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Full Length Research Paper

Effect of Liquid Mineral Feeding on Growth Performance, Immunological Profile and Digestibility of Grower and Finisher Pigs.

Gyeong-Il Kim, Muhammad Ammar Dilawar[1], Hong-Seok Mun[1], Hyeoung Seog Park[2], Chul-Ju Yang[1,*]

[1]Department of Animal Science and Technology, Sunchon National University, Suncheon 57922, South Korea
[2]EFC Co., Gwangyang 57714, Korea.

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A feeding trial was conducted to investigate the effects of supplementation of liquid minerals in drinking water on performance, digestibility and immunity of grower pigs. The purpose of the study was to replenish necessary minerals for pig's growth. A total of 80 pigs (3-way cross) [(Landrace × Yorkshire) × Duroc] weighing an average body weight of 26.35 kg were randomly assigned to 1 of 4 treatments which include a control group and supplementation of 0.02%, 0.1% and 0.2% liquid mineral (LM) in drinking water. Feed intake was significantly increased ($p<0.05$) in control group both for growing and finishing pigs than other treatments, due to which higher feed cost was associated with the control group. On the other hand, better feed conversion ratio ($p<0.05$) was seen in 0.2% LM than in control group (1.99 vs 2.45) for growing pigs. However, serum immunoglobulin concentration and digestibility remained unaffected ($p>0.05$). A non-significant increase in digestibility was seen in 0.2% LM. Furthermore, IgG was lowest in the control group in case of finishing pigs. Similarly, there was no significant difference in IgM and IgA concentration ($p>0.05$). This indicates that supplementation of liquid mineral showed promising effects on growth performance, immunity, and digestibility in grower pigs.

Keywords: Liquidmineral, Pigs, Immunity, Digestibility.

1. INTRODUCTION

Minerals are inorganic elements that constitute a small part of the pig's dietary requirement. Although minerals are present in a negligible amount as compared to other feedstuffs but it's importance to the health and well-being of the animal should not be taken for granted. Minerals are

*Corresponding Author's Email: yangcj@scnu.ac.kr

required for normal functioning of all biochemical processes in the body (Spears, 1999). For instance, zinc finds its role in proper functioning and development of the immune system (Fraker et al., 2005; Richards et al., 2010). Minerals which are classified as macrominerals or microminerals have diverse functions such as enzyme constituents for regulatory function and as cofactors for enzymatic reactions (National Research Council U.S 2012). Modern commercial pig farming cause different type of negative impact on physiological, microbiological and immunity status of pigs (Dębski, 2016). The necessity to include minerals in the swine diet was further emphasized with the increasing trend toward confined rearing of pigs, having no access to soil and forage.

Macrominerals like calcium (Ca), phosphorus (P), potassium (K) and magnesium (Mg) in swine diets known to have beneficiary effects in skeletal tissues formation, muscle contraction, energy metabolism, acid-base balance, neuron activity, enzyme cofactors and appetite (NRC, 2005) and was extensively studied. On the other hand, microminerals or trace mineral-related studies have given less focus throughout the years. Some microminerals include heavy metals such as arsenic, lead and mercury were known to have toxic properties to animals (Adamse et al., 2017). However, at a certain level, it has shown to have beneficial effects on pig growth and lipid metabolism. Few studies were made regarding its affectivity in the performance of swine.

Minerals were generally incorporated into feeds and efficiently absorbed from the pig's intestinal tract (McGlone and Pond, 2003).Major problem regarding dietary requirement of minerals are environmental concerns if exceeds physiological requirement(National Research Council U.S 2012). Besides than solid form, liquid form is known to be more readily absorbed and passes more easily in the pig's gut wall(Brooks et al., 2001).Due to these properties, administration of minerals in liquid form can be a better alternative for effective mineral absorption. The aim of the study was to determine the effect of supplementing liquid mineral on the growth performance, digestibility, and immunological profile of grower pigs.

2. MATERIALS AND METHODS

2.1.Animal Care

The experimental procedures used in the experiment were approved and carried out in accordance with the guidelines of Institutional Animal Care and Use Committee at Sunchon National University, Suncheon, South Korea.

2.2. Animals and Experimental design

A total of 80 crossbred (Landrace x Yorkshire x Duroc) grower pigs with an initial body weight (BW) of 26.35 kg were used for experimental trials. For growing phase trials, pigs were reared for 5-weeks and for finishing phase experiments pigs were reared from 5-7 weeks. Pigs were randomly allocated into four dietary treatments groups (20 pigs /group). Each group had 4 replicates (5 pigs per replicate). Pigs were reared in an environmentally controlled, slatted pig house of identical pen size (3.0×3.0 m).

2.3. Dietary Treatments

The dietary treatments were as follows: 1) control (normal drinking water), 2) 0.02% liquid mineral, 3) 0.1% liquid mineral, and 4) 0.2% liquid mineral. The liquid mineral was mixed with water according to its designated proportion and were fed into the animals through the nipple drinkers.

The diet used in the experiment was formulated to meet the nutrient requirements recommended by NRC (1998) (Table 1). The pigs have ad libitum access to feeds and water throughout the experiment.

2.4. Composition and source of liquid mineral

The liquid mineral (LM) used in the experiment was provided by the Korea Food Ingredients Association (Daejeon, South Korea). The liquid mineral was mainly made up of a mixture of minerals such as potassium (K), magnesium (Mg), sodium (Na) and fluorine (F) minerals. The minerals were extracted from the sericite and yellow clay by using citric acid and malic acid with water for the extraction process.

2.5. Measurement and Analysis

2.5.1. Growth Performance Traits

The pigs were weighed individually at the start of the experiment then weighed after 2 weeks and finally after 5 weeks for growing phase and after 7 weeks for finishing phase. Feed intake and weight gain were also recorded in the same pattern during the course of the whole experiment for each treatment and the feed conversion rates were calculated subsequently.

2.5.2. Immunoglobulin quantification

5 ml blood was collected at the end of the experiment for each phase of pig production (after 5 weeks for growing pigs; after 5 weeks for early finishing pigs and after 7

Table 1. Composition (%) of the experimental diet

Ingredient		Growing	Finishing
Yellow Corn		51.36	55.00
Unpolished rice		5.00	5.00
Rice Bran		2.00	3.00
Soybean meal		21.80	18.16
Rapeseed oil meal		1.72	3.00
[1]DDGS		6.00	6.00
Meat and bone meal		2.00	1.60
Beef tallow		4.78	3.16
Molasses		2.50	2.50
Salt		0.30	0.30
Limestone		0.84	1.00
Calcium phosphate		0.10	0.20
[3]Vitamin-mineral, premix		0.40	0.20
Choline chloride(50%)		0.05	
Amino acid additive		1.15	0.88
Total	-	100.00	100.00
[2] **Chemical composition**			
Crude protein	%	18.18	17.18
Crude fat	%	8.02	6.60
Calcium	%	0.80	0.80
Phosphorous	%	0.49	0.50
Lysine	%	1.20	1.10
Methionine	%	0.37	0.31

1 Corn distilled dried grains 2 Calculated values 3 Each kilogram contains vitamin (V) A 6000 IU; VD3 800 IU; VE 20 IU; VK3 2mg; VB1 2mg; VB2 4mg; VB6 2mg; VB12 1mg; pantothenic acid 11mg; niacin 10mg; biotin 0.02mg; copper 21mg; iron 100mg; zinc 60mg; manganese 90mg; iodine 1.0mg; cobalt 0.3 mg; selenium 0.3mg.

weeks for finishing pigs) from the jugular vein and was placed in SGS tube. The serum was separated from blood by centrifuging for 15 minutes at 3000 ppm (1610 x g at 4°C). After centrifugation, the concentration of serum IgG, IgM, and IgA were assayed using Pig IgG (Cat. No. E100-104), IgM (Cat. No. E100-100), and IgA (Cat. No. E100-102) ELISA Quantitation Kits (Bethyl Laboratories Inc., USA), respectively, according to the manufacturer's instructions. The absorbance of each well was measured within 30 min using a microplate auto reader (Thermo Lab Systems, Finland) at 450 nm. The results were expressed as mg/ml of serum.

2.5.3 Digestibility trial

Five pigs were reared for 5 weeks (growing, early and late finisher) to calculate the apparent digestibility (AD). Latin square experimental design was used. Each animal was allotted 1 week as resting period. Faecal samples were collected daily at 8:00 pm and were weighed and stored in a dry oven for 3 days at 60°C. After 3 days, samples were again weighed. Consumed feeds given were estimated as 8% of the animal's total body weight (BW). The digestibility was then calculated using the following formula:

$$\text{Apparent digestibility/AD (\%)} = \frac{\text{Amount of feed ingested - Amount of faecal}}{\text{Amount of feed ingested}} \times 100$$

2.5.4 Statistical analysis

All data were subjected to analysis of variance (ANOVA) using the general linear model procedures (GLM) of the Statistical Analysis System (SAS, 2003, Version 9.1, SAS Institute, Cary, NC, USA). The pen was used as the experimental unit to analyze growth performance and nutrient digestibility, whereas an individual pig was used as the experimental unit for analysis of serum immunoglobulins. Statistically significant effects were

Table 2. Effect of liquid mineral in the growth performance and feed efficiency in growing pigs.

Item	Control	Liquid mineral (LM)			SEM	p-value
		0.02%	0.1%	0.2%		
0 - 2 week						
Initial weight (kg)	26.36	26.35	26.35	26.35	0.92	1.0000
Final weight (kg)	35.80	36.24	36.15	36.80	1.20	0.9490
Weight gain (kg)	9.44	9.89	9.80	10.45	0.68	0.7801
Feed intake (kg)	21.31[b]	22.92[a]	20.57[b]	21.03[b]	0.43	0.0018
FCR (Feed/Gain)	2.26[a]	2.32[a]	2.10[ab]	2.01[b]	0.07	0.0183
3 - 5 week						
Initial weight (kg)	35.80	36.24	36.15	36.80	1.20	0.9490
Final weight (kg)	53.38	54.38	54.70	55.40	1.67	0.8576
Weight gain (kg)	17.58	18.14	18.55	18.60	0.80	0.7918
Feed intake (kg)	44.97[a]	42.83[a]	43.12[a]	36.93[b]	1.08	<.0001
FCR (Feed/Gain)	2.56[a]	2.36[a]	2.32[a]	1.99[b]	0.09	0.0003
0 - 5 week						
Initial weight (kg)	26.36	26.35	26.35	26.35	0.92	1.0000
Final weight (kg)	53.38	54.38	54.70	55.40	1.67	0.8576
Weight gain (kg)	27.01	28.02	28.35	29.05	1.13	0.6466
Feed intake (kg)	66.29[a]	65.75[a]	63.69[a]	57.96[b]	1.17	<.0001
FCR (Feed/Gain)	2.45[a]	2.35[a]	2.25[a]	1.99[b]	0.09	0.0032

[a,b] Values with different superscripts in the same row differ significantly ($P<0.05$)

further analyzed, and means were compared using Duncan's multiple range test. Probability values of $p< 0.05$ were considered as statistically significant, whereas $p< 0.10$ was considered a tendency.

3. RESULTS

3.1. Effect of different concentration of liquid mineral on growth performance of growing pigs

The effects of the different concentration level of LM in grower diets are presented in Table 2. The initial body weight of pigs did not differ ($p>0.05$) between the dietary treatments. At the end of 2nd week, pigs supplemented with 0.2% LM had a better ($p<0.05$) FCR. During the whole experimental period (0-5 weeks), diets with 0.2% LM consistently had better FCR without compromising weight gain and feed intake of the pigs ($p<0.05$).

3.2. Effect of different concentration of liquid mineral on growth performance of finishing pigs

The body weight, feed intake and FCR of finishing pigs are shown in Table 3. For the early finishing phase (up to a 5th week), pigs fed at 0.1% LM had better FCR among the treatments. However, at the late finishing phase (6th to 7th week), FCR was improved in the 0.2% LM ($P>0.05$). Overall,during the whole study period, 0.1% LM supplement had produced better growth performance among the treatments ($P<0.05$).

3.3. Effect of different concentration of liquid mineral on digestibility of growing to finishing pigs

There was no observed significant difference in apparent digestibility among the treatments for growing and finishing phase ($P>0.05$). However, the digestibility in control group tended to be lower than pigs fed with LM in case of late finishing as shown in Table 4.

Table 3. Effect of liquid mineral on the growth performance and feed efficiency in finishing pigs.

Item	Control	Liquid mineral (LM)			SEM	p-value
		0.02%	0.1%	0.2%		
0 - 5 week						
Initial weight (kg)	53.38	54.38	54.70	55.40	1.67	0.8576
Final weight (kg)	91.00	88.03	90.90	90.20	2.11	0.7339
Weight gain (kg)	37.63[a]	33.65[b]	36.20[ab]	34.80[ab]	1.05	0.0575
Feed intake (kg)	140.00[a]	121.25[b]	103.30[c]	142.50[a]	3.50	<.0001
FCR (Feed/Gain)	3.72[ab]	3.60[b]	2.85[c]	4.09[a]	0.14	<.0001
6 - 7 week						
Initial weight (kg)	91.00	88.03	90.90	90.20	2.11	0.7339
Final weight (kg)	103.88	100.53	103.35	105.53	2.26	0.4732
Weight gain (kg)	12.88[b]	12.50[b]	12.45[b]	15.33[a]	0.63	0.0052
Feed intake (kg)	54.35[a]	49.55[bc]	46.28[b]	52.12[ab]	1.44	0.0021
FCR (Feed/Gain)	4.22[a]	3.96[ab]	3.72[bc]	3.41[c]	0.15	0.0044
0 - 7 weeks						
Initial weight (kg)	53.38	54.38	54.70	55.40	1.67	0.8576
Final weight (kg)	103.88	100.53	103.35	105.53	2.26	0.4732
Weight gain (kg)	50.50	43.15	48.65	50.13	1.28	0.0780
Feed intake (kg)	194.35[a]	170.80[b]	149.58[c]	194.62[a]	3.99	<.0001
FCR (Feed/Gain)	3.85[a]	3.70[a]	3.07[b]	3.88[a]	0.12	<.0001

[a,b,c] Values with different superscripts in the same row differ significantly (*P*<0.05)

Table 4. Effect of liquid mineral on digestibility of growing and finishing pigs

Item	Control	Liquid mineral (LM)			SEM	p-value
		0.02%	0.1%	0.2%		
Digestibility (%)						
Growing	84.01	81.92	82.09	87.72	1.78	0.1432
Early finishing	81.32	83.60	85.37	83.68	1.08	0.0736
Late Finishing	80.74	83.96	83.22	83.52	1.04	0.1125

[a,b] Values with different superscripts in the same row differ significantly (*P*<0.05)

3.4. Effect of different concentration of liquid mineral on blood immunoglobulin profile (IgG, IgM, IgA) of growing, early finishing, and late finishing pigs

The supplementation of liquid mineral from growing to finishing stage produced no significant difference in immunoglobulin level of pigs among the treatments (p>0.05) as shown in Table 5.

4. DISCUSSIONS

Understanding the requirement of minerals and to fulfill the needs of animal has been increasingly important over the past few years. The main reason for this is increased awareness in the customers and vast variety of commercial products available to the customers. It is obvious that deleting a mineral from the diet could leads to the compromised performance and growth at some stage of

Table 5. Blood immunological profile (IgG, IgM, IgA) of growing and finishing pigs fed with liquid mineral

Immunoglobulin (mg/ml)	Control	Liquid Mineral (LM) 0.02%	0.1%	0.2%	SEM	*P*-value
Growing						
IgG	42.94	40.68	39.51	39.28	5.30	0.9369
IgM	12.87	12.84	11.63	11.33	0.79	0.5757
IgA	7.95	7.90	8.68	7.83	0.61	0.8159
Early finishing						
IgG	34.24	38.09	37.70	37.48	3.07	0.7528
IgM	10.48	9.70	9.91	9.70	0.33	0.3784
IgA	7.59	7.95	7.67	7.72	0.53	0.9632
Late finishing						
IgG	37.87	50.81	43.86	45.05	5.22	0.3766
IgM	15.66	16.82	15.30	14.58	1.61	0.8506
IgA	8.48	9.15	8.23	8.34	0.56	0.7174

[a,b] Values with different superscripts in the same row differ significantly ($P<0.05$)

life(Acda and Chae, 2002). In this study, liquid mineral supplementation in growing and finishing diets resulted in a better FCR compared with pigs that were fed diets devoid of liquid minerals. These results are in agreement with the previous study conducted by Creech et al. (2004), who reported pigs fed trace mineral diets have higher weight gain as compared with the control. Brooks et al. (2001)also reported that pig performance and FCR was improved due to liquid feeding as compared to traditional feeding and it increased the accuracy of rationing and flexibility in raw material use. In the present study, minerals were used in drinking water to ensure that every pig receive optimum level of nutrients required for better performance. The main drawback of minerals fed in diets is uniform mixing of micro nutrients into diets which hinders intake of minerals and vitamins and it is also not cost effective(Salinas-Chavira et al., 2018).A common practice in swine industry is to formulate diets that exceed recommendations which leads to excretion of minerals in the waste. Therefore, formulation of diets having mineral concentration close to the requirement is an appropriate mean of reducing wastage of minerals and protecting the environment (Creech et al., 2004). Mineral sources in the experiment were sericite and yellow clay which are known to be have rich in variety of minerals and it is also suggested by Burkett et al. (2009) is the inclusion of organic sources of minerals rather than inorganic forms to increase the bioavailability. Magnesium which is extracted mineral obtained from the sources have beneficial impact on certain aspects of pig production (Lipiński et al., 2011). It enhances the behavior and decreasing the stress which may help in the increased performance due to the LM in the supplemented groups. Due to the restriction on the use of antibiotics in the feed of animals as growth promoter, an intensive amount of research has been done on nutraceutical such as some minerals. The efficacy of minerals depends on the bioavailability and organic mineral complex are said to be more bio available because in case of inorganic minerals there is loss of minerals prior to the absorption (Upadhaya et al., 2017).

In this experiment, we determined whether liquid minerals could influence the cellular immune function like immunoglobulins (IgG, IgA and IgM). IgG plays an important role in the removing of invading microorganisms and providing a long lasting immunity (Taranu et al., 2012). IgM is considered to be first line of defence while IgA is found in secretions. A non-significant increase in IgG during early and late finishing pigs was seen in this study. The mechanism by which LM lead to an increase concentration of IgG is still unknown and needs to be explored. In case of late finishing pigs, nutrient digestibility was improved as compared to the control. The supplementation of organic minerals improved the digestibility of nutrients in male calves and chelate improved nutrient digestibility in weanling pigs (Zhang et al., 2013). We assume that the mineral mixture obtained from the sources could have positively interacted to enhance the growth performance and dry matter digestibility in case of finishing pigs.

In conclusion, our results indicated that LM containing different minerals can increase growth performance, produced better FCR, boost the immune status of the animal and can increase the digestibility. Thus, supplementation of minerals from organic sources in drinking water creates opportunities for environmental friendly strategies considering the mineral demands of the animals and reducing the excretion.

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