Effects of Different Products and Levels of Selenium on Growth, Nutrient Digestibility and Selenium Retention of Growing-finishing Pigs*

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ABSTRACT : This experiment was conducted to evaluate the effects of different selenium (Se) products (inorganic, organic A, organic B) added at two supplemental dietary Se levels (0.1 and 0.3 mg/kg) on growth performance, nutrient digestibility and Se retention in growing-finishing pigs. A 3×2 factorial arrangement of treatments was used in a RCB design, with a non-Se-fortified basal diet serving as the negative control. A total of 56 crossbred pigs (28 male and 28 female pigs) initially weighing an average 28.45±0.53 kg BW were allotted to each treatment with four pigs per pen on the basis of sex and weight. Two pigs per pen were selected and bled from the anterior vena cava at 3- weekly intervals to analyze Se concentration. In the growing phase (0-6 weeks), increased ADFI was observed when pigs were fed organic Se compared to those fed the control diet or inorganic Se treatment ($p<0.05$). Pigs fed inorganic Se had a great ADFI than pigs fed organic Se ($p<0.05$) in the late finishing phase (7-12 weeks), although there were no differences in whole period ADFI between organic or inorganic Se products. During 12 weeks of the whole experimental period, serum Se concentration increased linearly when dietary Se level increased regardless of Se products ($p<0.05$). Both dietary Se source ($p<0.05$) and Se level ($p<0.01$) influenced the Se concentration of various pig tissues at end of this experiment and Se content was the highest in the kidney. For the determination of nutrient digestibility, a metabolic trial was conducted in 3 replicates in randomized complete block (RCB) design. A total of 21 barrows (50.21±0.62 kg of average BW) were used in the metabolic study. Selenium supplementation had no effect on nutrient digestibility except for crude protein. Crude protein digestibility increased with dietary supplementation of organic Se (A) compared with other forms of Se products or control diet ($p<0.05$). Consequently, this experiment indicated that dietary Se products and levels had no effect on growth performance of pigs. Se concentration in tissues and serum was increased in proportion to dietary Se level, especially when organic Se was provided. Although pigs were fed organic forms of Se, bioavailability of organic forms varied among products, consequently bioactivity of organic products to the animals should be evaluated before practical application in animal feed. ***(Asian-Aust. J. Anim. Sci. 2006. Vol 19, No. 1 : 61-66)***

Key Words : Selenium Source, Growth, Nutrients Digestibility, Serum Se, Se Retention

INTRODUCTION

In 1987, the FDA approved 0.3 mg/kg of inorganic Se (sodium selenite or sodium selenate) added to animal feed, and restricted Se added to free mixed products to 200 mg/kg. Sodium selenite and sodium selenate had similar effects on animals but considering cost, sodium selenite is favored (Mahan, 2001). Also, the NRC (1998) established Se requirement at 0.1 mg/kg, based on several experiments of Se retention in tissues of growing-finishing pigs, but not considering the activation of glutathione peroxidase (GSH-Px) (Brady et al., 1979), the anti-oxidation enzyme responsible for preventing peroxidation of body tissue.

Recently, development and research on organic Se products have shown progress. Mahan and Cline (1999) showed that low level of organic Se (<0.1 mg/kg) had less effect than inorganic Se (sodium selenite) when applied to pigs improving the activity of GSH-Px, but had similar effects at a fortified level (0.3 mg/kg). However, Se transfer from dam to litter during gestation through placenta and lactation by colostrum and milk occurred more efficiently when sows were fed organic Se (Mahan and Kim, 1996; Mahan and Cline**,** 1999; Mahan et al., 2000). Organic Se consists of Se-containing amino acids and their analogues, among which selenomethionine accounts for over 40% of the total Se (Kelly and Power, 1995).

Selenomethionine is found in livestock feed, thus increasing Se retention delivered to humans through livestock products. On the other hand, inorganic Se forms, selenite or selenate, are effective sources in preventing Se deficiencies of livestock, but are ineffective in synthesis of selenocysteine containing selenoprotein, found in meats, milk and eggs. As Korean consumers are interested in Se-fortified functional animal products such as milk, egg and beef, but there has been no attempt to make Se-fortified animal products so far. Recently numerous Se products for supplementing animal feed have been introduced in the feed industries. Their efficacies and retention in animals should be evaluated. Consequently the object of this study

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Table 1. Formula and chemical composition of the experimental diets in growing and finishing phase (%)

Ingredients	Growing	Finishing-I	Finishing-II
Corn	68.70	76.72	83.91
SBM	28.07	20.85	14.24
Tallow	0.93	0.42	0.02
Limestone	0.85	0.73	0.75
DCP	0.85	0.68	0.48
Vit. Mix[1]	0.10	0.10	0.10
Min. mix[2]	0.10	0.10	0.10
Salt	0.30	0.30	0.30
Antibiotics[3]	0.10	0.10	0.10
Total	100.00	100.00	100.00
Chemical compositions			
ME (Kcal/kg)	3,265.50	3,265.41	3,265.35
CP (%)	18.00	15.50	13.20
Lys (%)	0.97	0.79	0.62
Met (%)	0.29	0.26	0.23
Cys (%)	0.33	0.29	0.26
Ca (%)	0.60	0.50	0.45
Total P (%)	0.53	0.48	0.42
Non-phytate P (%)	0.23	0.19	0.15
Se (mg/kg)	0.06	0.06	0.06

[1] Provided the followings by per kg vitamin mixture respectively: vitamin A, 8,000.00 IU; vitamin D, 31,600.00 IU; vitamin E, 17.40 IU; vitamin K, 32.40 mg; vitamin B_2, 3.20 mg; Ca Pantothenate, 8.00 mg; Niacin, 16.00 mg; Biotin, 0.06 mg; Ethoxquin, A 6,612.00 mg; vitamin B_{12}, 24.00 μg.

[2] Provided the followings by per kg mineral mixture respectively: Fe, 95.95 mg; Cu, 24.26 mg; Zn, 90.55 mg; Mn, 85.46 mg; Co, 1.29 mg; Ca, 2.08 mg; I, 13.20 mg.

[3] Virginiamycin (10 mg/kg) was added for the grower and finisher diets.

was to evaluate the effect of different Se products on growth performance and retention of Se in various tissues in pigs.

MATERIALS AND METHODS

This study was a 3×2 factorial arrangement of treatments in a RCB design, with a non-Se-fortified basal diet serving as the negative control. This experiment was conducted to evaluate the efficacy of the three Se products (sodium selenite, Se-enriched yeast-organic Se (A), organic Se (B) each at two supplemental dietary Se levels (0.1, 0.3 mg/kg) on serum Se, and tissue Se concentration in growing-finishing pigs.

A total of 56 crossbred pigs that weighed an average 28.45±0.53 kg BW were allotted to treatment groups on the basis of sex and weight. The experiment was conducted in two replicates with four pigs per pen. Pigs were housed in a conventional facility with a half-slotted concrete floor.

Experimental diets were formulated to contain 3,265 kcal ME/kg diet for 12 weeks of experimental periods, and CP was 18%, 15.50% and 13.20% for growing, early finishing and late finishing period, respectively. Lysine contents in experimental diets were 0.97%, 0.79% and 0.62% for growing (6 weeks), early finishing (3 weeks) and late finishing period (3 weeks), respectively. All other nutrients met or exceeded requirements of NRC (1998) standard.

Pigs were allowed *ad libitum* access to water and diets during the 12 weeks growth trial, and all diets were provided in mash form. Body weights and feed intake were measured at 3, 6, 9 and 12 wk from the beginning of experiment. Average daily gain (ADG), average daily feed intake (ADFI) and gain/feed (G/F) were calculated.

Blood samples were collected from the anterior vena cava from two pigs per pen at 3 weeks intervals for the 12 weeks experimental period. Collected blood samples were centrifuged at 3,000×g at 4°C, serum was separated, frozen and analyzed for Se concentrations.

At 12 weeks, 3 pigs per treatment were selected, killed by exsanguination, and samples of loin, liver, kidney and pancreas were collected, frozen, and analyzed for Se concentrations.

For the determination of Se and other nutrients digestibility, a metabolic trial was conducted. A total of 21 barrows (50.21±0.62 kg of average initial body weight) were used in a completely random design in 3 replicates over two periods. After 7 days of adaptation, pigs were fed their treatment diet in equal quantities twice daily and water was added while pigs consumed their ration for 5 days. Collected excreta were pooled, sealed in plastic bags and stored at -20°C then dried in an air-forced drying oven at 60°C for 72 h. Dried fecal samples were ground with 1 mm Wiley mill for chemical analysis. Total urine was collected daily in a plastic container containing 20 ml of 1.25 N HCl to minimize the N loss by evaporation of ammonia. Collected samples were filtered through glass wool to remove any contaminates and frozen, pooled for the 5 days collection period, and later analyzed for Se.

Proximate composition and diets, feces and urine were analyzed according to the methods of AOAC (1995). Diet, serum, and the various tissues were analyzed for their Se content with the fluorometric method of AOAC (1995).

The data obtained were subjected to a GLM analysis of SAS (1995) according to 3×2 factorial arrangement. The pen was considered the experimental unit for performance data. The main effect of Se source, which excluded the non-Se-fortified basal diet, was evaluated with a single degree of freedom. Regression analysis for Se level and the Se level×Se source interaction response included the basal diet within each Se group. Simple correlations were conducted between individual pig's serum constituents and Se tissue contents collected from these pigs.

RESULTS AND DISCUSSION

Growth performance

The experiment was conducted to evaluate the effect of

Table 2. Treatment effects of dietary Se products and levels on growth performance of growing-finishing pigs

Item	Con	Inorganic Se		Organic Se (A)		Organic Se (B)		SEM
		0.1 (mg/kg)	0.3 (mg/kg)	0.1 (mg/kg)	0.3 (mg/kg)	0.1 (mg/kg)	0.3 (mg/kg)	
Body weight								
Initial	28.44	28.43	28.47	28.60	28.23	28.55	28.73	0.77
3 wk	43.18	42.24	43.03	43.09	42.91	42.25	42.28	1.17
6 wk	61.43	59.50	63.76	62.43	62.13	60.58	60.20	1.55
9 wk	84.15	81.78	85.61	85.55	82.60	80.45	81.33	2.04
12 wk	104.86	101.51	103.90	101.69	103.29	96.40	100.43	2.37
ADG (g)								
0-3 wk	702	657	693	690	699	653	645	25
3-6 wk	869	822	988	921	915	873	854	24
0-6 wk	785	740	840	805	807	763	749	22
6-9 wk	1,082	1,061	1,040	1,101	975	946	1,006	29
9-12 wk	986	940	871	844	985	760	910	28[abfh]
0-12 wk	910	870	898	870	894	808	854	22
ADFI (g)								
0-3 wk	1,831	1,595	1,720	1,741	1,728	1,700	1,675	32[dg]
3-6 wk	2,347	2,145	2,510	2,621	2,566	2,633	2,516	57[abd]
0-6 wk	2,089	1,870	2,115	2,181	2,147	2,166	2,095	41[abd]
6-9 wk	3,155	2,899	3,158	3,044	2,887	2,838	2,881	58[abd]
9-12 wk	3,106	3,230	3,342	3,100	3,277	3,029	3,114	63[a]
0-12 wk	2,610	2,467	2,683	2,644	2,614	2,550	2,546	47
G/F								
0-3 wk	0.38	0.41	0.40	0.40	0.41	0.38	0.39	0.012
3-6 wk	0.37	0.38	0.39	0.35	0.36	0.33	0.34	0.009[a]
0-6 wk	0.38	0.40	0.40	0.37	0.38	0.35	0.36	0.009[a]
6-9 wk	0.34	0.37	0.33	0.36	0.34	0.33	0.35	0.008
9-12 wk	0.32	0.29	0.26	0.27	0.30	0.25	0.29	0.010[cf]
0-12 wk	0.35	0.35	0.34	0.33	0.34	0.32	0.34	0.008

[a] Dietary selenium source response ($p<0.05$). [b] Dietary selenium level ×source interaction ($p<0.05$).
[c] Linear response (includes basal) to inorganic Se ($p<0.01$). [d] Quadratic response (includes basal) to inorganic Se ($p<0.05$).
[e] Linear response (includes basal) to Organic Se (A) ($p<0.01$). [f] Quadratic response (includes basal) to organic Se (A) ($p<0.05$).
[g] Linear response (includes basal) to organic Se (B) ($p<0.01$). [h] Quadratic response (includes basal) to organic Se (B) ($p<0.01$).

Table 3. Treatment effects of dietary Se products and levels on serum Se concentration in growing-finishing pigs (mg/kg)

Item	Con	Inorganic Se		Organic Se (A)		Organic Se (B)		SEM
		0.1	0.3	0.1	0.3	0.1	0.3	
Initial	0.0905	-	-	-	-	-	-	
3 wk	0.1028	0.1246	0.1453	0.1517	0.1689	0.1682	0.1993	0.0045[acfhj]
6 wk	0.1417	0.1530	0.1666	0.1646	0.1930	0.1724	0.2053	0.0049[bdgij]
9 wk	0.1569	0.2075	0.2155	0.2034	0.2267	0.2029	0.2874	0.0072[cfhj]
12 wk	0.1726	0.2229	0.2315	0.2185	0.2435	0.2180	0.2931	0.0077[dfhj]

[a] Dietary Se source response ($p<0.01$). [b] Dietary Se source response ($p<0.05$).
[c] Dietary Se level response ($p<0.01$). [d] Dietary Se level response ($p<0.05$).
[f] Linear inorganic Se (include basal) response ($p<0.01$). [g] Linear inorganic Se (include basal) response ($p<0.05$).
[h] Linear organic Se (A) (include basal) response ($p<0.01$). [I] Linear organic Se (A) (include basal) response ($p<0.05$).
[j] Linear organic Se (B) (include basal) response ($p<0.01$).

different Se products and levels on growing-finishing pig performance, nutrients digestibility and Se retention in various tissues. The effects of different Se products and levels on pig performance are presented in Table 2. In the growing phase (0-6 weeks), when pigs were fed organic Se, ADFI was increased compared to those fed the control diet or inorganic Se. As pigs were fed inorganic Se in late finishing phase, ADFI was higher than that of organic Se ($p<0.05$). Growth performance was not affected by dietary Se products and levels, which agreed with the results of Mahan and Parrett (1996). Mahan and Cline (1999) demonstrated no difference in gain or feed intake of pigs fed various levels of Se from sodium selenite or Se-enriched yeast. The results of the present study demonstrated that different dietary Se products and levels did not influence growth performance in growing-finishing pigs.

Serum selenium

During the whole experimental period, serum Se

Table 4. Treatment effects of dietary Se products and levels on tissue Se concentration in finishing pigs (mg/kg)

Item	Con	Inorganic Se		Organic Se (A)		Organic Se (B)		SEM
		0.1	0.3	0.1	0.3	0.1	0.3	
Loin	0.2195	0.2710	0.3231	0.3369	0.3414	0.3346	0.4938	0.0141[acdfkl]
Pancreas	0.3638	0.4374	0.6540	0.4433	0.4845	0.4963	0.6988	0.0209[acdhjl]
Liver	0.6194	0.7084	0.7789	0.7547	0.8731	0.7628	1.2382	0.0400[acegjl]
Kidney	1.6797	1.9301	2.3455	2.0624	2.1184	1.9876	2.5908	0.0591[bcfil]

[a] Dietary Se source response ($p<0.01$). [b] Dietary Se source response ($p<0.05$).

[c] Dietary Se level response ($p<0.01$). [e] Dietary Se source×level interaction ($p<0.01$).

[f] Dietary Se source×level interaction ($p<0.05$). [f] Linear inorganic Se (includes basal) response ($p<0.01$).

[g] Linear inorganic Se (includes basal) response ($p<0.05$). [h] Quadratic inorganic Se (includes basal) response ($p<0.01$).

[i] Linear organic Se (A) (includes basal) response ($p<0.01$). [j] Linear organic Se (A) (includes basal) response ($p<0.05$).

[k] Quadratic organic Se (A) (includes basal) response ($p<0.01$). [l] Linear organic Se (B) (includes basal) response ($p<0.01$).

concentration increased in both Se treatment groups and control group. There was no Se level×Se source interaction for each subsequent measurement period. Supplementation of organic Se showed higher Se concentration in serum compared to inorganic source or control diet in the growing phase, but these improvements were attenuated in the finishing period. As dietary Se level increased, there was a linear increase in serum Se concentration ($p<0.01$ for 3 weeks and 9 weeks, $p<0.05$ for 6 weeks and 12 weeks; Table 3). Mahan and Cline (1999) reported that pigs fed 0.05 mg/kg inorganic Se had higher serum Se concentration than those fed organic form, and that at more than 0.05 mg/kg dietary Se levels, the organic form of Se had more effectively improved serum Se concentration than did the inorganic form. Anita et al. (2004) observed that the levels of erythrocytic lipid peroxidation, superoxide dismutase and glucose-6 phosphate dehydrogenase activities in buffaloes were lowerd by injection of Se and vitamin E.

Mahan and Parrett (1996) observed that serum Se concentration of growing-finishing pigs was higher when pigs were fed the inorganic form of dietary Se than those fed the organic form of dietary Se at 0.1 and 0.3 mg/kg, but at 0.5 mg/kg dietary Se level, organic Se treatment showed higher serum Se concentration compared to inorganic Se treatment. In the present experiment, the effect of dietary Se source on serum Se concentration of pigs showed similar results, serum Se concentration was higher when a low level of inorganic form was provided compared to organic Se treatment. However, organic form Se had more effectively elevated serum Se concentration than inorganic form when a high level of dietary Se, 0.3 mg/kg, was provided although there was a clear difference of efficacy between organic Se products.

Tissue selenium

When pigs were fed organic Se (B), higher Se concentration was observed in various tissues relative to those of organic Se (A), inorganic Se and control diet (Table 4). Dietary organic Se (B) was more effectively accumulated in loin, liver, pancreas and kidney compared to organic Se (A), whereas organic Se (A) treatment group showed similar or even lower tissue Se concentrations than those of the inorganic Se treatment group. Based upon the results, organic Se (A) was a poor quality product compared to organic Se (B) and its bioavailability was very similar to inorganic Se. The Se contents in loin, liver and kidney increased linearly ($p<0.01$) as dietary inorganic Se level increased and kidney Se showed a quadratic response as dietary inorganic Se level increased. When pigs were fed organic Se (B), Se contents in tissues increased linearly ($p<0.01$) as the dietary Se level increased.

The inorganic Se forms are reduced to the assumed intermediate, selenide (Se^{2-}), while the organic Se forms are transformed to the common intermediate, hydrogen selenide (H_2Se) by β-lyase. The common intermediate, selenide, is then used for the synthesis of selenoproteins (Lu et al., 1994).

Se-enriched yeast contains Se-containing amino acids and their analogues and of which more than 40% of the Se is contained in selenomethionine (Kelly and Power, 1995). Selenomethionine, a component of organic Se, can flow into the Se pool in animal body and to meet the animal's biological need for Se, and also, be taken up by liver and pancreas which tissues are active places to synthesize various proteins replaced by methionine (Behne et al., 1991). Liver and pancreas, as proliferating organs, took up essential Se more efficiently than non-proliferating/resting organs (Shiobara et al., 2000). Selenoproteins in the liver and kidney are known to be cellular GSH-Px and phospholipid hydroperoxide (Michelson, 1998). Liver is also a major tissue to synthesize selenoprotein P (Saito et al., 1999) and kidney synthesizes extracellular GSH-Px (Nakan et al., 1998). Kidney is also an excretion tissue of Se metabolites, and so, there are at least four types of selenoproteins, cellular GSH-Px, phospholipid hydroperoxide, extracellular GSH-Px and trimethylselenonium. Even though chemical forms of Se were not examined in the present experiment, it could be explained that different Se metabolism caused diverse increasing patterns of Se between liver and kidney. Taken together, pigs fed low dietary Se level (0.1 mg/kg) would appear similar of Se content between organic and inorganic Se treatment groups,

Table 5. Treatment effects of dietary Se products and levels on nutrients digestibility in finishing pigs

Item	Con	Inorganic Se		Organic Se (A)		Organic Se (B)		SEM
		0.1	0.3	0.1	0.3	0.1	0.3	
CP	88.04	88.86	88.56	92.88	90.37	88.58	88.93	0.53[a]
DM	90.14	90.09	91.81	93.82	90.46	91.58	90.42	0.38
Ash	65.48	64.59	74.04	72.99	62.54	70.77	56.35	1.49
Crude fat	88.18	78.14	90.74	90.03	83.32	82.26	82.43	1.53

[a] Dietary Se source response ($p<0.05$).

Table 6. Treatment effects of dietary Se products and levels on Se balance of growing pigs

Se balance (mg/d)	Con	Inorganic Se		Organic Se (A)		Organic Se (B)		SEM
		0.1	0.3	0.1	0.3	0.1	0.3	
Intake	0.6716	0.7791	1.1013	0.9099	1.1578	0.8669	1.1846	
Feces	0.0924	0.1152	0.1410	0.1468	0.2596	0.1326	0.2237	0.0177[eh]
Urine	0.0884	0.0973	0.4337	0.1460	0.1523	0.0849	0.2020	0.0287[acdfg]
Retention	0.4866	0.5666	0.5266	0.5458	0.7728	0.6924	0.7322	0.0284[ai]
Retention (% of intake)	72.46	72.73	47.82	62.96	65.24	76.10	63.23	2.53[bf]

[a] Dietary Se source response ($p<0.05$). [b] Dietary Se level response ($p<0.01$).
[c] Dietary Se level response ($p<0.05$). [d] Dietary Se source×level interaction ($p<0.01$).
[e] Linear inorganic Se (include basal) response ($p<0.05$). [f] Quadratic inorganic Se (include basal) response ($p<0.05$).
[g] Quadratic organic Se (A) (include basal) response ($p<0.05$). [h] Linear organic Se (B) (include basal) response ($p<0.01$).
[I] Quadratic organic Se (B) (include basal) response ($p<0.01$).

but as higher Se (0.3 mg/kg) was provided, Se retention and bioavailability could be differentiated by Se products.

Nutrient digestibility and selenium retention

The effect of different Se products and levels on pig nutrient digestibility are presented in Table 5. Selenium supplementation had no effect on nutrient digestibility except for crude protein. Crude protein digestibility was increased by dietary supplementation of organic Se (A) compared with other forms of Se or control diet. Nutrient digestibility of DM ($p = 0.09$) and crude fat ($p = 0.21$) tended to increase in organic Se (A) treatment group compared with other treatment groups or control group. Thomson and Scott (1970) and Ganter et al. (1975) reported decrease of pancreas weight in Se deficient chicks. Several researchers, however, reported that the protein content of the pancreas was similar between Se deficient and Se supplemented pigs (Adkins and Ewan, 1984) and rats (McConnell et al., 1974).

Pancreas, a secretary organ, has functions to synthesize and secrete digestive enzymes, therefore protein content of the organ represents the synthetic activity of pancreatic enzymes. Thomson and Scott (1970) described a decreased activity of pancreatic lipase and trypsin in chicks considered to be Se deficiency. They implied the loss of enzyme activity was due to the degeneration of tissue in the pancreas. However, signs of histological degeneration of this tissue weren't found in Se deficient pigs (Ewan et al., 1969). Adkin and Ewan (1984) demonstrated that DM digestibility and nitrogen retention were improved by the supplementation of 0.1 mg/kg inorganic Se in pigs, even though they couldn't find any positive effect of dietary Se on the activity of trypsin, chemotrypsin, α-amylase and lipase of pigs. In addition, the improvements of DM digestibility and nitrogen retention were observed more clearly when pigs were in the condition of Se deficiency.

As expected, Se intake was higher when pigs were fed 0.3 mg/kg diets than for the pigs fed the 0.1 mg/kg diets or control diets (Table 6). The amounts of Se excreted via feces ($p<0.05$) were greater when pigs were fed organic Se products (organic Se A or B) compared to inorganic source, and daily retention of Se was higher ($p<0.05$) in organic Se treatment groups compared with inorganic Se treatment groups. Between organic Se products, organic Se (B) was retained more efficiently in the animal body compared to organic (A) Se but the difference was not significant (Table 6).

The Se status of the animal does not seem to influence the absorption rate of either inorganic or organic Se compounds even when fed at high dietary levels (Kim and Mahan, 2001b). The seleno-amino acids from grains were absorbed effectively but a somewhat slower rate than the inorganic products (Groce et al., 1973). Mahan and Parrett (1996) demonstrated a higher apparent absorption of inorganic selenite compared with the organic Se source from yeast in growing pigs, but the retention of Se was higher when the organic form was provided. Results of Se retention in the present experiment were consistent with those of Mahan (1985), who reported that an increasing proportion of Se was excreted in the urine as inorganic Se intake was increased. The pigs fed inorganic Se therefore excreted more Se in the urine and less in the feces than

when organic Se was fed. However, approximately 20% more total Se was excreted in swine excrement when the inorganic Se form was provided at various dietary levels (Mahan and Parrett, 1996). Kim and Mahan (2001a) demonstrated that Se excretion by urine was the main route of excretion when pigs were fed inorganic forms but by the fecal route when Se-enriched yeast was provided.

In conclusion, the results of this experiment indicated that different Se products and levels had no effect on growth performance of pigs. In addition, Se concentrations in tissues and serum increased with dietary Se level, especially when organic Se was provided. Even though the same conception of organic Se, the bioavailability to pigs of different products varied, consequently bioavailability of different Se products should be evaluated before practical application in animal feeds.

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