Application Research Progress of Amino Acid Chelated Iron in Pig Nutrition

Guo Shijin[1,2*], Zhang Zhimei[1,2], Fu Shijun[1,2], Wang Jianjun[1,2], Tang Shiyun[1], Shen Zhiqiang[1,2]

1. Shandong Binzhou Animal Science & Veterinary Medicine Academy, Binzhou 256600, China; 2. Shandong Lvdu Ante Veterinary Drug Industry Co., Ltd., Binzhou 256600, China

Abstract Amino acid chelated iron is the third generation of iron additive, which is featured by high biological efficiency, low environmental pollution and high safety, and is widely used in pig industry. The mechanism of action of amino acid chelated iron, application of amino acid chelated iron in pig production and its application prospect are reviewed in the paper, so as to provide the basis for pig production.

Keywords Amino acid chelated iron; Pig; Application; Research progress

As an essential trace element for pigs, iron is very important for pig production, and plays an important role in sow performance, growth and development of piglets, metabolic process and physiological defense[1–3]. Iron is a cofactor of catalase in the body's antioxidation system, which plays an important role in preventing lipid oxidation and maintaining meat flavor. Iron is an indispensable activator of enzymes involved in redox reaction, such as superoxide dismutase (SOD), catalase (CAT), xanthine oxidase (XOD) and succinate dehydrogenase (SDH), which can reduce superoxide anions to hydroxyl radicals and generate water under the action of catalase or peroxidase, and reduce the damage of free radicals to meat, thus improving the quality of meat[4]. Studies have shown that the CAT activity in liver, thymus, spleen and bursa of fabricius of iron-deficient rats is significantly lower than that of normal rats, indicating that the ability of iron-deficient animals to scavenge hydrogen peroxide (H_2O_2) is reduced[5].

The development of iron additives has gone through three stages[6]. In the first stage, inorganic salts were commonly used, such as ferrous sulfate and ferrous carbonate, *etc*. Due to the low price and low cost, they had been widely used for a long time. However, inorganic iron sources easily absorbed moisture and aggregated and destroyed vitamins in feed, resulting in low absorption and utilization rate, and certain pollution to the environment[7]. In the second generation, simple organic acid salts were commonly used, such as ferrous citrate, ferric fumarate, *etc*. However, the above two generations had low biological value, and affected other components in the feed. Meantime, with the gradual strengthening of people's environmental awareness, researchers were encouraged to develop more effective and safe iron additives. Hence, the third generation of iron additive, chelate iron came into being. This kind of iron preparation has good chemical stability, high bioavailability, no stimulation and no toxicity, etc., which can supplement iron for the fetal suckling pigs via umbilical cord to placenta, with significantly better clinical application effect than the previous two generations of products[8].

1 Mechanism of Action of Amino Acid Chelated Iron

At present, the mechanism of amino acid chelated iron is still controversial. There are two main hypotheses: one is that amino acid chelated iron is completely absorbed by the absorption mechanism of peptides and amino acids, rather than by the absorption mechanism of inorganic iron in the small intestine. The core of this view is that iron ions bond with the ligand of amino acids by covalent bonds and ionic bonds, and are protected in the core of the complex, and the iron amino acid complex enters the blood as a whole through chorionic membrane of small intestine cells, mucosal cells and basal cell membrane. This is the hypothesis of complete absorption. However, there is no direct experimental evidence to prove that

Received: 2021–03–21 Accepted: 2021–04–15
Supported by Major Science and Technology Innovation Project of Shandong Province (2019JZZy 020609-03).
*Corresponding author. E-mail: gsj7877@126.com

amino acid iron complexes are absorbed in a monolithic form through the absorption mechanism of amino acids or peptides[9]. Another view is that iron at the center of the chelate with five- or six-membered rings can be absorbed as pinocytosis through the brush border of intestinal villi, and all chelates may be absorbed as amino acids or small peptides[10]. The high absorption and utilization rate of amino acid chelated iron can be explained by competitive mechanism: the iron element in amino acid chelated iron is protected by amino acids when entering into the intestine, which will prevent iron from antagonizing with other substances in the intestines into insoluble compounds, and iron will directly reach the brush border of small intestine and hydrolyze in absorption sites. The metals enter the intestinal epithelial cells as ions and are absorbed into the bloodstream, so the amount of iron entering the body increases. This view is known as the hypothesis of competitive absorption, which emphasizes that more iron reaches the absorption site than the inorganic form.

2 Application of Amino Acid Chelated Iron in Pig Production

2.1 Prevent anemia of piglets, improve immunity and promote growth A large number of studies have shown that amino acid chelated iron can increase feed intake and daily gain of piglets, improve feed conversion rate, reduce the diarrhea rate of piglets, and enhances the body immunity[11-13]. Tong *et al*.[14] found that amino acid chelated iron increased the daily gain of piglets by 9.24% and the growth rate by 1.56%. Piglets at 15-20 days of age had rosy skin, bright hair color and red visible mucosa, indicating that amino acid chelated iron increased hemoglobin level and improved iron-deficiency anemia of piglets. Xu *et al*.[15] conducted the experiment of glycine iron chelate and copper methionine chelate to prevent anemia in piglets. Sows in experimental group were fed diets supplemented with 150 mg/kg chelate iron glycine (Fe) and 10 mg/kg chelate iron glycine (Cu) before delivery to two weeks after delivery, and piglets were not injected with any iron preparation. The piglets in the control group were intramuscularly injected with 1 mL of ferric dextran on the 2nd day after birth, and were repeatedly injected once at the age of 2 weeks. The results showed that there were no significant differences in birth weight, litter weight at birth, body weight at two weeks of age and daily gain from 0 to 2 weeks between the two groups. The litter size at 2 weeks of age in the experimental group was significantly higher than that in the control group. The litter weight at 2 weeks of age in the experimental group was significantly higher than that in the control group. In 2010, Li *et al*.[16] explored the effects of iron and zinc glycine on production performance and blood biochemical indexes of weaned piglets. The results showed that dietary supplementation of iron and zinc glycine increased the activities of Cu-Zn superoxide dismutase, glutathione peroxidase and ceruloplasmin; improved the contents of serum iron and zinc, showing an upward trend with the increase of chelate supplemental amount; decreased the excretion of iron and zinc, and the content of fecal copper decreased with the addition of iron and zinc glycine. Therefore, adding iron and zinc glycine in the high copper diet could improve the activity of antioxidant enzymes and the contents of iron and zinc in serum, promote the absorption and utilization of trace elements, reduce the excretion, and improve the production performance of weaned piglets. Yu *et al*.[17] also found that when low-dose zinc glycine was added to the feed instead of zinc sulfate, the daily gain and feed conversion ratio of growing pigs were significantly improved. Sun [18] reported that compared with the addition of ferrous sulfate, adding amino acid iron complex to the diet of growing pigs improved the growth performance and apparent digestibility of iron, as well as skin redness and blood biochemical indexes. Ma *et al*.[19] found that dietary supplemented with iron glycinate increased the activities of SDH, CAT, XOD and AKP in serum to different degrees, and reduced the contents of serum nitrogen (SUN), calcium and phosphorus. Therefore, it affected the antioxidant capacity and serum biochemical indexes of piglets and improved the production performance of piglets. Meantime, it also reduced the emission of trace element iron in feces [20]. Xia *et al*.[21] reported that when 3/4 of inorganic iron in the basal diet was replaced by 3/8 amino acid chelated iron, the iron content in feces of growing pigs was reduced by 11.89%. Cai[22] studied the effects of different concentrations of iron glycine on growth performance and fur of weaned piglets. When the supplemental level was 0.029%, the daily gain was increased by 3.18%, the feed conversion ratio was decreased by 7.82%, and the skin color and clothing hair of piglets were significantly improved.

2.2 Improve the production performance of sows Iron glycine mainly improves production performance and blood

biochemical indexes of sows. Darneley [23] reported that if first farrowing Landrace× Large white sows were daily fed with 56.7 g of amino acid chelated iron from 28 d prior to delivery, the conception rate of sows at first mating was increased by 9%, and the first elimination rate was reduced by 4.2%; the neonatal mortality of piglets was decreased by 3.2%, and the number of piglets per fetus was increased by 4.4%; meantime, as sows were fed with amino acid chelated iron, the body condition of sows changed steadily, and the piglet breeding rate was still high until the 8th fetus, while the total feed intake and feed intake per sow were significantly reduced[23]. Gundel[24] put forward that if iron chelated feed was added to the diets of pregnant sows and suckling sows and the piglets were fed with iron chelated feed after birth, the litter size and litter weight of sows fed iron chelated diets were significantly increased. In 2002, Tong *et al.* [14] added ferrous sulfate and iron glycine chelate to the diet of sows, and the total litter size, live litter size and birth litter weight were increased by 3.60%, 3.77% and 4.75%, respectively, compared with the control group. Wang *et al.*[25] added ferrous glycinate chelate to the diet of sows one month before birth; the birth weight of piglets was 42.4% higher than that of the control group and the mortality rate was improved by 6.4%; the blood iron content was increased by 24.9%, and the iron content in colostrum of sows was 245% higher than that of the group without iron preparation. In 2009, Wang[26] added iron glycine chelate to the diet of sows and analyzed blood biochemical indexes such as hematoctet and hemoglobin content, and the results showed that iron glycine chelate had significant blood tonic effect and significantly reduced the incidence of anemia in sows and piglets. Both sows and piglets had not been attacked by eperythrozoosis throughout the trial period. The litter death rate and mummified fetus rate in experimental group were significantly decreased, and the growth rate of suckling piglets in experimental group was significantly higher than that in control group.

3 Application Prospect of Amino Acid Chelated Iron in Pig Industry

In conclusion, as the third generation of iron additives, amino acid chelated iron has significant effects on increasing feed intake, improving growth rate, promoting immunity, and perfecting production performance of pigs, and has an important role in protecting the environment, with broad application prospect. In the future, in-depth research should be carried out from the following aspects.

(1) Optimization of manufacturing processes. At present, the cost of amino acid chelated iron is high, and its selling price is more than 10 times that of inorganic iron. Therefore, the product formula and process design should be improved to optimize the process route and simplify the production procedure, thereby reducing the production cost.

(2) The absorption mechanism and metabolic principle of amino acid chelated iron and its effect on hematopoietic function of the body should be further studied, so as to provide the theoretical basis for the wider application of amino acid chelated iron in the future.

(3) The qualitative and quantitative detection technology of amino acid chelated iron should be further improved, to provide a basis for the correct application of the product.

References

[1] GIESE AC. Cell physiology (5th Ed)[M]. New York: Prenum Press, 1984: 236, 327, 435.

[2] POND WG. Swine production and nutrition[J]. Connecticut: AVI Publishing Company, 1984: 54–57.

[3] AISEN P. Iron transport and storage proteins[J]. Biochemistry, 1990(49): 357–393.

[4] BEARD JL, DAWSON HD. Iron. In: O'Dell BL, Sunde, RA, (Ed.), Handbook of nutritionally essential minerals[M]. New York: Marcel Dekker, Inc., 1997: 275–334.

[5] WU JS, WO YM, ZHOU YP. Effects of dietary iron deficiency on antioxidant function of broilers[J]. Chinese Journal of Animal Science, 1999(4): 5–7. (in chinese).

[6] ZHOU GL. Research and application progress of amino acid chelated iron[J]. Feed Review, 1998, 10(6): 10–12. (in chinese).

[7] HAN IK. Recent advances in animal nutrition and production of low pollution diets for monogastric animals[A]. Proceedings of first China/Korea joint dymposium on recent advances in animal nutrition and feed technology[M].Beijing: China Agricultural University Press, 1996: 9–26. (in chinese).

[8] CHEN FQ, JI F, CHENG MJ, *et al.* Effect of iron sources on the growth performance, immune function and iron status of weanling piglets[J]. China Animal Husbandry & Veterinary Medicine, 2008, 35(7): 11–14. (in chinese).

[9] HE LJ, CAI J, KONG SF. Research progress of iron absorption and transport mechanism[J]. Feed Research, 2011(12): 33–35. (in chinese).

[10] LI ZG, YUAN XB, YU B. Physiological function of irin amino acid chelate and its application in swine production[J]. Feed Industry, 2009, 30(20): 44–46. (in chinese).

[11] LIU HF, ZHOU AG, WANG ZS, *et al.* Effect of amino acid chelate iron on performance of lactating piglet[J]. China Feed, 2003(23): 16–20. (in chinese).

[12] WANG MZ, LIU MZ. Effect of amino acid

chelated iron on performance of early weaned piglets[J]. China Animal Husbandry & Veterinary Medicine, 2007, 34(10): 14–15.(in chinese).

[13] WANG MZ. Effects of amino acid chelated iron on performance and blood biochemical indexes of weaned piglets[D]. Lanzhou: Gansu Agricultural University, 2007. (in chinese).

[14] TONG JG, YI DW, TANG MH. Effect of iron-glycine chelate on sow productive performanee[J]. China Feed, 2002(19): 11–12. (in chinese).

[15] XU L, HAN YW, TENG B. Effect of glycine chelated iron and methionine chelated copper on preventing anemia in piglets[J]. Feed Industry, 2001, 22(11): 38–39. (in chinese).

[16] LI JT, CHEN BJ, YU HM, *et al*. The effect of iron-gly,zinc-gly in high level copper diet on the growth performance and related biochemical parameters of weanling piglets[J]. Journal of Agricultural University of Hebei, 2010, 33 (1): 74–78. (in chinese).

[17] YU HM, CHEN BJ, DONG XL. Effect of zinc glycin on growth performance and blood physiological and biochemical indices in weaning piglets[J]. Feed Research, 2007(1): 36–39. (in chinese).

[18] SUN TH, PIAO XS, GONG LM. Effects of iron-amino acid complex on growth performance and related parameters in growing pigs[J]. Chinese Journal of Animal Nutrition, 2006, 18(1): 12–18. (in chinese).

[19] MA WQ, FENG J. Effects of iron glycine chelate on oxidative enzymes and parameters in serum of weaned piglets[J]. Feed Industry, 2008, 29 (22): 28–30.(in chinese).

[20] HU P, CHENG MG, JIANG T, *et al*. Effects of iron-gly on the production performance of weaned piglets[J]. Feed Industry, 2011, 32(13): 29–32. (in chinese).

[21] XIA ZS, LIU D, LI YY, *et al*. Effects of trace mineral amino acid chelates on performance and serum trace mineral concentration of growing pigs[J]. Journal of Guangxi Agricultural and Biological Science, 2007,26 (S1): 49–53. (in chinese).

[22] CAI J. Effect on growth performance and hair color in weanling piglets by iron glycine chelate with different purity[J]. Feed Review, 2011(3): 40–42. (in chinese).

[23] DARNELEY AH.Improving reproductive performance with iron amino acid chelate [A]. The roles of amino acid chelates in animal nutririon[M]. 1996: 251–268.

[24] GUNDEL J, REGIUS A, HERMAN A. Supply to sows and piglets by iron chelates [A]. Proc of Intern Conf on Pig Production[C]. 1998: 21–23.

[25] WANG JT, LIU SD, SUN YD, *et al*. Effect of iron-glycine chelate on sow productive performanee[J]. Shanghai Journal of Animal Husbandry and Veterinary Medicine, 2000(5): 6–7. (in chinese).

[26] WANG L.Effects of adding glycine chelate on hemoglobin content, erythrocyte volume and reproductive performance of sows[J]. Feed China, 2009(24): 35–37. (in chinese).