10
Period II (day 15-28)							
ADG, lb	2.22	2.09	1.98	1.91	<.005	<.10	NS
ADFI, lb	6.22	6.04	5.78	5.78	<.10	NS	NS
ADG/ADFI	.36	.35	.34	.33	<.05	<.10	NS
PU, mg/100 mL	33.69	33.45	33.82	31.14	NS	NS	NS
Period III (day 29-42)							
ADG, lb	2.06	2.06	1.82	1.92	<.001	NS	NS
ADFI, lb	6.30	6.36	5.88	5.84	<.001	NS	NS
ADG/ADFI	.33	.33	.31	.33	<.10	<.10	<.05
PU, mg/100 mL	35.33	35.23	34.15	34.00	NS	NS	NS
Period IV (day 43-56)							
ADG, lb	1.89	1.89	1.73	1.88	NS	NS	NS
ADFI, lb	6.96	6.93	6.25	6.66	<.05	NS	NS
ADG/ADFI	.27	.27	.28	.28	NS	NS	NS
PU, mg/100 mL	31.26	29.53	30.34	31.08	NS	NS	NS
Period V (day 57-70)							
ADG, lb	1.74	1.87	1.62	1.63	<.005	NS	NS
ADFI, lb	7.41	7.25	6.56	6.80	<.05	NS	NS
ADG/ADFI	.24	.26	.25	.24	NS	NS	NS
PU, mg/100 mL	32.56	30.72	32.65	31.20	NS	NS	NS
Period VI (day 71-82)							
ADG, lb	2.10	2.02	1.61	1.85	<.01	NS	NS
ADFI, lb	7.69	7.45	6.25	6.89	<.05	NS	NS
ADG/ADFI	.28	.27	.26	.27	NS	NS	NS
Overall (day 0-82)							
ADG, lb	2.03	2.01	1.78	1.86	<.001	NS	NS
ADFI, lb	6.64	6.51	5.90	6.14	<.005	NS	NS
ADG/ADFI	.31	.31	.30	.30	NS	NS	NS
FFLG, lb	.71	.69	.61	.64	<.001	NS	NS
Ham wt., lb	21.17	21.65	20.32	20.56	NS	NS	NS
Longissimus wt., lb	26.04	25.97	24.83	25.44	NS	NS	NS
Shoulder wt., lb	26.42	26.64	25.92	26.19	<.10	<.05	NS
Total lean wt., lb	96.22	94.54	85.97	89.68	NS	NS	NS

[a]Control UC: Control diet + 13 ft^2/pig; Betaine UC: Betaine supplemented diet + 13 ft^2/pig; Control C: Control diet + 6.5 ft^2/pig; Betaine C: Betaine supplemented diet + 6.5 ft^2/pig.
[b]ADG=average daily gain; ADFI=average daily feed intake; PU=plasma urea concentration; FFLG=fat-free lean gain.

tion. Tenth-rib LMA and BF were measured by real-time ultrasound on days 1 and 77, and used to calculate FFLG. On day 77 all pigs were removed from the experiment.

FFLG Calculations

Note: Different equations (Eq. 1) were used for Experiment 1 and 2 because hot carcass weight were not obtained for Experiment 2.]

Eq. 1) **(Experiment 1)**
.95 [7.231 + (.437 . hot carcass wt., lb) - (18.746 . 10th rib BF depth, in.) + (3.877 . 10th rib LMA, in.^{2})]

Eq. 1) **(Experiment 2)**
.95 [3.95 + (.308 . live wt., lb) - (16.44 . 10th rib BF depth, in.) + (4.693 . 10th rib LMA, in.^{2})]

Eq. 2) **(Experiment 1 and 2)**
.95[(.418 . liveweight, lb.) - 3.65]

FFLG (lb/day) = (Equation 1-Equation 2)/Duration of the experiment

Results and Discussion

Experiment 1

Crowding decreased (P < .01) ADG for Periods I, II, III, V, and VI (Table 4). The control diet and the diet supplemented with betaine did not affect ADG throughout the experiment. However, in Period II, a trend (P < .10) for improved ADG resulted for pigs fed the control diet. Crowded pigs had reduced (P < .001) ADG throughout the entire experiment. Crowding decreased ADFI in all periods (P < .10) of the experiment and the overall (P < .005) experimental period. Feed intake was not affected by dietary treatment. However, there was a trend (P < .10) for crowded pigs fed betaine to consume more feed than pigs fed the control diet and crowded during Period I. Increased (P < .10) ADG/ADFI was observed in uncrowded versus crowded pigs in Period I. In Period II, ADG/ADFI was improved (P < .05) in uncrowded pigs versus crowded pigs, and tended (P < .10) to be improved in pigs fed the control diet versus the betaine-supplemented diet. In Period III, ADG/ADFI was improved (P < .05) in crowded pigs fed betaine, whereas

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Table 5. Effects of dietary betaine and methionine concentrations on growth performance, carcass characteristics, and plasma urea concentration (Experiment 2).

	Methionine 1		Methionine 2		Methionine 3		Methionine 4		Betaine	Methionine	Betaine× Methionine	Linear	Quadratic
	CON[a]	BET[b]	CON	BET	CON	BET	CON	BET	P-value				
Phase I													
ADG[c], lb	2.02	1.92	1.68	1.77	2.08	1.82	1.58	1.84	NS	<.05	<.10	<.10	NS
ADFI, lb	5.53	5.45	5.21	5.03	5.76	5.74	5.08	5.51	NS	<.05	NS	NS	NS
ADG/ADFI	.37	.35	.32	.35	.36	.32	.31	.34	NS	<.10	<.05	<.05	NS
PU, mg/100 mL	24.61	22.91	20.73	22.13	25.77	23.17	24.28	24.16	NS	NS	NS	NS	NS
Phase II													
ADG, lb	1.96	2.26	2.21	2.22	2.16	2.27	2.00	2.10		NS	NS	NS	NS
ADFI, lb	6.41	6.69	6.76	6.84	6.58	6.99	6.20	6.32	NS	NS	NS	NS	NS
ADG/ADFI	.31	.34	.33	.33	.33	.33	.32	.33	NS	NS	NS	NS	NS
PU, mg/100 mL	22.93	18.17	21.04	21.69	21.80	21.47	21.21	21.61	NS	NS	NS	NS	NS
Phase III													
ADG, lb	1.71	1.93	1.73	1.91	1.92	1.66	1.70	1.69	NS	NS	NS	NS	NS
ADFI, lb	6.22	6.51	6.10	6.74	6.69	6.07	6.40	6.46	NS	NS	NS	NS	NS
ADG/ADFI	.27	.30	.28	.29	.29	.28	.27	.26	NS	NS	NS	NS	NS
PU, mg/100 mL	17.71	14.40	14.75	16.08	18.86	15.42	15.95	13.73	NS	NS	NS	NS	
Overall													
ADG, lb	1.86	2.03	1.88	1.97	2.03	1.89	1.77	1.85	NS	NS	NS	NS	NS
ADFI, lb	5.91	6.25	5.94	6.40	6.31	6.15	5.90	6.00	NS	NS	NS	NS	NS
ADG/ADFI	.32	.33	.32	.31	.32	.31	.30	.31	NS	NS	NS	NS	NS
FFLG, lb	.61	.66	.58	.62	.63	.61	.56	.60	<.10	NS	NS	NS	NS
LMA, in.^{2}	5.95	6.04	5.65	5.86	5.93	5.74	5.46	6.01	NS	NS	NS	NS	NS
BF, in.	.96	.90	1.01	.98	1.08	.96	.94	.96	NS	NS	NS	NS	NS

[a]CON: Control diet (no betaine).
[b]BET: Betaine supplemented diet.
[c]ADG=average daily gain; ADFI=average daily feed intake; PU=plasma urea concentration; FFLG=fat-free lean gain.

the uncrowded pigs consuming the control diet had greater ADG/ADFI. However, overall ADG/ADFI was not affected by diet or space allocation. Plasma urea concentration was increased (P < .05) in crowded pigs during Period I. Diet or space allocation did not affect plasma urea concentration in the other periods or for the overall experimental period. Longissimus muscle weight, ham weight, and total pounds of lean were not affected by diet or space allocation. Shoulder weight was increased (P < .05) in pigs fed betaine and tended (P < .10) to be increased in uncrowded pigs. Fat-free lean gain was greater (P < .01) in uncrowded versus crowded pigs but no difference was observed in FFLG between pigs fed control and betaine-supplemented diets.

Experiment 2

In Phase I, increasing the methionine concentration in the diets linearly decreased (P < .05) ADG (Table 5). Plasma urea concentration, ADFI, and ADG/ADFI were not consistently affected by dietary methionine concentration or betaine. Longissimuss muscle area and BF were not affected by methionine concentration or betaine supplementation. Lean gain was increased (P < .10) in pigs fed betaine versus the pigs fed the control diet. Because the concentrations of dietary methionine used in this study appear to be above the requirement, the relationship between betaine and methionine could not be adequately evaluated.

Conclusions

Other recent data suggest that FFLG is improved by betaine supplementation when feed/energy intake is below normal; however, Experiment 1 did not show similar results. The efficacy and/or economic advantage of betaine should be analyzed in each production system. Additionally, this report suggests that the methionine requirement (estimated for pigs with similar lean growth potential and produced under similar management conditions) may be lower than current NRC recommendations for finishing pigs.

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