Impact Of Amino Acid Regimen on Milk Nutrient Yields by Sows Differing in Genetic Capacity for Lean Tissue Growth

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ASL-R1364

Summary and Implications

The impact of dietary amino acid regimen on the milk nutrient yield of sows differing in genetic capacity for lean tissue growth was determined. Primiparous sows with a high (.77 to .85 lb/day) or low (.53 to .62 lb/day) genetic capacity for lean tissue growth from 40 to 240 pounds body weight were evaluated. During lactation, sows were offered daily 14.3 pounds of one of four fortified corn-soybean meal diets containing .58, .77, .96 and 1.15% lysine (L). Litters were standardized to 14 pigs within eight hours postpartum. Milk yield (via a deuterium oxide dilution technique) and composition were determined over four-day intervals from day 2 to 26 postpartum. Based on net feed consumption and the composition of mobilized body tissues (via a comparative slaughter technique), the daily supplies of lysine and metabolizable energy (ME) available for milk synthesis were calculated.

The bodies of high lean growth (LG) sows possessed more proteinaceous tissues and protein and less fat tissue and lipid than low LG sows at the initiation of lactation. During lactation (days 2 to 28 postpartum), high LG sows (pooled across dietary regimens) consumed more feed, mobilized more body protein, and catabolized less body lipid than low LG sows, whereas milk yields were similar between genotypes. As total daily lysine supplies (from diet and mobilized tissues) increased, daily yields of milk, milk energy, and milk lysine increased, but the magnitude of the responses were less in the high LG sows. At low dietary lysine intakes, total lysine supply was limiting milk synthesis in both genotypes. As dietary lysine intake increased, total ME supply became more limiting than lysine, particularly in the high LG sows because of their inability to provide sufficient energy from mobilized body fat tissues.

Based on these data, milk, milk energy, and lysine yields of high and low lean growth genotype sows are similar when similar total supplies of lysine and energy are available. When energy supplies do not limit milk synthesis, the efficiency of utilization of digestible lysine for milk lysine production is similar between genotypes. Specifically, .85 to .87 Mcal ME and 1.95 to 2.05 grams (g) of digestible lysine are needed per pound of milk produced in sows nursing large litters. If it is assumed that each nursing pig requires daily 1.8 pounds of milk, then lactating sows require about 1.5 to 1.6 Mcal ME and 4.3 to 4.5 g of digestible lysine (5.0 to 5.3 g lysine from a corn-soy diet) for each pig nursed. Because of the limited supplies of mobilizable fat tissues in high lean growth sows, the provision of adequate dietary energy intakes to the sows is more critical in order to allow their maximum lactational capacity to be expressed.

Introduction

The lactational capacity of the female is determined by the genetic makeup of the animal. Across species, milk energy yields of mammals are estimated to average 125 kcal/kilo-gram$^{.75}$ of bodyweight/day. However, within a species, those genetic strains which are larger and later maturing possess greater lactational capacities. Larger, later maturing bovines have been reported to be capable of secreting 300 to 350 kcal of milk energy/kg$^{.75}$ bodyweight/day.

Environmental factors, such as litter size, dietary regimen and health status, determine the proportion of the genetic capacity that is expressed. Expression of milk synthesis in sows equivalent to 300 kcal milk energy/kg$^{.75}$ body weight is estimated to require litters of 14 or more pigs to create sufficient demand for milk. The ability of the sow to achieve this rate of milk synthesis is dependent on the availability of nutrients and energy from dietary ingredients and maternal body tissues. This study was conducted to determine the impact of lean growth genotype and dietary amino acid regimen on milk and milk nutrient yields in lactating sows.

Materials and Methods

Experimental treatments consisted of two lean growth (LG) genotypes and four dietary amino acid regimens. Primiparous sows of a high and low LG genotype with muscle tissue growth capacities from 40 to 240 lb body weight of .77 to .85 lb/day and .53 to .62 lb/day, respectively, were evaluated. Within each LG genotype, sows from two genetic strains were evaluated.

During lactation, sows were offered daily 14.3 pounds of one of four fortified corn-soybean meal diets containing .58, .77, .96 or 1.15% lysine (Table 1). The dietary amino acid regimens were formulated to be first limiting in lysine based on the amino acid profiles (relative to lysine) for lactating sows. Dietary lysine concentrations were achieved by altering the ratio of corn to soybean meal in the diets. The daily allowance of ME was estimated to meet the maintenance and milk synthesis needs of 365 pound sows nursing 14 pigs. Dietary vitamins and trace minerals were provided at a minimum of 350 and 250% of the estimated daily requirements of the 363-pound sows during lactation to ensure adequate supplies for milk synthesis.

Only sows that possessed a minimum of 14 functional nipples, farrowed a minimum of eight live pigs, and whose litters were successfully adjusted to 14 pigs by 8 hours postpartum were evaluated.

Table 1. Composition of lactation diets.

Ingredient	Dietary Lysine, %			
	.58	.77	.96	1.15
Corn	82.70	76.20	70.10	63.60
Soybean meal, dehulled	12.60	19.20	25.40	32.00
Dicalcium phosphate	3.05	2.90	2.75	2.60
Calcium carbonate	.61	.66	.71	.76
Salt	.50	.50	.50	.50
Trace mineral premix[a]	.09	.09	.09	.09
Vitamin premix[b]	.35	.35	.35	.35
Antibiotic[c]	.10	.10	.10	.10
Nutrient composition, calculated				
ME, kcal/lb	1470	1465	1461	1457
Crude protein, %	13.1	15.8	18.3	20.9
Amino acid, %				
Lysine	.58	.77	.96	1.15
Tryptophan	.16	.20	.24	.28
Threonine	.54	.64	.74	.84
Calcium, %	1.00	1.00	1.00	1.00
Phosphorus, %	.85	.85	.85	.85

[a]Supplied the following in the diet: Fe, 200 ppm; Mn, 25 ppm; Zn, 125 ppm; Cu, 13 ppm; I, 1.0 ppm; Se, .3 ppm.
[b]Supplied the following per pound of diet: vitamin A, 4,545 IU; vitamin D_3 227 IU; vitamin E, 26 IU; vitamin K (menadione sodium bisulfite complex), .57 mg; vitamin B_{12} .017 mg; riboflavin, 4.5 mg; D-pantothenic acid, 13.6 mg; niacin, 11.4 mg; choline chloride, 1.4 mg; thiamin, 1.1 mg; pyridoxine, 1.1 mg; folic acid, .34 mg; d-biotin, .23 mg.
[c]Supplied 50 mg chlortetracycline per pound of diet.

Sow feed intake, body weight, and backfat depth (2 inches off midline over the first, tenth, and last rib and last lumbar vertebrae) and individual pig weights were recorded on days 0 (within eight hours postpartum), 2, 6, 10, 14, 18, 22, and 26 and at weaning (day 28"1 postpartum).

Milk yield was determined from days 2 to 6, 6 to 10, 10 to 14, 14 to 18, 18 to 22, and 22 to 26 of lactation. Milk intakes of the fourth, fifth, ninth, and tenth heaviest pigs in each litter, based on their body weight on day 2 of lactation, were determined via a deuterium oxide dilution technique (Rudolph et al., 1984). Milk intakes of the remaining pigs in the litter were calculated by multiplying the average milk intake per metabolic weight of the four selected pigs times the metabolic weight of each pig in the litter. Milk yield from day 26 to day 28 postpartum was estimated by assuming that the milk intake per unit of litter gain was the same between days 22 and 26 and days 26 to 28 postpartum.

A milk sample was collected from each sow on day 2, 6, 10, 14, 18, 22, and 26 of lactation by infusing 10 U.S.P. units of oxytocin into an ear vein and manually expressing all milk available from the second and third functional anterior glands. Milk dry matter, protein, and fat content were determined chemically. Milk ash was assumed to be .9%. Milk lactose was estimated by the equation Lactose = milk dry matter - milk protein - milk fat - milk ash. The energy content of milk was estimated by multiplying the percentage of milk protein, fat, and lactose by 5.70, 9.40 and 4.15 kcal, respectively. Milk composition in each period was estimated by averaging the compositions of the milk samples collected at the beginning and end of each period.

On day 28 ("1) postpartum, sows were weaned at 6:00 to 7:00 a.m. and transported 3 miles to the Iowa State University Meat Lab. Sows were weighed, electrically stunned, and killed by exsanguination within two hours of arrival. The offal components of blood, head, heart-lungs, liver, kidneys, gastrointestinal tract (with digesta), leaf fat, and jowl trim were collected and weighed individually and then frozen together for subsequent chemical analysis. Hot carcass weights were recorded and the carcasses were chilled 20 to 24 hours at 32EF. The right side of the cold carcass was separated into wholesale cuts of ham, loin, shoulder, belly, ribs, jowl and feet-tail. The cuts were then frozen and stored for later physical dissection into tissue components of muscle, bone, skin, and fat, and each tissue was weighed. Weight losses which occurred during the storage and separation procedures were assumed to be water. The water lost was added back to each cut and tissue component based on the percentage of total carcass water within each tissue and the percentage of each tissue in a wholesale cut.

The dissected muscle tissue and offal components were weighed and their protein, ether extractable fat, and dry matter content were then determined. The chemical composition of the dissected bone, skin, and fat was estimated based on literature values. The weight and chemical composition of the offal components were corrected for digesta contents in the gastrointestinal tract by subtracting the estimated weight of digesta and its associated nutrient components adjusted for digestibility of nutrients in the feed ingredients used.

A comparative slaughter technique was used to estimate changes in sow body composition during lactation. Primiparous sows (high LG, n=13; low LG, n=9) fed the same dietary regimen (energy and amino acid intake over maintenance) and housed and managed in the same manner as the experimental sows were killed for estimation of the sow's body composition on day 2 postpartum. The initial body composition of the lactating sows on day 2 postpartum was estimated by regressing body tissue content of the sows killed within each sow genotype against empty body sow weight and sow backfat depth. Empty body weight of the lactating sows on day 2 postpartum was assumed to be body weight minus the weight of the digesta.

Based on the sow's dietary nutrient intakes and the nutrient composition of the mobilized maternal tissues, the amounts of lysine (digestible equivalent) and energy (dietary ME equivalent) available for sow maintenance and milk synthesis were calculated. Digestible equivalent lysine was calculated using digestibility coefficients of .80 and .85 for corn and soybean meal, respectively (NRC,1988), and lysine contents of mobilized body proteins of 7.1, 4.2, 4.6, 6.5, and 6.4% for muscle, skin, bone, fat and offal,

respectively. The ME equivalent energy was calculated using NRC (1988) values for the feed ingredients in the diets and assuming the ME equivalent available from mobilized body protein and lipid were 4.35 and 9.45 kcal/g, respectively.

Data were analyzed as a split plot design using the General Linear Model of SAS (1995). Sow LG genotype was considered the whole plot treatment and dietary lysine regimen the subplot treatment. The sow/litter was considered the experimental unit. Sows of similar weight and farrowing date formed replicates. Least square means are reported.

Results and Discussion

Thirty-two high lean growth (LG) genotype and twenty-eight low lean growth genotype sows and litters were evaluated (Table 2). Sow empty body weight (EBW) on day 2 postpartum was similar in the high and low LG sows; however, body composition differed markedly between genotypes at the initiation of lactation. High LG sows possessed more dissectable muscle and less dissectable fat tissue and back fat. Body nutrient content also differed with high LG sows possessing more body protein and less lipid. Litter size at day 2 postpartum averaged 14 pigs in both sow genotypes while litter weight was similar.

Sows from both genotypes consumed less feed than estimated to be needed to support maximum milk yield and consequently mobilized body tissues to provide additional energy and nutrients (Table 3). However, the amount of each tissue mobilized was dependent on LG genotype. High LG sows mobilized more muscle and less fat. Furthermore, high LG sows mobilized more body protein and less body lipid. High LG sows seemed to depend on mobilization of proteinaceous tissues stores to provide the necessary energy to fuel milk synthesis.

From days 2 to 28 postpartum, estimated milk, milk energy, and milk lysine yields were similar between LG genotypes (Table 3). A study conducted previously at our station to investigate the maximum lactational capacity of sows demonstrated that primiparous sows are capable of producing 383 kcal milk energy/kg$^{.75}$ body weight at peak lactation when sufficient suckling demand is provided (Sauber et al., 1994). The high and low LG sows in this study achieved peak daily milk energy yields of 307 and 335 kcal/kg$^{.75}$, respectively, which represent milk yields equivalent to 174 to 190% of that estimated by NRC (1988; 176 kcal/kg^{75}) and 80 to 87% of the yields achieved in sows experiencing maximum suckling demand. These values compare favorably to the milk energy yields of 300 to 350 kcal/kg^{75} body weight reported for the high producing dairy cow.

Table 2. Lactating sow and litter characteristics of the two lean growth (LG) genotypes on day 2 postpartum.

	LG Genotype	
Item	Low	High
Number of sow-litters	28	32
Sow characteristics		
Empty body weight, lb	350	367
Backfat depth, in[ab]	1.25	.71
Separable tissues		
Muscle, lb[b]	141	202
Fat, lb[b]	82	46
Body nutrients		
Protein, lb[b]	54	66
Lipid, lb[b]	113	72
Litter characteristics		
Pigs/litter	14	14
Litter weight, lb[c]	46	51

[a]Mean of 4 ultrasonic measurements 2 inches off midline over the first, tenth, and last ribs, and last lumbar vertebrae.
[b]LG genotype effect, P<.01.
[c]LG genotype effect, P<.05.

Table 3. Impact of lean growth (LG) genotype on lactating sow and litter performance from day 2 to 28±1 postpartum.

	LG Genotype	
Item	Low	High
Sow characteristics		
Body weight change, lb/day	-2.66	-2.49
Dietary nutrient and energy intakes		
Feed intake, lb/day[c]	9.39	11.46
Dietary lysine intake, g/day		
Total[c]	37	45
Digestible[c]	30	37
ME intake, Mcal/day[c]	13.76	16.76
Separable tissue changes		
Muscle, lb/day[c]	-1.32	-2.03
Fat, lb/day[c]	-1.19	-.36
Body nutrient changes		
Protein, lb/day[c]	-.48	-.60
Lipid, lb/day[c]	-1.29	-.52
Yield of milk component		
Milk, lb/day	23.8	23.5
Energy, Mcal/day	13.0	12.6
Lysine, g/day	46	45
Pigs/litter[a]	13.0	13.0

[a]Mean number of pigs per litter from d 2 to weaning.
[b]LG genotype effect, P<.05.
[c]LG genotype effect, P<.01.

Feed and ME intakes were similar among sows fed the four dietary amino acid regimens (Table 4) and therefore, as lysine concentration increased, daily dietary lysine intake increased. However, sows in the various treatment groups consumed only 60 to 84% of their daily feed allowance during lactation; thus, dietary energy and lysine intakes were below the targeted daily allowances. Actual dietary ME and lysine intakes for each of the four dietary amino acid regimens, respectively, were 16.0, 17.3, 15.3, and 17.4 Mcal/day and 29, 41, 46, and 62 g/day in the high LG sows and 15.2, 13.3, 13.5, and 14.2 Mcal/day and 29, 32, 40, and 51 g/day in the low LG sows.

The quantity and composition of maternal body tissue mobilized during lactation was dependent on dietary amino acid regimen as well as LG genotype (Table 4). As dietary lysine intake increased, mobilization of maternal body protein in both genotypes was reduced, indicating that lysine was becoming less limiting to milk synthesis. In contrast, the availability of energy for milk synthesis was becoming more limiting than amino acids, and the sows responded by mobilizing more maternal body lipid. Apparently because of lower maternal body fat stores, the high LG sows had to depend more on mobilized muscle tissue to meet their energy needs.

Litter size was similar among dietary amino acid regimens (Table 5); however, milk and milk energy and lysine yields were dependent on dietary amino acid regimen as well as the lean growth capacity of the sows. At the lowest dietary lysine intake, the high LG sows produced more milk and milk energy and lysine than the low LG sows. As dietary lysine intake increased, milk and milk energy and lysine yields increased in both genotypes; however, the magnitudes of the responses were less in the high LG sows. Thus, the high LG sows at the highest lysine intakes produced less milk and milk energy and lysine than the low LG sows resulting in a genotype by diet interaction.

Because of the use of the comparative slaughter technique in the present study, total lysine (digestible equivalent) and energy (ME equivalent) supplies available from dietary intakes plus mobilized body tissues for sow body maintenance and milk synthesis can be calculated (Table 6). As expected, as dietary lysine intake increased, total amount of digestible equivalent lysine available also increased. However, due to the mobilization of greater amounts of proteinaceous tissues, high LG sows had greater total supplies of lysine available at each level of dietary lysine intake. As dietary lysine intake increased and energy became more limiting to milk synthesis, ME from mobilized sow body tissues increased. Although sows in both genotypes responded by mobilizing more maternal body lipid, the high LG sows were only able to mobilize 3.17 to 4.22 Mcal ME daily from body stores compared with 5.03 to 8.09 Mcal ME in the low LG sows. Because of their limited ability to mobilize fat stores, high LG sows had smaller supplies of total ME equivalent at each level of dietary lysine intake. To compensate, high LG sows likely catabolized substantial quantities of amino acids for energy. Because of greater daily feed intakes and rates of mobilization of body protein stores,

Table 4. Impact of lean growth (LG) genotype and dietary lysine (L) regime on dietary nutrient intakes and empty body weight, backfat, separable tissue, and body nutrient changes in lactating sows from d 2 to 28±1 postpartum.

	LG	Dietary Lysine, %			
Item	Genotype	.58	.77	.96	1.15
Number of sows	Low	8	6	7	7
	High	9	9	7	7
Feed intake, lb/d[a]	Low	10.3	9.1	9.3	9.7
	High	10.9	11.8	10.5	11.9
Body wt change, lb/d	Low	-2.49	-2.89	-2.84	-2.41
	High	-2.81	-2.50	-2.57	-2.07
Separable tissue changes					
Muscle, lb/d[a]	Low	-1.50	-1.30	-1.38	-1.09
	High	-2.43	-2.17	-2.16	-2.00
Fat, lb/d[ac]	Low	-.80	-1.10	-1.41	-1.47
	High	-.31	-.30	-.52	-.31
Body nutrient changes					
Protein, lb/d[ac]	Low	-.49	-.57	-.49	-.38
	High	-.69	-.61	-.56	-.53
Lipid, lb/d[ac]	Low	-.86	-1.20	-1.48	-1.63
	High	-.38	-.45	-.69	-.56

[a]LG genotype effect, P<.05.
[b]Dietary lysine effect, P<.01.
[c]Dietary lysine effect, P<.05.
[d]LG genotype x dietary lysine effect, P<.10.

Table 5. Impact of lean growth (LG) genotype and dietary lysine (L) regimen on litter weight gains and milk yields from day 2 to 28±1 postpartum.

	LG	Dietary Lysine, %			
Item	Genotype	.58	.77	.96	1.15
Number of litters	Low	8	6	7	7
	High	9	9	7	7
Pigs/litter	Low	12.4	13.1	13.4	12.9
	High	13.1	13.0	12.8	12.9
Yield of milk components					
Milk, lb/day[bc]	Low	21.6	22.8	25.1	25.7
	High	22.7	23.8	24.0	24.1
Energy, Mcal/day[bc]	Low	11.45	12.21	13.62	14.81
	High	12.17	12.65	13.30	13.68
Lysine, g/day[bc]	Low	38	43	48	52
	High	42	46	48	49

[a]LG genotype effect, P<.05.
[b]Dietary lysine effect, P<.01.
[c]LG genotype x dietary lysine effect, P<.05.

greater total supplies of lysine were available to the high LG sows; however, due to the lower supplies of available ME, the high LG sows were not able to utilize the additional supplies of lysine to support milk synthesis.

In the high and low LG sows with similar daily supplies of available ME (19.18 and 19.96 Mcal) and lysine (46 and 45 g), daily yield of milk (10.3 and 10.4 kg), milk energy (12.2 and 12.2 Mcal) and milk lysine (42 and 43 g) were similar. Furthermore, when daily supplies of lysine and ME were similar, sows in both LG genotype required similar amounts of ME (1.86 to 1.92 Mcal) and digestible lysine (4.3 to 4.5 g) per kg of milk yield. However, at greater lysine intakes, the additional energy available from mobilized maternal tissues in the low LG sows allowed them to produce more milk likely due to the additional 1.3 to 1.7 Mcal ME supply available to these sows daily.

Based on these data, milk, milk energy, and lysine yields of high and low lean growth genotype sows are similar when similar total supplies of lysine and energy are available. When energy supplies do no limit milk synthesis, the efficiency of utilization of digestible lysine for milk lysine production is similar between genotypes with 1.95 to 2.05 g of digestible lysine needed per pound of milk produced.

Because of the limited body fat stores in high LG sows, provision of adequate dietary energy intakes is more critical in genetically lean sows in order to allow maximum lactational capacity to be expressed. If insufficient ME is consumed by high LG sows, dietary amino acid concentrations may need to be lowered to reduce the metabolic burden associated with eliminating the excess amino acids derived from the diet and mobilized body tissues to prevent further reduction in the available ME supplies for milk synthesis.

Table 6. Impact of lean growth (LG) genotype and dietary lysine (L) regimen on digestible equivalent lysine and ME equivalent energy from dietary intakes and mobilized body tissues from d 2 to d 28±1 postpartum.

	LG	Dietary Lysine, %			
Item	Genotype	.58	.77	.96	1.15
Digestible equivalent lysine, g/day					
Diet[ab]	Low	23	26	33	42
	High	23	33	38	51
Mobilized tissues[ab]	Low	16	19	16	12
	High	23	20	18	17
Total[ab]	Low	39	45	49	54
	High	46	53	56	68
ME equivalent energy, Mcal/day					
Diet[a]	Low	15.18	13.31	13.52	14.15
	High	16.01	17.26	15.32	17.37
Mobilized tissues[ab]	Low	5.03	6.65	7.69	8.09
	High	3.17	3.32	4.22	3.59
Total[a]	Low	20.21	19.96	21.21	22.24
	High	19.18	20.58	19.54	20.96

[a]LG genotype effect, P<.05.
[b]Dietary lysine effect, P<.01.
[c]LG genotype x dietary lysine effect, P<.05.

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