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Effect of a chromium yeast supplement in growing-finishing pig diets on performance, carcass traits and fatty acid composition of adipose tissue

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ABSTRACT

Ninety-six Pulavian x Pietrain crossbreed pigs (48 gilts and 48 barrows) were allotted to three treatments: 1. control with the basal diets for growing (25-65 kg body weight) and finishing period (65-105 kg BW); 2. 1 kg of basal diets supplemented with 0.2 mg kg^{-1} Cr from chromium yeast, and 3. 1 kg of basal diets supplemented with 0.5 mg kg^{-1} Cr from chromium yeast. The pigs were housed in pens (4 gilts or 4 barrows per pen). Feed and water were available *ad libitum* and individual live weights and pen feed consumption were recorded on days 30, 60, 90 and 110 (at slaughter) of the trial.

Average daily gains and feed utilization were not significantly affected by Cr supplementation. Backfat thickness over the shoulder as well as subcutaneous fat of ham were reduced significantly in pigs supplemented with Cr. Lean of ham increased significantly in both experimental groups. A significant reduction in saturated fatty acid (SFA) content and an increase in the polyunsaturated fatty acid (PUFA) level of backfat and of leaf fat was noticed in the experimental groups. These results indicate that dietary supplementation of organic chromium may increase muscle and decrease fat deposition with lower content of SFA and higher content of PUFA in adipose tissues of backfat and leaf fat.

KEY WORDS: growing-finishing pigs, organic Cr, carcass quality, fatty acids

INTRODUCTION

Chromium (Cr) is well known as an essential trace element for normal metabolism of carbohydrates, proteins and lipids in human and animal nutrition (Offenbacher and Pi-Suner, 1988; Mertz, 1993). It is physiologically active and non-toxic only in the trivalent form at concentrations of approximately 0.1 mg kg^{-1} diet. Chromium is known to take part in several biological functions; it is an active constituent of glucose tolerance factors (GTF), stimulates RNA synthesis and is a natural antioxidant (Evock-Clover et al., 1993; Mirsky,1993; Mowat,1993; Stearns et al.,1995). Mertz (1993) and Amoiken et al. (1995) demonstrated the positive effect of Cr on insulin and, therefore, on carbohydrate and protein metabolism. Seerley (1993) found that protein deposition could be increased and fat deposition reduced when Cr is supplemented. This author demonstrated that growth parameters of stressed animals supplemented with organic Cr were beneficially affected. Page et al. (1993) informed that chromium supplemented in the form of chromium picolinate to the diet at a rate of 0.2 mg kg^{-1} decreased backfat thickness and serum cholesterol levels in finishing pigs and increased loin eye area and percentage of lean.

The amount of fat in carcass tissue is an important concern in human nutrition, as people prefer lean meat because of the global trend towards reducing animal fat in diets. Thus, genetic or nutritional and pharmacological manipulation of fatty acid synthesis should lead to production of leaner animals. It was recently established that dietary polyunsaturated fatty acids inhibit lipogenesis and the activities of the lipogenic enzymes (Otten et al., 1993; Hillgartner et al., 1995). And so, the higher content of polyunsaturated fatty acids in fat tissue and diminished fat deposition caused by dietary organic chromium supplementation may have a positive effect on carcass characteristics. In recent studies, supplements of 0.2 and 0.5 mg kg^{-1} of organic chromium have been found effective in improving carcass characteristics in pigs (Evock-Clover et al., 1993; Page et al., 1993; Seerley, 1993; Lindemann et al.,1995; Wenk, 1995).

The aim of the present study was to assess the effect of organic chromium in the trivalent form supplemented to the diet in two different concentrations of 0.2 mg kg^{-1} and 0.5 mg kg^{-1} as chromium yeast (bioplex Cr[1]) on growth performance, carcass traits and fatty acid composition of backfat, leaf fat and intramuscular fat of growing-finishing pigs.

MATERIAL AND METHODS

Animals

Ninety-six Pulavian x Pietrain crossbreed pigs of both sexes (48 gilts and 48 barrows) from twelve litters of an experimental herd were randomly allotted to three treatments: 1. control with the basal diets for the growing (25-65 kg body weight) and finishing periods (65-105 kg BW); 2. basal diet + 0.2 mg Cr^{+3} from chromium bioplex[1] in 1 kg of diet; 3. basal diet + 0.5 mg Cr^{+3} from chromium bioplex[1]. The initial weight was 25 kg and slaughter weight was about 105 kg BW. The pigs were housed in pens with concrete slate floors (4 gilts or 4 barrows per pen). Feed and water were available *ad libitum*. Individual live weights and pen feed consumption were recorded on days 30, 60, 90 and 110 (at slaughter) of the trial. The temperature of the room was controlled and maintained at 22 ± 1^0C with air speed <0.05 cm s^{-1}.

Diets

Mixed basal diets were prepared from commercial feeds. The composition of the grower (up to 65 kg BW) and finisher diets is presented in Table 1. All nutrients including vitamins and trace elements were consistent with the level recommended by the Nutrients Requirements of Pigs (1993). Chromium in organic form as Cr bioplex[1] was added to the basal diet (Table 1) at 0.2 and 0.5 mg kg^{-1}.

Chemical composition, including DM, crude ash, crude fibre, ether extract, crude protein, minerals (Ca and P) and amino acid composition, was determined according to routine laboratory procedures (AOAC, 1980). Chromium in diets was analyzed as described by Anderson and Kozlovsky (1985).

Carcass measurements

Pigs were stunned by electric shock and then killed by exsanguination. After slaughter, the 12 right carcasses (6 gilts and 6 barrows) of each treatment were chilled overnight and the following data were recorded using the Polish Pig Progeny Station method: carcass weight, length of carcass, backfat thickness over the shoulder, between the third and fourth lumbar vertebra, on the midback between the third and fourth last rib and on the rump at three locations over the cranial, medial and caudal part of the gluteus muscle, loin and ham weight before the ham was further dissected into lean, subcutaneous fat and bone, loin eye area and weight of right side leaf fat.

Samples and analysis

About 20 g backfat from two layers and muscle tissue were removed from the middle part of *M. longissimus dorsi*. Samples of 20 g were excised from the leaf fat. All samples were stored at -20^0C until analysis. Total lipids were extracted quantitatively from tissue samples with chloroform-methanol (2:1 v/v) according

TABLE 1

Composition and nutrient content of the experimental diets

	Basal (Control)		Cr supplement of the diets			
			0.2 mg kg^{-1}		0.5 mg kg^{-1}	
	growing	finishing	growing	finishing	growing	finishing
Composition of the diets, g kg^{-1}:						
barley	295	275				
wheat	200	–				
triticale	300	600				
soyabean meal	100	50				
meat and bone meal	50	30				
fodder yeast	30	20				
lysine-HCl	1	1				
salt (NaCl)	3	3				
limestone	11	11				
mineral – vitamin premix[1]	10	10				
Nutrient content, g kg^{-1} dry matter						
dry matter	899.4	886.3	887.5	888.1	889.0	884.6
crude protein	178.3	150.1	178.4	149.8	179.0	150.3
lysine	9.1	7.5	9.2	7.5	9.2	7.4
methionine + cystine	5.6	4.8	5.5	4.8	5.6	4.7
ether extract	27.3	24.4	27.2	24.3	27.4	25.0
crude fibre	36.4	35.8	34.9	34.8	35.1	33.7
crude ash	45.6	39.2	44.8	38.7	45.3	39.6
Ca	7.3	5.2	7.4	5.2	7.4	5.3
P total	5.6	4.0	5.6	4.1	5.7	4.1
Cr, ppm	1.28	1.19	1.46	1.38	1.73	1.70
ME, MJ[2]	12.8	12.9	12.8	12.8	12.8	12.9

[1] the premix delivered (kg^{-1} feed): 8000 IU vit. A; 1600 IU vit. D3; 40 mg vit. E; 5 mg riboflavin; 20 mg niacin amide; 10 mg d – pantothenic acid; 200 mg choline chloride; 20 μg vit. B_{12}; 2 mg menadione; 0.3 mg folic acid; 30 mg Fe; 60 mg Zn; 20 mg Mn; 10 mg Cu; 1 mg J; 0.2 mg Se

[2] calculated values

to the method of Folch et al. (1957). About 10 mg of total lipids was used for preparation of fatty acid methyl esters as outlined by Rotenberg and Andersen (1980). The composition of fatty acid methyl esters was determined by gas-liquid chromatography (GLC). Heptadecanoic acid was added as the internal standard. About 1 mg of the esters was injected into a Perkin-Elmer gas chromatograph Model 900 equipped with an automatic Model AS 41 injection system and a flame ionization detector (FID). The methyl esters were analyzed using a 1.83 m x 6.35 mm glass column packed with 15% ethylene glycol succinate (EGS) on 80/100 mesh Chromosorb W, AW DMCS. Temperature: 140°C isothermal for 24 min, then programming an increase of 1.5°C min^{-1} to 190°C. Carrier gas : nitrogen, 20 ml/min. Authentic standards of typical fatty acids (Chrompack, The Netherlands) were used to identify peaks.

All chemical analyses were performed in duplicate.

Statistical analysis

Statistical significance of the difference between means of fatty acid contents and carcass quality data of treatments ($P<0.05$) was assessed by the t-Student test. The results are given as the arithmetic means and standard error of means (SEM).

RESULTS

Performance

Average daily gains were not affected significantly by Cr supplementation, but there was a trend, more markedly expressed in gilts than in barrows, for higher gain in the growing and finishing period (Table 2).

Carcass composition

Backfat thickness over the shoulder as well as subcutaneous fat of ham were reduced significantly in pigs supplemented with Cr (Table 3). Lean of ham increased significantly in both experimental groups receiving 0.2 mg and 0.5 mg Cr per kilogram of diet. The *longissimus dorsi* muscle area was 5.3-6.9% greater in pigs fed supplemented diets than in those given the control diet, but this effect was not significant (Table 3). Loin weight was higher in both experimental groups supplemented with Cr, but this effect was not significant. The weight of ham was significantly higher in gilts than in barrows in all experimental groups. Weight of leaf fat tended to be reduced in pigs fed supplemented diets compared

TABLE 2

Growth performance and feed conversion

Item	Control 1	Cr supplement of the diets		Sex		SEM[1]
		0.2 mg kg^{-1}	0.5 mg kg^{-1}	gilts	barrows	
Initial body weight, kg	25.6	25.2	25.3	25.5	25.3	0.8
Slaughter body weight, kg	105.3	105.9	105.4	106.3	104.8	1.7
Days on trial	113.0	111.3	109.7	111.1	111.5	1.8
Daily gains, g						
growing period	617	646	638	637	631	36
finishing period	793	804	822	817	795	47
whole fattening period	705	725	730	727	713	42
Feed conversion ratio, kg^{-1}						
growing period	2.85	2.76	2.81	2.77	2.85	0.11
finishing period	3.93	3.71	3.68	3.71	3.83	0.19
whole fattening period	3.39	3.24	3.25	3.24	3.34	0.17

[1] standard error of the mean

TABLE 3

Carcass traits and intramuscular fat content of muscles of fattening pigs

Item	Control	Cr supplement of the diets		Sex		SEM[1]
	I	0.2 mg kg^{-1}	0.5 mg kg^{-1}	gilts	barrows	
Dressing, %	78.6	77.8	77.3	77.5	78.3	1.4
Length of carcass, cm	81.3	82.1	82.4	82.3	81.5	2.1
Backfat thickness, mm						
over the shoulder	36.4^{a}	28.2^{b}	26.6^{b}	29.2	31.6	3.4
on the midback	21.3	18.4	18.2	17.9	20.7	2.3
on the rump, mean of 3 measurements	27.2	23.3	22.7	23.5	25.2	2.9
average of 5 measurements	27.9^{a}	23.3^{b}	22.6^{b}	23.7	25.6	2.6
Loin weight, kg	8.86	9.38	9.47	9.25	9.23	0.52
Loin eye area, cm^2	43.3	45.6	46.3	46.0	44.2	3.1
Intramuscular fat in loin, %	1.56	1.49	1.53	1.49	1.57	0.11
Ham weight, kg	9.16	9.04	9.16	9.36^{a}	8.87^{b}	0.46
Lean of ham, %	61.4^{a}	65.8^{b}	65.3^{b}	64.6	63.8	3.2
Subcutaneous fat of ham, %	22.2^{a}	20.1^{b}	19.8^{b}	20.0	21.4	1.5
Intramuscular fat in ham, %	1.68	1.59	1.63	1.60	1.66	0.12
Weight of right side leaf fat, kg	1.21	1.12	1.14	1.06	1.26	0.12

[1] standard error of the mean

a, b – $P \leqslant 0.05$

with those receiving the control diet, but the effect was not significant. Intramuscular fat content in loin and ham was not affected by Cr supplementation (Table 3).

Fatty acid composition

Fatty acid composition of backfat in pigs was influenced by supplementing with Cr, causing a significant reduction in saturated fatty acid (SFA) content and also a significant increase in the polyunsaturated fatty acid (PUFA) level (Table 4). This effect was more pronounced in gilts than in barrows (Table 4). A similar effect was noticed in fatty acid composition of leaf fat in pigs supplemented with Cr in comparison to values obtained in control pigs (Table 5). The tendency for higher PUFA and lower SFA contents was also observed in the intramuscular fat of the *longissimus dorsi* muscle of pigs fed the Cr supplement (Table 6).

DISCUSSION

The results of these experiments do not support those of some other authors (Lindemann et al., 1993, 1995) demonstrating improved productivity (daily gains, feed utilization) when pigs were fed on diets supplemented with organic Cr. Our results show only a trend of better feed utilization and average daily gains, more markedly expressed in gilts than in barrows. The results of our observations indicate that organic chromium supplementation decreased some of the adipose parameters (backfat thickness over the shoulder, backfat thickness in the midback and rump taken from five measurements, subcutaneous fat of ham) and increased carcass lean (lean of ham). Additionally, the composition of fatty acids showed a trend for higher content of polyunsaturated fatty acids and lower for saturated fatty acids. These data may also have potential benefits through diminishing the activities of lipogenic enzymes when used for human consumption. The molecular basis for the inhibitory effects of PUFA on lipogenesis, insulin and thyroid hormones are positive factors while glucagon is a negative one (Hillgartner et al.,1995). Growth hormone, glucocorticoids, and insulin-like growth factors (IGF) also regulate the activities of lipogenic enzymes, but the roles of these agents in the dietary regulation of lipogenic enzymes are unknown in animals and humans. The amount of fat deposition and the simultaneous accretion of muscle in pigs fed Cr are similar to the effects of exogenous growth hormone and β-adrenergic agonists (Pringle et al., 1993; Amoiken et al., 1995). The best known effects of Cr on insulin receptor sensitivity and increased protein synthesis in muscle, together with higher growth hormone secretion, may to some extent explain the mechanism of the observed results in

TABLE 4

Fatty acid composition of backfat of fattening pigs, % of identified FA

Fatty acids	Control	Cr supplement of the diets		Sex		SEM[1]
	I	0.2 mg kg^{-1}	0.5 mg kg^{-1}	gilts	barrows	
Saturated FA	41.24^{a}	39.16^{ab}	38.72^{b}	39.14	40.28	2.14
14:0	1.38	1.21	1.26	1.25	1.31	0.10
16:0	24.32^{a}	22.67^{ab}	22.16^{b}	22.74	23.38	1.03
18:0	15.21	14.89	15.02	14.86	15.28	0.82
20:0	0.33	0.30	0.28	0.29	0.31	0.05
Monounsaturated FA	50.68	51.42	51.75	51.51	51.05	2.56
16:1	2.71	2.86	2.85	2.84	2.78	0.29
18:1	47.01	47.62	47.97	47.72	47.34	1.59
20:1	0.96	0.94	0.93	0.95	0.93	0.08
Polyunsaturated FA	8.08^{a}	9.42^{b}	9.53^{b}	9.35^{a}	8.67^{b}	0.56
18:2	6.92^{a}	8.12^{b}	8.17^{b}	8.02^{a}	7.46^{b}	0.49
18:3	0.47	0.52	0.56	0.56	0.48	0.19
20:4	0.69	0.78	0.80	0.77	0.73	0.13
Ratio UFA : SFA	1.42^{a}	1.55^{ab}	1.58^{b}	1.56	1.48	0.12

[1] standard error of the mean

a, b – $P \leqslant 0.05$

TABLE 5

Fatty acid composition of leaf fat of fattening pigs, % of identified FA

Fatty acids	Control I	Cr supplement of the diets		Sex		SEM[1]
		0.2 mg kg^{-1}	0.5 mg kg^{-1}	gilts	barrows	
Saturated FA	54.29^{a}	52.75^{b}	52.37^{b}	52.63	53.65	1.46
14:0	1.52	1.36	1.37	1.36	1.48	0.16
16:0	29.12	28.34	28.18	28.23	28.85	0.93
18:0	23.24	22.71	22.56	22.73	22.95	0.86
20:0	0.41	0.34	0.26	0.31	0.37	0.17
Monounsaturated FA	38.58	38.89	39.40	39.22	35.68	1.27
16:1	2.28	2.33	2.35	2.36	2.28	0.21
18:1	35.54	35.76	36.23	36.02	35.66	1.29
20:1	0.76	0.80	0.82	0.84	0.74	0.15
Polyunsaturated FA	7.13^{a}	8.36^{b}	8.23^{b}	8.15	7.67	0.51
18:2	6.56^{a}	7.63^{b}	7.48^{b}	7.44	7.02	0.48
18:3	0.39	0.46	0.47	0.46	0.42	0.05
20:4	0.18	0.27	0.28	0.25	0.23	0.04
Ratio UFA : SFA	0.84	0.90	0.91	0.90	0.86	0.06

[1] standard error of the mean

a, b – $P \leqslant 0.05$

TABLE 6

Fatty acid composition of intramuscular fat in the *longissimus dorsi* muscle of fattening pigs, % of identified FA

Fatty acids	Control	Cr supplement of the diets		Sex		SEM[1]
	I	0.2 mg kg^{-1}	0.5 mg kg^{-1}	gilts	barrows	
Saturated FA	42.40	41.08	41.09	40.78	42.26	0.89
14:0	1.31	1.25	1.25	1.24	1.30	0.06
16:0	26.03	25.12	25.36	24.88^{a}	26.12^{b}	0.73
18:0	14.67	14.43	14.21	14.36	14.52	0.32
20:0	0.39	0.28	0.27	0.30	0.32	0.03
Monounsaturated FA	48.41	48.83	48.34	49.01	48.05	1.03
16:1	3.08	3.37	3.37	3.31	3.23	0.29
18:1	44.17	44.20	43.74	44.47	43.62	0.98
20:1	1.16	1.26	1.23	1.23	1.20	0.09
Polyunsaturated FA	9.19^{a}	10.09^{ab}	10.57^{b}	10.21	9.69	0.58
18:2	6.96^{a}	7.36^{ab}	7.82^{h}	7.56	7.20	0.53
18:3	0.81	0.95	0.94	0.94	0.86	0.14
20:4	1.42	1.78	1.81	1.71	1.63	0.16
Ratio UFA : SFA	1.36	1.43	1.43	1.45	1.37	0.08

[1] standard error of the mean

a, b – $P \leqslant 0.05$

reduced lipogenesis and increased muscle accretion in pigs. Many of the effects attributed to chromium cannot be explained by the action of these hormones only.

In our study, a supplement of 0.2 mg kg^{-1} of organic chromium was effective, and carcass leanness did not improve when the concentration was raised to 0.5 mg kg^{-1}. Thus the recommended and safe supplement dosage under experimental conditions could be the lower amount of 0.2 mg kg^{-1} of organic chromium.

The favourable responses to dietary Cr supplementation seem to be related and dependent on some other dietary constituent and to different degrees of stress connected with individual or group feeding (Boleman et al., 1995). Other metabolic, hormonal and enzymatic factors such as endogenous muscle proteinase (calpain-calpastatin) may be involved and need further investigation (Pringle et al., 1993).

CONCLUSIONS

Supplementation of diets with chromium (0.2 or 0.5 mg kg^{-1}) in organic form as a chromium yeast (bioplex Cr) did not significantly affect the performance of growing-finishing pigs, but decreased the amount of fat in the carcass (backfat thickness over the shoulder, backfat thickness in the midback and rump taken from five measurements, subcutaneous fat of ham) and increased carcass lean (lean of ham). There was a trend for reduction in saturated fatty acid content and increase in PUFA of adipose tissue in supplemented pigs. Dietary chromium supplementation accelerates development of lean body weight in growing-finishing pigs and may improve the efficiency of productivity when applied in conventional diets that do not supply adequate levels of this trace element.

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STRESZCZENIE

Wpływ dodatku drożdży Cr do paszy na wzrost tuczników, jakość tuszy i skład kwasów tłuszczowych w tkankach

Trzy grupy mieszańców ras Puławska x Pietrain (po 16 loszek i po 16 wieprzków), dobranych losowo, żywiono mieszanką standardową typu PT-1 (25-65 kg masy ciała tuczników) i PT-2 (65-105 kg). Grupa I stanowiła kontrolę, do mieszanki dla grupy II dodano 0,2 mg Cr na1 kg paszy, dla grupy III 0,5 mg Cr, w postaci drożdży Cr (bioplex Cr). Tuczniki miały stały dostęp do paszy

i wody. Zwierzęta trzymano grupowo po 4, w jednym kojcu. Ważono je indywidualne w 30, 60, 90 i 110 (przy uboju) dniu doświadczenia.

Nie stwierdzono istotnego wpływu dodatku Cr na przyrosty i wykorzystanie paszy. Grubość słoniny nad łopatką oraz udział tłuszczu podskórnego w szynce były istotnie ($P<0,05$) mniejsze u tuczników otrzymujących w paszy dodatek Cr. Udział mięsa w szynce był istotnie większy u tuczników żywionych dietą z dodatkiem Cr, niezależnie od jego poziomu w paszy. Istotne zmniejszenie poziomu kwasów tłuszczowych nasyconych a zwiększenie udziału kwasów tłuszczowych wielonienasyconych stwierdzono w słoninie i sadle tuczników otrzymujących dodatek Cr. Dodatek Cr wpłynął także na zwiększenie zawartości kwasu linolowego w tłuszczu polędwicy.