Chromium, Tryptophan, and Picolinate in Diets for Pigs and Poultry.

Timothy Guinn Page
Louisiana State University and Agricultural & Mechanical College

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Chromium, tryptophan, and picolinate in diets for pigs and poultry

Page, Timothy Guinn, Ph.D.
The Louisiana State University and Agricultural and Mechanical Col., 1991

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CHROMIUM, TRYPTOPHAN, AND PICOLINATE IN DIETS FOR PIGS AND POULTRY

A Dissertation

Submitted to the Graduate Faculty of the Louisiana State University and Agricultural and Mechanical College in partial fulfillment of the requirements for the degree of Doctor of Philosophy in The Department of Animal Science

by

Timothy Guinn Page
B.S., Sam Houston State University, 1976
M.Ed., Sam Houston State University, 1980
December 19, 1991
ACKNOWLEDGEMENTS

During my years at LSU I was a recipient of much kindness and goodwill. For this I am very grateful. What I owe Dr. L. Lee Southern I cannot repay. I am most appreciative of his continual encouragement, scientific prowess, and sage literary advice throughout this educational journey. I owe a particular voice of thanks to Terry L. Ward, friend and colleague, for his perspiration, patience and countless hours of assistance, labor, and technical knowledge. I am also grateful to committee members, Dr. D. L. Thompson, Jr., Dr. J. A. Hebert, Dr. L. D. Bunting, Dr. P. E. Humes, Dr. S. S. Nicholson, and Dr. L. C. Kappel for their guidance and input. I would like to thank Don Williams, the Swine Farm allies, and Valerie Achee for their friendship and meticulous care in handling the animals on my research projects. I also would like to express my appreciation to Nutrition 21 for furnishing the chromium picolinate.

This is the time to acknowledge my other debts: to Debbie, Kevin, and Kit for things whereof one cannot speak; to my parents for teaching me by example of what I ought to be to my children, Sunni and Seth, and to them I owe thanks for providing me with the smiles and memories required to complete this project as well as providing me with excuses for delaying it. When Dylan Thomas dedicated his Collected Poems 1943-1951 to his wife, Caitlin, he wrote in the Note: "These poems, with all their crudities, doubts and
confusions, are written for the love of Man and in praise of God, and I'd be a damn' fool if they weren't." My book is more humble. Moreover, the doubts are obvious; the crudities and confusions are, I trust, less so, and fewer. But it, too, is dedicated to someone's wife - mine - for I would be a damn fool if it wasn't. Thanks a bunch Cheryl for the love and sacrifices.

Finally - but how can I ever thank Foy and Nell?

Tim Page

Baton Rouge, Louisiana
December 19, 1991
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ABSTRACT

Six experiments were conducted to evaluate the effects of supplemental dietary tryptophan (TRP), picolinate (Pic), CrCl₃·6H₂O, chromium picolinate (CrPic), or a combination of Pic and CrCl₃·6H₂O on growth performance, liver mineral concentrations, insulin, growth hormone, organ weights, and serum and carcass traits of pigs. One experiment was conducted to evaluate the effect of CrPic on serum cholesterol (CH), egg CH, egg quality, and egg production of laying hens.

Dietary TRP, Pic, CrCl₃·6H₂O, and a combination of Pic and CrCl₃·6H₂O did not affect growth performance, liver mineral concentrations, insulin, growth hormone, and serum and carcass traits of pigs. The effects of CrPic on pig growth performance, growth hormone, and insulin were not consistent. Organ weights were not affected (P > .10) by CrPic. However, CrPic, when provided at the 100 or 200 ppb level of Cr, increased (P < .01) loin eye area and percentage of muscling, reduced (P < .01) 10th rib fat thickness, and reduced (P < .05) serum CH in growing-finishing pigs. Chromium was equally effective in pigs from the Louisiana State University Agricultural Center Swine Unit as well as pigs from a different ancestral source.

The effects of graded levels of CrPic also were evaluated in laying hens. Egg CH, Haugh units, and specific gravity of eggs were not affected (P > .10) by CrPic
supplementation. Percentage of egg fat and CP were inconsistently reduced (P < .10) by CrPic. However, egg production was increased (P < .04) and serum CH was reduced (P < .08) by CrPic, especially at 100 and 200 ppb Cr.

Supplemental dietary CrPic increases muscling and decreases fat and serum CH in growing-finishing pigs. Laying hen egg production also is increased and serum CH is reduced by CrPic supplementation.
INTRODUCTION

Pig and poultry producers are continually searching for more economical and efficient ways to produce a greater quantity of quality product. Throughout the pig industry, the emphasis is on lean pork. Currently, the use of partitioning agents such as beta adrenergic agonists and porcine somatotropin are achieving desirable changes in the carcass traits of pigs (Chung et al., 1985; Etherton et al., 1986, 1987; Bergen et al., 1989). However, these products have not reached the market due to the lack of Food and Drug Administration approval. In addition, consumer acceptance is not guaranteed.

The health-conscious public has presented a challenge to the poultry industry as well, to reduce egg cholesterol. Poultry research has extensively examined reducing egg cholesterol and increasing egg production without favorable results. The problems the pig and poultry industries are facing, producing a healthier product for human consumption and more of it, possibly may be solved through the manipulation of specific nutrients in diet formulation. The use of tryptophan, picolinate, and chromium in pig and poultry diets to effectively produce a greater quantity of quality product is the focus of this dissertation.

Tryptophan is an essential amino acid for pigs and poultry. Although tryptophan is present in most proteins, it
is present in only small amounts, and therefore, the requirement in the diet is low compared with the other essential amino acids (NRC, 1984, 1988). Tryptophan has been linked to many factors that influence and regulate vital biological mechanisms (Sidransky, 1985). Sidransky et al. (1984) reported that tryptophan exhibited hormone-like properties in promoting protein synthesis in rat liver. Lin et al. (1988) reported that maximal activity of porcine skeletal muscle ribosomal fraction was increased by excess dietary tryptophan. Tryptophan's ability to enhance hepatic protein synthesis and possibly protein synthesis in other organs and tissues may extend its requirement beyond that of a simple constituent of protein. If an increase in protein synthesis results in an overall net increase in muscle tissue deposition, then the use of excess tryptophan in pig diet formulation may increase porcine muscling and decrease fat.

The use of L-tryptophan by humans as a treatment for maladies such as insomnia, premenstrual syndrome, and depression increased during the 1980s. However, in 1989, an unusual syndrome was reported with symptoms of muscle soreness, swelling, and itching skin (Hertzman et al. 1990; Silver et al., 1990). Another symptom was an abnormally high muscle esinophil count. The new syndrome, esinophilia-myalgia (EMS), was finally linked to patients that had been taking doses of L-tryptophan. Scientists now believe that the cause of EMS was not L-tryptophan; rather, evidence
points to a contaminant in the L-tryptophan. Even though the contaminant has not been identified, researchers point to a change in manufacturing procedure as the cause for the contamination. Chung et al. (1991) reported that oral ingestion of L-tryptophan is safe for pigs, even in considerable excess of the requirement.

In mammals, more than 90% of the tryptophan is degraded in the liver through the kynurenine pathway (Sidransky, 1985). Tryptophan metabolism gives rise to the vitamin, niacin, as well as the hormone, serotonin. Certainly, high protein diets, especially those high in soybean protein, require very little if any niacin fortification because of the excess tryptophan contained in these diets. Another tryptophan metabolite is the pyridine-2-carboxylic acid, commonly called picolinic acid, or picolinate. Hahn and Evans (1973) detected a zinc-binding ligand in the luminal wash and intestinal mucosal cells of rats. A similar ligand was detected in the pancreatic secretions and pancreatic extracts from dogs (Evans et al., 1975). This zinc-binding ligand was later identified as picolinate (Evans and Johnson, 1980b). Picolinate has been proposed to have a physiological role in the absorption of zinc and other metals (Evans and Johnson, 1980b; Seal and Heaton, 1985; Johnson et al., 1988; Aggett et al., 1989). Evans and Johnson (1980a) reported that picolinate had a growth stimulating effect on rats; however, Hill et al. (1987) observed no effect of picolinate
on gain, feed efficiency, or zinc status of 5 to 10 kg pigs. The availability of endogenous picolinate is dependent on the level of dietary tryptophan. Other factors that may affect the availability of picolinate are: 1) cations compete for coordination with picolinate and 2) inborn errors of tryptophan metabolism that affect its conversion to picolinate.

Chromium is one of the metals whose absorption has been reported to be facilitated by picolinate (Evans, 1982). The absorption rate of inorganic forms of chromium is only .05 to 1% (Kumpulainen, 1988). The exact site and mode of action of trivalent chromium as it influences various aspects of metabolism have not been resolved. However, the association of chromium status with growth (Mertz and Roginski, 1969), glucose tolerance (Schwartz and Mertz, 1959), insulin-receptor binding reaction (Mertz, 1969), lipid metabolism (Riales and Albrink, 1981), amino acid uptake (Weser and Koolman, 1969), and protein synthesis (Okada et al., 1983) indicate that chromium is an essential dietary trace element in animal nutrition.

Chromium is required for maintenance of normal glucose tolerance (Mertz, 1969). Patients on total parenteral nutrition (TPN) have been shown to need chromium supplements to avoid severe glucose intolerance and weight loss (Freund et al., 1979; Hauer and Kaminski, 1978). Chromium concentration is higher in protein than synthetic amino acid
mixtures, fat, carbohydrates, or electrolyte solutions. Most TPN solutions contain approximately a 3 to 5% synthetic amino acid solution. When patients on TPN began showing severe glucose intolerance and weight loss were supplemented with 150 µg of chromium/day, the glucose intolerance was reversed and weight gain resulted (Freund et al., 1979). The American Medical Association (1979) recommends daily supplementation of TPN solutions with chromium.

Since the glucose tolerance factor (GTF) was identified (Schwartz and Mertz, 1957) and the active ingredient was determined to be chromium (Schwartz and Mertz, 1959), the structure of the compound and the role of chromium have been the subject of extensive investigation. The best known function of the GTF is stimulation of the action of insulin in chromium deficient tissue (Mertz, 1969). Insulin, a polypeptide hormone, promotes anabolic processes and inhibits catabolic ones in muscle, liver, and adipose tissue. Insulin stimulates the active transport of glucose and amino acids into muscle cells and protein synthesis is enhanced. Glycolysis and oxidative phosphorylation of glucose derivatives provide the energy required for such metabolic activity.

It is now accepted that the action of insulin is not restricted to carbohydrate metabolism. Glucose-independent effects on amino acid transport and utilization for protein synthesis have been shown (Krahl, 1961). Roginski and Mertz
(1968) reported that insulin in vivo stimulated the incorporation of three amino acids into heart and liver protein in rats that were supplemented with 2 ppm chromium in the drinking water. Weser and Koolman (1969) demonstrated that amino acid incorporation in rat liver nuclei was much greater in the presence of chromium than in the control or in the presence of other transition metals such as iron, manganese, and mercury. The significance of this data is that it supports the hypothesis of chromium acting as a cofactor for insulin. It can now be applied to two insulin-responsive steps in amino acid metabolism which are independent of the action of insulin on glucose utilization.

Chromium has long been linked to lipid metabolism. Schroeder et al. (1970) first established the hypothesis that chromium deficiency may be a risk factor in atherosclerotic disease. This hypothesis was based not only on studies in chromium-deficient rats showing elevation of serum cholesterol and production of aortic plaques, but also on epidemiological studies in man correlating low tissue chromium levels, particularly those in the aorta, with increased incidence of cardiovascular diseases. Schroeder et al. (1970) also reported an average 12.2% decline in the serum cholesterol concentrations in seven patients supplemented with 2 mg of chromium/day. Doisy et al. (1976), using a chromium-rich brewer's yeast, found a highly significant reduction of serum cholesterol from 236 to 200
mg/100 ml in 16 healthy subjects after one month of supplementation. Offenbacher and Pi-Sunyer (1980), in elderly humans, reported a strong cholesterol-lowering effect from supplementation with brewer's yeast chromium, but not from supplementation with chromium-deficient torula yeast.

The nutritional status and function of chromium in livestock species also have been investigated. Abraham et al. (1980) reported that chromium reduced cholesterol-induced atherosclerotic plaques in rabbits. Samsell and Spears (1989) indicated that chromium supplementation lowered fasting plasma glucose concentrations in lambs fed a low fiber diet. Chang et al. (1991) suggested that calves fed corn silage following market-transit stress may be deficient in chromium, and supplemental GTF chromium decreased serum cortisol and improved immune status. Chromium has been shown to increase turkey breast size (Anderson et al., 1989) as well as promote growth of turkey poults (Steele and Rosebrough, 1979). Hill and Matrone (1970) and Hafez and Kratzer (1976) reported that chromium reduced the toxicity of vanadium in growing chicks. Jensen and Maurice (1980) reported that chromium was not effective in reversing the adverse effects of vanadium on albumen quality. Currently, the NRC (1984, 1988) does not recommend dietary chromium supplementation in poultry and pig diets, even though Jensen et al. (1978) and Steele et al. (1977) have determined that chromium is biologically active in poultry and pigs.
The NRC (1989) recommends a chromium intake of 50-200 μg/day for human adults. Schroeder (1971) indicated that most plant products are low in chromium. Pig and poultry diets are primarily composed of ingredients from plant origin and therefore, may be deficient in dietary chromium, especially for optimal pig and poultry productivity.

The evidence that dietary tryptophan, picolinate, and chromium may improve animal efficiency and productivity warranted investigation to determine if nutritional manipulation of these nutrients would affect the quantity and quality of pig and poultry products. Therefore, the objective of this study was to evaluate the effects of supplemental dietary tryptophan, picolinate, and(or) chromium on growth performance, liver mineral concentrations, hormones, organ weights, and serum and carcass traits of pigs, and egg production and egg quality of poultry.
Literature Cited


INTRODUCTION
The importance of tryptophan (TRP) in swine nutrition has been known for some time (Boomgaardt and Baker, 1973; Lewis et al., 1977; Lin et al., 1986). The TRP requirement for swine (NRC, 1988) is low compared to other essential amino acids. However, tryptophan's role in regulation of protein synthesis may extend its requirement beyond the level that maximizes growth and feed efficiency. Sidransky et al. (1984) indicated that administration of TRP increased polyribosomal aggregation, protein synthesis, and levels of cytoplasmic poly(A)mRNA in rat liver. Lin et al. (1988) reported that dietary TRP concentrations required for maximal growth in pigs were less than that needed for maximal activity of the muscle ribosomal fraction. Tryptophan also has been shown to stimulate nucleocytoplasmic translocation of mRNA and concomitant protein synthesis in rat liver (Sidransky et al., 1990).

These studies suggest that the recommended dietary TRP (NRC, 1988) concentrations may not lead to maximal protein accretion in pigs. Lenis et al. (1990) reported that excess dietary TRP increased daily gain of fast-growing boars and gilts, but that it did not affect the carcass traits measured. Therefore, the purpose of this investigation was
to evaluate the effect of excess dietary TRP on growth and carcass characteristics of finishing pigs.

MATERIALS AND METHODS

General. An experiment was conducted with crossbred (Yorkshire × Hampshire × Duroc) finishing pigs from the Louisiana State University Agricultural Center Swine Unit. A randomized complete block design was used and pigs were allotted to treatment on the basis of weight; ancestry and gender were equalized across treatments. Pigs were penned in an open front building with a solid concrete floor in 1.5 × 6.1 m pens during the entire trial. Average initial weight of pigs was 55.1 kg and the experimental period was 53 d. Each treatment was replicated four times with three pigs per replicate. Weight gain and feed consumption were measured every 2 wk until experiment completion. Treatment diets and water were provided on an ad libitum basis.

The experiment consisted of the following treatments: 1) Corn-soybean meal basal (B, Table 1.1), 2) B + .05% L-TRP, 3) B + .10% L-TRP, 4) B + .20% L-TRP. The basal diet used was formulated to contain .12% TRP (120% of the NRC recommendation, 1988), and .72% lysine (.16% lysine from L-lysine·HCl), and it met or exceeded the requirements of finishing pigs for all other nutrients.

Carcass Evaluation. At the termination of the trial, all pigs were slaughtered in a commercial facility and hot
### TABLE 1.1. PERCENTAGE COMPOSITION OF THE BASAL DIET

<table>
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<td>Corn</td>
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<td>Soybean meal, 44% CP</td>
<td>12.10</td>
</tr>
<tr>
<td>Defluorinated rock phosphate</td>
<td>1.00</td>
</tr>
<tr>
<td>Limestone</td>
<td>.55</td>
</tr>
<tr>
<td>Vitamin-mineral premix(^b)</td>
<td>.55</td>
</tr>
<tr>
<td>L-Lysine·HCl</td>
<td>.20</td>
</tr>
</tbody>
</table>

\(^a\)Calculated to provide .72% Lys and .12% Trp (NRC, 1988).

\(^b\)The vitamin premix provided the following per kg of diet: 4,400 IU vitamin A, 440 IU vitamin D3, 11 IU vitamin E, 1.1 mg vitamin K activity as menadione dimethylprimidinol bisulfite, 22 mg pantothenic acid, 22 mg niacin, 4.4 mg riboflavin, 440 mg choline chloride, 220 µg biotin, 22 µg vitamin B\(_2\)). The mineral premix provided the following per kg of diet: .1 mg Se, 1 mg I, 30 mg Mn, 8.75 mg Cu, 87.5 mg Fe, 75 mg Zn, 2.5 g NaCl.
carcass weights were obtained for dressing percentage calculation. Fat thickness over the loin eye muscle at the 10th rib and loin eye area (by tracing the longissimus muscle surface at the 10th rib) were adjusted to 104.3 kg by methods approved by the NSIF (1988). Percentage of muscling was obtained by the National Pork Producers Council method (1988).

**Statistical Analysis.** Data were analyzed by analysis of variance procedures (Steel and Torrie, 1980). Linear and quadratic contrasts were used to evaluate treatment effects. Single degree of freedom comparisons also were used to test treatment differences. Dressing percentage was analyzed using final BW as a covariate. The pen of pigs served as the experimental unit.

**RESULTS**

Daily gain was not affected \((P > .10)\) by level of TRP (Table 1.2). However, feed intake was increased \((P < .05)\) linearly by incremental TRP addition. This increase in feed intake resulted in a concomitant linear reduction \((P < .01)\) in efficiency of feed utilization. Dressing percentage, percentage of muscling, and 10th rib fat were not affected \((P > .10)\) by TRP addition to the diet. Loin eye area was lower \((P < .03)\) in pigs fed .22 and .32\% TRP than in pigs fed .12 and .17\% TRP.
TABLE 1.2. EFFECT OF EXCESS DIETARY TRYPTOPHAN ON GROWTH AND CARCASS CHARACTERISTICS OF FINISHING PIGS*

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<td>.951</td>
<td>.949</td>
<td>.938</td>
<td>.026</td>
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<td>3.19</td>
<td>3.28</td>
<td>.09</td>
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<tr>
<td>Gain/feed(^c)</td>
<td>.316</td>
<td>.302</td>
<td>.297</td>
<td>.286</td>
<td>.005</td>
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<td>Dressing percentage</td>
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<td>72.2</td>
<td>70.9</td>
<td>73.1</td>
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<tr>
<td>Percentage of muscling</td>
<td>52.4</td>
<td>52.0</td>
<td>51.4</td>
<td>52.5</td>
<td>.8</td>
</tr>
<tr>
<td>Loin eye area(^d), cm(^2)</td>
<td>34.6</td>
<td>34.0</td>
<td>31.7</td>
<td>32.9</td>
<td>.8</td>
</tr>
<tr>
<td>10th rib fat, cm</td>
<td>2.83</td>
<td>2.96</td>
<td>3.04</td>
<td>2.72</td>
<td>.17</td>
</tr>
</tbody>
</table>

*Data are means of four replicates of three pigs each. Pigs averaged 55.1 kg initially and the experimental period was 53 d.

\(^b\) Linear effect, P < .05.

\(^c\) Linear effect, P < .01.

\(^d\) Dietary TRP levels of .12 and .17% different (P < .03) from .22 and .32% Trp.
DISCUSSION

Although TRP is present in many proteins, it is present in only small amounts (much lower than most of the other amino acids) in mammalian hepatic proteins (Block and Weiss, 1956). Normally, TRP is the least abundant amino acid in proteins. A number of foodstuffs have been found to be deficient or limited in TRP, such as corn (NRC, 1988). Because TRP is present in protein in low concentrations, the requirement of TRP in the diet is low compared with that of the other essential amino acids (NRC, 1988).

In addition to being an essential building block in proteins, TRP has other important effects that influence and regulate vital biological mechanisms (Sidransky, 1985). Supplemental TRP, at 2000 ppm, to a laying hen basal diet containing .16% TRP resulted in a reduction in total liver lipids (Rogers et al., 1991). Sidransky et al. (1984) reported that TRP has hormone-like properties in promoting protein synthesis in rat liver primarily in two ways: 1) enhancement of mRNA synthesis and 2) altering the permeability of the nuclear envelope and facilitating translocation of mRNA from the nucleus to cytoplasm. These results suggest that TRP rapidly binds with hepatic proteins (possibly glycoproteins) associated with the nuclear membrane. This leads to an increase in the activity of enzymes involved in phosphorylation, dephosphorylation, in
release of nuclear mRNA into the surrounding environment, and an increased synthesis of hepatic proteins (Sidransky, 1985).

There is very little information regarding tryptophan's role in regulation of porcine protein synthesis. Dietary TRP concentrations that supported maximal growth rate for pigs were less than that needed for maximal activity of the skeletal muscle ribosomal fraction (Lin et al., 1988). These findings indicate that the use of maximal growth rate for determination of optimal dietary amino acid concentrations, such as TRP, may not lead to maximal protein synthetic activity of muscle ribosomes. The ability of TRP to stimulate muscle protein synthesis and deposition was not evident in the present study. Loin eye area was lower in pigs fed .22 and .32% TRP than in pigs fed .12 and .17% TRP. Dressing percentage and percentage of muscling were not affected by excess dietary TRP.

Chung et al. (1991) reported that the addition of .1 or 1% TRP to a corn-soybean meal basal diet containing .185% TRP had no effect on daily gain, feed intake or feed efficiency of finishing pigs. Growth performance data of the present study do not concur with these findings. Feed intake of finishing pigs was linearly increased by incremental TRP additions of .05, .10, and .20% to a .12% TRP basal diet, while feed efficiency was reduced. However, daily gain was not affected by TRP addition to the diet.
IMPLICATIONS

Excess dietary tryptophan did not exhibit positive effects on growth, feed efficiency or carcass characteristics of finishing pigs fed corn-soybean meal diets.
Literature Cited


CHAPTER 2
EFFECT OF CHROMIUM ON GROWTH, SERUM TRAITS, LIVER MINERAL CONCENTRATIONS AND CARCASS CHARACTERISTICS OF FINISHING PIGS

INTRODUCTION

Chromium (Cr) has been shown to promote growth in turkey pouls (Steele and Rosebrough, 1979; Rosebrough and Steele, 1981), mice (Schroeder et al., 1963), rats (Schroeder, 1966; Mertz and Roginski, 1969), and rainbow trout (Tacon and Beveridge, 1982). Britton et al. (1968) indicated that Cr increased N utilization in lambs and Cr also has been shown to increase percentage of turkey breast (Anderson et al., 1989). Chromium supplementation reversed glucose intolerance, reduced insulin requirements, and resulted in weight gain and the disappearance of encephalopathy in humans receiving long-term parenteral nutrition (Freund et al., 1979).

These studies provide a strong indication that Cr has a vital function in animal and human nutrition; however, the NRC (1988) currently does not recommend Cr supplementation to swine diets, even though biological activity of glucose tolerance factor Cr has been shown in swine (Steele et al., 1977). The NRC (1989) recommends a safe and adequate intake of 50-200 µg/d for human adults. Therefore, the purpose of this investigation was to evaluate the effect of Cr on growth, serum traits, liver mineral concentrations, and carcass characteristics of finishing pigs.
MATERIALS AND METHODS

General. An experiment was conducted with crossbred (Yorkshire × Hampshire × Duroc) finishing pigs from the Louisiana State University Agricultural Center Swine Unit. A randomized complete block design was used and pigs were allotted to treatment on the basis of weight; ancestry and gender were equalized across treatments. Pigs were penned in an open front building with a solid concrete floor in 1.5 x 6.1 m pens during the entire trial. Average initial weight of pigs was 61.7 kg and the experimental period was 43 d. Each treatment was replicated four times with three (replicate 4) or four (replicates 1 to 3) pigs per replicate. Weight gain and feed consumption were measured every 2 wk until experiment completion. Treatment diets and water were provided on an ad libitum basis.

The experiment consisted of the following treatments: 1) Corn-soybean meal basal (B, Table 2.1), 2) B + 30 ppm Cr, 3) B + 60 ppm Cr. Chromium was provided by CrCl\textsubscript{3}·6H\textsubscript{2}O. The basal diet used was formulated to contain 110% of the lysine requirement (NRC, 1988) for finishing pigs and it met or exceeded the requirements for all other nutrients.

Blood Analysis. Near the termination of the trial, all pigs were fasted overnight and then allowed to consume feed ad libitum for 30 min the following morning. Pigs were bled 3 h after the initiation of feeding. All blood samples were obtained via the anterior vena cava and centrifuged at 1020
<table>
<thead>
<tr>
<th>Ingredients</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>82.20</td>
</tr>
<tr>
<td>Soybean meal, 44% CP</td>
<td>15.70</td>
</tr>
<tr>
<td>Defluorinated rock phosphate</td>
<td>.95</td>
</tr>
<tr>
<td>Limestone</td>
<td>.60</td>
</tr>
<tr>
<td>Vitamin-mineral premix</td>
<td>.55</td>
</tr>
</tbody>
</table>

*Calculated to provide 110% of the Lys recommended by the NRC (1988).

The vitamin premix provided the following per kg of diet: 4,400 IU vitamin A, 440 IU vitamin D3, 11 IU vitamin E, 1.1 mg vitamin K acitiviy as menadione dimethylprimidinol bisulfite, 22 mg pantothenic acid, 22 mg niacin, 4.4 mg riboflavin, 440 mg choline chloride, 220 µg biotin, 22 µg vitamin B₁₂. The mineral premix provided the following per kg of diet: .1 mg Se, 1 mg I, 30 mg Mn, 8.75 mg Cu, 87.5 mg Fe, 75 mg Zn, 2.5 g NaCl.
×g for 20 min at 4 °C. Fresh serum was analyzed immediately for urea N, glucose, Ca, inorganic P, total protein, alkaline phosphatase, and triglyceride concentration (Anonymous, 1980; Gilford System 203, Ciba Corning Diagnostics Corp., Oberlin, OH). Serum was analyzed for cholesterol using the Lieberman-Burchard method (Technicon, 1974) with serum that had been frozen (-20 °C).

Carcass Evaluation. At the termination of the trial, pigs were slaughtered in a commercial facility and hot carcass weights were obtained for dressing percentage calculation. Carcass measurements were obtained following a 24 h chill at 2 °C. Backfat thickness (mean of three measurements taken at the first rib, last rib and last lumbar vertebrae), fat thickness over the loin eye muscle at the 10th rib, carcass length, and loin eye area (by tracing the longissimus muscle surface at the 10th rib) were adjusted to 104.3 kg by methods approved by the NSIF (1988). Percentage of muscling was obtained by the National Pork Producers Council method (1988).

Liver samples were wet ashed (AOAC, 1984) and analyzed for Cu, Zn, and Fe content via atomic absorption spectrophotometry (Anonymous, 1982; Atom Comp Series 800 with TI 7d00 ASR, Thermal/Jarrell-Ash Division of Fisher Scientific Co., Waltham, MA).

Statistical Analysis. Data were analyzed by analysis of variance procedures (Steel and Torrie, 1980). Linear and
quadratic contrasts were used to evaluate treatment effects. Dressing percentage was analyzed using final BW as a covariate. The pen of pigs served as the experimental unit and the model included weight as a block effect.

RESULTS

Daily gain and feed intake were not affected (P > .10) by Cr, although, there was a tendency for daily gain (P = .13) and feed intake (P = .19) to be linearly reduced in pigs supplemented with Cr (Table 2.2). Efficiency of feed utilization was not affected (P > .10) by treatment. Serum glucose, urea N, Ca, inorganic P, total protein, alkaline phosphatase, and cholesterol were not affected (P > .10) by Cr addition to the diet (Table 2.3). Serum triglyceride concentration was lower (Cr quadratic, P < .10) in pigs receiving 60 ppm Cr than in the control pigs or in pigs receiving 30 ppm Cr (Table 2.3). Liver mineral concentrations of Cu, Zn, and Fe were not affected (P > .10) by Cr (Table 2.3).

Loin eye area, carcass length, dressing percentage and percentage of muscling were not affected (P > .10) by dietary Cr supplementation (Table 2.4). Mean backfat thickness and 10th rib fat also were not affected (P > .10) by Cr; however, pigs receiving 30 and 60 ppm Cr had a tendency to have less (P = .18) 10th rib fat than the control pigs (Table 2.4).
<table>
<thead>
<tr>
<th>Item</th>
<th>Basal (B)</th>
<th>B + 30 ppm Cr</th>
<th>B + 60 ppm Cr</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gain, kg/d</td>
<td>.982</td>
<td>.959</td>
<td>.925</td>
<td>.022</td>
</tr>
<tr>
<td>Feed intake, kg/d</td>
<td>3.18</td>
<td>3.09</td>
<td>2.98</td>
<td>.09</td>
</tr>
<tr>
<td>Gain/feed</td>
<td>.310</td>
<td>.311</td>
<td>.311</td>
<td>.006</td>
</tr>
</tbody>
</table>

*Data are means of four replicates of three (replicate 4) or four (replicates 1 to 3) pigs each. Pigs averaged 61.7 kg initially and the experimental period was 43 d.

*Chromium was provided by CrCl$_3$·6H$_2$O.
<table>
<thead>
<tr>
<th>Item</th>
<th>Basal (B)</th>
<th>B + 30 ppm Cr</th>
<th>B + 60 ppm Cr</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cholesterol, mg/dl</td>
<td>82.5</td>
<td>87.2</td>
<td>87.9</td>
<td>2.3</td>
</tr>
<tr>
<td>Glucose, mg/dl</td>
<td>90.8</td>
<td>94.7</td>
<td>89.7</td>
<td>5.6</td>
</tr>
<tr>
<td>Urea N, mg/dl</td>
<td>14.9</td>
<td>15.8</td>
<td>15.6</td>
<td>.8</td>
</tr>
<tr>
<td>Total protein, g/dl</td>
<td>5.9</td>
<td>6.3</td>
<td>6.2</td>
<td>.2</td>
</tr>
<tr>
<td>Triglyceride, mg/dl</td>
<td>173</td>
<td>174</td>
<td>170</td>
<td>1</td>
</tr>
<tr>
<td>Ca, mg/dl</td>
<td>9.9</td>
<td>9.9</td>
<td>9.7</td>
<td>.1</td>
</tr>
<tr>
<td>Inorganic P, mg/dl</td>
<td>8.2</td>
<td>8.0</td>
<td>7.9</td>
<td>.2</td>
</tr>
<tr>
<td>Alkaline phosphatase, U/L</td>
<td>182</td>
<td>177</td>
<td>185</td>
<td>16</td>
</tr>
<tr>
<td>Liver Cu, μg/g of dry tissue</td>
<td>21</td>
<td>19</td>
<td>22</td>
<td>1</td>
</tr>
<tr>
<td>Liver Zn, μg/g of dry tissue</td>
<td>841</td>
<td>746</td>
<td>735</td>
<td>44</td>
</tr>
<tr>
<td>Liver Fe, μg/g of dry tissue</td>
<td>135</td>
<td>110</td>
<td>136</td>
<td>11</td>
</tr>
</tbody>
</table>

*Data are means of four replicates of three (replicate 4) or four (replicates 1 to 3) pigs each. Pigs averaged 61.7 kg initially and the experimental period was 43 d.

*Chromium was provided by CrCl₃·6H₂O.

*Chromium quadratic effect, P < .10.
**TABLE 2.4. EFFECT OF CHROMIUM ON CARCASS CHARACTERISTICS OF FINISHING PIGS**

<table>
<thead>
<tr>
<th>Item</th>
<th>Basal (B)</th>
<th>B + 30 ppm Cr</th>
<th>B + 60 ppm Cr</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dressing percentage</td>
<td>72.7</td>
<td>73.5</td>
<td>72.1</td>
<td>.8</td>
</tr>
<tr>
<td>Carcass length, cm</td>
<td>79.2</td>
<td>79.9</td>
<td>79.9</td>
<td>.7</td>
</tr>
<tr>
<td>Mean backfat thickness, cm</td>
<td>3.39</td>
<td>3.19</td>
<td>3.25</td>
<td>1.32</td>
</tr>
<tr>
<td>10th rib fat thickness, cm</td>
<td>2.91</td>
<td>2.87</td>
<td>2.67</td>
<td>.11</td>
</tr>
<tr>
<td>Loin eye area, cm²</td>
<td>34.7</td>
<td>32.1</td>
<td>34.4</td>
<td>1.1</td>
</tr>
<tr>
<td>Percentage of muscling</td>
<td>52.7</td>
<td>52.4</td>
<td>53.7</td>
<td>.6</td>
</tr>
</tbody>
</table>

*Data are means of four replicates of three (replicate 4) or four (replicates 1 to 3) pigs each. Pigs averaged 61.7 kg initially and the experimental period was 43 d.*

*Chromium was provided by CrCl₃·6H₂O.*
DISCUSSION

The exact site and mode of action of Cr as it influences various aspects of metabolism have not been resolved. The association of Cr status with growth (Schroeder et al., 1963; Mertz and Roginski, 1969), glucose tolerance (Schwartz and Mertz, 1959; Roginski and Mertz, 1969), lipid metabolism (Schroeder and Balassa, 1965; Riales and Albrink, 1981; Abraham et al., 1982; Mossop, 1983), amino acid utilization (Mertz, 1969; Roginski and Mertz, 1969; Weser and Koolman, 1969), and protein synthesis (Okada et al., 1983, 1984; Ohba et al., 1986; Anderson et al., 1989) indicate that Cr has an essential role in animal nutrition. However, growth performance, as well as serum cholesterol, glucose, urea N, and total protein of finishing pigs were not affected by dietary Cr supplementation in the present study. Serum triglyceride concentration was lower in pigs receiving 60 ppm Cr.

Mertz (1969) hypothesized that Cr facilitates the insulin-receptor binding reaction and thereby potentiates metabolic processes regulated by insulin in various target tissues. Since the glucose tolerance factor was identified (Schwartz and Mertz, 1957) and the active ingredient was thought to be Cr (Schwartz and Mertz, 1959), the structure of the glucose tolerance factor and the role of Cr have been the subject of extensive investigation. The best known function of the glucose tolerance factor is to stimulate the action of
the anabolic hormone insulin (Mertz, 1969). Insulin, a polypeptide hormone, promotes anabolic processes and inhibits catabolic ones in muscle, liver, and adipose tissue. Insulin stimulates the active transport of glucose and amino acids into muscle cells, and protein synthesis is enhanced. In the present study, Cr did not affect selected carcass traits that are a reflection of muscling and protein synthesis, such as loin eye area and percentage of muscling. Chromium supplementation, as CrCl₃·6H₂O, of corn-soybean meal diets does not affect growth, serum traits, liver mineral concentrations, or carcass characteristics of finishing pigs. The absorption rate of inorganic Cr is only .05 to 1% (Kumpulainen, 1988). Chromium’s absorption may be facilitated by the inorganic compound, picolinate (Evans, 1982). The inability of Cr to affect finishing pigs may be due to the inorganic form of Cr that was used in the present study. Therefore, further swine studies need to be conducted with organic forms of Cr.

IMPLICATIONS

Inorganic chromium, in the form of CrCl₃·6H₂O, may be less bioavailable than organic forms of chromium (Mertz, 1969; Votava et al., 1973; Offenbacher and Pi-Sunyer, 1980). Additional research needs to be conducted with organic forms of chromium to determine if chromium supplementation of swine diets could possibly affect swine productivity.
Literature Cited


INTRODUCTION

Chromium (Cr) has been shown to be biologically active in the rat (Mertz, 1965; Mertz and Roginski, 1969; Mertz, 1969), man (Glinsmann and Mertz, 1966), the laying hen (Jensen et al., 1978), the squirrel monkey (Davidson and Blackwell, 1968), and swine (Steele et al., 1977). Chromium is considered essential for maintenance of normal glucose tolerance (Schwartz and Mertz, 1959) and in a metabolic role as a cofactor for insulin (Schwartz and Mertz, 1957; Mertz, 1969). Steele et al. (1977) indicated that the glucose tolerance factor was "biologically active" in swine by potentiating the action of insulin. Glucose-independent effects of Cr on amino acid transport and utilization for protein synthesis also have been shown (Weser and Koolman, 1969; Okada et al., 1983, 1984).

The absorption and utilization of Cr may be dependent upon its association with an organic molecule (Mertz, 1969; Votava et al., 1973; Offenbacher and Pi-Sunyer, 1980) such as the metal chelator, picolinate (Pic), (Cousins and Smith, 1980; Evans and Johnson, 1980ab). Although there is no recommendation for Cr in swine (NRC, 1988), most swine diets are primarily composed of ingredients from plant origin, which are usually low in Cr (Schroeder, 1971). Therefore,
the purpose of this investigation was to assess the effect of Cr picolinate (CrPic) on growth performance, serum traits and carcass traits of growing-finishing pigs.

MATERIALS AND METHODS

General. Three experiments were conducted with crossbred (Yorkshire × Hampshire × Duroc) growing-finishing pigs from the Louisiana State University Agricultural Center Swine Unit. Pigs were penned in total confinement on totally slatted floors in 1.8 × 2.4 m pens during the growing period and in an open-front building with a solid concrete floor in 1.5 × 6.1 m pens during the finishing period. Randomized complete block designs were used and pigs were allotted to treatments on the basis of weight, and ancestry and gender were equalized across treatments. All treatments were replicated four times within each experiment with three pigs per replicate in Exp. 1, and four pigs per replicate in Exp. 2 and 3. The average initial weight of the pigs was 37.8, 30.5, and 22.4 kg in Exp. 1, 2, and 3, respectively, with experimental periods of 73, 83, and 98 d. Gain and feed consumption were taken every 2 wk until experiment completion for all three experiments. Treatment diets and water were provided on an ad libitum basis.

Experiment 1 was conducted to determine the effect of Cr, as CrPic (chromium tripicolinate, 12% Cr; Nutrition 21, 1010 Turquoise Street, San Diego, CA) on growth and serum and
carcass traits of growing-finishing pigs. The basal diet used (Table 3.1) was formulated to contain 120% of the lysine requirement (NRC, 1988) for growing and finishing pigs, and it met or exceeded the requirements for all nutrients. In Exp. 1, the basal diet was supplemented with 0, 25, 50, 100, or 200 ppb Cr. Supplemental Cr was provided by CrPic. Experiment 2 was similar to Exp. 1 except the Cr levels used were 0, 100, 200, 400, and 800 ppb Cr provided by CrPic. Experiment 3 was conducted to determine the effects of picolinate (Pic) and (or) inorganic Cr from CrCl₃·6H₂O, and organic Cr from CrPic. The diets used were: 1) Basal (B), 2) B + 1467 ppb Pic, 3) B + 200 ppb Cr from CrCl₃·6H₂O, 4) B + 1467 ppb Pic + 200 ppb Cr from CrCl₃·6H₂O, 5) B + 100 ppb Cr from CrPic, 6) B + 200 ppb Cr from CrPic. The concentration of Pic (1467 ppb) in Diets 2 and 4 was identical to the quantity of Pic provided by 200 ppb CrPic in Diet 6.

Blood Analysis. Two blood samples were collected from each pig at the termination of the experiments. A fasting blood sample was collected 16 h post feeding. Two days following this first blood collection, pigs were fasted overnight, allowed to consume feed ad libitum for 30 min the following morning, and bled 3 h after the initiation of feeding. All blood samples were obtained via the anterior vena cava and centrifuged at 1020 × g for 20 min at 4 °C. In Exp. 1, alkaline phosphatase (AP), Ca, total protein (TP), urea N (BUN), and glucose (GLU) were analyzed using fresh
<table>
<thead>
<tr>
<th>Ingredients</th>
<th>Grower</th>
<th>Finisher</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>73.30</td>
<td>80.00</td>
</tr>
<tr>
<td>Soybean meal, 44% CP</td>
<td>24.70</td>
<td>17.95</td>
</tr>
<tr>
<td>Defluorinated rock phosphate</td>
<td>.75</td>
<td>.90</td>
</tr>
<tr>
<td>Limestone</td>
<td>.70</td>
<td>.60</td>
</tr>
<tr>
<td>Vitamin-mineral premix(^b)</td>
<td>.55</td>
<td>.55</td>
</tr>
</tbody>
</table>

*Calculated to provide 120% of the Lys as recommended by NRC (1988).

\(^b\)The vitamin premix provided the following per kg of diet: 4,400 IU vitamin A, 440 IU vitamin D₃, 11 IU vitamin E, 1.1 mg vitamin K activity as menadione dimethylprimidinol bisulfite, 22 mg pantothenic acid, 22 mg niacin, 4.4 mg riboflavin, 440 mg choline chloride, 220 µg biotin, 22 µg vitamin B₆. The mineral premix provided the following per kg of diet: .1 mg Se, 1 mg I, 30 mg Mn, 8.75 mg Cu, 87.5 mg Fe, 75 mg Zn, 2.5 g NaCl.
serum, and inorganic P (IP), triglyceride (TG), cholesterol (CH), growth hormone (GH), and insulin (IN) were analyzed using serum that had been frozen (-20 °C). In Exp. 2, Ca and BUN were analyzed using fresh serum, and IP, TG, CH, GH, and IN were analyzed using serum that had been frozen (-20 °C). In Exp. 3, BUN was analyzed using fresh serum, and TG, CH, GH, and IN were analyzed using serum that had been frozen (-20 °C). In all experiments, serum collected from the fasted samples was analyzed for TG and IP (Anonymous, 1980; Gilford System 203, Ciba Corning Diagnostics Corp., Oberlin, OH); and for CH using the Lieberman-Burchard method (Technicon, 1974). Serum collected from the non-fasted samples was analyzed for AP, Ca, BUN, TP, and GLU concentrations (Anonymous, 1980; Gilford System 203, Ciba Corning Diagnostics Corp., Oberlin, OH).

Serum IN concentrations were determined using a commercially available RIA kit (ICN Biomedicals, Inc., Costa Mesa, CA). All samples were analyzed in duplicate in a single assay to avoid inter-assay variation. Sensitivity of the assay was 1.4 μU/ml, and intra-assay CV was 5.7.

Growth hormone was measured by means of a double-antibody RIA based on antiserum (AFP-10318545) against porcine GH (pGH). Highly purified pGH was radioiodinated via the chloramidine-T method (2.5 μg/μg of GH, 0 °C for 30 sec).

\(^1\)Provided by Dr. A.F. Parlow, Pituitary Horm. & Antisera Center, Harbor-UCLA Med. Center, 1000 W. Carson St., Torrance, CA 90509.
The antiserum was diluted 1:150,000 in PBS containing .033 M EDTA, .112% normal rhesus monkey serum (Calbiochem Corp., San Diego, CA) and 33% noninhibitory horse serum; 300 µl of this solution was used per tube. The horse serum was added to minimize and to stabilize nonspecific binding of radioiodinated pGH to the assay tubes. Antiserum (Calbiochem Corp., San Diego, CA) against rhesus monkey immunoglobulin-G was diluted 1:21 and was used at 200 µl/tube to precipitate the primary antibody. Cross-reactivities of other porcine pituitary hormones in the assay were (% relative to pGH): prolactin .08, FSH .12, LH .001 and thyroid stimulating hormone .004. Inhibition curves produced by serial dilutions of porcine sera and pituitary extracts were parallel to those produced by the reference standard (USDA-pGH-B1; National Hormone and Pituitary Agency, Baltimore, MD). Sensitivity of the assay averaged .1 ng; the sample size was 200 µl in a typical assay. Intra- and interassay CV were 8 and 11% for a pool of serum assayed in six separate assays.

**Carcass Evaluation.** Upon termination of the experiments, all pigs were slaughtered in a commercial facility and hot carcass weights were obtained for dressing percentage calculation. Selected carcass measurements were obtained following a 24 h chill at 2°C. Fat thickness over the loin eye muscle at the 10th rib (TRF) and loin eye area (LEA, by tracing the longissimus muscle surface at the 10th rib) were adjusted to 104.3 kg by methods approved by the
NSIF (1988). Percentage of muscling (PM) was obtained by the National Pork Producers Council method (1988).

**Statistical Analysis.** Data were analyzed by analysis of variance procedures (Steel and Torrie, 1980). Linear, quadratic, and cubic contrasts were used to evaluate treatment effects in Exp. 1 and 2. Treatment means in Exp. 3 were separated by meaningful nonorthogonal single degree of freedom comparisons. The pen of pigs served as the experimental unit in all experiments. Dressing percentage (DP) was analyzed using final BW as a covariate.

**RESULTS**

Average daily gain was increased by the 50 and 200 ppb Cr additions, but reduced by 100 ppb Cr addition in Exp. 1 (Cr quadratic, P < .03) (Table 3.2). Feed intake and efficiency of feed utilization were not affected (P > .10) by Cr. Serum CH was reduced (Cr linear, P < .01) in pigs fed 100 and 200 ppb Cr. Growth hormone was not affected (P > .10) by Cr; however, GH tended to be higher in pigs receiving the 50 ppb level of Cr. Serum IN was higher (P < .03, quadratic) in pigs fed 100 ppb Cr than in pigs fed the basal diet or other Cr levels. Carcass traits were not affected (P > .10) by Cr; however, TRF tended to be lower, and LEA and PM higher in pigs fed CrPic. Serum AP, TP, GLU, Ca, IP, TG, and BUN were not affected (P > .10) by treatment in Exp. 1 or in Exp. 2 and 3 (Table 3.3; Appendix A, B, and C).
<table>
<thead>
<tr>
<th>Item</th>
<th>Basal (B)</th>
<th>B + 25 ppb Cr</th>
<th>B + 50 ppb Cr</th>
<th>B + 100 ppb Cr</th>
<th>B + 200 ppb Cr</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gainb, kg/d</td>
<td>.807</td>
<td>.807</td>
<td>.840</td>
<td>.759</td>
<td>.870</td>
<td>.017</td>
</tr>
<tr>
<td>Feed intake, kg/d</td>
<td>2.79</td>
<td>2.61</td>
<td>2.77</td>
<td>2.62</td>
<td>2.84</td>
<td>.08</td>
</tr>
<tr>
<td>Gain/feed</td>
<td>.291</td>
<td>.311</td>
<td>.304</td>
<td>.290</td>
<td>.307</td>
<td>.010</td>
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<tr>
<td>Cholesterol, mg/dl</td>
<td>82.0</td>
<td>84.7</td>
<td>83.9</td>
<td>73.1</td>
<td>73.3</td>
<td>3.2</td>
</tr>
<tr>
<td>Growth hormone, ng/ml</td>
<td>2.18</td>
<td>2.94</td>
<td>5.26</td>
<td>2.60</td>
<td>2.41</td>
<td>.99</td>
</tr>
<tr>
<td>Insulinb, μU/ml</td>
<td>13.1</td>
<td>14.8</td>
<td>12.7</td>
<td>19.8</td>
<td>12.5</td>
<td>1.8</td>
</tr>
<tr>
<td>10th rib fat, cm</td>
<td>2.83</td>
<td>2.42</td>
<td>2.33</td>
<td>2.66</td>
<td>2.44</td>
<td>.18</td>
</tr>
<tr>
<td>Loin eye area, cm²</td>
<td>34.9</td>
<td>35.9</td>
<td>35.3</td>
<td>34.2</td>
<td>37.2</td>
<td>1</td>
</tr>
<tr>
<td>Percentage of muscling</td>
<td>52.9</td>
<td>54.7</td>
<td>54.5</td>
<td>53.6</td>
<td>54.3</td>
<td>.7</td>
</tr>
</tbody>
</table>

'1Data are means of four replicates of three pigs each. Pigs averaged 37.8 kg initially and the experimental period was 73 d.

2Chromium quadratic effect, P < .03.

3Chromium linear effect, P < .01.
TABLE 3.3. SERUM TRAITS OF GROWING-FINISHING PIGS UNAFFECTED BY TREATMENT (EXP. 1, 2 and 3)

<table>
<thead>
<tr>
<th>Item</th>
<th>Mean ± SEM</th>
<th>Exp. 1</th>
<th>Exp. 2</th>
<th>Exp. 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alkaline phosphatase, U/L</td>
<td>213.4 ± 17.6</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Total protein, g/dl</td>
<td>6.6 ± .1</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Inorganic P, mg/dl</td>
<td>8.4 ± .2</td>
<td>8.6 ± .2</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Ca, mg/dl</td>
<td>9.5 ± .1</td>
<td>10.3 ± .2</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Urea N, mg/dl</td>
<td>14.0 ± .7</td>
<td>14.7 ± .9</td>
<td>13.5 ± .6</td>
<td>-</td>
</tr>
<tr>
<td>Glucose, mg/dl</td>
<td>91.2 ± 2.4</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Triglyceride, mg/dl</td>
<td>38.1 ± 2.8</td>
<td>46.2 ± 6.9</td>
<td>28.0 ± 1.8</td>
<td>-</td>
</tr>
</tbody>
</table>

*Data are means of four replicates of three pigs each. Pigs averaged 37.8 kg initially and the experimental period was 73 d.

*Data are means of four replicates of four pigs each. Pigs averaged 30.5 kg initially and the experimental period was 83 d.

*Data are means of four replicates of four pigs each. Pigs averaged 22.4 kg initially and the experimental period was 98 d.
In Exp. 2, feed intake was reduced (P < .05) linearly by incremental Cr addition which resulted in a concomitant linear reduction (P < .05) in daily gain (Table 3.4). Feed efficiency was not affected (P > .10) by Cr. Serum CH was reduced (Cr quadratic, P < .06) 14% by the 100 ppb Cr level and by 9% by the 400 ppb level. Slight reductions in CH also were seen in pigs receiving 200 and 800 ppb Cr. Serum GH was increased incrementally up to 400 ppb Cr but not by the 800 ppb level (Cr quadratic, P < .08). Insulin was not affected (P > .10) by dietary Cr. All levels of dietary Cr had a very positive effect on carcass traits. Tenth rib fat thickness was reduced (Cr quadratic, P < .01) by Cr addition with an average reduction of 23% for pigs receiving CrPic compared with pigs fed no CrPic. Dressing percentage was increased (Cr linear, P < .07), and LEA and PM were increased (Cr quadratic, P < .01) by Cr addition.

Feed intake was increased (P < .07) and feed efficiency decreased (P < .01) in pigs fed Cr from CrPic compared to pigs not receiving CrPic in Exp. 3 (Table 3.5). Daily gain, CH, GH, IN, and DP were not affected (P > .10) by treatment. Tenth rib fat thickness was again reduced (P < .01) and LEA and PM increased (P < .01) in pigs fed Cr from CrPic compared with pigs fed the basal diet. Chromium chloride and(or) Pic did not affect (P > .10) carcass traits of pigs.
TABLE 3.4. EFFECT OF CHROMIUM PICOLINATE ON GROWTH AND SERUM AND CARCASS TRAITS OF GROWING-FINISHING PIGS (EXP. 2) *

<table>
<thead>
<tr>
<th>Item</th>
<th>Basal (B)</th>
<th>B + 100 ppb Cr</th>
<th>B + 200 ppb Cr</th>
<th>B + 400 ppb Cr</th>
<th>B + 800 ppb Cr</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gain&lt;sup&gt;b&lt;/sup&gt;, kg</td>
<td>.910</td>
<td>.899</td>
<td>.904</td>
<td>.854</td>
<td>.827</td>
<td>.025</td>
</tr>
<tr>
<td>Feed intake&lt;sup&gt;b&lt;/sup&gt;, kg</td>
<td>2.74</td>
<td>2.64</td>
<td>2.68</td>
<td>2.43</td>
<td>2.53</td>
<td>.07</td>
</tr>
<tr>
<td>Gain/feed</td>
<td>.333</td>
<td>.340</td>
<td>.332</td>
<td>.351</td>
<td>.330</td>
<td>.007</td>
</tr>
<tr>
<td>Cholesterol&lt;sup&gt;c&lt;/sup&gt;, mg/dl</td>
<td>101.8</td>
<td>87.7</td>
<td>97.1</td>
<td>93.1</td>
<td>97.7</td>
<td>2.3</td>
</tr>
<tr>
<td>Growth hormone&lt;sup&gt;d&lt;/sup&gt;, ng/ml</td>
<td>1.93</td>
<td>2.13</td>
<td>3.45</td>
<td>3.56</td>
<td>2.12</td>
<td>.80</td>
</tr>
<tr>
<td>Insulin, µU/ml</td>
<td>15.3</td>
<td>16.0</td>
<td>13.0</td>
<td>15.0</td>
<td>14.1</td>
<td>2.1</td>
</tr>
<tr>
<td>10th rib fat&lt;sup&gt;e&lt;/sup&gt;, cm</td>
<td>3.15</td>
<td>2.34</td>
<td>2.63</td>
<td>2.20</td>
<td>2.46</td>
<td>.11</td>
</tr>
<tr>
<td>Loin eye area&lt;sup&gt;f&lt;/sup&gt;, cm²</td>
<td>34.0</td>
<td>40.4</td>
<td>39.9</td>
<td>41.7</td>
<td>40.3</td>
<td>1.2</td>
</tr>
<tr>
<td>Percentage of muscling&lt;sup&gt;g&lt;/sup&gt;</td>
<td>51.7</td>
<td>56.1</td>
<td>54.7</td>
<td>57.4</td>
<td>56.2</td>
<td>.7</td>
</tr>
<tr>
<td>Dressing percentage&lt;sup&gt;h&lt;/sup&gt;</td>
<td>65.9</td>
<td>66.4</td>
<td>67.4</td>
<td>68.1</td>
<td>68.0</td>
<td>.7</td>
</tr>
</tbody>
</table>

*Data are means of four replicates of four pigs each. Pigs averaged 30.5 kg initially and the experimental period was 83 d.

<sup>b</sup>Chromium linear effect, P < .05.

<sup>c</sup>Chromium quadratic effect, P < .06.

<sup>d</sup>Chromium quadratic effect, P < .08.

<sup>e</sup>Chromium quadratic effect, P < .01.

<sup>f</sup>Chromium linear effect, P < .07.
TABLE 3.5. EFFECT OF PICOLINATE (PIC), INORGANIC CHROMIUM FROM CHROMIUM CHLORIDE HEXAHYDRATE, AND ORGANIC CHROMIUM FROM CHROMIUM PICOLINATE ON GROWTH AND SERUM AND CARCASS TRAITS OF GROWING-FINISHING PIGS (EXP. 3)*

<table>
<thead>
<tr>
<th>Item</th>
<th>Basal (B)</th>
<th>B + 1467 ppb PIC</th>
<th>B + 200 ppb Cr&lt;sup&gt;&lt;sup&gt;b&lt;/sup&gt;&lt;/sup&gt;</th>
<th>B + 1467 ppb PIC + 200 ppb Cr&lt;sup&gt;&lt;sup&gt;b&lt;/sup&gt;&lt;/sup&gt;</th>
<th>B + 100 ppb Cr&lt;sup&gt;&lt;sup&gt;c&lt;/sup&gt;&lt;/sup&gt;</th>
<th>B + 200 ppb Cr&lt;sup&gt;&lt;sup&gt;c&lt;/sup&gt;&lt;/sup&gt;</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gain, kg/d</td>
<td>.686</td>
<td>.709</td>
<td>.727</td>
<td>.730</td>
<td>.730</td>
<td>.723</td>
<td>.021</td>
</tr>
<tr>
<td>Feed intake&lt;sup&gt;d&lt;/sup&gt;, kg/d</td>
<td>2.09</td>
<td>2.18</td>
<td>2.08</td>
<td>2.25</td>
<td>2.30</td>
<td>2.25</td>
<td>.07</td>
</tr>
<tr>
<td>Gain/feed&lt;sup&gt;e&lt;/sup&gt;</td>
<td>.328</td>
<td>.326</td>
<td>.349</td>
<td>.330</td>
<td>.317</td>
<td>.321</td>
<td>.004</td>
</tr>
<tr>
<td>Cholesterol, mg/dl</td>
<td>72.3</td>
<td>77.5</td>
<td>80.4</td>
<td>76.3</td>
<td>81.7</td>
<td>68.0</td>
<td>1.1</td>
</tr>
<tr>
<td>Growth hormone, ng/ml</td>
<td>2.61</td>
<td>1.61</td>
<td>2.37</td>
<td>2.99</td>
<td>1.23</td>
<td>1.55</td>
<td>.62</td>
</tr>
<tr>
<td>Insulin, μU/ml</td>
<td>19.5</td>
<td>20.5</td>
<td>20.6</td>
<td>17.7</td>
<td>22.3</td>
<td>22.5</td>
<td>2.1</td>
</tr>
<tr>
<td>10th rib fat&lt;sup&gt;f&lt;/sup&gt;, cm</td>
<td>3.07</td>
<td>2.98</td>
<td>2.90</td>
<td>3.14</td>
<td>2.54</td>
<td>2.39</td>
<td>.13</td>
</tr>
<tr>
<td>Loin eye area&lt;sup&gt;g&lt;/sup&gt;, cm&lt;sup&gt;2&lt;/sup&gt;</td>
<td>31.5</td>
<td>31.8</td>
<td>31.2</td>
<td>30.7</td>
<td>38.1</td>
<td>38.4</td>
<td>.9</td>
</tr>
<tr>
<td>Percentage of muscling&lt;sup&gt;h&lt;/sup&gt;</td>
<td>52.3</td>
<td>52.2</td>
<td>52.3</td>
<td>51.2</td>
<td>54.8</td>
<td>55.7</td>
<td>.6</td>
</tr>
<tr>
<td>Dressing percentage</td>
<td>74.6</td>
<td>74.9</td>
<td>74.6</td>
<td>74.1</td>
<td>75.1</td>
<td>74.2</td>
<td>.5</td>
</tr>
</tbody>
</table>

*Data are means of four replicates of four pigs each. Pigs averaged 22.4 kg initially and the experimental period was 98 d.

<sup>b</sup>Chromium was provided by CrCl₃·6H₂O in Diets 3 and 4.

<sup>c</sup>Chromium was provided by chromium picolinate in Diets 5 and 6.

<sup>d</sup>Feed intake increased (P < .07) in pigs fed chromium picolinate.

<sup>e</sup>Feed efficiency decreased (P < .01) in pigs fed chromium picolinate.

<sup>f</sup>10th rib fat reduced (P < .01) in pigs fed chromium picolinate.

<sup>g</sup>Loin eye area and percentage of muscling increased (P < .01) in pigs fed chromium picolinate.
DISCUSSION

The effect of dietary Cr on animal productivity previously has been investigated. The majority of the research, however, used inorganic forms of Cr as the Cr source. Steele and Rosebrough (1979) reported that Cr, as CrCl$_3$·6H$_2$O, improved the growth rate of turkey poults, and Anderson et al. (1989) reported that supplemental Cr (CrCl$_3$·6H$_2$O) increased the percentage of turkey breast. Hill and Matrone (1970) and Hafez and Kratzer (1976) reported that Cr (CrCl$_3$·6H$_2$O) reduced the toxicity of vanadium in growing chicks. Jensen and Maurice (1980) reported that Cr (CrCl$_3$·6H$_2$O) was not effective in reversing the adverse effects of vanadium on albumen quality. Chromium (CrCl$_3$·6H$_2$O) also has been shown to stimulate the growth of male rats (Schroeder et al., 1963) as well as rats fed a low protein diet (Mertz and Roginski, 1969). Chromium, as CrCl$_3$·6H$_2$O, did not affect growth, serum traits, or carcass traits of finishing pigs (Page et al., 1990).

The NRC (1988) makes no recommendation for Cr in swine. However, in 1989, the recommended safe and adequate intake of Cr for adult humans was established at 50-200 µg/d (NRC, 1989). Several studies have reported that the dietary Cr intake for normal subjects may not meet the suggested minimum daily intake of 50 µg (Anderson and Kozlovsky, 1985). The analysis by Schroeder (1971) of Cr in foods indicated extensive Cr losses due to refining, processing, and soil
leaching, and it also has been shown that the Cr intake of Americans is lower than that of people in third-world countries (Schroeder, 1968; Schroeder et al., 1970).

The Cr intake of swine may be insufficient for optimum productivity and the form of Cr present in the diet may be less bioavailable than other forms. Mertz (1969), Votava et al. (1973), and Offenbacher and Pi-Sunyer (1980) have shown that the absorption of adequate Cr only occurs when it is associated with a specific organic molecule.

Several studies have been conducted to find a substance that would facilitate absorption of Cr. A metabolite of tryptophan, Pic, has been identified as an effective chelator of metals (Evans, 1982), and Pic has been proposed to have a physiological role in the absorption of zinc (Evans, 1982; Krieger et al., 1984). In contrast, Hill et al. (1987) observed no effect of Pic on gain, feed efficiency or zinc status of 5-10 kg pigs. The results of Exp. 3 concur with these findings in that gain and feed efficiency were not affected in pigs receiving Pic.

Chromium has long been linked to lipid metabolism. Several studies have shown that Cr supplementation results in decreases in serum triglycerides and total CH, and with increases in HDL CH (Riales and Albrink, 1981; Mossop, 1983). Rats fed a low Cr diet exhibited increased serum CH, aortic lipids, and plaque formation (Schroeder and Balassa, 1965), while Abraham et al. (1982) provided evidence that Cr not
only decreased CH accumulation in rabbits, but that it also increased the removal rate of CH already deposited in the aorta. Serum TG and GLU were not affected by Cr; however serum CH was consistently reduced in pigs receiving Cr from CrPic in our study.

Serum AP, Ca, and IP were measured to assess the mineral status of the pigs and to get an indication of possible Cr toxicity. However, serum AP, Ca, and IP were not affected by Cr and(or) Pic in the present study and no visible signs of toxicity were observed.

The most striking effect of CrPic in the present study on swine productivity occurred in carcass muscling and fat. Loin eye area and PM were consistently increased and TRF decreased in pigs fed CrPic. The reduction in TRF and increase in muscling observed in this study are similar to results reported from feeding beta adrenergic agonists but are less than some responses from injection of GH (Machlin, 1972; Chung et al., 1985; Etherton et al., 1986, 1987; Bergen et al., 1989). In Exp. 1, the 100 ppb Cr level did not affect LEA, but a 6% decrease in TRF was observed. Pigs receiving 200 ppb Cr exhibited a 7% increase in LEA and a 14% decrease in TRF. In Exp. 2, LEA was increased 19 and 17% at 100 and 200 ppb Cr, respectively, while TRF was decreased 26 and 16%. Comparable results were obtained in Exp. 3 with pigs receiving 100 ppb Cr having 21% more LEA and 17% less TRF. Loin eye area was increased 22% and TRF reduced 22% in
pigs fed 200 ppb Cr. In Exp. 2, GH was higher in pigs receiving Cr, but GH was not affected by treatment in Exp. 1 and 3.

The mechanism or mechanisms of action of Cr that produces an increase in LEA and PM and a decrease in TRF and CH was not elucidated in this study. Although there has been extensive investigation, the exact site and mode of action of Cr as it influences various aspects of metabolism and productivity have not been completely resolved. Chromium has been shown to affect carbohydrate metabolism and the hormone IN (Schwarz and Mertz, 1959; Mertz, 1969; Roginski and Mertz, 1969). Insulin acts by attaching to specific receptors on the surface of cells and Cr may either increase the number of IN receptors on the cell surface or increase the affinity of IN to the receptors, or possibly a combination of the two mechanisms (Anderson et al., 1987). Insulin was not consistently affected by Cr in the present study. Chromium also has been shown to affect amino acid incorporation and utilization (Roginski and Mertz, 1969), nuclear protein synthesis (Weser and Koolman, 1969) and RNA synthesis (Okada et al., 1983, 1984; Ohba et al., 1986). The phenomenon of Cr affecting nuclear protein and RNA synthesis is of particular interest; however, further research is needed to determine if Cr causes muscle hypertrophy and reduction in fat accretion in a particular regime.
IMPLICATIONS

The manipulation or use of nutrients to quantitatively improve carcass quality in pigs has been somewhat static since protein quality and use of amino acids in swine diets was shown to affect carcass quality. The results of this investigation suggest that the supplementation of chromium, in the form of chromium picolinate, will increase loin eye area and percentage of muscling, and decrease tenth rib fat and serum cholesterol in growing-finishing pigs.


CHAPTER 4
EFFECT OF CHROMIUM PICOLINATE ON GROWTH, SERUM AND CARCASS
TRAITS, AND ORGAN WEIGHTS OF GROWING-FINISHING PIGS
FROM DIFFERENT ANCESTRAL SOURCES

INTRODUCTION

Chromium (Cr) has been linked to carbohydrate (Schwartz
and Mertz, 1959; Mertz, 1969; Roginski and Mertz, 1969),
lipid (Schroeder and Balassa, 1965; Riales and Albrink, 1981;
Abraham et al., 1982; Mossop, 1983), amino acid (Roginski and
Mertz, 1969), and protein metabolism (Weser and Koolman,
1969; Okada et al., 1983, 1984; Ohba et al., 1986). The NRC
The biological activity of Cr has been linked to glucose
tolerance (Mertz, 1969), stabilization of nucleic acids
(Hermann and Speck, 1954; Wacker and Vallee, 1959a,b), and
gene expression (Okada et al., 1984).

Recent investigations by Page et al. (1991a,b) have
shown that Cr, in the organic form of chromium picolinate
(CrPic), increases muscle and decreases 10th rib fat and
serum cholesterol (CH) in growing-finishing pigs. Presently,
the NRC (1988) makes no recommendation for supplementation of
Cr to swine diets. However, Steele et al. (1977) indicated
that Cr was biologically active in swine, and Cr
supplementation has improved animal productivity in some
species (Schroeder et al., 1963; Hill and Matrone, 1970;
Steele and Rosebrough, 1979; Anderson et al., 1989). Results
of the previous studies in our laboratory were very positive. However, we were concerned that the effects of Cr could be site and/or pig ancestry specific. Therefore, the objective of this experiment was to evaluate the effect of Cr, in the form of CrPic, on growth, serum and carcass traits, and organ weights of growing-finishing pigs from different ancestral sources.

MATERIALS AND METHODS

General. An experiment was conducted with two different ancestral populations of pigs. An equal number of crossbred growing-finishing pigs with similar physical characteristics were selected and obtained from the Louisiana State University Agricultural Center Swine Unit (LSU pigs) and from a Texas commercial swine producer (CB pigs). The LSU pigs were transported approximately 75 miles and the CB pigs were transported approximately 480 miles to the Dean Lee Research Station in Alexandria, LA. The LSU pigs were Yorkshire × Hampshire × Duroc crosses. The CB pigs were typical commercial pigs and conformed to the type of pigs currently being produced in the industry. Pigs were allotted to treatment in a completely random design; sex was equally represented within each pen. Each treatment was replicated five times with five pigs per replicate. Pigs were penned in an open sided building during the entire trial. Pen floors were 75% aluminum slatted and 25% solid concrete (1.52 × 4.27
Average initial weight of the pigs was 21.9 kg (22.8, LSU pigs; 21.1, CB pigs) and the experimental period was 102 d. Feed intake and weight gain were measured every 2 wk. Treatment diets and water were provided on an ad libitum basis.

A corn-soybean meal basal diet (Table 4.1) was used in this experiment. It was formulated to contain 120% of the lysine requirement (NRC, 1988) for growing and finishing pigs, and it met or exceeded the requirements for all nutrients. The LSU and CB pigs were each allotted to the basal diet (B) or the B + 200 ppb Cr from CrPic (chromium tripicolinate, 12% Cr; Nutrition 21, 1010 Turquoise Street, San Diego, CA).

**Blood Analysis.** Fasting (16 h) blood samples were taken three days before trial termination. Three days following this first blood collection, pigs were fasted overnight, allowed to consume feed ad libitum for 30 min the following morning, and bled 3 h after the initiation of feeding. Blood was obtained via the anterior vena cava and centrifuged at 1020 x g for 20 min at 4°C. Blood urea N (BUN) was analyzed using fresh serum, and CH, non-esterfied fatty acids (NEFA), glucose (GLU), growth hormone (GH), and insulin (IN) were analyzed using serum that had been frozen (-20°C). Serum collected from the fasted samples was analyzed for CH using the Lieberman-Burchard method (Technicon, 1974). Blood urea N (Anonymous, 1980; Gilford System 203, Ciba Corning
### TABLE 4.1. PERCENTAGE COMPOSITION OF THE BASAL DIET

<table>
<thead>
<tr>
<th>Ingredients</th>
<th>Grower</th>
<th>Finisher</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>76.60</td>
<td>83.70</td>
</tr>
<tr>
<td>Soybean meal, 48% CP</td>
<td>21.35</td>
<td>14.20</td>
</tr>
<tr>
<td>Defluorinated rock phosphate</td>
<td>.80</td>
<td>1.00</td>
</tr>
<tr>
<td>Limestone</td>
<td>.70</td>
<td>.55</td>
</tr>
<tr>
<td>Vitamin-mineral premix&lt;sup&gt;b&lt;/sup&gt;</td>
<td>.55</td>
<td>.55</td>
</tr>
</tbody>
</table>

*Calculated to provide 120% of the Lys recommended by NRC (1988).

<sup>b</sup>The vitamin premix provided the following per kg of diet: 4,400 IU vitamin A, 440 IU vitamin D3, 11 IU vitamin E, 1.1 mg vitamin K activity as menadione dimethylprimidinol bisulfite, 22 mg pantothenic acid, 22 mg niacin, 4.4 mg riboflavin, 440 mg choline chloride, 220 μg biotin, 22 μg vitamin B<sub>2</sub>. The mineral premix provided the following per kg of diet: .1 mg Se, 1 mg I, 30 mg Mn, 8.75 mg Cu, 87.5 mg Fe, 75 mg Zn, 2.5 g NaCl.
Diagnostics Corp., Oberlin OH), NEFA (Wako NEFA C test kit, Wako Chemicals USA, Inc., Richmond, VA), GLU (Anonymous, 1980; Gilford System 203, Ciba Corning Diagnostics Corp., Oberlin, OH), IN, and GH concentrations were measured using serum collected from the non-fasted samples.

Serum IN concentrations were determined using a commercially available RIA kit (ICN Biomedicals, Inc., Costa Mesa, CA). All samples were analyzed in duplicate in a single assay to avoid inter-assay variation. Sensitivity of the assay was 1.4 μU/ml, and intra-assay CV was 5.7 (ICN Biomedicals, Inc.).

Growth hormone was measured by means of a double-antibody RIA based on antiserum (AFP-10318545¹) against porcine GH (pGH). Highly purified pGH (AFP-7696B¹) was radioiodinated via the chloramine-T method (2.5 μg/μg of GH, 0 °C for 30 sec). The antiserum was diluted 1:150,000 in PBS containing .033 M EDTA, .112% normal rhesus monkey serum (Calbiochem Corp., San Diego, CA) and 33% noninhibitory horse serum; 300 μl of this solution was used per tube. The horse serum was added to minimize and to stabilize nonspecific binding of radioiodinated pGH to the assay tubes. Antiserum (Calbiochem Corp., San Diego, CA) against rhesus monkey immunoglobulin-G was diluted 1:21 and was used at 200 μl/tube.

¹Provided by Dr. A.F. Parlow, Pituitary Horm. & Antisera Center, Harbor-UCLA Med. Center, 1000 W. Carson St., Torrance, CA 90509.
to precipitate the primary antibody. Cross-reactivities of other porcine pituitary hormones in the assay were (% relative to pGH): prolactin .08, FSH .12, LH .001 and thyroid stimulating hormone .004. Inhibition curves produced by serial dilutions of porcine sera and pituitary extracts were parallel to those produced by the reference standard (USDA-pGH-B1; National Hormone and Pituitary Agency, Baltimore, MD). Sensitivity of the assay averaged .1 ng; the sample size was 200 μl in a typical assay. Intra- and interassay CV were 8 and 11% for a pool of serum assayed in six separate assays.

Carcass Evaluation. At the termination of the trial, the two pigs with a BW closest to the mean weight of pigs in a pen were selected and slaughtered at the Louisiana State University Animal Science Meats Laboratory for the purpose of obtaining weights (as a percentage of BW) of the liver, heart and kidneys, as well as other selected carcass data. One loin and ham were removed uniformly from each carcass. Loin weight (as a percentage of BW) and ham specific gravity [weight in air/(weight in air-weight in H₂O)] were determined from these wholesale cuts.

A longissimus muscle chop (2.54 cm thick) was cut from each loin at the third rib for determination of percentage of longissimus muscle moisture, fat, and CP. All loin samples used for chemical analysis were taken with a 2.54 cm coring device from the center of the loin chop. Percentage of
longissimus muscle moisture was determined by freeze drying approximately 2 g of wet loin. Percentage of longissimus muscle fat was determined by extracting approximately 2 g of freeze dried loin with anhydrous diethyl ether in a continuous reflux Soxhlet extraction apparatus for 48 h. The samples were removed from the extraction apparatus and the ether allowed to evaporate for 24 h. The samples were then redried in a drying oven and percentage of fat estimated as loss in weight from extraction. Longissimus muscle CP percentage was determined by the Kjeldahl N method (AOAC, 1984). The samples were diced into small pieces before CP percentage was determined.

The remaining three pigs per replicate were slaughtered in a commercial facility. Hot carcass weights were determined on all pigs for dressing percentage calculation and carcass measurements were obtained following a 24 h chill at 2°C. Loin eye area (by tracing the longissimus muscle surface at the 10th rib) and TRF (fat thickness over the loin eye muscle at the 10th rib) were adjusted to 104.3 kg by methods approved by the NSIF (1988). Percentage of muscling was obtained by the National Pork Producers Council method (1988).

Statistical Analysis. Data were analyzed by analysis of variance procedures (Steel and Torrie, 1980) appropriate for factorially arranged treatments within a completely randomized design. The preplanned set of single degree of
freedom comparisons was used to test treatment differences. Dressing percentage, liver weight, heart weight, and kidney weight were analyzed using final BW as a covariate. Initial BW was used as a covariate for analyses of daily gain, feed intake, and feed efficiency. The covariate, final BW, was not significant (P > .10) for dressing percentage, heart weight, and kidney weight, and it was removed from the model. The pen of pigs served as the experimental unit.

RESULTS

Average daily gain and feed intake were higher (P < .01) in CB pigs than in LSU pigs (Table 4.2). Daily gain, feed intake, and feed efficiency were not affected (P > .10) by CrPic.

Serum urea N, NEFA, and IN were not affected (P > .10) by CrPic and(or) source of pig (Table 4.3). Serum GH was not affected by CrPic (P > .10), but it was higher (P < .01) in LSU pigs than in CB pigs. Serum CH was reduced (P < .01) 19% by CrPic (Table 4.3).

Heart weight (Table 4.3), as a percentage of BW, was not affected (P > .10) by CrPic or source of pig. Liver and kidney weights were higher (P < .01) in LSU pigs than in CB pigs. However, liver weight was increased by CrPic in LSU pigs but decreased in CB (Cr x source of pig, P < .08).

Percentage of longissimus muscle moisture, fat, and CP were not affected (P > .10) by CrPic (Table 4.4). However,
TABLE 4.2. EFFECT OF CHROMIUM PICOLINATE ON GROWTH, FEED INTAKE AND FEED EFFICIENCY OF GROWING-FINISHING PIGS FROM DIFFERENT ANCESTRAL SOURCES

<table>
<thead>
<tr>
<th>Item</th>
<th>Basal (B) LSU</th>
<th>Basal (B) CB</th>
<th>B + 200 ppb Cr LSU</th>
<th>B + 200 ppb Cr CB</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gain(^b,) kg/d</td>
<td>.712</td>
<td>.867</td>
<td>.743</td>
<td>.829</td>
<td>.025</td>
</tr>
<tr>
<td>Feed intake(^b,) kg/d</td>
<td>2.18</td>
<td>2.76</td>
<td>2.28</td>
<td>2.57</td>
<td>.08</td>
</tr>
<tr>
<td>Gain/feed</td>
<td>.326</td>
<td>.313</td>
<td>.326</td>
<td>.322</td>
<td>.005</td>
</tr>
</tbody>
</table>

\(^a\) Data are means of five replicates of five pigs each. Pigs averaged 21.9 kg initially and the experimental period was 102 d. Pigs were obtained from two different ancestral sources, Louisiana State University Agricultural Center Swine Unit (LSU pigs) and a commercial producer (CB pigs).

\(^b\) Source of pig effect, \(P < .01\).
<table>
<thead>
<tr>
<th>Item</th>
<th>Basal (B)</th>
<th>B + 200 ppb Cr</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LSU</td>
<td>CB</td>
</tr>
<tr>
<td>Urea N, mg/dl</td>
<td>13.4</td>
<td>12.6</td>
</tr>
<tr>
<td>Free fatty acids, μeq/l</td>
<td>159.5</td>
<td>166.9</td>
</tr>
<tr>
<td>Cholesterol b, mg/dl</td>
<td>103.0</td>
<td>106.2</td>
</tr>
<tr>
<td>Glucose, mg/dl</td>
<td>84.7</td>
<td>87.6</td>
</tr>
<tr>
<td>Growth hormone c, ng/ml</td>
<td>4.21</td>
<td>2.96</td>
</tr>
<tr>
<td>Insulin, μU/ml</td>
<td>23.9</td>
<td>22.7</td>
</tr>
<tr>
<td>Heart, % of BW</td>
<td>.30</td>
<td>.28</td>
</tr>
<tr>
<td>Liver c, % of BW</td>
<td>1.44</td>
<td>1.38</td>
</tr>
<tr>
<td>Kidney c, % of BW</td>
<td>.29</td>
<td>.25</td>
</tr>
</tbody>
</table>

*Data are means of five replicates of five pigs each. Pigs averaged 21.9 kg initially and the experimental period was 102 d. Pigs were obtained from two different ancestral sources, Louisiana State University Agricultural Center Swine Unit (LSU pigs) and a commercial producer (CB pigs).

b Chromium effect, P < .01.

c Source of pig effect, P < .01.

c Chromium × source of pig interaction, P < .08.
TABLE 4.4. EFFECT OF CHROMIUM PICOLINATE ON MEAT AND CARCASS TRAITS OF GROWING-FINISHING PIGS FROM DIFFERENT ANCESTRAL SOURCES

<table>
<thead>
<tr>
<th>Item</th>
<th>Basal (B)</th>
<th>BS + 200 ppb Cr</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LSU</td>
<td>CB</td>
</tr>
<tr>
<td>Loin fatb, %</td>
<td>5.68</td>
<td>7.58</td>
</tr>
<tr>
<td>Loin moistureb, %</td>
<td>71.6</td>
<td>70.3</td>
</tr>
<tr>
<td>Loin crude protein, %</td>
<td>24.2</td>
<td>24.0</td>
</tr>
<tr>
<td>Loin weight, % of BW</td>
<td>9.50</td>
<td>9.92</td>
</tr>
<tr>
<td>Ham specific gravityc</td>
<td>1.055</td>
<td>1.049</td>
</tr>
<tr>
<td>Dressing percentage</td>
<td>74.5</td>
<td>75.1</td>
</tr>
<tr>
<td>10th rib fatd, cm</td>
<td>3.26</td>
<td>3.42</td>
</tr>
<tr>
<td>Loin eye areae, cm²</td>
<td>32.0</td>
<td>31.7</td>
</tr>
<tr>
<td>Percentage of musclingf</td>
<td>50.4</td>
<td>49.6</td>
</tr>
</tbody>
</table>

Data are means of five replicates of five pigs each. Pigs averaged 21.9 kg initially and the experimental period was 102 d. Pigs were obtained from two different ancestral sources, Louisiana State University Agricultural Center Swine Unit (LSU pigs) and a commercial producer (CB pigs).

b Source of pig effect, P < .06.

b Chromium x source of pig interaction, P < .03.

c Chromium effect, P < .01.

d Source of pig effect, P < .08.

e Chromium x source of pig interaction, P < .06.
percentage of longissimus muscle moisture was higher (P < .06) and percentage of longissimus muscle fat lower (P < .06) in LSU pigs than in CB pigs. Dressing percentage and loin weight were not affected (P > .10) by CrPic or source of pig (Table 4.4). Ham specific gravity increased in CB pigs fed CrPic and decreased in LSU pigs fed CrPic (Cr x source of pig, P < .03). Tenth rib fat was reduced (P < .01) 20% by CrPic, while LEA and PM were increased (P < .01) 13 and 6%, respectively, in pigs fed CrPic (Table 4). The increase in LEA and PM was greater in CB pigs than in LSU pigs (Cr x source of pig, P < .06).

DISCUSSION

The results of the present study agree with data previously reported (Page et al., 1991a,b). Chromium, in the form of CrPic, decreased TRF and increased LEA and PM in growing-finishing pigs, regardless of ancestral source. Page et al. (1990, 1991a) reported that inorganic chromium, as CrCl3·6H2O, did not affect growth performance or carcass traits of finishing pigs. This supports the hypothesis that Cr, in an organic form, such as CrPic, is more bioavailable than inorganic forms (Mertz, 1969; Votava et al., 1973; Offenbacher and Pi-Sunyer, 1980).

The ability of Cr to reduce CH was evident in this experiment which agrees with other animal studies where Cr reduced CH and serum lipids (Schroeder and Balassa, 1965;
Riales and Albrink, 1981; Abraham et al., 1982; Mossop, 1983; Page et al., 1991b). Non-esterfied fatty acids, or free fatty acids, were measured in this study to gain more information on the mechanism of action of Cr in regard to fat and lipid metabolism. An increase in NEFA would indicate an increase in the process of fat degradation or lypolysis in adipose tissue (Mersmann and MacNeil, 1985). However, the breakdown of triglyceride to glycerol and free fatty acids, and therefore an increase in NEFA, was not observed in this trial. Chromium also has been shown to affect the anabolic hormone IN (Schwartz and Mertz, 1959; Roginski and Mertz, 1969), and insulin's ability to attach to receptors on the cell surface may be coupled to Cr (Anderson et al. 1987). However, IN concentration was not affected by Cr or by source of pig. Growth hormone, which when administered to pigs causes a reduction in fat and an increase in muscle, was not affected by CrPic, but was lower in CB pigs than in LSU pigs.

Blood urea N concentration depends on the quantity and quality of protein in the diet (Eggum, 1970), and BUN is used as an indication of protein quality or protein utilization. Lower BUN are attributed to greater protein utilization. In the present study, BUN was not affected by Cr or by source of pig, indicating that protein utilization was not affected.

The level of Cr selected for this study was 200 ppb, which was the level that consistently increased muscling and decreased 10th rib fat in our previous studies (Page et al.,
Again, 200 ppb Cr was effective in producing desirable changes in carcass traits and in reducing CH in growing-finishing pigs. The gene pool at our swine research center is somewhat limited and may not exemplify the typical commercial crossbred pigs in today's industry; however, Cr was equally effective in positively affecting carcass traits and CH in pigs from our swine center, as well as pigs from a different ancestral background.

IMPLICATIONS

Currently, there is no recommendation for the supplementation of chromium in swine diets (NRC, 1988). However, the results of this investigation indicate that pig productivity may be improved in growing-finishing pigs, regardless of ancestral source, by CrPic supplementation. The consistent positive effects are an increase in muscle and a decrease in fat and serum cholesterol.
Literature Cited


CHAPTER 5

EFFECT OF CHROMIUM PICOLINATE ON SERUM CHOLESTEROL, EGG PRODUCTION, EGG CHOLESTEROL, AND EGG QUALITY OF LAYING HENS

INTRODUCTION

The nutritional status of chromium (Cr) in poultry previously has been investigated. Jensen et al. (1978) determined that Cr was biologically active in the laying hen, and Polansky et al. (1989) reported decreases in tissue Cr during turkey egg production. Hill and Matrone (1970) and Hafez and Kratzer (1976) reported that Cr reduced the toxicity of vanadium in growing chicks. Jensen and Maurice (1980) and Ben Abdeljelil and Jensen (1990) reported that Cr was not effective in reversing the adverse effects of vanadium on albumen quality. Growth rate of turkey poult's was improved by Cr (Steele and Rosebrough, 1979; Rosebrough and Steele, 1981) and supplemental Cr increased the percentage of turkey breast (Anderson et al., 1989).

Dietary Cr has been linked to lipid metabolism and accumulation in humans and animals. Several studies have shown that Cr supplementation decreases serum triglycerides and total cholesterol (CH) and increases HDL CH (Riales and Albrink, 1981; Mossop, 1983). Abraham et al. (1982) reported that Cr decreased CH accumulation in rabbits and increased the removal rate of CH already deposited in the aorta. Page et al. (1991a,b) reported that Cr decreased CH and 10th rib
fat in growing-finishing pigs. These studies provide a strong indication that Cr has a vital role in animal and human nutrition; and the NRC (1989) recommends an intake of 50-200 μg/d for human adults. The NRC (1984) currently does not recommend Cr supplementation to poultry diets. Therefore, the purpose of this investigation was to evaluate the effect of Cr on serum CH, egg production, egg CH, and egg quality of laying hens.

MATERIALS AND METHODS

General. An experiment was conducted with Hyline 36 commercial type laying hens (approximately 41 wk of age) from the Louisiana State University Agricultural Center Poultry Unit. A randomized complete block design was used. Hens were penned individually in cages (.30 × .41 m) in an open-sided building during the trial. Each treatment was replicated 10 times with one hen per replicate. The hens were fed a corn-soybean meal laying hen basal diet (Table 5.1, formulated to meet or exceed the requirements for all nutrients, NRC, 1984) for 1 wk. The hens were then allotted to treatment, and were fed the experimental diets for the 28 d experiment. The experiment consisted of the following treatments: 1) Corn-soybean meal basal (B), 2) B + 50 ppb Cr, 3) B + 100 ppb Cr, 4) B + 200 ppb Cr, 5) B + 400 ppb Cr, 6) B + 800 ppb Cr. Chromium picolinate (CrPic, chromium tripicolinate, 12% Cr; Nutrition 21, 1010 Turquoise Street,
### TABLE 5.1. PERCENTAGE COMPOSITION OF THE BASAL DIET

<table>
<thead>
<tr>
<th>Ingredients</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>60.00</td>
</tr>
<tr>
<td>Soybean meal, 44% CP</td>
<td>25.00</td>
</tr>
<tr>
<td>Tallow</td>
<td>5.00</td>
</tr>
<tr>
<td>Dicalcium phosphate</td>
<td>2.50</td>
</tr>
<tr>
<td>Oyster shell flour</td>
<td>7.00</td>
</tr>
<tr>
<td>Salt</td>
<td>.25</td>
</tr>
<tr>
<td>Vitamin and mineral premix*</td>
<td>.25</td>
</tr>
</tbody>
</table>

*Supplied per kg of diet: 11,000 IU vitamin A, 1650 IU vitamin D₃, 8.25 IU vitamin E, .73 mg menadione sodium bisulfite, 1 mg thiamine, 4.4 mg riboflavin, 33 mg niacin, 8.1 mg d-pantothenic acid, .45 mg folic acid, .05 mg biotin, 2.2 mg pyridoxine, .01 mg vitamin B₁₂, 400 mg choline, 60 mg Mn, 44 mg Zn, 20 mg Fe, 2 mg Cu, 1.2 mg I, .20 mg Co.
San Diego, CA) provided the Cr additions. Treatment diets and water were provided on an ad libitum basis.

**Blood Analysis.** At the termination of the trial, hens were fasted 16 h and then a blood sample was obtained via heart puncture. Blood samples were centrifuged at 1020 × g for 20 min at 4 °C. Serum was analyzed for CH using the Lieberman-Burchard method (Technicon, 1974) with serum that had been frozen (-20 °C).

**Egg Analysis.** Egg production was recorded daily and eggs were collected on Days 2, 9, 16, and 23 for determination of specific gravity \((\text{weight in air}/(\text{weight in air} - \text{weight in water}))\) and Haugh units\(^1\). Egg specific gravity and Haugh units were measured for the purpose of evaluating egg quality. Eggs were collected on Days 0, 7, 14, 21, and 28 for CH analysis. To determine yolk CH, eggs were hard-cooked by immersion in boiling water for 5 min. Yolks were removed and weighed. The entire yolk was blended with a volume of isopropyl alcohol proportional to the yolk weight (10 ml/g of yolk). Cholesterol content of this extract (mg per g wet weight) was determined by an automated procedure (Technicon, 1974) based on the Lieberman-Burchard method. One egg was collected on Day 22 for determination of percentage of egg fat using the acid hydrolysis method (AOAC Method 925.32, 1984), and one egg was collected on Day 24 for

\(^1\text{Haugh unit} = 100 \times \log_{10}(\text{Albumen height} + (7.57 - (1.7 \times (\text{Egg weight}^{1/3}))))\).
determination of percentage of egg CP by the Kjeldahl N method (AOAC, 1984).

Statistical Analysis. Data were analyzed by analysis of variance procedures (Steel and Torrie, 1980). Linear, quadratic, and cubic contrasts were used to evaluate treatment effects. Egg production, specific gravity, Haugh units, and CH were measured over time and analyzed by split-plot analyses using hen(trt*rep) as the error term in the model. A hen served as the experimental unit.

RESULTS

Egg CH, Haugh units, and specific gravity were not affected (P > .10) by time or by a time X treatment interaction (Appendix D). Therefore, only overall treatment means are presented. Egg CH was not affected (P > .10) by CrPic supplementation; however, CH tended to be lower in eggs from hens receiving 100 and 200 ppb Cr (Table 5.2). By Day 28 of the trial, egg CH was reduced (Cr quadratic, P < .05, Appendix D) by CrPic supplementation to the diet. Serum CH was reduced (Cr quadratic, P < .10) by CrPic addition, particularly at the 200 and 400 ppb levels of Cr (Table 5.2). Haugh units and specific gravity were not affected (P > .10) by CrPic (Table 5.2). Percentage of egg fat was higher in eggs from hens receiving 100 and 200 ppb Cr and lower in eggs from hens receiving 50, 400, and 800 ppb Cr (Cr quadratic, P < .10). Percentage of egg CP was reduced (Cr quadratic, P <
### TABLE 5.2. EFFECT OF CHROMIUM PICOLINATE ON SERUM CHOLESTEROL, EGG PRODUCTION, EGG CHOLESTEROL AND EGG QUALITY OF LAYING HENS

<table>
<thead>
<tr>
<th>Item</th>
<th>Basal (B)</th>
<th>B + 50 ppb Cr</th>
<th>B + 100 ppb Cr</th>
<th>B + 200 ppb Cr</th>
<th>B + 400 ppb Cr</th>
<th>B + 800 ppb Cr</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Haugh units</td>
<td>82.5</td>
<td>82.6</td>
<td>84.6</td>
<td>82.0</td>
<td>85.0</td>
<td>79.7</td>
<td>1.8</td>
</tr>
<tr>
<td>Specific gravity</td>
<td>1.086</td>
<td>1.085</td>
<td>1.084</td>
<td>1.084</td>
<td>1.084</td>
<td>1.085</td>
<td>001</td>
</tr>
<tr>
<td>Egg fat percentage&lt;sup&gt;b&lt;/sup&gt;</td>
<td>10.4</td>
<td>10.2</td>
<td>10.6</td>
<td>10.8</td>
<td>10.0</td>
<td>9.9</td>
<td>.2</td>
</tr>
<tr>
<td>Egg protein percentage&lt;sup&gt;c&lt;/sup&gt;</td>
<td>12.7</td>
<td>12.2</td>
<td>12.2</td>
<td>12.2</td>
<td>12.6</td>
<td>12.3</td>
<td>.2</td>
</tr>
<tr>
<td>Egg cholesterol, mg/g yolk</td>
<td>12.1</td>
<td>12.1</td>
<td>11.7</td>
<td>11.9</td>
<td>12.1</td>
<td>11.9</td>
<td>.2</td>
</tr>
<tr>
<td>Serum cholesterol&lt;sup&gt;b&lt;/sup&gt;, mg/dl</td>
<td>100.3</td>
<td>91.2</td>
<td>108.3</td>
<td>80.8</td>
<td>76.6</td>
<td>93.4</td>
<td>10.2</td>
</tr>
<tr>
<td>Egg production&lt;sup&gt;d&lt;/sup&gt;, %</td>
<td>75.8</td>
<td>79.3</td>
<td>81.1</td>
<td>83.2</td>
<td>76.1</td>
<td>77.7</td>
<td>2.7</td>
</tr>
</tbody>
</table>

<sup>a</sup>Data are means of 10 replicates of one hen each except for egg cholesterol, Haugh units, and specific gravity. Egg cholesterol is the mean of eggs from 10 replicates collected on Days 0, 7, 14, 21, and 28 and Haugh units and specific gravity are the means of eggs from 10 replicates collected on Days 2, 9, 16, and 23. The experimental period was 28 d. Chromium was provided by chromium picolinate.

<sup>b</sup>Chromium quadratic effect, P < .10.

<sup>c</sup>Chromium quadratic effect, P < .02.

<sup>d</sup>Chromium cubic effect, P < .04.
.02) by CrPic supplementation to the diet (Table 5.2). Egg production was incrementally increased (Cr cubic, \( P < .04 \)) by CrPic through 200 ppb Cr (Table 5.2).

**DISCUSSION**

Laying hen diets are primarily composed of ingredients from plant origin which have been shown to be low in Cr (Schroeder, 1971). Therefore, laying hen diets may be low in Cr for optimal hen productivity. Currently, the NRC (1984) makes no recommendation for Cr supplementation to conventional poultry diets; however, it does recommend supplementing 3 mg of Cr per kg to chemically defined diets.

Chromium's ability to affect animal productivity has been previously investigated. Most of this research used an inorganic form of Cr as the Cr source. Schroeder et al. (1963) and Mertz and Roginski (1969) reported that Cr, as \( \text{CrCl}_2 \cdot 6\text{H}_2\text{O} \), stimulated the growth rate of rats. Chromium research with poultry also has used \( \text{CrCl}_2 \cdot 6\text{H}_2\text{O} \) (Steele and Rosebrough, 1979; Jensen and Maurice, 1980; Anderson et al., 1989). Chromium, as \( \text{CrCl}_2 \cdot 6\text{H}_2\text{O} \), did not affect growth or carcass traits of finishing pigs (Page et al., 1990, 1991a), but an organic source of Cr (CrPic) increased loin eye area and percentage of muscling and decreased 10th rib fat thickness and serum CH in growing-finishing pigs (Page et al., 1991a,b).
The present study used CrPic as an organic source of Cr. Several researchers have shown that adequate absorption and utilization of Cr is dependent on its association with an organic molecule (Mertz, 1969; Votava et al., 1973; Offenbacher and Pi-Sunyer, 1980). A tryptophan metabolite, picolinate, has been identified as an effective chelator of metals (Cousins and Smith, 1980; Evans and Johnson, 1980a,b; Evans, 1982) and therefore, may increase the absorption or utilization of Cr. In this study, criteria used to evaluate egg quality, such as Haugh units, specific gravity, and egg CH were not affected by CrPic. However, serum CH of laying hens was reduced by CrPic. Although inconsistent, CrPic also reduced percentage of egg fat and CP.

An unanticipated result was observed in laying hen egg production. Egg production was incrementally increased by 50, 100, and 200 ppb Cr additions to the diet. Presently, we have no explanation for this increase in egg production; however, Cr, as CrPic, has been shown to increase the productivity of pigs (Page et al., 1991a,b), but the mechanism of action has not been resolved.

IMPLICATIONS

The results of the present study indicate that chromium, as chromium picolinate, reduces serum cholesterol and increases egg production in laying hens. Further studies need to be conducted to investigate the mechanism of action.
of chromium and to determine if chromium can affect other areas of lipid metabolism in the laying hen, such as egg cholesterol and egg fatty acid profile.
Literature Cited


SUMMARY AND CONCLUSIONS

Six experiments were conducted to evaluate the effects of supplemental dietary tryptophan, picolinate, CrCl$_3$·6H$_2$O, chromium picolinate, or a combination of picolinate and CrCl$_3$·6H$_2$O on growth performance, liver mineral concentrations, insulin, growth hormone, organ weights, and serum and carcass traits of pigs. One experiment was conducted to evaluate the effect of chromium picolinate on serum cholesterol, egg cholesterol, egg quality, and egg production of laying hens.

Excess dietary tryptophan did not affect finishing pig daily gain. However, feed intake was increased by incremental tryptophan addition and feed efficiency was decreased through .32% dietary tryptophan. Loin eye area was lower in pigs fed .22 and .32% tryptophan than in pigs fed .12 and .17% tryptophan. Dressing percentage, percentage of muscling, and 10th rib fat were not affected by tryptophan addition to the diet. Excess dietary tryptophan does not improve growth performance or carcass quality of finishing pigs.

Chromium, as CrCl$_3$·6H$_2$O, and(or) picolinate did not consistently affect growth performance, liver mineral concentrations, hormones, organ weights, and serum and carcass traits of pigs. However, chromium (100 or 200 ppb), as chromium picolinate, increased loin eye area and
percentage of muscling by approximately 18 and 7%, respectively, and decreased 10th rib fat by 20%. These positive effects were observed in pigs from the Louisiana State University Agricultural Center Swine Center as well as pigs from a different ancestral source. Serum cholesterol was consistently reduced in pigs fed chromium picolinate. Growth performance was not affected by chromium picolinate. The effects of chromium picolinate on porcine insulin and growth hormone were not consistent and a conclusion cannot be drawn from the results obtained in this study. Other serum and carcass traits measured were not affected by chromium picolinate.

Chromium, as chromium picolinate, decreased serum cholesterol and increased egg production in laying hens. Egg cholesterol tended to be lower in eggs from hens fed chromium picolinate, but the effect was not significant. Egg quality was not affected by chromium picolinate.

Chromium, as chromium picolinate, improves pig and poultry productivity and the use of chromium picolinate in pig and poultry diets increases the quantity and quality of pig and poultry products.
### APPENDIX A. EFFECT OF CHROMIUM PICOLINATE ON SERUM TRAITS OF GROWING-FINISHING PIGS (CHAPTER 3, EXP. 1)

<table>
<thead>
<tr>
<th>Item</th>
<th>1 Basal (B)</th>
<th>2 B + 25 ppb Cr</th>
<th>3 B + 50 ppb Cr</th>
<th>4 B + 100 ppb Cr</th>
<th>5 B + 200 ppb Cr</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alkaline phosphatase, U/L</td>
<td>214.5</td>
<td>224.9</td>
<td>205.7</td>
<td>199.4</td>
<td>222.4</td>
<td>17.6</td>
</tr>
<tr>
<td>Total protein, g/dl</td>
<td>6.6</td>
<td>6.7</td>
<td>6.6</td>
<td>6.5</td>
<td>6.5</td>
<td>.1</td>
</tr>
<tr>
<td>Inorganic P, mg/dl</td>
<td>8.4</td>
<td>8.3</td>
<td>8.4</td>
<td>8.2</td>
<td>8.5</td>
<td>.2</td>
</tr>
<tr>
<td>Ca, mg/dl</td>
<td>9.5</td>
<td>9.6</td>
<td>9.5</td>
<td>9.4</td>
<td>9.3</td>
<td>.1</td>
</tr>
<tr>
<td>Urea N, mg/dl</td>
<td>14.6</td>
<td>13.7</td>
<td>14.0</td>
<td>13.8</td>
<td>13.9</td>
<td>.7</td>
</tr>
<tr>
<td>Glucose, mg/dl</td>
<td>90.9</td>
<td>88.7</td>
<td>92.4</td>
<td>94.8</td>
<td>89.3</td>
<td>2.4</td>
</tr>
<tr>
<td>Triglyceride, mg/dl</td>
<td>37.2</td>
<td>38.5</td>
<td>42.7</td>
<td>34.3</td>
<td>37.7</td>
<td>2.8</td>
</tr>
</tbody>
</table>

*Four replicates per treatment with three pigs per replicate. Pigs averaged 37.8 kg initially and the experimental period was 73 d.*
APPENDIX B. EFFECT OF CHROMIUM PICOLINATE ON SERUM TRAITS OF GROWING-FINISHING PIGS (CHAPTER 3, EXP. 2)*

<table>
<thead>
<tr>
<th>Item</th>
<th>1 Basal (B)</th>
<th>2 B + 100 ppb Cr</th>
<th>3 B + 200 ppb Cr</th>
<th>4 B + 400 ppb Cr</th>
<th>5 B + 800 ppb Cr</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inorganic P, mg/dl</td>
<td>8.8</td>
<td>8.5</td>
<td>8.8</td>
<td>8.4</td>
<td>8.6</td>
<td>.2</td>
</tr>
<tr>
<td>Ca, mg/dl</td>
<td>10.4</td>
<td>10.2</td>
<td>10.5</td>
<td>10.0</td>
<td>10.3</td>
<td>.2</td>
</tr>
<tr>
<td>Urea N, mg/dl</td>
<td>15.5</td>
<td>13.0</td>
<td>15.9</td>
<td>14.1</td>
<td>15.2</td>
<td>.9</td>
</tr>
<tr>
<td>Triglyceride, mg/dl</td>
<td>46.2</td>
<td>45.8</td>
<td>45.1</td>
<td>44.5</td>
<td>49.4</td>
<td>6.9</td>
</tr>
</tbody>
</table>

*Four replicates per treatment with four pigs per replicate. Pigs averaged 30.5 kg initially and the experimental period was 83 d.
APPENDIX C. EFFECT OF PICOLINATE (PIC), INORGANIC CHROMIUM FROM CHROMIUM CHLORIDE HEXAHYDRATE, AND ORGANIC CHROMIUM FROM CHROMIUM PICOLINATE ON SERUM TRAITS OF GROWING-FINISHING PIGS (CHAPTER 3, EXP. 3)

<table>
<thead>
<tr>
<th>Item</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urea N, mg/dl</td>
<td>13.1</td>
<td>13.8</td>
<td>13.3</td>
<td>13.9</td>
<td>13.5</td>
<td>13.3</td>
<td>.6</td>
</tr>
<tr>
<td>Triglyceride, mg/dl</td>
<td>26.9</td>
<td>26.9</td>
<td>27.8</td>
<td>30.0</td>
<td>30.1</td>
<td>26.4</td>
<td>1.8</td>
</tr>
</tbody>
</table>

*Four replicates per treatment with four pigs per replicate. Pigs averaged 22.4 kg initially and the experimental period was 98 d.

"Chromium was provided by CrCl$_3$·6H$_2$O.

"Chromium was provided by chromium picolinate."
APPENDIX D. EFFECT OF CHROMIUM PICOLINATE ON WEEKLY EGG CHOLESTEROL, HAUGH UNITS, AND SPECIFIC GRAVITY OF EGGS FROM LAYING HENS (CHAPTER 5)*

<table>
<thead>
<tr>
<th>Item</th>
<th>Basal (B)</th>
<th>B + 50 ppb Cr</th>
<th>B + 100 ppb Cr</th>
<th>B + 200 ppb Cr</th>
<th>B + 400 ppb Cr</th>
<th>B + 800 ppb Cr</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Egg cholesterol, mg/dl</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Day 0</td>
<td>11.9</td>
<td>11.9</td>
<td>11.6</td>
<td>11.9</td>
<td>11.9</td>
<td>12.0</td>
<td>.3</td>
</tr>
<tr>
<td>Day 7</td>
<td>12.0</td>
<td>12.4</td>
<td>11.3</td>
<td>12.4</td>
<td>12.1</td>
<td>11.8</td>
<td>.3</td>
</tr>
<tr>
<td>Day 14</td>
<td>12.1</td>
<td>11.8</td>
<td>11.5</td>
<td>11.7</td>
<td>12.0</td>
<td>11.9</td>
<td>.3</td>
</tr>
<tr>
<td>Day 21</td>
<td>12.0</td>
<td>12.1</td>
<td>12.5</td>
<td>11.9</td>
<td>12.2</td>
<td>12.4</td>
<td>.4</td>
</tr>
<tr>
<td>Day 28</td>
<td>12.4</td>
<td>12.0</td>
<td>11.5</td>
<td>11.6</td>
<td>11.7</td>
<td>12.1</td>
<td>.3</td>
</tr>
<tr>
<td>Haugh units</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Day 2</td>
<td>83.9</td>
<td>86.1</td>
<td>87.0</td>
<td>85.2</td>
<td>87.0</td>
<td>84.4</td>
<td>2.1</td>
</tr>
<tr>
<td>Day 9</td>
<td>76.1</td>
<td>77.1</td>
<td>82.4</td>
<td>77.0</td>
<td>78.4</td>
<td>73.7</td>
<td>3.0</td>
</tr>
<tr>
<td>Day 16</td>
<td>84.3</td>
<td>82.4</td>
<td>87.0</td>
<td>83.0</td>
<td>86.8</td>
<td>84.1</td>
<td>2.6</td>
</tr>
<tr>
<td>Day 23</td>
<td>81.6</td>
<td>82.0</td>
<td>79.8</td>
<td>83.9</td>
<td>85.9</td>
<td>81.0</td>
<td>2.9</td>
</tr>
</tbody>
</table>

Specific gravity
| Day 2   | 1.0814   | 1.0817       | 1.0810         | 1.0784         | 1.0780         | 1.0811         | .0020 |
| Day 9   | 1.0911   | 1.0870       | 1.0873         | 1.0872         | 1.0875         | 1.0870         | .0015 |
| Day 16  | 1.0838   | 1.0826       | 1.0798         | 1.0822         | 1.0787         | 1.0804         | .0018 |
| Day 23  | 1.0899   | 1.0904       | 1.0872         | 1.0863         | 1.0888         | 1.0920         | .0014 |

*Data are means of 10 replicates of one hen each. Chromium was provided by chromium picolinate. The experimental period was 28 d.
VITA

Timothy Guinn Page was born on November 29, 1954 in Kerrville, Texas. He entered Sam Houston State University in August, 1973 and received a Bachelor of Science degree in Agriculture Education in December, 1976 and a Master of Education degree in Agriculture Education in August, 1980. He then taught Vocational Agriculture in Madisonville, Texas for 12 years before entering Louisiana State University to pursue the degree of Doctor of Philosophy. Mr. Page is a member of Delta Tau Alpha Agricultural Honor Society. He received the Agriculture Outstanding Student Teacher Award while attending Sam Houston State University and he served on the Board of Directors of Vocational Agriculture Teachers Association of Texas. He won a Certificate of Excellence for Outstanding Research Paper Presentation at the 80th Annual Meeting of The Poultry Science Association.

DOCTORAL EXAMINATION AND DISSERTATION REPORT

Candidate: Timothy Guinn Page

Major Field: Animal Science

Title of Dissertation: Chromium, Tryptophan, and Picolinate in Diets for Pigs and Poultry

Approved:

[Signatures]

Major Professor and Chairman

Dean of the Graduate School

EXAMINING COMMITTEE:

[Signatures]

Date of Examination:

November 12, 1991