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Evaluation of iron dextran application programs to prevent iron deficiency anemia in piglets

Avaliação de programas para aplicação de ferro dextrano na prevenção da anemia ferropriva de leitões

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ABSTRACT

To evaluate the effect of different iron dextran application programs on the performance, fecal score, and skin color of suckling piglets, as well as sow performance, 288 piglets from 24 sows were allocated to four treatments in six replications with 12 piglets per experimental unit, in a block design. The treatments were as follows: T200_000, T200_100, T200_200, and T100_100, whose respective values (in mg) corresponded to the applications of the first dose of iron dextran on the second day of life and of the second dose on the 10th day. Piglets on T200_000 and T200_200 showed the highest feed intake. In the period from 10 to 22 days, piglets receiving T100_100 exhibited the highest fecal score. On the 10th day of age, the lowest lightness (L*) value on the ear was obtained with T200_100, and the highest with T100_100. Treatments T200_000, T200_100, and T200_200 generated the highest red color (a*) intensity on the ear, whereas T100_100 provided the lowest hue and parameter b* values on the leg and snout. On the 22nd day

of age, the highest b* and hue values of the ear and snout were found in the group fed T100_100. In conclusion, all evaluated programs were efficient in preventing iron deficiency anemia in newborn piglets. To reduce expenses, we recommend administering a single dose of 200 mg of iron dextran to piglets on the second day of life.
Keywords: Diarrhea; Dose; Hemoglobin; Intake; Skin color; Suckling.

RESUMO

Foram utilizados 288 leitões de 24 matrizes, distribuídos em delineamento em blocos com quatro tratamentos, seis repetições, com 12 leitões por unidade experimental com objetivo de avaliar diferentes programas de aplicação de ferro dextrano sobre desempenho, escore fecal e coloração de pele de leitões em aleitamento, assim como as repercussões sobre o desempenho das matrizes. Os tratamentos consistiram em: T200_000; T200_100; T200_200; e T100_100; nos quais os valores corresponderam, respectivamente (em mg), à aplicação da primeira dose de ferro dextrano no segundo dia de vida e à aplicação da segunda dose no 10º dia. Os leitões que foram submetidos a T200_000 e a T200_200 tiveram maior consumo de ração. No período de 10 a 22 dias, os leitões de T100_100 obtiveram maior escore fecal. Ao 10º dia de idade dos leitões, o menor valor de luminosidade (L*) da orelha foi em T200_100 e o maior valor em T100_100. A maior intensidade da cor vermelha (a*) na orelha foi obtida em T200_000, T200_100 e T200_200. Na tonalidade e no parâmetro b* do pernil e do focinho, T100_100 foi aquele que apresentou menor valor. No 22º dia de idade dos leitões, o maior valor de b* e da tonalidade da orelha e do focinho foi verificado em T100_100. Conclui-se que todos os programas avaliados foram eficientes na prevenção da anemia ferropriva em leitões neonatos. Visando a redução de gastos, recomenda-se a administração de uma única dose de 200 mg de ferro dextrano no segundo dia de vida dos leitões.
Palavras-chave: aleitamento, coloração de pele, consumo, diarreia, dose, hemoglobina.

INTRODUCTION

Microminerals participate in a wide range of biochemical processes vital to piglets during the growth phase, a period of major physiological and immunological changes. Therefore, adequate supplementation in this stage is essential to ensure better productive and reproductive performance in the future of these animals (Pissinin, 2016). In fact, some authors consider minerals from organic sources more easily bioavailable for swine nutrition, compared with inorganic sources (Luiggi, 2014).
Iron is one of the most important minerals for piglets, as its deficiency is associated with iron deficiency anemia, a condition responsible for causing various disorders such as diarrhea, decreased growth rate, and even death (Lachowicz et al., 2014). Iron deficiency often occurs due to the following factors: poor transfer of iron from the sow through the placenta, colostrum, and milk; reduced body iron reserve in neonates; and the rapid rate of weight gain relative to other species (Szudzik et al., 2019). In addition, pig farming practices prevent contact with the soil, which is the main source of iron for piglets in the wild (Egeli et al., 1999).
Piglets regularly become anemic within two weeks of farrowing (Svoboda & Drabek, 2005). However, parenteral administration (intramuscular or subcutaneous) of iron has been effective

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in preventing iron deficiency anemia (Svoboda et al., 2017; Pu et al., 2018).

Excess iron can alter systemic metabolism (Chen et al., 2019). For instance, when supplemented iron exceeds the binding capacity of transferrin in serum, free iron catalyzes radicals into reactive oxygen species (ROS), inducing oxidative stress (Starzynski et al., 2013; Chen et al., 2019).

Clinical analysis techniques are costly and time-consuming, causing stress in the animals, which drives the search for reliable alternatives. Thus, the use of instrumental analysis tools, e.g. colorimetry, is an option for researchers and producers, as the colorimeter is one of the most robust and accurate pieces of equipment for analyzing skin color (Langeveld et al., 2021; Matias et al., 2015).

The objective of this study was to evaluate different programs of application of iron dextran on the performance, fecal score, and skin color of piglets during the suckling period, as well as implications on sow performance.

MATERIAL AND METHODS

This study complied with the ethical norms for research on animals and was conducted after approval by the Ethics Committee on Animal Use (CEUA) at the Federal University of São João Del Rei (UFSJ) (approval no. 027/2020).

The study was carried out on a commercial pig farm characterized as farrow-to-finish, located in the municipality of Lagoa Dourada - MG, Brazil.

The experiment was laid out in a randomized block design with four treatments, six replications, and 12 piglets per experimental unit (litter). A total of 288 clinically healthy piglets from 24 sows (commercial strain – TOPIGS) were used. Each block consisted of 12 sows, so as to maintain a homogeneous distribution of farrowing numbers between treatments.

Treatments were as follows: T200_000, T200_100, T200_200, and T100_100, whose values (in mg) corresponded to the application of the first dose of iron dextran on the second day of life and the second dose on the 10th day, respectively.

Each treatment consisted of a group of 72 piglets, which were subjected to different frequencies and doses of iron dextran (Dexiron, Fatec, Brazil – with an iron concentration of 100 mg mL^{-1}). In all treatments, iron dextran was administered intramuscularly in the cervical region.

Eight days before the expected farrowing date, the sows were transferred from the pregnancy to the maternity ward. Before housing the sows, the maternity room was washed and disinfected and left empty for four days.

The maternity facility had a roof with zinc tiles, polyethylene lining, a 1 m-high brick short side wall, metal screens, and polyethylene curtains on the sides. Sows were housed in individual metal cages. Piglets were provided with a creep in front of the sow feeder, with cement floors and heating by an incandescent lamp. The part opposite the creep consisted of a nipple drinker for the piglets of each litter, and a duckbill drinker for sows was attached to the side of the feeder.

The farrowing crate was suspended, with hollow expanded plastic floors and slate sides, which prevented the piglets from coming into contact with each other and thus reduced the chances of disease transmission between the litters.

Sows were not fed on the farrowing date. From the second day onward, they received a feed that was formulated to meet the nutritional requirements as proposed by Rostagno et al. (2017). Table 1 shows the composition of the diet used to feed the sows. Feed intake was determined daily by measuring the feed supplied and orts in the troughs the next day. Water was provided *ad libitum* through duckbill drinkers throughout the experimental period. To weigh the feed, a scale with 1 g precision and maximum capacity of 10,000 g was used.

Table 1. Centesimal, energy, and chemical composition of the diet used in the feeding of sows from the 2nd day of lactation

Ingredient	Centesimal composition
Corn	57.44
Soybean meal	30.00
Oil	4.00
Sugar	4.00
Dicalcium phosphate	1.70
Limestone	1.30
Salt	0.50
Vitamin-mineral mix[1]	0.50
L-lysine	0.19
Vacci-Casco®[2]	0.10
Cobrevacc®[3]	0.07
L-threonine	0.07
Amoxan®[4]	0.06
Prophorce®[5]	0.05
DL-methionine	0.02
Total	100
Calculated composition	Nutritional value
Crude protein (%)	18.60
Metabolizable energy (Kcal kg^{-1})	3.468
Total lysine (%)	1.17
Digestible lysine (%)	0.99
Calcium (%)	1.0
Total phosphorus (%)	0.64

[1]Vitamin-mineral mix (amount per kg of product): Folic Acid (min.) 120 mg, Pantothenic Acid (min.) 3,200 mg, BHT (min.) 100 mg, Biotin (min.) 40 mg, Cobalt (min.) 40 mg, Copper (min.) 2,000 mg, Choline (min.) 60 g, Colistin 8,000 mg, Iron (min.) 20 g, Iodine (min.) 200 mg, Manganese (min.) 14 g, Niacin (min.) 6,000 mg, Selenium (min.) 80 mg, Vitamin A (min.) 2,000,000 IU, Vitamin B1 (min.) 300 mg, Vitamin B12 (min.) 4,000 mcg, Vitamin B2 (min.) 1,000 mg, Vitamin B6 (min.) 400 mg, Vitamin D3 (min.) 400,000 IU, Vitamin E (min.) 10,000 IU, Vitamin K3 (min.) 400 mg, Zinc (min.) 20 g. [2]Amount per kg of product: B.H.T (min.) 10 g, Biotin (min.): 340 mg, Methionine (min.) 200 g. [3]Amount per kg of product: Copper (min.): 115 g, Zinc (min.): 20 g. [4]Amount per 100 g of product: Amoxicillin trihydrate 56.63 g, Kaolin q.s. 100 g. [5] (Amount per kg of product): Total butyric acid (min.) 600 g.

Soon after birth, all piglets in the experiment had their nasal passages and bodies cleaned to avoid suffocation and a drop in body temperature. Subsequently, the navel was dried and disinfected. Then, the piglets were identified with an earring, according to the order of birth, and weighed individually.

After the time required for colostrum ingestion, the weight and number of piglets were equalized between litters, before applying the first dose of iron dextran.

The experiment was divided into two periods: one to nine days; and 10 to 22 days of age, which were used to evaluate the effect of different programs of iron dextran application to newborn piglets. The litters in the four treatments included both sexes, which were identified individually so as to maintain individual history until weaning at 22 days.

For all treatments, until the piglets' ninth day of age, no other supplemental source of nutrients was available besides colostrum, breast milk, water, and application of iron dextran.

For intramuscular application of iron dextran, the piglets were restrained by an assistant, who displaced the skin to the side with their thumb before inserting the needle. This was done so that the site of insertion of the needle into the muscle would be covered by subcutaneous tissue and skin after its removal, thereby preventing the backflow of iron after removing the needle.

In the period between the 10th and the 22nd day of age, the litters received commercial pelleted feed *ad libitum* (Table 2), in specific feeders for suckling piglets. Feed intake was measured daily, by quantifying the feed supplied and orts on the next day.

Table 2. Chemical composition of commercial feed used to feed piglets from the 10th day of age

Chemical composition (per kg of feed)	Nutritional value
Crude protein min. (g kg^{-1})	200
Ether extract min. (g kg^{-1})	35
Crude fiber max. (g kg^{-1})	35
Mineral matter max. (g/kg)[1]	90
Calcium min. (g kg^{-1})	7.5
Calcium max. (g kg^{-1})	12
Phosphorus min. (mg kg^{-1})	6,000
Iron min. (mg kg^{-1})	157.5

[1] Amount per kg of feed: Vitamin A (min.): 12,000 IU, Vitamin D3 (min.): 3,000 IU, Vitamin E (min.): 120 IU, Vitamin K3 (min.): 12 mg, Vitamin B1 (min.): 3.6 mg, Vitamin B2 (min.): 9 mg, Vitamin B6 (min.) 4.5 mg, Vitamin B12 (min.): 36 mcg, Niacin (min.): 72 mg, Calcium pantothenate (min.): 36 mg, Folic Acid (min.): 1.2 mg, Biotin (min.): 0.33 mg, Methionine (min.): 4,400 mg, Lysine (min.): 15 g , Choline Chloride (min.): 1770 mg, Copper (min.): 200 mg, Manganese (min.): 45 mg, Zinc (min.): 3000 mg, Iodine (min.): 1.8 mg, Selenium (min.): 0.4 mg, Sodium (min.): 4,000 mg, Colistin: 200 mg, Tiamulin: 135 mg, Amoxicillin: 300 mg.

Throughout the experimental period, ventilation and room temperature were controlled by opening or closing the curtains installed on the sides of the shed. The thermal environment was measured daily, at 14h00, and maximum (ºC) and minimum (ºC) temperatures, black globe temperature (ºC), and relative humidity (RH, %) were recorded. The equipment used was a digital thermo-hygrometer as well as maximum and minimum thermometers, which were placed inside the shed at half-height of the animals' bodies, outside the stalls. The black globe was placed 1.50 m above the floor of sow and piglet facilities. Based on the collected data, the thermal comfort inside the facility was evaluated by calculating the black globe humidity index (BGHI).

The average daily feed intake (ADFI) of the sows was determined from the second day post-farrowing until weaning.

For the analysis of piglet performance variables, the litter was considered an experimental unit. Performance was evaluated based on the following production traits: average daily weight gain (ADG), feed intake (ADFI), and body weight at 1, 10, and 22 days of life. Diarrhea occurrences were compiled from the piglets’ second day of age until weaning, and divided into two phases within the experimental period: from the second to the ninth day; and from the 10th day of age until weaning.

The incidence of diarrhea was assessed by the same observer, who checked the consistency of stools and classified them into the following scores: 1 – hard and firm; 2 – normal consistency; 3 – soft, non-diarrheal; and 4 – watery, characteristic of diarrhea.

Color measurements were performed on the piglets’ 1st, 10th, and 22nd days of life, on four animals randomly selected from each litter. The measurements were performed on three body parts, on each piglet: ear (external), hind leg (inner skin covering the leg, close to the inguinal region), and snout. For each measurement, readings were taken in three different positions, which were obtained by moving the equipment so as to cover practically the entire surface of the region.

Color was determined by s portable colorimeter (CR 400, Konica Minolta) operating in the CIELAB system, which evaluates color by the reflectance of light in three dimensions corresponding to the letters L* (brightness), a* (green/red), and b* (blue/yellow). An L* value equal to zero corresponds to black, whereas 100 corresponds to white. The values of a* vary from –a, which represents green, to +a, which corresponds to red; and b* values range from –b, which represents blue, to +b, which corresponds to yellow (BRIDI & SILVA, 2009).

Weight, weight gain, intake, fecal score, and color data were subjected to analysis of variance (ANOVA) using SAEG (System fot Statistical and Genetic Analysis) statistical software. When necessary, the Student-Newman-Keuls (SNK) test was applied to compare the means. For all statistical procedures, probability values lower than 0.05 were considered significant.

RESULTS AND DISCUSSION

Table 3 describes the maximum and minimum temperatures, black globe temperature, and ambient temperature at 14h00, as well as RH and BGHI, recorded from two to nine and 10 to 22 days of age.

According to Ferreira (2016), maternity is a critical phase in which the temperature needs of the piglets and the sow, which are opposite, must be reconciled simultaneously. In fact, for the sow, the ideal temperature range is

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between 16 and 21 ºC, and RH should be maintained between 60 and 80%.

Table 3. Mean values and standard deviation of ambient temperature, maximum and minimum temperature, black globe temperature, and black globe humidity index (BGHI) and relative humidity in the experimental room.

Climatic variable	**Period**	
	2 to 9 days	**10 to 22 days**
Temperature at 14h00 (ºC)	25.20 ± 2.15	25.64 ± 1.80
Minimum temperature (ºC)	18.20 ± 1.99	18.73 ± 2.87
Maximum temperature (ºC)	26.50 ± 3.14	26.18 ± 1.47
Black globe temperature (ºC)	28.20 ± 3.16	28.27 ± 2.20
Relative humidity (%)	43.20 ± 13.45	39.45 ± 7.59
BGHI (K)	72.92 ± 2.54	72.76 ± 2.50

Therefore, according to the temperature and RH data obtained during the experimental period, the sows were kept in an environment with a maximum temperature above thermoneutrality. This may have influenced their productive performance, resulting in lower feed intake, increased body wear, and reduced milk production and piglet growth rate (Castro et al., 2011).

However, the most appropriate tool to assess the environmental condition for pigs is BGHI, which considers the temperature, radiation, and RH of the environment. According to Turco (1998), the ideal BGHI value to meet the thermal comfort conditions of sows in the maternity ward should be around 70%. Thus, based on the BGHI values observed in the maternity ward during the two experimental periods, we can conclude that the sows were kept in an environment close to the ideal.

Table 4 shows the mean values of weight, daily weight gain, and feed intake of piglets subjected to different iron application programs according to age.

No difference (P>0.05) was observed for average weight (AW) or ADG between iron application programs. However, piglets subjected to the programs of T200_000 and T200_200 showed higher ADG (P<0.05) than those receiving the T200_100 and T100_100 programs.

Table 4. Mean values of average weight (AW), average daily weight gain (ADG), and average daily feed intake (ADFI) of piglets subjected to different iron dextran application programs.

Parameter	**Period (days)**	**Treatment**				**p-value**	**CV (%)**
		T200_000	**T200_100**	**T200_200**	**T100_100**		
AW (g)	2	1371	1434	1212	1427	NS	8.6
	10	3322	3512	3156	3509	NS	14.0
	22	6440	6742	6407	6423	Ns	11.0
ADG (g/piglet/d)	2 a 9	216.67	230.83	215.83	231.33	NS	18.0
	10 a 22	274.67	280.33	283.33	256.50	Ns	11.5
	2 a 22	249.17	258.83	253.83	245.67	NS	12.5
ADFI (g/piglet/d)	10 a 22	2.92a	2.16b	2.87a	2.32b	<0.03	21.1

Means followed by different letters in the same row differ by the Student-Newman-Keuls test (P<0.05).

Besides representing or resulting in anemia, iron deficiency may lead to reduced weight gain, apathy, inability to resist circulatory strain, changes in respiratory rate after light exercise, and reduced appetite.

In this respect, in aiming to reduce the occurrence of iron deficiency anemia in piglets, several studies corroborate the finding that the administration of 200 mg of iron dextran intramuscularly or subcutaneously in a single dose increases iron and hemoglobin levels in the blood, improving piglet performance variables (Wang & Kim, 2012; Stojanac et al., 2016; Novais et al., 2016).

In the present study, there was no difference between the iron dextran application programs regarding the AW or ADG variables, suggesting that all these methods were efficient in controlling iron deficiency anemia in the piglets.

Additionally, other studies have shown that split administration of iron doses can improve the use of this mineral, increasing blood iron and hemoglobin levels, alleviating oxidative stress, and promoting increased weight gain in piglets (Starzynski et al., 2013; Chen et al., 2019 Szudzik et al., 2019). Nevertheless, in the present case, splitting the iron dose into two applications did not influence AW or ADG, which can be explained by the difference in iron concentration in the doses that were used. In fact, the above-mentioned studies involved two administrations of ±40 mg of iron dextran and, unlike in the present study, the doses were applied on the piglets' 3rd and 14th days of age.

Overall, the ADFI of piglets from 10 to 22 days of age was relatively low, which is consistent with the results obtained by Ferreira et al. (2001), who observed that suckling piglets had a feed intake lower than 5.0 g/piglet/day. This is because milk supplies most of the nutritional requirements for growth; thus, anemic piglets could become lethargic, which would reduce their feed intake. In addition, in suckling piglets, feed intake may be associated with milk intake, i.e. piglets that ingest a larger amount of milk may decrease their ingestion of food.

Table 5 shows the ADFI of the sows during the experimental periods according to the treatments to which the piglets were subjected.

Table 5. Average daily feed intake (ADFI) of the sows during the experimental periods, according to the iron dextran application programs for the piglets.

Variable	Period	Treatment				p-value	CV (%)
		T200_00 0	T200_10 0	T200_20 0	T100_10 0		
ADFI (kg)	2 to 9 days	4.15	4.08	3.97	4.37	NS	17.8
	10 to 22 days	5.32	5.28	4.90	5.56	NS	16.0
	2 a 22 days	4.71	4.84	4.55	5.11	NS	16.5

The iron application programs for the piglets had no effect on the ADFI of the sows in the different lactation periods (P>0.05).

Feed intake by lactating sows is related to the performance of the suckling piglets. This is because the piglets' growth rate is primarily influenced by the amount of milk ingested, as it is their main source of nutrients (Wang et al., 2014). Therefore, the sow ADFI results are consistent with the ADG of the piglets observed in the present study, and no difference was detected between the iron application groups.

Iron deficiency anemia leads to a decrease in appetite, reducing the piglets' suckling intensity (Vitor & Mary, 2012). This, in turn, may cause the sows to reduce their feed intake, since the need for milk production will be smaller. Nonetheless, the iron application programs for the piglets did not influence the sows' ADFI or the piglets' ADG, suggesting that all the evaluated programs provided an adequate amount of iron for these animals.

Table 6 displays the fecal score data of piglets supplemented with iron dextran in different administration programs, from two to nine and 10 to 22 days of age.

Table 6. Fecal score of piglets subjected to different iron dextran application programs in the periods from two to nine and 10 to 22 days of age

Period	**Treatment**				**p-value**	**CV (%)**
	T200_000	**T200_100**	**T200_200**	**T100_100**		
2 to 9 days	2.019	2.017	2.016	2.018	NS	4.3
10 to 22 days	2.091ab	2.028b	2.066b	2.141a	<0.003	7.9

Means followed by different letters in the same row or in the same column indicate a significant statistical difference by the Student-Newman-Keuls test (P<0.05).

Iron supplementation programs did not influence (P>0.05) fecal score from two to nine days of age. From 10 to 22 days, however, the supplementation programs affected (P<0.05) this variable, which was higher in the piglets receiving the T100_100 program than in those subjected to programs T200_100 and T200_200. Piglets that did not receive the second dose of iron (T200_000) showed intermediate fecal score values.

Iron is essential for bacterial growth, and, in fact, an excess of this mineral significantly favors this activity (Mateos et al., 2004). Therefore, iron doses above required could stimulate bacterial growth and impair the animal's health state.

Starzyński et al. (2013) and Chen et al. (2019) observed an increase in the concentration of hepcidin in the blood plasma of piglets supplemented with higher concentrations of iron dextran. Hepcidin is a peptide hormone secreted by the liver that acts as a negative regulator of iron absorption in the small intestine. Therefore, an increase in hepcidin release results in a higher concentration of iron in the gastrointestinal tract (GIT), which may favor the incidence of diarrhea in piglets, due to the growth of pathogenic bacteria.

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However, in the present study, piglets that received doses with higher concentrations of iron dextran (T200_100 and T200_200) exhibited lower fecal scores. This means that iron doses up to 400 mg, split into two applications, do not alter the gut microbiota of piglets.

According to Pluske et al. (2018), the diarrhea index is associated with worsening of intestinal health in piglets. Pu et al. (2018) and Chen et al. (2019) found that iron dextran supplementation to piglets improves gut health, which may result in a lower incidence of diarrhea in these animals.

Thus, the T100_100 iron administration program may not have been as efficient as the others in terms of improving the intestinal health of the piglets, which led to their higher fecal score. It is important to emphasize, however, that none of the iron administration programs resulted in diarrhea in the piglets.

Tables 7 and 8 show the mean index data for parameters L*, a*, b*, and hue of the skin on the ear, leg, and snout of the piglets at 10 and 22 days of age, respectively, as a function of iron dextran application programs.

Table 7. Mean values of parameters L*, a*, b*, and hue of the skin on the ear, leg, and snout of piglets subjected to different iron dextran application programs, at 10 days of age

Site	Parameter	Treatment T200_000	T200_100	T200_200	T100_100	p-value	CV (%)
Ear	L*	59.81 ± 1.7ab	59.50 ±1.2b	59.53±1.7ab	61.57±1.4a	<0.010	2.3
	a*	9.92 ± 1.3a	9.86 ± 0.9a	10.02 ± 0.7a	8.83 ± 0.7b	<0.045	7.8
	b*	3.80 ± 0.3	3.57 ± 0.4	4.04 ± 0.8	3.73 ± 0.7	NS	15.9
	Hue	21.18 ± 3.5	20.02 ± 3.5	22.02 ± 5.2	19.09 ± 3.8	NS	19.2
Leg	L*	57.48 ± 1.2	59.64 ± 0.8	58.01 ± 2.9	56.44 ± 1.5	<0.248	3.1
	a*	12.03 ± 0.1	12.17 ± 0.6	12.67 ± 1.1	12.75 ± 0.9	NS	7.3
	b*	2.77b ± 0.2b	3.91 ± 0.4a	3.79 ± 0.4a	1.84 ± 0.3c	<0.001	11.4
	Hue	12.84b ± 0.1b	18.28 ±2.1a	16.79 ± 3.0a	8.49 ± 1.2c	<0.001	13.6
Snout	L*	60.25 ± 1.1	59.01 ± 1.8	59.46 ± 1.3	60.97 ± 0.6	<0.072	2.1
	a*	13.79 ± 1.2	12.99 ± 0.5	13.42 ± 1.1	13.63 ± 0.9	<0.393	6.2
	b*	7.25a ± 0.6a	7.74 ± 0.6a	7.25 ± 0.5a	6.49 ± 0.6b	<0.002	6.7

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	Hue	28.29 ± 3.5ab	30.98 ±1.5a	28.48±2.9 ab	24.66 ± 3.0c	<0.001	6.9

Means followed by different letters in the same row differ by the Student-Newman-Keuls test (P<0.05).

On the piglets’ 10th day of age, there was no difference (P>0.05) between the iron dextran application programs regarding the b* and hue color parameters on the ear; or L* and a* on the leg and snout. On the other hand, the iron application programs altered (P<0.05) the color parameters L* and a* on the ear and the b* and hue on the leg and snout.

The lowest lightness index (L*) on the ear was provided by treatment T200_100, whereas iron dextran supplementation at T100_100 provided the highest indices, and T200_000 and T200_200 intermediate values. A greater intensity of the red color (a*) on the ear was observed in piglets under the T200_000, T200_100, and T200_200 programs, compared with those that received iron dextran supplementation at T100_100.

As for the b* and hue color parameters on the leg, the lowest indices were observed in the piglets in the T100_100 group, whereas the animals in the T200_000 program exhibited intermediate indices and those under T200_100 and T200_200 the highest indices.

The lowest b* index on the snout was found in the animals in the T100_100 group compared with the piglets that received iron dextran supplementation through programs T200_000, T200_100, and T200_200, which showed higher indices. As for the hue parameter, piglets subjected to the T100_100 program had the lowest index among the treatment groups.

On the piglets’ 22nd day of age, there was no effect (P>0.05) of iron dextran supplementation programs on the leg color parameters L*, a*, b*, or hue. However, the different iron application programs changed (P<0.05) the b* and hue parameters on the piglets' ear and snout.

The highest b* and hue indices on the ear were found in the animals supplemented with iron by the T100_100 program, among all supplementation methods.

The highest b* index on the snout was observed in the animals that received the administration of iron dextran at T100_100, whereas the piglets in the T200_000 and T200_200 groups obtained the lowest indices, and those under T200_100 intermediate values. As regards the hue of the snout, a higher index was found in the animals of the T100_100 group, while the piglets under T200_200 obtained the lowest indices and those that received T200_000 and T200_100 showed intermediate results.

The typical picture of iron deficiency anemia in piglets can be observed by examining the color of the mucous membranes, since anemic animals do not have the characteristic pink ears and snout (Vitor & Mary, 2012). This happens because iron is one of the components of hemoproteins, myoglobin, and hemoglobin, which have the ability to react with oxygen, changing tissue color. In fact, the iron-porphyrin group constitutes a significant staining agent, with high absorption intensity in the visible region. As a result, iron deficiency in the body results in a more whitish skin color.

Indeed, when in oxidation states +2 (ferrous ion) and +3 (ferric ion), iron cations represent the coordination center of porphyrin, constituting the metalloporphyrin known as “heme”, which consists of the prosthetic group of hemoproteins that can bind molecular oxygen (O_2). Porphyrins and metalloporphyrins have a very high molar absorptivity coefficient (see Lambert-Beer Law), being responsible for a considerable part of the coloration of hemoproteins. Therefore, altering the iron ligands (which is the case of molecular oxygen) can significantly modify both the color itself (maximum absorption wavelength, i.e., the type of color displayed) and its intensity (Huang & Groves, 2018; Gebicka, 2020).

Quantifying the evolution of skin color appears to be complex, as *in vivo* fluctuations in erythema can affect melanin values and vice versa (Matias et al., 2015). Knowing that melanin absorbs light over a wide range of wavelengths, attention is needed on the part of the analyzer to discriminate between melanin, erythema (i.e. the redness of hemoglobin), and healthy skin (Baquie and Kasraee, 2014). In our study, we sought to carry out the respective photometric analysis in an adequate optical window, that is, in a spectral window in which less interference would affect measurement precision.

Thus, in the present study, the piglets that received 100 mg in the first dose of iron dextran showed higher L* and lower a* indices on the ear, as well as lower b* and hue indices on the leg and snout on the 10th day of age, indicating that their skin became paler. This suggests that the application of 100 mg was less efficient in inducing an increase in iron, hemoglobin, and myoglobin levels in the tissues of the piglets, compared with the application of doses with a higher concentration of iron dextran.

However, after the second dose of iron dextran application, the T100_100 program increased the b* and hue color indices in the piglets' ear and snout, suggesting that the administration of the second iron dose improved blood iron and hemoglobin levels, reducing the pallor of the piglets' skin.

CONCLUSIONS

All iron application programs evaluated in the present study are efficient in preventing iron deficiency anemia in newborn piglets. However, to reduce the cost of the product and the labor involved in the second application of iron, we recommend administering a single dose of 200 mg of iron dextran to piglets on their second day of life.

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