Oral iron administration in suckling piglets – a review

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Abstract

Iron deficiency is presently a serious problem in suckling piglets on pig farms. The most often used method of anaemia prevention in piglets is parenteral administration of iron dextran. Oral iron represents an alternative to this method. The goal of this article is to review current knowledge on oral iron administration in suckling piglets. The substances that can be used for this purpose include iron dextran, iron salts, iron chelates, carbonyl iron, an iron polymaltose complex and iron microparticles. The different methods of oral iron administration in piglets are discussed.

Anaemia, haemoglobin, iron dextran, pig

Anaemia due to iron deficiency is a well-known problem in swine production. It is caused by the limited foetal iron reserves of new-born piglets, low iron milk content and the high growth rate of suckling piglets (Venn et al. 1947). Iron is given mostly by intramuscular (i.m.) administration of iron dextran (200 mg Fe) at days 2–3 of life. Without additional iron supplementation, the piglets will develop anaemia 7–10 days after birth (Szabo and Bilkei 2002). This method gives good results in the prevention of anaemia in piglets, though it is not free from the risk of negative effects. The possible risks include iatrogenic disease transmission, formation of abscesses and acute toxicity (Maes et al. 2011). Oral iron administration is an alternative to parenteral administration. The goal of the article is to review current knowledge on oral iron administration in suckling piglets.

Iron dextran

Iron dextran is used routinely for parenteral administration in suckling piglets. It can also be used for oral administration. Because of its large molecular size, an iron dextran complex is absorbed by a different mechanism than iron salts (Svoboda and Drábek 2005). Given orally, iron dextran is transferred to the epithelial cells of the small intestine within about 20 h from the administration by pinocytosis. The enterocytes remain functional for about 7 days and transfer iron dextran to the blood plasma and lymph (Klobasa et al. 1991). It is then taken up from the blood by the reticuloendothelial system, with the dextran being decomposed by lysosomal enzymes and iron being stored in the form of ferritin (Katkiewicz et al. 1986).

In order to attain maximal efficiency, it must be given as soon as possible after parturition. When given later, absorption is decreased due to intestinal closure (Iben 1998). It should be performed within 6 h (Heinritzi and Plonait 1997), 8 h (Lemacher nad Bostedt 1994) or 10 h (Glawischnig et al. 1987) of birth.

There have been no reports of toxic effects after oral iron dextran administration to date. This may be attributed to the relatively slower transfer of iron dextran from the enterocytes to the blood plasma or lymphatics (Kolb and Hoffmann 1989).

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Literature reports concerning the efficiency of oral iron dextran administration vary. According to Glawischnig et al. (1987), the efficiency of a single oral dose of 200 mg Fe (iron dextran) in anaemia prevention in piglets was comparable to 200 mg Fe as iron dextran given parenterally. Svoboda and Drábek (2002) also found that a single oral administration of iron dextran (230 mg Fe) prevented anaemia in piglets and resulted in growth comparable to parenterally treated piglets. Both authors conclude that the piglets should have free access to creep feed containing enough iron.

In contrast, Iben (1998) found that a single oral dose of iron dextran (230 mg Fe) was not sufficient for the prevention of anaemia in piglets and that a second dose had to be given by injection.

Witchi and Heinritzi (2001) prevented anaemia in piglets with a double oral administration of 115 mg Fe in the form of iron dextran. The first dose was given 8–12 h *post partum* and the second at the age of 12 days. Piglets treated with oral iron dextran achieved higher weight gains than piglets given iron by other methods.

Recently, Streyl et al. (2015) used an oral combination of toltrazuril and iron dextran (228 mg). They found that this combination was effective for the prevention of coccidiosis and anaemia in suckling piglets.

Iron salts

Iron salts must contain iron in the bivalent form of Fe^{2+}. The substances that have been used in pigs are iron sulphate, iron fumarate, and iron lactate (Svoboda and Drábek 2005). According to Dietzfelbinger (1987), bivalent iron can be up to 16 × better absorbed than trivalent iron. In an acid environment Fe^{3+} ions form high molecular iron hydroxide that is almost undissociable and is excreted in the faeces (Schmitz and Müller 1971). Iron is absorbed in the cranial part of the small intestine (the duodenum and the upper part of the jejunum). According to Egeli and Framstad (1999) iron given orally is available for haemoglobin synthesis sooner than parenteral iron dextran.

The oral administration of iron in the form of salts is considered to be safer than iron injection. What is known as mucosal blockage of iron absorption occurs in the small intestine. The iron excess in mucosal cells can be deposited in the form of ferritin to prevent oxidative damage by ionic iron. This system has limited capacity, however, and a very high dose can overcome this blocking mechanism, resulting in toxicity (Smith 1997). Nikolskaja and Iwanow (1970) and Nordt et al. (1999), for example, found lesions in the gastrointestinal tract (GIT) and liver necrosis in piglets given iron sulphate and fumarate.

Intestinal disorders that may occur in the postnatal period can have an impact on the utilisation of oral iron (Radostits et al. 1994). For example, transmissible gastroenteritis can have a detrimental effect on the absorption of iron from the intestinal tract (Ackerman et al. 1972).

The practice of administering oral iron in the form of a paste directly into the mouth of piglets is often used (Egeli and Framstad 1998). Its advantage is that the iron paste can be used as a source of minerals, vitamins and probiotics (Kotrbáček 2001). Oral administration of iron fumarate has been used successfully in human medicine (Davidsson et al. 2000; Lares-Assef et al. 1999).

The time at which the first dose of oral iron should be given to newborn piglets is controversial. Furugouri and Kawabata (1976, 1979) stated that the intestine fully performs the function of iron absorption from the birth of piglets. Kallela and Karlsson (1972) achieved even better efficiency of oral fumarate in the prevention of piglet anaemia when administration was carried out at 3 to 8 h following birth compared to 3 days after birth. However, there are also other factors to consider. It is known that iron can catalyse production of free radicals and cause oxidative stress (Dziaman et al. 2011). This risk is

especially high in new-born piglets with insufficient reserves of vitamin E. The levels of this important antioxidant increase due to colostrum intake (Loudenslager et al. 1986). For this reason, we recommend the oral administration of iron salts at the age of 3 days.

In a study by Kotrbáček (2001), an oral dose of 100 mg Fe given to 1 day old piglets in the form of iron fumarate had comparable efficiency as i.m. administration of 200 mg Fe (iron dextran). The trial was concluded at the age of 21 days.

According to the results of Svoboda and Drábek (2002), a dose of 200 mg Fe as iron fumarate given orally on days 6 and 11 was necessary to achieve the same efficiency as parenteral iron dextran.

The efficiency of iron lactate as a supplement for the prevention of anaemia in suckling piglets was evaluated by Svoboda et al. (2004). The piglets were given 134 mg Fe in the form of iron lactate at the age of 3 and 10 days. This method prevented the development of anaemia in piglets and resulted in a growth rate comparable to a group treated with iron dextran.

Svoboda et al. (2005) also evaluated the efficiency of iron lactate in the form of a granular mixture offered to piglets *ad libitum*. The mixture consisted of 70% iron lactate, 20% lactoferrin, and 10% whey powder. The product contained 99.5 mg Fe/kg and vanilla flavour was added daily. The authors found that the intake of the supplement was extremely small and did not prevent anaemia.

Kolb and Hofmann (1987) found that feeding sows from 2 days before parturition until weaning (28 days of age) with 4 g Fe as iron sulphate was effective in anaemia prevention in piglets. The feeding of sows with this dose of iron resulted in extremely high concentrations of Fe in their faeces. Therefore, the piglets could receive enough iron by eating a small amount of faeces. In contemporary pig production this method can no longer be functional with the use of slotted areas for faeces.

Chelates

Iron chelates remain intact in the gastrointestinal tract due to their high stability and are absorbed as an amino acid complex or small peptides. They are very well absorbed, though a proportion of them is excreted by the kidneys (DeWayne 1975).

Different forms of oral administration have been used with iron chelates in piglets (Svoboda and Drábek 2005). The addition of iron chelates to drinking water as a sole source of iron was not efficient in preventing anaemia in suckling piglets (Egeli et al. 1998). The reason for this is that piglets suckle milk and are not really interested in other water sources (Egeli and Framstad 1998).

Amino acid chelated iron is believed to cross the placental barrier more readily than other iron compounds (Ashmead 1993). Paul et al. (1978) and Wei et al. (2005) found that milk iron can be improved by feeding sows with amino acid chelated iron. Several studies have, for this reason, attempted to prevent anaemia in suckling piglets by treating pregnant sows with iron chelates.

Egeli et al. (1998), for example, achieved a slight increase of haemoglobin (Hb) and red blood cells (RBC) in piglets from sows that were given iron chelates (300 mg Fe daily) during the last three weeks of gestation. This was of no practical significance because parenteral iron administration was necessary to prevent the development of anaemia in piglets.

Wei et al. (2005) found that adding 120 mg Fe/kg in the form of an amino acid complex to the diet of sows improved the iron status of piglets by means of the placental and mammary transfer of iron. However, this was not sufficient to replace parenteral iron administration.

A single oral administration of iron methionine at a dose of 200 mg Fe on day 3 for the prevention of anaemia in piglets was evaluated by Kegley et al. (2002). This method was

not sufficient to meet the iron requirements of piglets until weaning on day 21 of life. The authors conclude that a second dose at ca 10 days of age would be necessary.

Iron chelates have also been used in a product based on voluntary intake by piglets. Svoboda and Drábek (2003) found that voluntary consumption of amino acid chelated iron resulted in the prevention of anaemia in the majority of weaned piglets. The piglets were offered a mineral supplement with amino acid chelated iron (110 g Fe/kg) *ad libitum* from day 2 to day 14 of life. The supplement was placed on a low feeding slab to improve its accessibility to the piglets.

A product for voluntary consumption containing both iron chelates and salts was evaluated by Maes et al. (2011). The product contained 24% Fe with iron fumarate, iron glycine chelate, iron amino acid chelate and iron sulphate. The authors found that the haemoglobin concentration at weaning was higher in piglets supplemented with oral iron than in those given parenteral administration.

Carbonyl iron

Carbonyl iron powder is a preparation with elemental uncharged iron. It has been shown that carbonyl iron can be absorbed and used for haemoglobin synthesis in humans (Gordeuk et al. 1990). It is less toxic compared to iron salts (Gordeuk et al. 1987). The conversion of carbonyl iron into soluble ionised iron is necessary for absorption. The solubility of carbonyl iron is influenced by gastric pH. It is less soluble at a higher pH (Swain et al. 2003).

The efficiency of carbonyl iron in preventing anaemia in piglets was evaluated by Svoboda et al. (2007). A double dose of 230 mg carbonyl iron on days 3 and 9 of life resulted in a significant increase in Hb, but did not prevent the development of anaemia. This was probably due to the relatively high pH of the gastric content in suckling piglets which had a negative effect on its utilisation in the GIT.

Iron polymaltose complex

Iron polymaltose complex (IPC) is a new compound used for anaemia prevention. Its efficiency and safety has been described in several human studies (Ackerman et al. 1972; Bernat 1981). It binds in the Fe^{3+} form and is practically non-toxic because iron is released from the complex gradually and is absorbed by active transport (Braude et al. 1962).

Svoboda et al. (2008) found a comparable efficiency of IPC with iron fumarate in the prevention of anaemia in suckling piglets.

Iron microparticles

The new technology of encapsulation can improve the bioavailability of oral iron (Zimmermann 2004). Antileo et al. (2016) used microparticles made from iron sulphate and porcine erythrocytes for the prevention of anaemia in suckling piglets. They managed to prevent the development of anaemia with this supplement divided into 3 doses. The piglets were given an oral dose of 84 mg Fe on days 2, 8 and 14 of life. The haematological indices were monitored up to the age of 21 days.

Conclusion

The advantage of oral administration is that iron absorption can be precisely adjusted to the needs of the organism. It is increased with higher erythropoiesis or decreased in conditions of iron overload (Lipinski et al. 2013).

The most suitable way would be a voluntary iron intake by the piglets. Such a method would cause less discomfort to piglets and save time to the farmer. According to Maes et al. (2011), parenteral iron administration required on average 30 s more time than placing a product for voluntary intake.

However, the efficiency of voluntary iron intake is not consistent and depends on many factors, including the chemical form of iron, the application regimen, and attractiveness to the piglets (Maes et al. 2011). For or example, Svoboda et al. (2005) found that the use of an iron lactate supplement for voluntary intake was not efficient in preventing anaemia in piglets.

In contrast, Maes et al. (2011) managed to prevent anaemia in piglets with the use of iron-rich feed containing both iron chelates and salts. Maes et al. (2011) attribute good results to the feed additive itself and to the special feeding device that stimulates the rooting behaviour of piglets (Kuller et al. 2010).

The addition of iron to drinking water was not efficient in preventing anaemia in suckling piglets (Egeli et al. 1998). When piglets suckle milk they are not really interested in other water sources (Egeli and Framstad 1998).

Individual oral administration is the most accurate method of iron supplementation for piglets. According to Marchant-Forde (2001), oral and parenteral iron administrations do not differ in terms of the time necessary to carry out the procedure and welfare indices.

In contrast, Valenzuela (2016) found that oral administration required more time to deliver than parenteral treatment. Oral iron supplementation also caused higher behavioural disruption in piglets. According to the authors, the negative welfare effects were probably caused by increased handling time and the aversive flavour of the supplement. They suggest that a training of the staff carrying out the procedure in order to reduce the handling time should be considered.

It is difficult to give exact recommendations on the dosage and administration mode for oral iron preparations that would be efficient on most pig farms. The need for supplementary iron can differ because it depends on iron requirements and its availability from other sources. We conclude that the method of oral iron administration should be adjusted to the specific needs of the particular farm.

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