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Robert L. Fischer
University of Nebraska - Lincoln

Phillip S. Miller
University of Nebraska - Lincoln, pmiller1@unl.edu

Austin Lewis
University of Nebraska - Lincoln, alewis2@unl.edu

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The Effect of Compensatory Growth on Organ Weights and Carcass Composition in Growing Gilts

Robert L. Fischer
Phillip S. Miller
Austin J. Lewis[1]

Summary and Implications

An experiment was conducted to examine the effects of compensatory growth and amino acid supply on organ weights and carcass characteristics in growing gilts. Gilts were fed either a corn-soybean meal diet or a corn-soybean meal diet supplemented with crystalline lysine. Pigs were randomly allotted to either a 21-day ad libitum eating period or a 42-day restricted-realimentated feeding period. The restricted-realimentated (RR) feeding period consisted of a 21-day restriction period and a 21-day ad libitum eating period (realimentation). During the restriction period, pigs were fed to maintain body weight. Results indicated that during the restriction period, gilts had a decrease ($P < 0.01$*) in the weight of the liver, kidneys and small intestine. During the first week of ad libitum eating, organ weights of gilts in the RR group increased dramatically. Weights of the liver and stomach of gilts in the RR group were greater (*$P < 0.05$*) than the ad libitum (AL) fed gilts during week one of ad libitum eating. In addition, weights of the kidneys, small intestine and mesentery were not different between feeding regimens after the first week of ad libitum eating. Carcass and ultrasound measurements taken before and after the restriction period showed a numerical decrease in tenth-rib backfat and an increase in longissimus muscle area during the 21-day restriction period. These measurements are consistent with the decrease (*$P < 0.01$*) in the percentage of carcass fat and an increase (*$P < 0.05$*) in carcass protein percentage caused by restricted feeding. Although the carcass protein percentage was greater in the RR gilts at the start of the ad libitum eating period, carcass protein accretion was greater (*$P < 0.01$*) in the AL gilts versus the RR gilts during weeks one and two of ad libitum eating. Gilts in the RR group exhibited compensatory organ growth during the first week of the ad libitum eating period. Also, during a restriction period, growing gilts are able to use fat stores and repartition visceral protein to maintain lean muscle deposition.*

Growing pigs often face environmental and health challenges which limit energy and nutrient intake. This research has identified that protein from liver and other visceral depots can be used to help provide amino acids for muscle growth during prolonged feed restriction. Also, the weight and composition of visceral organs are restored quickly when refeeding commences. Because these tissues account for a significant portion of pig's daily energy requirement, fundamental knowledge documenting how key organs respond to energy and nutrient intake will ultimately help provide insight into how pigs will adapt to specific nutritional regimens. Additional research is needed to see how organs and muscle adaptations change as the pig progresses through the growing and finishing phases.

Introduction

When a growing pig's development is restricted by a period of environmental stress, such as reduced nutrient availability, severe temperature extremes, or disease, it exhibits a period of decreased growth. Upon removal of such stresses, the animal exhibits an accelerated and more efficient rate of growth than that which is normal for animals of the same chronological age. Bohman (1955) termed this abnormally rapid growth relative to age "compensatory growth." Carcass composition, organ size and metabolic activities are altered during a restriction-realimentation period. Animals are able to recover from periods of undernutrition by prolonging the growth period, increasing appetite and rate of gain, reducing their maintenance energy requirement, and

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increasing efficiency of energy use for body gain. The maintenance energy requirement is reduced in restricted fed animals because of a decrease in basal metabolism rate. Thus, during the early stages of realimentation a greater fraction of the net energy of the diet is available for productive processes in animals exhibiting compensatory growth.

The primary objective of this research was to investigate the effects of feed restriction and realimentation on the response of plasma urea concentration in gilts fed a traditional corn-soybean meal diet or a lysine-supplemented, corn-soybean meal diet. The second objective was to examine organ adaptations and the gilt's ability to deposit lean tissue after a period of feed restriction. The restriction-refeeding model has been used in order to: 1) investigate how organs adapt (provide nutrients) during a period of feed restriction (e.g., with disease and (or) high environmental temperatures); and 2) examine how growth rate (often accelerated upon refeeding after feed restriction) is related to and (or) controlled by changes in visceral organ metabolic activity.

Table 1. Ingredient and calculated composition of diets, as-fed basis.

Item	Corn-soybean meal	Corn-soybean meal + lysine
Ingredient, %		
Corn	74.02	77.85
Soybean meal (46.5% CP)	21.40	17.25
Tallow	2.00	2.10
Lysine	—	.15
Dicalcium phosphate	1.05	1.15
Limestone	.43	.40
Salt	.30	.30
Vitamin premix[a]	.70	.70
Trace mineral premix[b]	.10	.10
Calculated nutrient content		
Crude protein, %	16.30	14.30
ME[c], Mcal/lb	1.55	1.55
Lysine, %	.89	.89
Calcium, %	.65	.65
Phosphorus, %	.55	.55

[a] Supplied per kilogram of diet: retinyl acetate, 3,088 IU; cholecalciferol, 386 IU; α-tocopherol acetate, 15 IU; menadione sodium bisulfite, 2.3 mg; riboflavin, 3.9 mg; d-pantothenic acid, 15.4 mg; nicacin, 23.2 mg; choline, 77.2 mg; vitamin B_{12}, 15.4 µg.
[b] Supplied per kilogram of diet: Zn (as ZnO), 110 mg; Fe (as $FeSO_4 \cdot H_2O$), 110 mg; Mn (as MnO), 22 mg; Cu (as $CuSO_4 \cdot 5\ H_2O$), 11 mg; I (as $Ca(IO_3) \cdot H_2O$), .22 mg; Se (as Na_2SeO_3), .3 mg.
[c] Metabolizable energy.

Procedures

Forty-six crossbred gilts with an initial weight of 73 lb were used. Four gilts were randomly selected for an initial slaughter group to determine initial organ weights and carcass composition. Eighteen gilts were allocated to have ad libitum access to either a corn-soybean meal diet or a corn-soybean diet with supplemental lysine. Within this group, six pigs, three from each diet treatment, were slaughtered on weeks one, two and three of the experiment. Twenty-four gilts were offered a maintenance level of feed for 21 days. Feed allotments were adjusted every three days to minimize weight loss or gain. At the end of the 21-day feed restriction period, the restricted pigs weighed 73 lb. On day 21, six restricted gilts were randomly selected for slaughter. The remaining 18 gilts were allowed ad libitum access to either the corn-soybean meal or the lysine-supplemented diet until slaughter. Within this group, six pigs, three from each diet treatment were slaughtered on weeks four, five and six of the experiment. All pigs were individually penned in an environmentally controlled room.

Diets were corn-soybean meal-based and formulated to contain one of two crude protein percentages (16.3 or 14.3%; Table 1). All other nutrient concentrations were equal to, or in excess of, NRC (1998) requirements. During the feed restriction period gilts were fed the 16.3% CP corn-soybean meal diet. Daily feed allotments during the feed restriction period were based on each pig's maintenance energy requirement. Because nutrient densities were not adjusted during the restriction period, daily intakes of all nutrients were less than NRC (1998) requirements for growth.

Pig weights were recorded weekly during the ad libitum period and every three days during the restriction period. Feed consumption was measured weekly for the ad libitum (AL) groups and daily during the realimentation period for the restricted-realimented (RR) groups. Blood samples were collected weekly for both feeding groups and daily during the first week of ad libitum feeding. Ultrasound scan measurements of backfat and loin area at the 10th rib were made weekly by a certified technician. Carcass measurements and organ weights were collected at slaughter. Gastrointestinal contents were removed to determine empty body weight (live weight minus gastrointestinal content weight). The right half of each carcass was ground and a subsample was obtained to determine the percentage of protein, fat, water and ash in each carcass.

Data were analyzed as a completely randomized design using the GLM procedure of SAS (1996). The main effects in the statistical model were feeding regimen (AL or RR) and diet (corn-SBM or corn-SBM + lysine). The data were analyzed within week of ad libitum eating. Therefore, comparisons were made between gilts that had ad libitum access to feed for an equal amount of time. The comparisons that were analyzed were between gilts slaughtered on weeks one and four, weeks two and five, and weeks three and six. In addition, gilts slaughtered at the start of the trial were compared to gilts slaughtered after the restriction period

Table 2. Organ weights, carcass measurements, and carcass composition of gilts slaughtered on day 0 versus gilts slaughtered after a 21-d restriction period.

Item	d 0[a]	d 21[b]	FR[c]
Body Weight, lb	73.32	72.77	NS
Organs			
Heart, lb	.36	.33	NS
Liver, lb	1.34	1.04	0.01
Kidney, lb	.32	.22	0.01
Pancreas, lb	.15	.14	NS
Lungs, lb	.90	.86	NS
Stomach, lb	.55	.49	0.05
Small intestine, lb	2.28	1.56	0.01
Large intestine, lb	1.14	1.07	NS
Mesentery, lb	.82	.64	0.05
Carcass measurements			
First-rib backfat, in	.33	.65	0.05
Tenth-rib backfat, in	.25	.23	NS
Last-rib backfat, in	.22	.25	NS
Last-lumbar backfat, in	.20	.13	0.05
Longissimus muscle area, in^2	3.15	4.13	0.01
Carcass length, in	22.63	22.83	NS
Hot carcass weight, lb	45.18	52.46	0.01
Empty body weight, lb	71.51	71.71	NS
Carcass Percentage			
Protein, %	17.70	18.97	0.05
Fat, %	15.89	9.43	0.01
Water, %	62.17	67.96	0.01
Ash, %	2.18	2.56	0.01

[a]d 0 = gilts slaughter at the start of the trial.
[b]d 21 = gilts slaughter after a 21-d restriction period.
[c]FR = feeding regimen P-value and NS = nonsignificant effect, P > 0.10.

Table 3. Organ weights of gilts fed a corn-soybean meal or lysine-supplemented, corn-soybean meal diet during two different feeding regimens.

Diets		Corn-soybean meal		Corn-soybean meal+lysine		P-Value[b]		
Item	Feeding regimen[a]	AL	RR	AL	RR	FR	D	FR x D
Week 1								
Body weight, lb		90.78	97.02	93.27	92.54	NS	NS	NS
Heart,lb		.40	.38	.41	.39	NS	NS	NS
Liver, lb		1.86	1.94	1.66	1.90	< 0.05	< 0.05	NS
Kidney, lb		.39	.41	.37	.33	NS	< 0.05	NS
Stomach, lb		.74	.84	.66	.82	< 0.05	< 0.05	NS
Small intestine, lb		3.00	2.76	2.75	2.69	NS	NS	NS
Large intestine, lb		1.70	1.74	1.40	1.59	NS	NS	NS
Mesentery, lb		1.09	1.29	1.14	.92	NS	NS	< 0.05
Week 2								
Body weight, lb		109.30	106.57	105.11	108.55	NS	NS	NS
Heart, lb		.46	.48	.43	.50	NS	NS	NS
Liver, lb		1.93	1.94	1.85	2.13	< 0.05	NS	< 0.05
Kidney, lb		.44	.45	.42	.44	NS	NS	NS
Stomach, lb		.82	.90	.76	.99	<0.05	NS	NS
Small intestine, lb		2.56	2.77	2.48	2.86	NS	NS	NS
Large intestine, lb		1.83	1.92	1.74	1.82	NS	NS	NS
Mesentery, lb		1.23	1.16	1.27	1.29	NS	NS	NS
Week 3								
Body weight, lb		117.90	131.13	116.14	132.81	< 0.01	NS	NS
Heart, lb		.50	.49	.62	.53	NS	< 0.05	NS
Liver, lb		2.35	2.34	2.05	2.38	NS	NS	NS
Kidney, lb		.48	.51	.48	.50	NS	NS	NS
Stomach, lb		.93	.91	.79	.98	NS	NS	< 0.05
Small intestine, lb		2.85	2.81	2.93	2.95	NS	NS	NS
Large intestine, lb		2.00	2.11	1.95	2.14	NS	NS	NS
Mesentery, lb		1.71	1.68	1.54	1.54	NS	< 0.05	NS

[a]AL = ad libitum group and RR = restricted-realimentated group.
[b]FR = feeding regimen; D = diet; and NS = nonsignificant effect, P > 0.10.

to examine the effects of restriction on body composition. The model used was as follows: $Y_{ijk} = \mu + \alpha_i + \beta_j + (\alpha\beta_{ij}) + e_{ijk}$ where Y_{ijk} is the observed value for a dependent variable on the kth pig (k = 1, 2,...46), μ is the overall mean, α_i is the effect of the ith feeding regimen (i = 1, 2), β_j is the effect of the jth diet (j = 1,2), and e_{ijk} is the random error term. In all statistical analyses, pig was the experimental unit.

Results

Growth performance, plasma urea concentrations, and ultrasound measurement data from this experiment were reported in the 2000 Nebraska Swine Report.

Organ weights, carcass measurements, and carcass composition of the initial slaughter groups are shown in Table 2. During the restriction period, weights of the liver, kidney, stomach, and the small intestine were decreased ($P < 0.01$) in the restricted gilts compared with gilts at the start of the trial. Carcass measurements showed a decrease ($P < 0.05$) in last-lumbar backfat, and an increase in first-rib backfat ($P < 0.05$), longissimus muscle area ($P < 0.01$), and hot carcass weight ($P < 0.01$) during the restriction period. During the restriction period, gilts were able to increase the percentage of protein ($P < 0.05$), water ($P < 0.01$), and ash ($P < 0.01$). During this same period there was a decrease ($P < 0.01$) in the percentage of carcass fat in the restricted gilts compared with the initial slaughter group.

Organ weights during the three weeks of ad libitum eating are shown in Table 3. Liver weight of the RR gilts increased dramatically during the first week of ad libitum feeding and was greater ($P < 0.05$) than that of the AL gilts throughout the ad libitum eating period. During week one, liver weights were heavier ($P < 0.05$) in gilts fed the corn-soybean meal diet versus the lysine-supplemented diet. There was a feeding regimen × diet interaction ($P < 0.05$) observed during week two of the ad libitum feeding period for liver

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weight. This interaction seems to be a result of the increased metabolic demands of the liver because of the increase in feed intake of the RR gilts fed the lysine-supplemented diet. Kidney weights were greater ($P < 0.05$) in gilts fed the corn-soybean meal diet versus the lysine-supplemented diet during week one. Stomachs of the RR gilts were heavier ($P < 0.05$) than those of AL gilts during weeks one and two and were heavier ($P < 0.05$) in gilts fed the corn-soybean meal versus the lysine supplemented diet during week 1. There was a feeding regimen× diet interaction ($P < 0.05$) observed during week three of the ad libitum feeding period for stomach weight. This interaction seems to be a result of differences in feed intake, gilts in the AL group fed the corn-soybean meal diet consumed more feed than did gilts fed the lysine-supplemented diet, however, the opposite effect was seen in the RR group. The weight of the small intestine in the RR gilts almost doubled during the first week of ad libitum eating (Table 2 and 3), but there were no differences between feeding or diet treatments during the ad libitum eating period. Heart and large intestinal weights showed no differences between initial slaughter group, or between feeding treatments during the ad libitum eating period.

Carcass accretion of protein, fat, water, and ash are shown in Table 4. There were no differences between feeding or diet treatments for carcass fat accretion during the entire ad libitum eating period. Carcass protein, water, and ash accretion were greater ($P < 0.05$) in the AL versus RR gilts during weeks one and two of the ad libitum eating period. There was no effect of feeding or diet treatment during week 3 for carcass accretion of protein, water or ash.

Table 4. Carcass accretion in gilts fed a corn-soybean meal or lysine-supplemented, corn-soybean meal diet during two different feeding regimens.

Diets		Corn-soybean meal		Corn-soybean meal+lysine		P-Value[b]		
Item	Feeding regimen[a]	AL	RR	AL	RR	FR	D	FR x D
Week 1								
Body weight, lb		90.78	97.02	93.27	92.54	NS	NS	NS
Protein, lb/d		.37	.24	.47	.23	< 0.01	NS	NS
Fat, lb/d		.41	.47	.38	.40	NS	NS	NS
Water, lb/d		1.65	.81	1.83	.95	< 0.01	NS	NS
Ash, lb/d		.06	.03	.09	.02	< 0.01	NS	NS
Week 2								
Body weight, lb		109.30	106.57	105.11	108.55	NS	NS	NS
Protein, lb/d		.30	.25	.34	.25	< 0.01	NS	NS
Fat, lb/d		.35	.42	.46	.38	NS	NS	NS
Water, lb/d		1.24	.83	1.30	.87	< 0.01	NS	NS
Ash, lb/d		.05	.03	.05	.03	< 0.01	NS	NS
Week 3								
Body weight, lb		117.90	131.13	116.14	132.81	< 0.01	NS	NS
Protein, lb/d		.28	.27	.28	.30	NS	NS	NS
Fat, lb/d		.52	.52	.44	.51	NS	NS	NS
Water, lb/d		.93	1.02	1.01	1.14	NS	NS	NS
Ash, lb/d		.04	.04	.04	.03	NS	NS	NS

[a]AL = ad libitum group and RR = restricted-realimentated group.
[b]FR = feeding regimen; D = diet; and NS = nonsignificant effect, P > 0.10.

These results indicate that organs exhibit a compensatory growth response after a period of feed restriction. This is best illustrated by the dramatic increase in organ weights during the first week of the ad libitum eating period. During the 21-day restriction period, gilts in the RR group were able to increase the protein percentage in the carcass, but during the ad libitum eating period carcass protein accretion was lower compared to the AL gilts. This decrease in carcass protein accretion and increase in organ weights during weeks one and two of the ad libitum eating indicates that the majority of the protein intake was being used for organ growth. This may suggest that after a restriction period the amino acid concentration and/or pattern may need to be adjusted to support organ growth and carcass protein accretion. Further research is needed to explore the metabolic pathways by which pigs are able to use fat stores and deposit lean muscle tissue during a period of feed restriction.

[1]Robert L. Fischer is a research technologist and graduate student, Phillip S. Miller is an associate professor, and Austin J. Lewis is a professor in the Department of Animal Science.