EFFECTS OF BRANCHED CHAIN AMINO ACIDS ON SOW AND LITTER PERFORMANCE [1]

S. A. Moser, M. D. Tokach [2], J. L. Nelssen, R. D. Goodband, and J. A. Loughmiller

Summary

Three hundred-six sows were used to evaluate effects of the interrelationship among valine, isoleucine, and leucine on sow and litter performance. Eight dietary treatments were arranged as a 2×2×2 factorial with two levels of valine (.80 and 1.20%), isoleucine (.68 and 1.08%), and leucine (1.57 and 1.97%). Litter weaning weight, litter weight gain from d 2 to weaning, and sow backfat loss increased as dietary valine increased but were not affected by dietary isoleucine or leucine. Increasing dietary valine, isoleucine, or leucine did not affect milk fat, DM, CP, or lactose. These results confirm the importance of dietary valine for increased litter weaning weight, independent of either additional dietary isoleucine or leucine.

(Key Words: Valine, Isoleucine, Leucine.)

Introduction

Research conducted prior to 1990 evaluating the valine, isoleucine, and leucine requirements of lactating sows utilized litters with nine or fewer pigs weaned and preweaning growth rates that were 50% of current production rates. Increased genetic selection and improvements in management have dramatically increased the production capability of the modern commercial sow. These high producing sows require considerably higher levels of total dietary valine because of increased milk production. More recently, research conducted at Kansas State University has found that increasing total dietary valine from .75 to 1.15% in lactation diets resulted in increased litter weight gain. Recent research has found that increasing both dietary valine and isoleucine in lactation diets increased litter weaning weights. Therefore, the objective of this experiment was to determine if the improved litter weaning weights observed with the increased dietary valine was specific for valine or if other branch chain amino acids (isoleucine or leucine) also will improve litter weaning weights.

Procedures

Three hundred-six primiparous and multiparous sows (36 to 41 per treatment) from the Kansas State University Swine Teaching and Research Center were used in this experiment. All sows were maternal line (PIC Line C-22) and were bred to terminal line (PIC Line 326) boars. During gestation, sows were housed in outside dirt lots and fed in individual stalls. Gestating sows were fed 4 to 5 lb/d depending on body condition. The gestation diet was a sorghum-soybean meal-based diet formulated to .65% total lysine, .90% Ca, and .80% P. On d 109 of gestation, sows were moved into farrowing crates in an environmentally regulated farrowing house. All sows were fed the gestation diet until farrowing, at which time sows were allotted to one of eight dietary treat-

[1]Appreciation is expressed to Lonza, Inc., Fair Lawn NJ, for partial financial assistance in this trial. We also express appreciation to the Kansas DHIA for their assistance with chemical analysis of milk samples.

[2]Northeast Area Extension Office, Manhattan, KS.

ments. Treatments were allotted randomly within groups of eight as sows farrowed to minimize variation in lactation length between treatments. Litter size was equalized by 24 h after farrowing, and all sows began the study with at least 10 pigs. Sows were allowed ad libitum access to feed and water from parturition until weaning. Orts were collected and weighed on d 7 and 14 and at weaning to determine the sow's average daily feed intake. Creep feed was not offered to litters. Backfat was measured using real-time ultrasound 6 cm off the midline on both sides of the body at the last rib. Pigs and sows were weighed on d 0, 7 and 14 and at weaning. Sows farrowed from November 1996 through December 1997. Three or four observations were made per treatment for each lactation group, and 12 lactation groups (blocks) were used.

The lactation diets (Table 1) were formulated to meet or exceed amino acid requirement estimates based on ratios relative to lysine, except for valine, isoleucine, and leucine. All other nutrients were in excess of published requirement estimates. Diets were formulated to .90% total lysine, .90% Ca, and .80% P. The control diet was formulated to contain .80% valine, .68% isoleucine and 1.57% leucine. Cornstarch was replaced in .40% increments with L-valine, L-isoleucine, L-leucine, or a combination of each to provide the remaining seven experimental diets. The treatments included two levels of valine (.80 and 1.20%), isoleucine (.68 and 1.08%), and leucine (1.57 and 1.97%).

Sixteen sows per treatment were milked manually on d 14 to 16 of lactation. All sows were milked approximately 2 h after the noon feeding. Sows were separated from their litters for a minimum of 30 min before milking. Milk letdown was enhanced by infusing 10 IU of oxytocin into an ear vein of the sow. Sows were restrained, and 75 mL of milk was collected from the first two productive glands on both sides of the body. Samples from each gland were pooled for chemical analysis and stored at 35 to 40°F. All analyses were conducted within 48 h after collection.

Table 1. Diet Composition (As-Fed Basis)[a]

Ingredients	%
Corn	71.08
Soybean meal (46.5% CP)	20.06
Choice white grease	3.00
Monocalcium phosphate (21% P)	2.25
Limestone	1.08
Cornstarch[b]	1.20
Salt	.50
Sow add pack	.25
Vitamin premix	.25
Trace mineral premix	.15
L-Lysine-HCl	.15
L-Threonine	.016
L-Tryptophan	.016

[a]Basal diet was formulated to 15.5% CP, .90% lysine, .80% valine, .68% isoleucine, 1.57% leucine, .90% Ca, and .80% P.
[b]Cornstarch was replaced in .40% increments with L-valine, L-isoleucine, L-leucine, or a combination of each to provide remaining seven experimental diets.

Lactation group was used to block all response criteria. Litter size after cross-fostering was used as a covariate for litter weights, litter weight gain, and ADFI. Lactation length was used as a covariate for litter weaning weight, litter weight gain from d 2 to weaning, sow weight change and backfat change from d 0 to weaning, and ADFI. Initial sow weight and beginning backfat measurement also were used as covariates for sow weight change and backfat change, respectively. Parity was a significant covariate for milk fat, lactose, and DM but not for CP or ash. Contrasts were the following: main effects of valine, isoleucine, and leucine and all two-way and three-way interactions.

Results

No valine × isoleucine × leucine interactions affected the number of pigs after fostering, number of pigs weaned, or lactation length ($P>.15$; Table 2). Also no three-way interactions among the amino acids affected any of the litter weights or litter weight gain measurements (P>.15). Valine × isoleucine × leucine interactions tended to affect total branched chain amino acid intake (P<.08) and sow backfat change (P<.13). There was a tendency for valine × isoleucine interactions affecting litter weight on d 7 (P<.11) and d 14 (P<.12). These interactions appeared to be results of increased litter weight with increasing isoleucine in sows fed .80% valine, whereas increasing isoleucine decreased litter weights in sows fed 1.20% valine.

Valine. Dietary valine had no effect on number of pigs weaned ($\bar{x}$ = 10.6; Table 2) or survival rate after cross-fostering ($\bar{x}$ = 94.5%). Comparing the overall effects shows that increasing dietary valine from 47.52 to 63.87 g/d (.80 to 1.20%), regardless of isoleucine or leucine, increased (P<.06) litter weights throughout each week as well as the overall 21 d lactation period (Table 2). Valine and TBCAA intakes increased (P<.0001), whereas leucine and lysine intake decreased (P<.01) as dietary valine increased (Table 3). Sow ADFI (P>.50) and sow weight loss (P>.30) were not affected. As dietary valine increased from .80 to 1.20%, sow backfat loss increased (P<.02).

Isoleucine. Dietary isoleucine had no effect (P>.10) on number of pigs weaned, pig survival rate, litter weights, litter weight gains, (Table 2), sow weight change, and sow backfat change (Table 3). Dietary isoleucine had no effect on sow feed intake (P>.42; Table 3), but isoleucine and TBCAA intakes increased (P<.0001) as isoleucine increased. Valine intake decreased (P<.002) with increased dietary isoleucine.

Leucine. Dietary leucine had no effect on number of pigs weaned, pig survival rate, litter weights, or litter weight gain (Table 2). Sow backfat loss (P>.29) was not affected by increased dietary leucine; however, sow BW loss (P<.15) had a tendency to decrease (Table 3). Daily leucine and TBCAA intakes (P<.0001) increased as dietary leucine increased and daily lysine intake decreased (P<.0004). Leucine had no effect on sow ADFI (P>.58).

Milk Composition. Increasing dietary valine, isoleucine, and leucine did not affect milk DM, CP, fat, or lactose (Table 4). The addition of dietary isoleucine caused milk ash to decrease (P<.05), but increasing valine and leucine had no effect.

Discussion

Increasing dietary valine from .80% to 1.20% increased litter weaning weight by 4.4 lb and litter weight gain from d 2 to weaning by 3.7 lb, independent of dietary isoleucine and leucine. This suggests that increasing dietary valine increases milk production as measured by litter weaning weights regardless of dietary isoleucine or leucine.

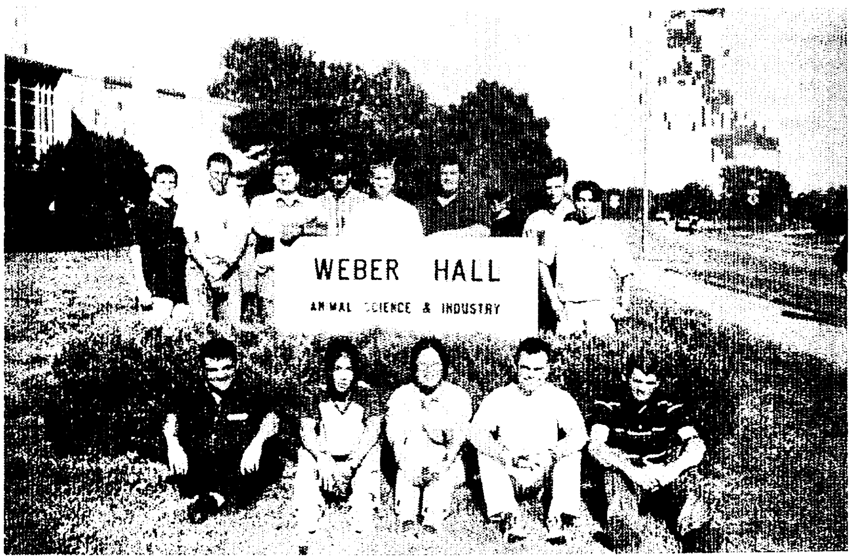
This response to valine has been observed in previous experiments conducted with high-producing sows at Kansas State University. In an experiment reported in the 1994 KSU Swine Day Report of Progress, as the valine level was increased from .75 to 1.15%, litter weaning weights linearly increased by 8.2 lb and litter weight gain increased by 7.5 lb. In our experiment, no change in sow weight or ADFI was observed when additional valine was added. However, an increase occurred in last rib backfat loss, but it was minimal (.06 in). Previous research elicited the same lack of response for sow weight change and ADFI, but last rib backfat also did not change.

Previous research has reported that increasing isoleucine from .50 to 1.20% increased litter weaning weight, with the greatest response achieved when isoleucine was increased from .50 to .85%. The isoleucine level of .85% in that experiment is intermediate to our levels of .68 and 1.08%. Our data do not necessarily refute the previous data, because we observed a numerical increase in litter weaning weight and litter weight gain when sows were fed the low level of valine (.80%) and the high level of isoleucine (1.08%).

Our study showed no response to the addition of leucine. Diets formulated to meet conventional lysine requirements don't appear to be deficient in leucine.

Research using mammary vein cannulation in sows and dairy cows has shown that isoleucine and valine are taken up by the mammary gland in amounts 30 to 80% greater than their output in milk protein. The branched chain amino acids seem to serve a purpose other than milk protein synthesis. Valine and isoleucine likely are used as energy sources in the mammary gland. Milk composition was not altered when valine was added to the diet, so we can conclude that the increase in litter weaning weight could be attributed to increased milk yield, although milk yield was not measured directly in this experiment. Leucine had no effect on any of the milk criteria in our experiment.

The valine requirement of high-producing lactating sows appears to be greater than current estimates by the National Research Council and Agricultural Research Council. The increases in litter weights and litter weight gain with increased valine, independent of isoleucine and leucine, indicate that the response is due entirely to valine and not to the total branched chain amino acid level of the diet. In conclusion, leucine and isoleucine did not elicit the same magnitude of response; thus, the importance of valine for milk production must be considered when formulating lactation diets.



Swine Nutrition Graduate Students: Front row (L to R), Manual De La Llatta, Ann Amornthewaphat, Hong Cao, Patrick O'Quinn and Dustin Dean. Back row (L to R), Matt Steidinger, Jason Woodworth, Joe Loughmiller, Craig Maloney, David Lee, Grant Grinstead, Rob Musser, Joel DeRouchey, and Jin-Seong Park. Not pictured, Sharlie Moser.

Table 2. Effects of Increasing Isoleucine, Leucine, and(or) Valine on Litter Growth Performance[a]

Valine, %	.80				1.20				
Isoleucine, %	.68		1.08		.68		1.08		
Leucine, %	1.57	1.97	1.57	1.97	1.57	1.97	1.57	1.97	
Item TBCAA, %[b]	3.05	3.45	3.45	3.85	3.45	3.85	3.85	4.25	SE
No. of sows	40	38	39	38	38	36	36	41	-
Mean parity	2.0	2.2	2.1	2.1	2.0	2.3	2.2	2.1	.14
No. of pigs after fostering	11.1	11.2	11.3	11.1	11.3	11.2	11.1	11.0	.16
No. of pigs weaned	10.6	10.5	10.5	10.6	10.6	10.5	10.6	10.6	.13
Lactation length, d	20.5	20.9	20.7	20.8	21.0	20.8	20.8	20.6	.24
Litter wt, lb									
Day 2	42.8	42.3	44.1	43.7	43.7	45.0	43.0	44.3	.95
Day 7[d]	65.8	64.5	66.9	66.5	68.5	69.0	66.1	67.9	1.46
Day 14[d]	103.1	102.2	105.7	103.8	108.2	108.1	103.5	107.2	2.22
Weaning[cd]	135.9	135.6	138.8	139.2	143.4	142.5	138.3	143.0	2.88
Litter wt gain, lb									
Day 2 to 7[d]	22.9	22.0	22.9	22.9	24.9	24.0	23.1	23.6	.88
Day 2 to 14[d]	60.2	59.7	61.5	60.2	64.6	63.1	60.6	63.1	1.79
Day 2 to weaning[cd]	93.3	93.3	94.9	95.6	99.7	97.6	95.3	98.9	2.48

Statistical Analysis (P <)

	Interactions				Main Effects		
Item	Val×Ile× Leu	Ile × Leu	Val × Leu	Val × Ile	Leu	Ile	Val
Mean parity	.89	.18	.73	.79	.30	.99	.50
No. of pigs after fostering	.78	.43	.60	.32	.57	.45	.84
No. of pigs weaned	.94	.46	.92	.85	.60	.97	.70
Lactation length, d	.69	.65	.19	.48	.81	.95	.55
Litter weights							
Day 2	.96	.99	.18	.15	.51	.67	.29
Day 7	.92	.58	.33	.11	.88	.94	.06
Day 14	.44	.65	.31	.12	.91	.83	.05
Weaning	.54	.44	.63	.17	.62	.81	.03
Litter weight gain, kg							
Day 2 to 7	.82	.36	.88	.27	.64	.55	.05
Day 2 to 14	.32	.57	.59	.25	.83	.61	.06
Day 2 to weaning	.47	.36	.91	.32	.76	.91	.04

[a]Litter size after cross-fostering was used as a covariate.
[b]Total branched-chain amino acids (isoleucine + valine + leucine).
[c]Lactation length was used as a covariate.
[d]Parity was used as a covariate.

Table 3. Effects of Increasing Isoleucine, Leucine, and(or) Valine on Sow Feed Intake, Body Weight, and Backfat Changes[a]

Valine, %	.80				1.20				
Isoleucine, %	.68		1.08		.68		1.08		
Leucine, %	1.57	1.97	1.57	1.97	1.57	1.97	1.57	1.97	
Item TBCAA, %[b]	3.05	3.45	3.45	3.85	3.45	3.85	3.85	4.25	SE
Daily intake									
ADFI, lb[c]	13.1	12.7	13.0	12.9	13.1	12.9	12.6	12.9	.20
Lysine, g[c]	55.3	52.2	53.6	52.2	52.2	50.9	53.3	51.0	.80
Valine, g[c]	47.8	48.6	46.1	47.5	64.0	66.1	63.1	62.0	.90
Isoleucine, g[c]	40.7	40.5	57.8	60.5	38.6	40.4	60.4	58.1	.85
Leucine, g[c]	88.8	102.2	88.4	105.1	83.7	102.5	85.4	102.6	1.48
TBCAA, g[c]	177.4	191.3	192.3	213.1	186.4	209.1	208.9	222.8	3.12
Sow BW, lb									
Day 0	438.3	457.9	451.3	442.2	448.9	451.3	450.4	450.6	8.91
Change[d]	-9.48	-7.58	-9.37	-4.87	-11.99	-8.44	-11.60	-8.09	3.33
Sow backfat, mm									
Day 0	.62	.57	.60	.56	.57	.60	.60	.63	.03
Change[e]	-.04	-.03	-.03	-.04	-.06	-.06	-.08	-.04	.02

Statistical Analysis (P <)

	Interactions				Main Effects		
Item	Val × Ile × Leu	Ile × Leu	Val × Leu	Val × Ile	Leu	Ile	Val
Daily intake							
ADFI	.73	.24	.42	.35	.58	.42	.59
Lysine	.23	.81	.69	.23	.0004	.85	.01
Valine	.14	.32	.62	.39	.21	.002	.0001
Isoleucine	.003	.64	.24	.33	.39	.0001	.40
Leucine	.25	.69	.16	.85	.0001	.32	.01
TBCAA	.08	.82	.84	.94	.0001	.0001	.0001
Sow BW							
Day 0	.29	.23	.76	.88	.60	.94	.65
Change	.78	.79	.94	.82	.15	.70	.35
Sow backfat							
Day 0	.94	.86	.05	.32	.67	.56	.54
Change	.13	.91	.32	.95	.29	.97	.02

[a]Lactation length and parity were used as covariates.
[b]Total branched-chain amino acids (isoleucine + valine + leucine).
[c]Pigs equalized after cross fostering was used as a covariate.
[d]Initial BW was used as a covariate.
[e]Beginning backfat measurement was used as a covariate.

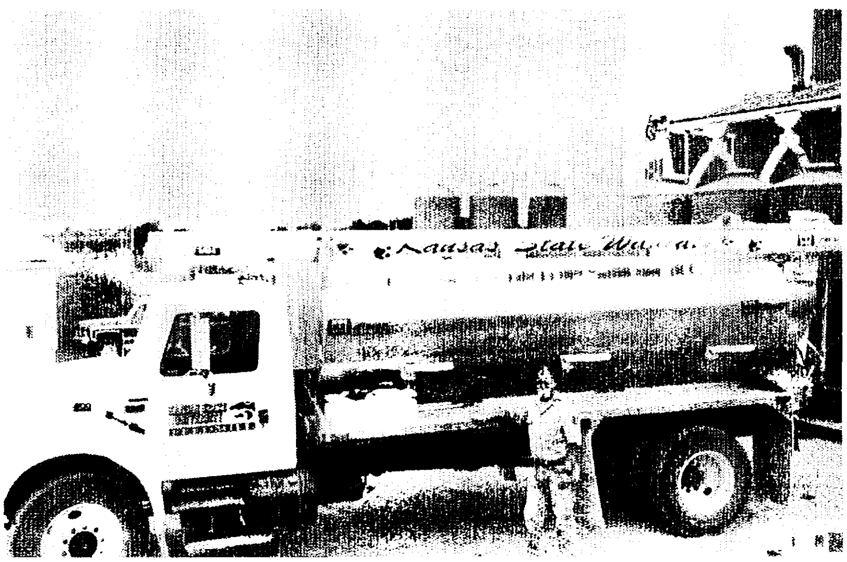
Table 4. Effects of Valine, Isoleucine, and Leucine on Milk Composition[a]

Valine, %	.80				1.20				
Isoleucine, %	.68		1.08		.68		1.08		
Leucine, %	1.57	1.97	1.57	1.97	1.57	1.97	1.57	1.97	
Item / TBCAA, %[b]	3.05	3.45	3.45	3.85	3.45	3.85	3.85	4.25	SE
Milk urea nitrogen, mg/dl[c]	49.23	47.65	48.74	50.11	52.26	51.61	50.44	50.76	1.84
DM, %[c]	16.76	17.06	16.91	16.67	16.63	16.84	16.76	16.97	.23
CP, %	4.60	4.58	4.49	4.55	4.55	4.47	4.47	4.51	.08
Fat, %[c]	5.12	5.40	5.31	5.21	4.95	5.23	5.37	5.43	.18
Lactose, %[c]	5.82	5.75	5.87	5.87	5.89	5.89	5.83	5.87	.06
Ash, %	4.50	4.07	4.11	4.14	4.27	4.31	4.06	4.18	.12

Statistical Analysis (P <)

	Interactions				Main Effects		
	Val × Ile × Leu	Ile × Leu	Val × Leu	Val × Ile	Leu	Ile	Val
Milk urea nitrogen	.70	.44	.98	.37	.92	.89	.07
DM	.39	.42	.58	.44	.46	.96	.76
CP	.86	.37	.72	.63	.98	.39	.35
Fat	.75	.23	.75	.22	.30	.22	.91
Lactose	.89	.51	.46	.13	.79	.54	.31
Ash	.27	.10	.09	.96	.47	.05	.97

[a]Values represent the means of 16 sows/treatment.
[b]Total branched-chain amino acids (isoleucine + valine + leucine).
[c]Parity was used as a covariate.



Terry Gugle, ASI Feedmill Manager.