SWINE UPDATE

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Dietary Carnitine and Chromium Improve Energy Status of Gestating Sows

Carnitine and chromium are both essential for proper energy metabolism in swine. Carnitine is a vitamin-like compound that is needed for the transport of long- and medium-chain fatty acids across the mitochondrial membrane for Vitamin B oxidation. Chromium is a trace mineral that is essential for activating specific enzymes and stabilizing proteins and nucleic acid. Chromium has been shown to improve insulin sensitivity and glucose uptake.

In experiments conducted over the past eight years, feeding sows a diet with either carnitine or chromium has been shown to improve sow reproductive performance, but only recently has an experiment been conducted to evaluate the effects when both are added to the diets fed to sows. In a previous *Swine Update*, we reported that when carnitine and/or chromium are added to diets of gestating sows, farrowing rate was improved with the greatest improvement observed from the diet containing both carnitine and chromium. We also observed that when the treatments were fed for two parities, more sows completed the entire test period and thus produced more pigs when fed diets with carnitine or chromium compared to control sows. Because both carnitine and chromium influence energy metabolism, these results suggest that associated improvements in reproductive performance may reflect enhanced energy status of the sows. In addition, an additive response may be observed from feeding both carnitine and chromium because each influences a different phase of energy metabolism. So the objective of this experiment was to determine the influence of dietary carnitine and(or) chromium on daily blood parameter profiles, as indicators of energy status.

Procedures

A total of 44 sows (average birth weight=458 lb; parity=2.0) were used. Sows (PIC C-22) were randomly allotted to one of four dietary treatments based on parity and weight at initial breeding. Dietary treatments were corn-soybean meal-based and were formulated to meet or exceed National Research Council nutrient requirement estimates. Treatments were arranged in a 2 by 2 factorial design with main effects of dietary carnitine (0 or 50 ppm) and chromium (0 or 200 ppb). Sows were fed the experimental treatments starting at the initial breeding, through gestation, the following lactation, wean-to-breeding interval, and approximately 28 days into the subsequent gestation, at which time blood was collected. Sows were fed 4.5 pounds of gestation diet from breeding until day 100 of gestation, then 6.5 pounds until they farrowed. Lactation diet was fed ad libitum from farrowing until weaning.

Approximately five days before blood collection, the sows were fitted with indwelling cephalic vein catheters. Blood was collected from each sow at feeding – once every 15 minutes for the first 3 hours after feeding, and at 6, 9, 15, 20, and 24 hours after feeding – for a total of 18 collections from each sow. Samples were then analyzed to determine insulin, glucagon, glucose, insulin-like growth factor 1 (IGF-1), insulin-like growth factor binding protein-3 (IGFBP-3), non-esterfied fatty acids (NEFA), plasma urea nitrogen (PUN), glycerol, triglycerides, and leptin as indicators of energy status.

Results and Discussion

Both carnitine and chromium influenced the energy status of the sows in our experiment. Chromium had its greatest effect immediately after feeding by improving insulin sensitivity and glucose uptake, whereas carnitine had its greatest effect from six to 24 hours after the meal by improving fatty acid utilization and decreasing muscle breakdown. The most dramatic improvement in energy status occurred in the sows fed both carnitine and chromium because the benefits from both feed additives were realized.

Research has shown that chromium, as a component of the glucose-tolerance factor, will improve insulin sensitivity and consequently glucose uptake. In our study, sows fed diets containing chromium had lower glucose, insulin, and c-peptide concentrations compared to other sows. Insulin is the major anabolic hormone in the body, and rising insulin concentrations act as a signal for greater glucose uptake and overall energy storage. In our experiment, sows fed diets containing chromium had lower mean insulin concentrations compared to sows fed

diets without chromium. We also observed that the food-induced glucose peak was lower for sows fed chromium, even though these sows also had lower insulin concentrations. This suggests that insulin sensitivity was enhanced and the uptake of glucose by peripheral tissue was more efficient. The fact that glucose was lower when sows were fed diets with chromium — even though all sows were fed the same amount of feed and consequently had the same amount of glucose intake — also supports our hypothesis that glucose uptake was enhanced.

We also observed that sows fed diets with chromium had higher glycerol and non-esterified fatty acid (NEFA) concentrations compared to sows fed diets without chromium. Glycerol and NEFA are released from the adipose tissue as energy substrates in times of fasting or greater energy demand. The rise in glycerol and NEFA suggests that sows fed diets with chromium exhibited greater lipolysis, especially from three to 24 hours after the meal, compared to other sows.

Previous research with finishing pigs showed that dietary carnitine improved fatty acid utilization and decreased muscle degradation. In our experiment, sows fed diets with carnitine had lower circulating NEFA compared to sows fed diets without carnitine. Because there was no change in glycerol concentration, the lower NEFA would reflect the ability of sows to use the fatty acids for energy more efficiently when fed diets containing carnitine and not a decrease in lipolysis.

Sows fed diets with carnitine also had lower plasma urea nitrogen (PUN) compared to sows not fed carnitine. PUN increases as a result of muscle breakdown, especially in times of greater energy demand or fasting. The reduction of PUN in our study would reflect less muscle catabolism because it occurred mostly from six to 24 hours after the meal. These results suggest that since the sows fed diets with carnitine were able to use the fatty acids more efficiently, they did not need to break down as much muscle for energy production.

We also observed that sows fed diets with carnitine tended to have higher IGF-1 and IGFBP-3 concentrations. Insulin-like growth factor 1 is an important hormone that promotes muscle fiber proliferation and differentiation in neonates. Insulin-like growth factor binding protein 3 is the major binding protein of IGF-1 in swine and functions by binding free IGF-1, extending its half-life. The increase in IGF-1 and IGFBP-3 observed from feeding sows diets with carnitine could explain the improvements in offspring muscling previously observed.

Sows fed diets with carnitine also had higher leptin concentrations compared to other sows. Leptin acts as an energy abundance signal that is released from tissues such as adipose, placenta, and uterus. Leptin is needed for proper reproductive function in males and females. Increasing leptin in other animals has been shown to improve reproductive performance. Therefore, the improvements in reproductive performance previously observed from feeding sows carnitine may be explained by our finding that carnitine will increase circulating leptin.

Conclusion

Sows fed the diets containing both carnitine and chromium exhibited the greatest improvement in energy status because the benefits of both carnitine and chromium were observed. The improvements in insulin sensitivity and glucose clearance were observed immediately after the meal, and the improvement in fatty acid utilization was observed from six to 24 hours after the meal in sows fed both carnitine and chromium. Feeding sows diets with both carnitine and chromium had no deleterious effects on energy utilization compared to control sows.

Both carnitine and chromium will influence the energy status of gestating sows fed one meal per day. The previously observed improvements in sow productivity from feeding carnitine and/or chromium might be explained by improvements in energy status we observed in this trial. However, initial differences in feed intake, sow energy status, energy demand, or productivity level may influence the degree of improvement observed from feeding either or both of these feed additives.

Table 1. Influence of L-carnitine and(or) chromium picolinate on blood parameters[a]

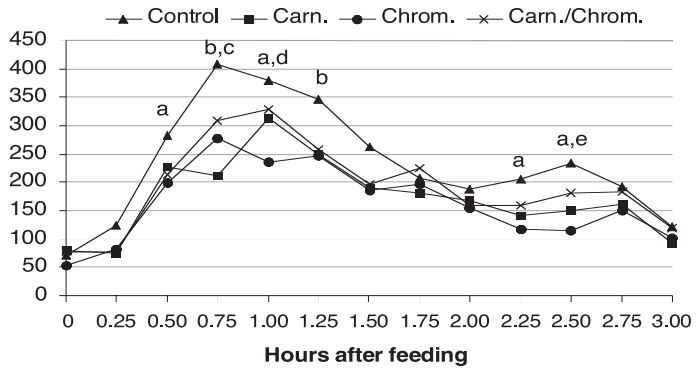
	Carnitine, ppm	0	50	0	50		Probability, P <		
Item	Chromium, ppb	0	0	200	200	SEM	Carn.	Chrom.	C x C
C-peptide of insulin, nmol/L[b]		0.485	0.417	0.391	0.430	0.018	0.31	0.004	0.0001
Insulin, pmol/L[b]		190.5	148.3	135.0	158.5	15.6	0.32	0.02	0.0004
Glucose, mmol/L[b]		4.42	4.41	4.30	4.22	0.07	0.25	0.0006	0.42
NEFA, mmol/L[b]		0.145	0.135	0.167	0.138	0.008	0.002	0.03	0.10
IGF-1, nmol/L[b]		14.34	17.91	14.08	15.12	1.97	0.11	0.28	0.37
Glucagon, pmol/L[b]		30.95	30.84	32.85	30.81	1.24	0.33	0.39	0.37
Urea nitrogen, mmol/L[b]		4.61	3.64	4.32	4.46	0.21	0.04	0.18	0.005
Glycerol, mmol/L[c]		0.043	0.042	0.051	0.049	0.005	0.73	0.008	0.70
Triglyceride, mmol/L[c]		0.263	0.277	0.276	0.276	0.026	0.60	0.69	0.61
IGFBP-3, nmol/L[c]		4.70	4.86	4.72	5.40	0.23	0.06	0.19	0.22
Leptin, mg/L[b]		0.80	1.84	1.12	1.22	0.38	0.02	0.56	0.06

[a]Values represent a total of 44 sows (BW = 208 kg; parity = 2.0) with 10 or 12 sows per treatment.

[b]Values represent the mean of samples collected at feeding, once every 15 minutes for the first 3 hours after feeding, and at 6, 9, 15, 20, and 24 hours after feeding.

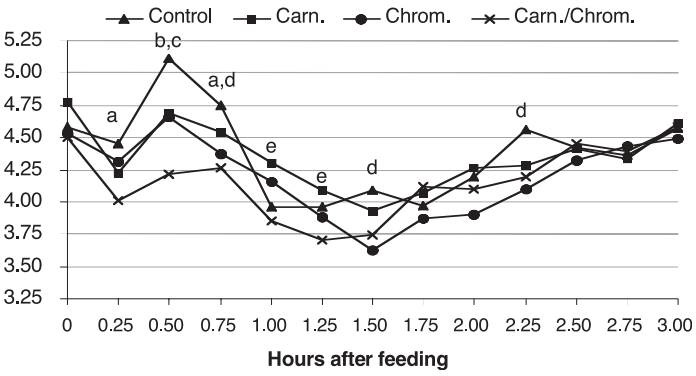
[c]Values represent the mean of samples collected at feeding, 30 minutes, 1, 2, 6, and 20 hours after feeding.

Figure 1. Influence of L-carnitine and(or) CrP on insulin (pmol/L).



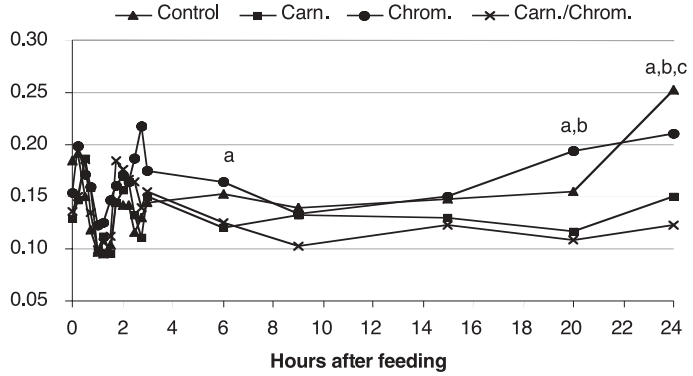
[a]Control > Chrom.; $P < 0.05$. [b]Control > others; $P < 0.05$.
[c]Carn./Chrom. > Carn.; $P < 0.05$. [d]Carn./Chrom > Chrom.; $P < 0.05$.
[e]Control > Carn.; $P < 0.05$.

Figure 2. Influence of L-carnitine and(or) CrP on glucose (mmol/L).



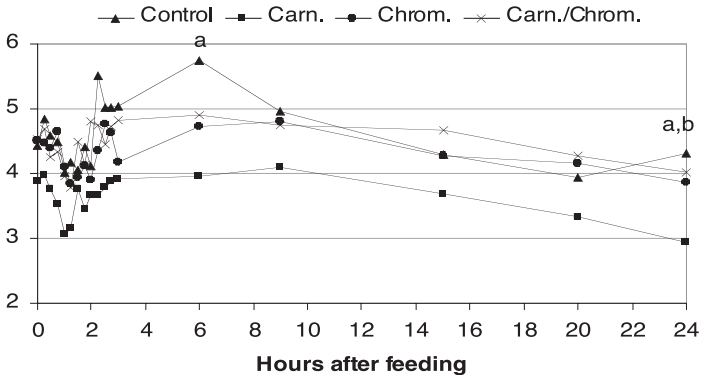
[a]Control > Carn./Chrom.; $P < 0.05$. [b]Control > others; $P < 0.05$.
[c]Carn./Chrom. < others; $P < 0.05$. [d]Control > Chrom.; $P < 0.05$.
[e]Carn. > Carn./Chrom.; $P < 0.05$.

Figure 3. Influence of L-carnitine and(or) CrP on NEFA (mmol/L).



[a]Chrom. > Carn.; $P < 0.05$. [b]Chrom. > Carn./Chrom.; $P < 0.05$.
[c]Control > Carn. and Carn./Chro.; $P < 0.05$.

Figure 4. Influence of L-carnitine and(or) CrP on plasma urea nitrogen (mmol/L).



[a]Control > Carn.; $P < 0.05$. [b]Carn./Chrom. > Carn.; $P < 0.05$.

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Jim L. Nelssen
Extension Specialist
Swine

Robert D. Goodband
Extension Specialist
Swine

Mike D. Tokach
Extension Specialist
Swine

Steve Dritz
Swine Specialist
Food Animal Health and
Management Center

Kansas State University
Cooperative Extension Service
Department of Animal Sciences & Industry
Weber Hall, Room 213
Kansas State University
Manhattan, Kansas 66506