Effects of Chromium Picolinate (CrP) on Growth Performance and Carcass Characteristics of Fattening Pigs Treated With or Without Porcine Somatotropin (pST)

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ABSTRACT : Objectives of this study was to investigate effects of supplemental chromium (Cr) as CrP in growing pigs treated with pST. Seventy two Landrace pigs weighing average 60 kg were alloted to the three treatments during the 52-d experimental period: control (corn-soybean basal diet); pST treatment (4 mg/head/day); pST + CrP treatment (4 mg and 200 ppb/head/day). Upon termination of feeding trial weighing average 105 kg, thirty-six pigs randomly selected from each treatment were slaughtered to compare carcass traits. For the study of lipid metabolism, eighteen pigs were alloted to the same treatments. Adipose tissue samples from eighteen pigs were collected to investigate lipid metaboism. All treated samples with pST and pST + CrP showed improvements in daily weight gain, regardless of sex. Feed/gain ratio significantly improved in pigs treated with pST and pST + CrP. Dressing percentages were higher in pigs treated with pST and pST + CrP. Carcass grades were significantly higher in pigs treated with pST and pST + CrP. Lipolysis of adipose tissue measured *in vitro* was significantly increased in pigs treated with pST, lipogenesis *in vitro* showed opposite tendency. Even though the current data does not show synergistic effects on the above parameters when CrP and pST were supplied at the same time, but CrP supplementation tended to improve growth performance and carcass traits of pigs treated with pST.
(**Key Words** : Pigs, Porcine Somatotropin, Chromium Picolinate, Lipid Metabolism)

INTRODUCTION

It has been well known that administration of porcine somatotropin (pST) to finishing pigs resulted in increase of feed efficiency and rate of gain, enhanced lean tissue accretion, and decreased fat deposition (Etherton et al., 1987; McLaren et al., 1990; Thiel et al., 1993; Lefaucheur et al., 1992). Even though the exact mechanisms of pST actions have not been elucidated, researchers generally believe that pST increases protein accretion through the action of insulin-like growth factor-I and decreases fat accumulation by enhancing lipolysis through the action of pST itself. Recently Dunshea et al. (1992) suggested that the decrease in lipid accretion of pST-treated pigs was the result of a decreased rate of synthesis, and Harris et al. (1993) indicated that these reductions seemed to result from suppression of genes that encode for the lipogenic enzymes.

Meanwhile, chromium is currently regarded as an essential micronutrient (Christina et al., 1993). Since the natural form chromium in diets is less absorbed and utilized, the organic form of chromium called Chromium Picolinate, in which chromiums are chelated with picolinate, is now utilized for people as well as animals. In recent studies by Page et al. (1993), 200 ppb of chromium decreased backfat thickness and increased lean tissue accretion in pigs, possibly due to enhancement of lipolysis and protein synthesis. Interestingly enough, one can hypothesize that both pST and CrP improve growth performance and carcass traits of pigs through the similar mode of actions, such as alterations of lipid and protein metabolisms.

However, no one has studied the possible synergistic effects of pST and CrP in pigs. Therefore, this study was conducted to evaluate the effects of pST administration and CrP supplement on growth performance, carcass traits, and lipolysis of adipose tissue and to determine whether simultaneous treatments of pST and CrP would induce synergistic effects on the above parameters in pigs.

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MATERIALS AND METHODS

Animals and diets

Seventy-two pure Landrace pigs (36 barrows + 36 gilts) with an average initial BW of 60 kg were used in this study. The fattening pigs were alloted on the basis of weight and sex and randomly assigned to one of three experimental treatments. Experimental treatments consisted of daily injections of porcine Somatotropin (recombinantly derived porcine somatotropin; Lucky, Seoul, Korea; 4 mg/head), and daily injections of pST (4 mg/head) plus CrP supplemented (200 ppb). To investigate lipolytic and lipogenic activities in adipose tissue, eighteen pigs with an average initial BW of 60 kg (9 barrows + 9 gilts) were alloted on the basis of weight and randomly assigned to one of the above experimental treatments. pST was injected daily to the tailhead area subcutaneously at approximately 10 o'clock. The automatic injector (16 gauge × 3.8 cm) was utilized and placebo was distilled water (1 ml/head/day).

Experimental diets were formulated on the basis of the NRC as shown in table 1. There were four pigs per pen and six pens per treatment. Pigs were housed in 2.4 m × 3.4 m pens in an open-front building with solid concrete floors. Pigs had *ad libitum* access to feed and water.

Table 1. Ingredient and chemical composition of the experimental diet (as-fed basis)

Index	Finishing phase (60-110 kg)
Ingredient composition (%)	
Corn, Yellow	66.85
Soybean meal	25.00
Lard	5.00
L-Lysine HCl	0.40
Limestone	0.70
Dicalcium phosphate	1.40
Salt	0.40
Vitamin & Mineral premix[1]	0.25
Chemical composition[2]	
DE (mcal/kg)	3.60
Crude protein (%)	16.50
Calcium (%)	0.80
Phosphorus (%)	0.68
Lysine (%)	1.28

[1] The vitamin & mineral premix contained the following per kg: vitamin A, 2,000,000 IU; vitamin D_3, 400,000 IU; vitamin E, 250 IU; vitamin K, 200 mg; d-panthothenic acid, 3,000 mg; vitamin B_1, 20 mg; vitamin B_2, 700 mg; vitamin B_6, 200 mg; vitamin B_{12}, 2,200 mg; niacin, 8,000 mg; choline chloride, 30,000 mg; folic acid, 40 mg; BHT, 6,000 mg; Mn, 12,000 mg; Cu, 500 mg; Fe, 4,000 mg; Zn, 15,000 mg; I, 1,250 mg; Co, 100 mg; Mg, 2,000 mg.

[2] Calculated values.

Parameters analyzed

All the chemical reagents were purchased from sigma otherwise noted, pigs were weighed individually and feed intake per pen were recorded weekly. To investigate production of chuck, loin, tender, bacon, and rib and carcass grades, thirty-six pigs were slaughtered at the end of the experimental period. Prior to storing carcass in a refrigerator (−10℃) to determine carcass grades, carcass was weighed and evenly devided by an electrical saw.

Lipolytic and lipogenic activities of adipose tissue were determined by the following tissue culture system. Ten to twenty mg of adipose tissue isolated from the back of pigs was incubated in HEPES buffer (25 mM) supplemented with glucose (500 mM), 3% bovine serum albumin (BSA; 4% fatty acid free fraction V). Fatty acid synthesis was measured by incorporation of [1-^{14}C] glucose into fatty acids. According to Allee et al. (1971), upon commencement of the incubation, [1-^{14}C] glucose (0.5 μci/ml) was added. The incubation proceeded for 2 h and then the reaction was terminated by placing the culture flasks into a refrigerator. The tissues were collected and homogenized in a brinkman polytron homogenizer at 10 setting for 30 sec. The homogenates were then extracted using the Dole's extraction mixture [isoprophylalcohol (40): n-hexane (10): 1N H_2SO_4 (1)] according to the procedure of Rodbell (1964). After the lipid phase was separated, aliquots of the lipid phase were evaporated to dryness. Radioactivity was determined with 10 ml of the scintillation solution (New England Nuclear, Boston, MA) using a liquid scintillation spectrophotometer (LS 100C, Beckman). To investigate lipolytic activity, the production of NEFA was measured by the Kelly Method (1965) after 100 mg of adipose tissue was incubated in Krebs-Ringer buffer supplemented with BSA (8% fatty acid free fraction V) for 2 h under the condition of 37℃, and 95% O_2 + 5% CO_2.

Data were analyzed using GLM procedure of SAS (1985). Duncan's multiple range test was utilized to detect significant differences among the treatments.

RESULTS AND DISCUSSION

Table 2 shows effects of CrP on growth performance in pigs injected with pST. The treatments of pST and pST + CrP increased average daily gain (ADG) by 9 to 9.8%, respectively, in barrows and by 10 and 13.3%, respectively, in gilts. However, there was no significant

difference between sex. Thus, these data do not agree to the result of Campbell (1988) which pST administrations showed more positive effects on gilts.

Table 2. Effect of chromium picolinate (CRP) on growth performance in pigs injected with pST

Items		Initial body wt. (kg)	Final body wt. (kg)	Average daily gain (g/day)	Feed intake (kg/day)	Feed : gain
Sex	Treatment					
Barrow	Control	61.0	101.8	782.7	3.04	3.76
	pST[1]	61.2	105.8	858.3	2.73	3.06
	CrP + pST[2]	61.2	106.3	867.5	2.67	3.14
Gilt	Control	62.4	104.3	806.6	2.97	3.95
	pST	62.2	108.6	891.0	2.79	3.36
	CrP + pST	62.1	110.5	930.1	2.88	3.29
Mean	Barrow	61.2	104.6	836.2	2.82	3.32
	Gilt	62.3	107.8	876.0	2.88	3.54
	Control	61.7	103.0	794.6	3.01	3.86
	pST	61.7	107.2	874.7	2.76	3.18
	CrP + pST	61.7	108.4	898.8	2.78	3.25
SEM[3]		7.1	12.6	158.9	0.20	0.20
Interaction;						
Treatment		NS[4]	NS	0.0362*	0.0301*	0.0392*
Between sex		NS	NS	NS	NS	NS
Treatment × sex		NS	NS	NS	NS	NS

[1] 4 mg/day injected.
[2] CrP (200 ppb) supplemented and pST (4 mg/day) injected.
[3] Standard error of mean.
[4] Non-significant.
* Significant at; $p < 0.05$.

Even though the groups of pST and CrP + pST significantly increased ADG ($p < 0.05$) by 10.1 and 13.1 %, repectively, there was no significant difference in feed intake per kg gain among the treatments. Average daily feed intake (ADFI) was decreased ($p < 0.01$) by 0.03 kg/head/day and 0.37 kg/head/day in the treatments of pST and pST + CrP, respectively, clearly supporting the pST effects on growth performance. This appears to agree to the observation by Boyd and Bauman (1989) that pST treatment was followed by a decrease in feed intake. Christina et al. (1993) reported that weight gain increased by 25% when pST (100 μg/head/day) was injected in barrows (30-60 kg). However, pST treatments increased weight gain by only 14% in this experiment. Even if the results of this experiment do not correspond to those of Campbell et al. (1988), which finishing pigs (60-100 kg) had more retained proteins than growing pigs (25-50 kg), the difference might be due to the followings. Firstly, since economical dose of pST is 50-100 μg/head/day (Chung, 1990; Christina et al., 1993), the level of pST in this experiment might not be enough to get the maximum effect. Secondly, it might be caused by the low levels of crude protein (16.5%) in the diets compared with the crude protein contents (19.8%) utilized in other reports (Evock, 1988; Campbell et al., 1988; McLaren et al., 1987).

With regards to feed efficiency, pST and CrP + pST treatments enhanced feed intake by 22.9 and 19.7%, respectively, in gilts and by 20.1 and 17.6%, respectively, in barrows. Christina (1993) reported that CrP supplementation (300 ppb) improved growth performance and feed efficiency in growing pigs (30-60 kg). In our

study, Crp + pST group was more efficient than pST group in enhancing growth performance. Thus, CrP might have synergistic effects on feed efficiency in pigs administered pST.

pST and CrP + pST groups decreased backfat thickness of barrows by 45.5 and 52.4%, respectively and by 62.5 and 36.8%, respectively, in gilts. Carcass percentage was decreased in barrows by 2.3 and 2.5%, respectively, and by 4.5% in gilts (table 3). pST and CrP + pST groups decreased carcass weight by 5.3 and 4.0%, respectively, in barrows and by 2.5 and 1.5%, respectively, in gilts, but there was no significant difference among treatments. pST administration increased the byproducts, which agreed to the results by Chung et al. (1985) and Goodband et al. (1990).

Table 3. Effects of chromium picolinate (CRP) on carcass characteristics in pigs injected with pST

Items		Slaughter wt. (kg)	Carcass wt. (kg)	Carcass percentage (%)	Backfat thickness (cm)
Sex	Treatment				
Barrow	Control	112.0	83.5	74.6	3.2
	pST[1]	108.7	79.3	72.9	2.2
	CrP + pST[2]	109.8	80.3	72.8	2.1
Gilt	Control	105.3	80.4	76.1	2.6
	pST	107.8	78.4	72.8	1.6
	CrP + pST	107.8	79.2	72.8	1.9
Mean	Barrow	110.2	81.0	73.5	2.5
	Gilt	107.0	79.3	74.3	2.0
	Control	108.7	81.9	75.4	2.9
	pST	108.3	78.8	72.9	1.9
	CrP + pST	108.8	79.7	73.4	2.0
SEM[3]		9.04	4.1	1.3	0.4
Interaction;					
Treatment		NS[4]	NS	0.0002**	0.0001**
Between sex		0.0032*	NS	NS	0.0033*
Treatment × sex		NS	NS	NS	NS

[1] 4 mg/day injected.
[2] CrP (200 ppb) supplemented and pST (4 mg/day) injected.
[3] Standard error of mean.
[4] Non-significant.
* Significant at; $p < 0.05$.
** Significant at; $p < 0.001$.

Although the number of animals was not sufficient to validate the effect by treatment, there were 12 A grades in pST group, but no A grade in control group as shown in table 4. Eight of pST-treated pigs showed A grades, however, only 5 of pST + CrP-treated pigs showed A grade, therefore pST and CrP had no synergy effect on carcass grade.

Effects of CrP and pST on cut meats are shown in table 5. Carcass dressing percentage of pST-treated and Crp + pST-treated pigs increased by 6% compared with control pigs ($p < 0.01$). Between sex, dressing percentage of barrow was slightly higher than that of gilt ($p < 0.01$). Our study has shown that in pST treatment groups lipid deposition was decreased by 50% and protein accretion was increased by 6% in both gilts and barrows. These experimental data were slightly lower than those of Etherton (1989) and Steele et al. (1989). Table 6 shows the contents of by-products from each treatment. pST and CrP + pST treatment decreased the amount of by-products compared with control ($p < 0.05$), in which there was sex

Table 4. Effect of chromium picolinate (CrP) and pST on carcass grades in pigs injected with pST

Items		Carcass grade			
		A	B	C	D
		Frequency			
Sex	Treatment;				
Barrow	Control			4	2
	pST[1]	2		4	
	CrP + pST[2]	2	2	2	
Gilt	Control		1	5	
	pST	6			
	CrP + pST	3	2	1	
Mean	Barrow	4	2	10	2
	Gilt	9	3	6	0
	Control		1	9	2
	pST	8	0	4	
	CrP + pST	5	4	3	

[1] 4 mg/day injected.
[2] CrP (200 ppb) supplemented and pST (4 mg/day) injected.

effect, pST injection tended to decrease weights of head, leg, blood, intestine, and bone ($p < 0.05$). It was expected that daily feed intake might be increased since overall weight of by-products was significantly increased in the groups of pST treatment, however, decreases of daily feed intake in pST treatment implied that increases of by-product weight were due to pST effect.

The results of effects of CrP and CrP + pST on lipogenic and lipolytic activity are shown in tabel 7. In barrows, lipolytic activities were 33.63, 41.65, 48.27 μeq/mg for control, pST, CrP + pST treatment, respectively. Lipolytic activity was numerically maximum for CrP + pST treatment ($p < 0.05$). In gilts, lipolytic activities were 30.81, 40.12, 43.46 μeq/mg, respectively. CrP + pST treatment was the highest, too ($p < 0.05$). Lipolytic activity in gilts was significantly lower than that of barrows (38.13 μeq/mg vs 41.18; $p < 0.05$). However, there were no interactions between sex as well as among treatments. The utilization of pST and CrP resulted in improved lipolytic activity, however the mechanism was unknown. It is assumed that the simultaneous administration of CrP and pST, different from only pST administration, may affect the activity of hormone-sensitive lipase, directly or indirectly, and this activated

Table 5. Effects of chromium picolinate (CrP) and pST on cut meats in pigs injected with pST

Items		Dress percentage	Chuck	Loin	Tender loin	Bacon	Rib
Sex	Treatment;	(%)			(kg)		
Barrow	Control	42.47	5.33	6.43	1.03	9.36	1.85
	pST[1]	46.08	5.39	6.65	1.08	8.93	1.92
	CrP + pST[2]	46.54	5.53	6.90	1.18	8.93	2.05
Gilt	Control	45.20	5.15	6.72	0.99	8.67	2.00
	pST	47.15	5.45	7.39	1.17	8.87	1.88
	CrP + pST	46.67	5.33	6.93	1.18	8.43	2.00
Mean	Barrow	45.03	5.41	6.06	1.09	9.07	1.94
	Gilt	46.34	5.31	7.01	1.11	8.65	1.96
	Control	43.83	5.24	6.57	1.00	9.01	1.92
	pST	46.60	5.42	7.02	1.12	8.90	1.90
	CrP + pST	46.61	5.42	6.92	1.18	8.68	2.03
SEM[3]		1.85	0.37	0.64	0.11	0.86	0.26
Interaction;							
Treatment		0.0009**	NS	NS	0.0024**	NS	NS
Between sex		0.0418*	NS	NS	NS	NS	NS
Treatment × sex		NS[4]	NS	NS	NS	NS	NS

[1] 4 mg/day injected.
[2] CrP (200 ppb) supplemented and pST (4 mg/day) injected.
[3] Standard error of mean.
[4] Non-significant.
* Significant at $p < 0.05$.
** Significant at $p < 0.001$.

Table 6. Effects of chromium picolinate (CrP) on by-products from pigs injected with pST

Items		By-products	Head	Leg	Blood	Intestine	Repro[1]	Fat	Bone
Sex	Treatment;	(%)	.....	.....	.....	(%)	.....	.....	.....
Barrow	Control	57.14	6.10	1.90	2.62	13.10	0.85	17.97	7.70
	pST[2]	52.34	6.48	1.97	2.55	14.05	0.67	10.70	8.56
	CrP + pST[3]	50.92	6.23	1.92	2.73	13.52	0.88	9.73	8.85
Gilt	Control	51.24	6.03	1.77	2.32	11.42	0.45	13.81	8.00
	pST	50.63	6.53	1.97	2.57	14.37	0.43	8.87	8.88
	CrP + pST	49.98	6.47	1.98	2.55	12.56	0.35	9.79	8.65
Mean	Barrow	53.47	6.34	1.93	2.63	13.56	0.80	12.80	8.37
	Gilt	50.62	6.27	1.91	2.48	12.78	0.41	10.83	8.51
	Control	54.19	6.07	1.83	2.47	12.26	0.65	12.89	7.85
	pST	51.49	6.51	2.00	2.56	14.21	0.55	9.79	8.72
	CrP + pST	50.45	6.35	1.95	2.64	13.03	0.62	9.76	8.75
SEM[4]		3.48	0.37	0.14	0.30	1.92	0.14	2.09	0.40
Interaction;									
Treatment		0.0366*	0.0202*	NS	NS	NS	NS	0.0001**	0.0001**
Between sex		0.0200*	NS	NS	NS	NS	0.0001**	0.0081**	NS
Treatment × sex		NS[5]	NS	NS	NS	NS	0.0471*	NS	NS

[1] Repro : reproductive organs.
[2] 4 mg/day injected.
[3] CrP (200 ppb) supplemented and pST (4 mg/day) injected.
[4] Standard error of mean.
[5] Non-significant.
* Significant at $p < 0.05$.
** Significant at $p < 0.001$.

lipase may stimulate lipolytic activity in adipose tissue. Therefore, the addition of CrP and pST in feed may result in fat reduction in pig tissue. The effects of pST and CrP + pST on lipogenic activity were significantly different between sex and between treatments. In gilts, lipogenic activities were 158.52, 142.31, 132.59 nmole/mg for control, pST, CrP + pST treatments, respectively ($p < 0.05$). In barrows, 153.74, 135.77, 128.75 nmole/mg, respectively. Lipogenic activity in gilts was significantly higher than in barrows between sex (144.47 vs 139.42 nmole/mg; $p < 0.01$). Lipogenic activity was higher in gilts, however, in barrows, lipolytic activity was higher. Lipogenic activity of pST + CrP treatment decreased by 19.5% compared with control. Mikel et al. (1993) reported that pST antagonized insulin and decreased lipogenic activity. pST increased the level of insulin in blood, however, decreased the sensitivity of insulin on tissue, and eventually, increased glucose level, however, these effects were not caused by decrease of specific binding on insulin-receptor site (Boyd, 1989). Furthermore, since the increase of pST level in blood subsequently increased NEFA level, pST may directly increase lipolytic activity (Bauman, 1992).

In growing pigs, when pigs were allowed *ad libitum* access to the diet, pST treatment enabled energy not to synthesize lipid. This fact was observed by *in vivo* (Dunshea et al., 1992) and *in vitro* (Walton and Etherton, 1986) experiments. When pigs fed highly limiting feed, pST treatment showed increased protein accretion and mobilized the body fat, resulting in the decrease of backfat. A decrease of lipogenic activity by pST treatment was related with the decrease of lipogenic enzyme activity, such as acetyl-CoA carboxylase and fatty acid synthase. It was known that mRNA on fatty acid synthase was decreased, possibly resulting from decrease of gene transcription. The result of this study indicated that pST treatment decreased lipogenic activity and increased lipolytic activity, which regulating the level of NEFA in blood.

Consequently, even though the current data do not show synergy effect on the above parameters when CrP and pST were supplemented at the same time, CrP supplementation tended to improve growth performance and carcass traits of pigs treated with pST. In addition, it

is required to conduct cell culture study to further elucidate the synergy effect of both pST and CrP and their exact mechanism in the animal tissue.

Table 7. Effects of chromium picolinate (CrP) on lipid metabolism of adipose tissue in pigs injected with pST

Item		Lipogenic activity[1]	Lipolytic activity[2]
Sex	Treatment;		
Barrow	Control	153.74	33.63
	pST[3]	135.77	41.65
	CrP + pST[4]	128.75	48.27
Gilt	Control	158.52	30.81
	pST	142.31	40.12
	CrP + pST	132.59	43.46
Mean	Barrow	139.42	41.18
	Gilt	144.47	38.13
	Control	156.13	32.22
	pST	139.04	40.89
	CrP + pST	130.67	45.86
SEM[5]		9.45	3.94
Interaction;			
Treatment		0.0001**	0.0001**
Between sex		0.0264*	0.0016*
Treatment × sex		NS[6]	NS

[1] nmol glucose incorporated into total lipids/mg.
[2] eq non-esterified fatty acid (NEFA) released/mg.
[3] 4 mg/day injected.
[4] CrP (200 ppb) supplemented and pST (4 mg/day) injected.
[5] Standard error of mean.
[6] Non-significant.
* Significant at $p < 0.05$.
** Significant at $p < 0.001$.

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