Korean Journal Of Agricultural Science

pISSN : 2466-2402
eISSN : 2466-2410

ANIMAL

Effects of *Curcuma aromatica* or inositol monophosphate supplementation on growth performance and immune status of lactating sows and piglets

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Abstract

The aim of the present study was to investigate the influences of *Curcuma aromatica* or inositol monophosphate supplementation on body weight of sows at different stages, feed intake, backfat thickness of sows at different stages, body weight of piglets at different stages, and immunoglobulin G (IgG) concentration in sow blood and milk. Eighteen crossbred (Landrace × Yorkshire) sows (249.9 ± 3.2 kg) and their litters were used in a 28-day feeding trial to observe the effects of *Curcuma aromatica* or inositol monophosphate as dietary supplements on performance and IgG concentration of blood and milk in lactating sows and piglets. The dietary treatments comprised a control corn-soybean-based basal diet (CON); control diet + *Curcuma aromatica* at 0.5% (CA), and control diet + inositol monophosphate at 0.10% (IMP). Sow body weight at different stages, average daily feed intake, and sow backfat thickness at different stages were not affected in all three treatment groups. The body weight of piglets at weaning and average daily gain of piglets born to sows from the IMP group showed significant improvement compared to piglets of sows from the CA treatment group. Treatment had no effect on the IgG levels in blood and milk. In conclusion, supplementation of 0.5% CA or 0.10% IMP in sows has no effect on growth performance and IgG in sows and piglets compared with the control diet.

Key words: *Curcuma aromatica*, growth performance, immunoglobulin G, inositol monophosphate, lactating sows

Citation: Hossain MM, Lim CB, Kim IH. Effects of *Curcuma aromatica* or inositol monophosphate supplementation on growth performance and immune status of lactating sows and piglets. Korean Journal of Agricultural Science 50:271-279. https://doi.org/10.7744/kjoas.20230022

Received: February 15, 2023

Revised: April 26, 2023

Accepted: May 11, 2023

Introduction

In the last few decades, fundamental nutrition research with several new technologies has led to a shift from free-range to intensive pig rearing. However, the consistent use of antibiotics has resulted in the growth of microorganisms that are resistant to the antibiotics (Sørum and Sunde, 2001) raising human and animal health concerns. This has resulted in the imposition of ban by several countries including South Korea on the usage of antibiotics as growth promoter (Ma et al., 2021). Consequently, it has become very important to develop alternatives, such as dietary natural additives, to enhance

intestinal physiological functions. Several available alternatives which are widely used include probiotics, prebiotics, and phytogenic feed additives. Such phytogenic feed additives include a wide range of plants like turmeric, garlic, neem, cinnamon, thyme, anise, and ginger (Islam et al., 2020; Rashid et al., 2020; Hossain et al., 2022).

Curcuma aromatica (CA) is commonly known as wild turmeric and used as a spice, coloring material, and medicinal plant in Australia, China, and Southeast Asia (Kaliyadasa and Samarasinghe, 2019). It has been shown that the rhizome of the *Curcuma aromatica* has a high concentration of phytochemicals including alkaloids, flavonoids, curcuminoids, tannins, and terpenoids (Anoop, 2015; Kanase and Khan, 2018). It shows several biological activities, like anti-inflammatory, wound healing activity, anti-platelet activity, anti-oxidant (Sikha et al., 2015), anti-microbial (Araújo and Leon, 2001), anti-coagulant, anti-diabetic, and anti-ulcer (Lokova et al., 2001). Some researchers found improved growth and digestibility by the inclusion of turmeric in pig diet (Maneewan et al., 2012; Alagbe, 2017). Alagbe (2017) found higher final live weight and improved feed conversion ratio when up to 6% termeric powder were added in weaner pig ration.

Inositol monophosphate (inositol-1-phosphate, IMP), is a member of inositol phosphates. inositol has various phosphorylated form and plays a major role in signaling secondary messenger systems, including insulin signal transduction (Larner, 2002; Uarquin et al., 2019), nerve guidance, cellular calcium concentration maintenance (Gerasimenko et al., 2006), and the gene expression (Steger et al., 2003). It is an intermediate product which is dephosphorylated to give free myo-inositol (Nunes et al., 2006; Parthasarathy et al., 2006). Dephosphorylation results in the release of free phosphoric acid groups as a phosphorus source in the body. In the animal body phosphorus is the second highest inorganic compound after calcium. Moran et al. (2019) found in the nursery piglet supplemented with inositol to improve average daily gain (ADG) and the highest ADG was found in pigs fed diets with 0.15% of inositol. Myo-inositol could play a crucial role in improving growth rate in pigs (Moran et al., 2019), but mode of action is still unclear and requires further investigation. Moreover, immunoglobulin G (IgG) is the most abundant antibody in the blood in pigs, as well as in other animals. This IgG transfers from sows to the piglets through milk. Considering the IgG an important parameter for immunity status we assumed that it will be improved through supplementation of inositol monophosphate or *Curcuma aromatica*. To date, there are very few studies which evaluated the supplementation of inositol monophosphate or *Curcuma aromatica* to determine performance in pigs. Therefore, the objective of this study was to evaluate and compare the effect of CA and IMP as feed additive on performance and IgG concentration of blood and milk in lactating sows and piglets in the 28-day trial.

Material and Methods

The Animal Care and Use Committee at Dankook University (Cheonan, Korea). has evaluated and approved all the experimental procedures and protocols that describe the care of animals (DK-4-1345).

Animals, housing, and experimental design

A total of eighteen sows (Landrace × Yorkshire) and their piglets were used in this 28-day experiment. Sows having an initial average BW of 249.9 ± 3.2 kg were assigned randomly to 1 of 3 treatments with 6 replicates per treatment. The dietary treatments comprised of; Control, corn-soybean-based basal diet (CON); basal diet + *Curcuma aromatica* at 0.5% (CA); and, basal diet + inositol monophosphate at 0.10% (IMP). Treatment diets were provided to sows starting from the 108th day of gestation. Around seven days before the date of parturition, all the sows were safely transferred to farrowing

crates (2.20 m × 1.60 m). Piglets were weaned at 3-weeks of age. To standardize the piglet number, cross fostering was done within the treatments during the first 48 h post-partum to have 10 piglets per sow per treatment. Teeth clipping, ear tagging, and iron injections were performed then. All animals were reared in environmentally controlled sheds. The temperature of the farrowing shed was kept at 20℃ with supplemental heat provided by lights, and the farrowing crate contained air conditioning for the newborn pigs to keep them comfortable.

Diets and feeding

A corn-soybean based diet was fed to the sows as a control (CON) diet (Table 1). For treatment group *Curcuma aromatica* at 0.5% or inositol monophosphate (IMP) at 0.10% were added to the control diet. Around 2.5 $kg \cdot d^{-1}$ of designated diet was given to treatment group from 108th day of gestation. Allowed meals were divided and given to sows twice daily. On the parturition day, all the sows were deprived of feed. They were fed experimental diet until weaning day. Feed allowance was increased gradually to reach *ad libitum* within 2 weeks. All diets were formulated according to the guideline of National Research Council (NRC, 2012) nutrient requirements. Sows and piglets were endowed with an *ad libitum* drinking water.

Table 1. Composition of experimental diets (as-fed basis).

Ingredient ($g \cdot kg^{-1}$)	Lactation diet
Maize	510.0
Soybean meal	267.3
Rice bran	50.0
Wheat bran	10.0
Rapeseed meal	35.0
Di-calcium phosphate	16.4
Tallow	60.5
Molasses	35.0
Limestone	7.6
Salt	5.0
Vitamin premix[y]	1.0
Trace mineral premix[z]	1.0
L-lysine-HCl (780 $g \cdot kg^{-1}$)	1.2
Analysed nutrient content ($g \cdot kg^{-1}$)	
Metabolizable energy ($MJ \cdot kg^{-1}$)	14.47
Dry matter	888.7
Crude protein	183.4
Crude fat	91.6
Calcium	10.6
Lysine	10.8
Total phosphorus	7.3
Iron ($mg \cdot kg^{-1}$)	25.0

[y] Provided per kilogram (Kg) of complete diet: vitamin-A, 12,100 IU; vitamin-K3, 1.5 mg; riboflavin, 6 mg; vitamin-D3, 2,000 IU; vitamin-E, 48 IU; niacin, 40 mg; biotin, 0.2 mg; D-pantothenic, 17 mg; choline, 166 mg; folic acid, 2 mg; vitamin B6, 2 mg; and vitamin B12, 28 μg.
[z] Provided per kilogram (Kg) of complete diet: Cu (as $CuSO_4.5H_2O$), 15 mg; Mn (as MnO_2), 54 mg; Zn (as $ZnSO_4$), 50 mg; Se (as $Na_2Se_3.5H_2O$); and I (as KI), 0.99 mg, 0.25 mg.

Sampling and measurements

On the preceding day of farrowing, the backfat thickness of the sows were recorded using a real-time ultrasound instrument (Piglot 105, SFK Technology, Herlev, Denmark) from around the 10th rib. Sow body weight was checked within a few hours after farrowing. After farrowing, piglets were ear-notched and weighted individually. Each piglet weight (BW) was checked out on 0, and 21 days and the number of piglets for each sow was recorded to acquire the piglet survival rate. On the weaning day, backfat thickness as well as live body weight of the sows were recorded again. Daily feed intake of sows was also recorded.

Blood samples were collected from sows through jugular puncture at 110th day of gestation and at weaning (day 21) following the method of a previous study (Biswas and Kim, 2022). About 5-mL blood was collected into K_3EDTA tubes were used to collect and cold storing of blood samples. Centrifugation was done (3,000 rpm, 15 min, 4℃) separated serum was then stored at -4℃ for upcoming IgG concentration measurement using automatic biochemistry blood analyzer (Hitachi 747, Hitachi Inc., Tokyo, Japan). Colostrum and milk IgG were assayed by ELISA in whole colostrum and milk using a pig IgG ELISA Quantitation Kit (Ref. E100-104, Bethyl Laboratories, Texas, USA). The procedures described by Devillers et al. (2004) were followed.

Statistical analyses

In this study, the sow was considered as the experimental unit. The main value was differentiated by Duncan multiple range test. The farrowing group was used as a block. In backfat thickness calculation farrowing fat depths were used as covariates. Birth weight worked as a covariate on piglet weaning weight. The level of significance was set at $p < 0.05$.

Results

Growth performance

The effects of *Curcuma aromatica* or inositol monophosphate on growth performance of lactating sows and piglets are shown in Table 2. Sow body weight in different stages, average daily feed intake, sow backfat thickness in different stages were not affected ($p > 0.05$) in all three treatment group. IMP treatment group showed higher weaning weight ($p < 0.05$) compared to the CA treatment group in piglets, but both treatment was not different control group. Average daily gain in piglets from the IMP treatment was significantly higher ($p < 0.05$) than the CA treatment.

Blood and milk IgG levels

Immunoglobulin in blood of sow in different stages and piglets was not altered though the feeding of *Curcuma aromatica*, or inositol monophosphate (Table 3). The immunoglobulin concentration in both colostrum and milk was not changed ($p < 0.05$) through the supplementation of *Curcuma aromatica,* or inositol monophosphate in lactating sow (Table 4).

Table 2. Effect of *Curcuma aromatica* and inositol monophosphate on growth performance of lactating sows and piglets.

Item	CON	CA	IMP	SE
Parity	3.0	3.0	3.0	-
Litter				
No. of pigs	10.2	10.8	10.3	0.5
Weaned pigs	10.0	10.7	10.2	0.5
Sow body weight (kg)				
Before farrowing	252.2	248.1	249.5	7.7
After farrowing	222.5	221.2	219.7	6.8
Weaning	216.4	217.6	214.8	10.1
Body weight loss	35.8	30.6	34.8	3.9
ADFI (kg)				
Lactating	5.85	5.6	5.04	0.26
Sow backfat thickness (mm)				
Farrowing	16.8	16.1	17.6	7.7
Weaning	12.6	12.1	13.4	6.8
Backfat thickness loss	4.2	4.0	4.2	0.6
Piglets				
Piglet survival (%)	98.0	99.1	99.0	1.2
Initial weight (kg)	1.47	1.33	1.43	0.08
Weaning weight (kg)	6.98ab	6.21b	7.36a	0.28
Average daily gain (g)	230ab	203b	251a	10.0

CON, basal diet; CA, basal diet + *Curcuma aromatica* 0.5%; IMP, basal diet + inositol monophosphate 0.10%; SE, standard error; ADFI, average daily feed intake.

a, b: Means in the same row with different superscripts differ ($p < 0.05$).

Table 3. Effect of *Curcuma aromatica* and inositol monophosphate on blood IgG concentration in lactating sows and piglets.

Item ($mg \cdot dL^{-1}$)	CON	CA	IMP	SE
Sow IgG				
Farrowing	706	755	691	54
Weanling	896	922	905	59
Piglet IgG				
Weanling	271	315	270	18

CON, basal diet; CA, basal diet + Curcuma aromatica 0.5%; IMP, basal diet + inositol monophosphate 0.10%; SE, standard error; IgG, immunoglobulin G.

Table 4. Effect of *Curcuma aromatica* and inositol monophosphate on IgG concentration of milk in lactating sows.

Item (%)	CON	CA	IMP	SE
IgG ($mg \cdot g^{-1}$)				
Colostrum	68.20	70.60	71.20	1.20
Milk	0.42	0.41	0.42	0.02

CON, basal diet; CA, basal diet + Curcuma aromatica 0.5%; IMP, basal diet + inositol monophosphate 0.10%; SE, standard error; IgG, immunoglobulin G.

Discussion

Inositol is a nutrient that is necessary for the proper functioning of the body in a broad range of organisms. In eukaryotic cells, signal transduction pathways need inositol as a component of phosphoinositides since it is an essential component of these molecules (Overduin et al., 2001). In the animal studies, phytase addition in protein-reduced diets increased feed conversion, but myo-inositol did not affect growth. Myo-inositol raised plasma levels. Myo-inositol increased cell machinery for food absorption and protein production in cell culture, depending on concentration (Ogunribido et al., 2022). But due to lack of study in livestock we cannot compare the effects of inositol. There is no significant difference in the piglet's initial weight, weaning weight, and average daily gain in CON and IMP in this study. In previous study showed that inositol supplemented diet improves the body weight gain in non-ruminant animal (Pirgozliev et al., 2007). Jiang et al. (2009) demonstrated that Myo-inositol can inhibit free radical generation and prevent oxidative damage. Also in this study, in IMP supplemented group, the body weight gain of piglets was higher compared to CA supplemented group. There is not much research into the effects of IMP on animals. But we can assume that dephosphorylation of IMP provides free phosphoric acid groups in body fluid and tissue of sows, at the same time, through milk to give piglets as an absorbable phosphorus (Böck and Klaushofer, 1975). In animal body, there were 80% of total body phosphorus is localized within the bone and the remaining 20% in cells enables the regeneration of energy-supplying (Breves and Schröder, 1991). Inclusion of inositol monophosphate at 0.10% on higher body weight during the weaning over *Curcuma aromatica* at 0.05% in the present study showed that supplementation of inositol in lactating sow had a greater metabolic impact in body weight of piglets during weaning stage. However further study required for more clear understanding. In tissues and cells of pigs as well as other mammals, inositol exists predominantly as myo-inositol which is the isomeric form of inositol or phosphatidylinositol (Holub, 1986; Michell, 2008). Hawthorne and White (1976) also explained that inositol phospholipid is a cellular mediator that helps to pass signals between cells in the body, which regulates the metabolism of animals. Inositol phospholipid is a very essential part in the structure of phospholipid (type of fat molecule that make cell membranes) (Alberts et al., 2002). In the gastrointestinal tract (GIT), these cell membranes are important in epithelial cells, and this surface of the GIT helps to absorb nutrients. By supporting the process and function of these epithelial cells, ultimately inositol phospholipid helps the digestion and absorption of piglets. On the other hand, CA can improve nutrients digestibility, metabolism, and prevent biliary disorders and anorexia (Al-Sultan and Gameel, 2004), which also helps to improve feed efficiency. Different body weight in piglets may be due to the lower dose of CA used in this experiment. Lowered birth weight in the CA group is another cause of lower weaning piglet's weight.

Milk is the secretion from mammary gland and colostrum is the most important one which is the first secretion of the mammary gland after farrowing. After being exposed to the external environment and pathogens, it is essential for piglets to consume colostrum at the appropriate time in order to get adequate nutrients and passive immunoglobulins from the sow (Le Dividich et al., 2005). Colostrum contains more immunoglobulins (Ig) and carries less amount of lactose and lipids than milk (Quesnel et al., 2012). IgG is a common antibody present in blood circulation which play an important role in immune system of animal. IgG concentration in blood, colostrum, and milk is considered as a profile about the health of sow and piglets. In this study, the IgG level in colostrum and milk in all the three treatments was similar. Due to limited study on CA or IMP supplementation on blood IgG the exact mechanism of this result is unknown. The immune system of piglet reflects the immune status of sow (Scharek et al., 2005). According to Rooke et al. (2003) weaning piglets had the highest blood IgG level because of their mother's highest levels. In this study piglets show similar IgG level, maybe because of similar blood IgG level from their mother. Bate et al. (1992) noted that phosphate-containing molecules give rise to antibodies of broad

specificity. Combined with this study we assume that even though it is not a significant increase, IMP can improve the IgG level of the sow. Therefore, the supplementation of CA or IMP on a higher dose may improve the IgG level on pigs. At the same time, in-depth studies were required to know the best supplementation concentration for both health and safety.

Conclusion

In conclusion, supplementation of 0.5% CA or 0.10% IMP failed to impact the growth performance and IgG of sow and piglets compared to control group. But this study still assists the researcher to reveal these two kinds of feed additive in farrowing sow and piglets which will help in further research.

Conflict of Interests

No potential conflict of interest relevant to this article was reported.

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