

THE EFFECT OF AN IRON GLYCINE CHELATE SUPPLEMENT ON THE HAEMOGLOBIN AND THE HAEMATOCRIT VALUES AND REPRODUCTIVE TRAITS OF SOWS

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Abstract

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The present study was performed to investigate, whether or not, iron glycine chelate given to sows, in late pregnancy and lactation, could enhance reproductive traits. A supplement of 62.5 g/ton of iron glycine chelate given in the sows feed for 0 (control), 2, 4, 6 or 8 weeks prior to farrowing was provided. The haemoglobin (Hb) and haematocrit (Hct) values of sows and their piglets, the litter size at birth and at weaning, the birth weight, %stillborn, %mummified fetuses, the growth rate of the suckling piglets, the weaning weight of the piglets and the proportion of anemic sows and piglets were measured. On average, the Hct was $33.7 \pm 2.7\%$ in sows and $32.2 \pm 3.9\%$ in piglets, while the Hb was 11.3 ± 0.9 g/dl in sows and 10.8 ± 1.3 g/dl in piglets. The proportion of sows and piglets with Hb levels below 8 g/dl (anemia) was low and not significantly different between the groups. No evidence of eperythrozoonosis was observed in either sows or piglets. The Hct and Hb values for the sows and piglets were positively correlated. The number of piglets born alive/litter, the piglet birth weight and the number of piglets at weaning did not differ significantly between the groups. The proportion of stillborn and mummified fetuses per litter were highest in the control group. The growth rate of the suckling piglets in the treatment groups was significantly greater than in the control group. This indicated that a supplement of iron chelate in the sow's diet might have a beneficial effect on the growth rate of the suckling piglets.

Keywords : sow, piglet, anemia, glycine chelate

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บทคัดย่อ

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ผลของการเสริมธาตุเหล็กไกลซีนคีเลตในอาหารแม่สุกรต่อค่าฮีโมโกลบิน ฮีมาโตคริต และสมรรถภาพการสืบพันธุ์

การทดลองครั้งนี้มีวัตถุประสงค์เพื่อพิสูจน์ผลของการเสริมธาตุเหล็กอินทรีย์ในอาหารสุกรในช่วงท้ายของการอุ้มท้องและช่วงเลี้ยงลูกว่าสามารถเพิ่มสมรรถภาพการสืบพันธุ์ในแม่สุกรได้หรือไม่ ธาตุเหล็กถูกเสริมในอาหารแม่สุกรในปริมาณ 62.5 กรัม/ตัน เป็นเวลา 0 (กลุ่มควบคุม) 2 4 6 และ 8 สัปดาห์ ก่อนคลอด ทำการเจาะเลือดแม่และลูกสุกรเพื่อวัดระดับ ฮีโมโกลบิน และค่าเม็ดเลือดแดงอัดแน่น เปรียบเทียบขนาดครอกแรกคลอดและหย่านม น้ำหนักแรกคลอด อัตราการตายแรกคลอด อัตราแม่มีอัตราการเจริญเติบโตของลูกสุกรดูนม น้ำหนักหย่านม และสัดส่วนของสุกรที่เลือดจาง โดยเฉลี่ยค่าเม็ดเลือดแดงอัดแน่นในแม่สุกรเป็น $33.7 \pm 2.7\%$ และในลูกสุกรเป็น $32.2 \pm 3.9\%$ ในขณะที่ค่าฮีโมโกลบินในแม่สุกรเป็น 11.3 ± 0.9 กรัม/ดล. และในลูกสุกรเป็น 10.8 ± 1.3 กรัม/ดล. สัดส่วนของแม่และลูกสุกรที่มีค่าฮีโมโกลบินต่ำกว่า 8 กรัม/ดล. (เลือดจาง) มีน้อยมากและไม่แตกต่างกันระหว่างกลุ่ม ไม่พบอุบัติการณ์ของอัมพาตหรือโรทูนทั้งในแม่และในลูกสุกร ค่าฮีโมโกลบิน และเม็ดเลือดแดงอัดแน่นในแม่และลูกสุกรมีความสัมพันธ์กันอย่างมีนัยสำคัญ จำนวนลูกสุกรมีชีวิตแรกคลอดต่อครอก น้ำหนักแรกคลอด และจำนวนลูกสุกรหย่านมต่อครอกไม่มีความแตกต่างกันระหว่างกลุ่ม สัดส่วนของลูกตายแรกคลอดและแม่มีสูงที่สุดในกลุ่มที่ไม่ได้รับการเสริมธาตุเหล็ก อัตราการเจริญเติบโตของสุกรในกลุ่มที่เสริมธาตุเหล็กไกลซีนคีเลตสูงกว่ากลุ่มที่ไม่ได้เสริมธาตุเหล็กไกลซีนคีเลตอย่างมีนัยสำคัญ การทดลองนี้แสดงให้เห็นว่าการเสริมธาตุเหล็กอินทรีย์ในอาหารแม่สุกรอาจมีผลดีต่ออัตราการเจริญเติบโตของลูกสุกร

คำสำคัญ : แม่สุกร ลูกสุกร เลือดจาง ไกลซีนคีเลต

Introduction

Iron is an essential element for blood production, oxygen conveyance and energy generation. Iron deficiency can cause stunted growth, reduced resistance against disease, decreased feed efficiency, inferior reproductive performance, anemia, diarrhea and, in some cases, piglets may die. Furthermore, it has been reported that iron deficiency increases the severity of some infectious agents that cause blood loss, such as *Trichuris suis* in pigs (Pederson et al., 2001).

It is well established that amino acids, such as histidine or glycine, significantly increase the efficiency of iron absorption (Ashmead, 2001^a; Jeppsen, 2001). It has been shown that a supplement of iron glycine chelete in pregnant women, for 13 weeks, resulted in fewer iron deficiency problems and increased haemoglobin levels

compared with supplements of ferrous sulfate (Szarfarc et al., 2001). Iron glycine chelete had a small molecule, stable against acidity in the stomach (Ashmead, 2001^b), able to transfer through the placenta to the fetuses (Michel, 1992; Vallet et al., 1996) whilst also increasing the iron concentration in the milk (Brady et al., 1978). Glycine chelete is mainly absorbed from the stomach and the duodenum (Pizarro et al., 2002). In many agricultural countries, iron chelete is added to food to prevent and reduce iron deficiency problems (Gibson, 1997).

In pigs, iron transport to the developing fetus during pregnancy, involves in part, uteroferrin, a secreted progesterone-induced protein from the uterus. A decrease in the synthesis of uteroferrin protein in late pregnancy is suggested to be partly responsible for neonatal piglets suffering from anemia (Michel et al., 1992). During

pregnancy, the level of serum iron in sows is lowest on day 80 of gestation, when the rate of transfer of iron to the developing fetuses is high, while fetal serum iron declines throughout gestation, reaching its lowest level on day 100 (Richards, 1999). Vallet et al. (2002) found that the haematocrit and fetal plasma iron, at 105 days of gestation in the pig, is positively correlated with fetal weight, as well as placental efficiency. During early pregnancy in pigs, increasing plasma iron concentrations has no effect on the uterine content of uteroferrin (Vallet et al., 2001). The effect of exogenous iron on the reproductive performance of the pig is still equivocal. Under farm conditions, it has been shown that a supplement of amino acid-chelated iron during the last 3 weeks of gestation did not significantly increase haemoglobin or haematocrit levels in sows (Egeli et al., 1998). In contrast, Guise and Penny (1990) demonstrated that an injection of iron (1600 mg) given to sows 3 weeks before farrowing, resulted in a slight increase in the number of piglets born alive/litter and a decreased number of dead piglets/litter. A supplement of amino acid chelated iron given in pig feed during late pregnancy needs to be investigated to obtain more information about its effect under farm conditions, the optimum time for iron supplementation and its impact on suckling piglets.

The present study was performed to elucidate the effect of 62.5 g/ton, iron glycine chelate supplement, given to sows for 2, 4, 6 or 8 weeks prior to farrowing, as well as during lactation, on both haematology and reproductive efficiency. The parameters measured included the haemoglobin and both haematocrit values found in sows and their piglets, their birth weight, stillbirth rate, growth rate of suckling piglets and the weaning weight of the piglets.

Materials and Methods

Experimental farm and general management

The experiment was conducted in a 600-sow herd in the central region of Thailand. The farm has 2 breeding units. Each unit contained of both gestation and farrowing

housing. During the gestation period, the sows were fed about 1.6 kg feed daily and during lactation fed to appetite. Water was provided ad libitum to all sows. On average, the lactation length was 31.6 ± 5.4 days. All sows included in the experiment were managed under normal farm management procedures and given the same nutrition. All the piglets were injected with 100 mg iron dextran within 3 days of birth. The experiment was carried out over a period of 4 months, from December 2002 to March 2003.

Experimental design

Sows in the gestation unit were assigned into 5 groups (Table 1). They were fed with a sow feed, which contained 3,200 cal DE/kg, 17% protein, 5% fat and 1% lysine. After blood samples were taken from the first group, the feed was supplemented with 62.5 g/ton of iron glycine chelate (Iron-G 100® 12.5% Ferrous iron and 16% Glycine). All sows in the herd consumed the same feed through gestation and through the lactation period. Sows that farrowed during the third, fifth, seventh and ninth weeks after the iron was added, were labeled as treatments 1, 2, 3 and 4, respectively (consumed iron glycine chelate for at least 2, 4, 6 and 8 weeks before farrowing, respectively). Blood and reproductive data were collected one week after the sows in each group farrowed.

Blood collection

Blood was collected from all sows and from 2 randomly selected piglets from every other litter. The blood was collected from the jugular vein of the sows and from the anterior vena cava of the piglets. The samples were kept in an EDTA tube at 4 °C and were sent to the laboratory of the Department of Physiology, Faculty of Veterinary Science, Chulalongkorn University within 24 hours of collection. Haemoglobin (Hb, g/dl), haematocrit (Hct, %) and the presence of eperythrozoonosis were studied. Hb was analyzed by the cyanomethaemoglobin colorimetric method. Hct was analyzed using micro-haematocrit centrifugation and a micro-haematocrit

reader. Eperythrozoonosis was investigated by a direct thin smear method on duplicate slides.

Reproductive performance monitored

Reproductive data at farrowing was recorded for all sows. The variables recorded included the total number of piglets born per litter (TB), the number of piglets born alive per litter (BA), the proportion stillborn in the litter (%), the proportion of mummified fetuses (%), the individual birth weights of the piglets (kg), the number of piglets at weaning, piglets weight at weaning and the growth rate of suckling piglets. Since cross fostering was performed during the trial, the growth rate of piglets for litters with or without cross fostering were also analyzed separately.

Statistical analyzes

Statistical analyzes were carried out using SAS (SAS, 1989). Analysis of variance was used to investigate continuous traits, including Hb and Hct in sows and piglets, TB, BA, stillborn (%), mummified fetuses (%), birth weight of the piglets, number of piglets at weaning, piglets weight at weaning and the growth rate of suckling piglets. These factors were tested for significance but only factors with a significance level of $p < 0.10$ remained in the final models. Statistical models for Hb and Hct included the effect of the treatment and the farrowing month. The model for birth weight included the effect of treatment and included TB as covariance. The model for growth rate and individual weaning weight, included the effect of treatment, the farrowing month and the lactation length. The model for litter size included the effect of treatment and parity (primiparous vs multiparous sows). Least-squares means were obtained for each class of effects and the combination of effects and were compared using t-tests.

A chi-square test was used to analyze proportional data i.e., proportion of anemic sows and piglets. Anemia was defined as sows or piglets with a Hb below 8 g/dl (Brady et al., 1978). Pearson's correlation was used to study the relationship between Hct or Hb and some continuous

reproductive traits as well as to study the correlation of sows Hb and Hct and piglets Hb and Hct.

Results

Haematology

Blood was successfully collected from 97 sows and 98 piglets. Ninety-three sows weaned their litters, while 4 sows were culled before weaning. On average, Hct was $33.7 \pm 2.7\%$ in sows and $32.2 \pm 3.9\%$ in piglets, while Hb was 11.3 ± 0.9 g/dl in sows and 10.8 ± 1.3 g/dl in piglets. No evidence of eperythrozoonosis was observed either sows or piglets.

Hct and Hb levels in sows and piglets, by group, are presented in Table 2. No statistical significant difference between the groups was found ($p > 0.05$). The proportion of sows with a Hb ≤ 8 g/dl was 0, 0, 7.1, 0 and 0 % in the control and treatments 1-4, respectively (no significance, $p > 0.05$). The proportion of piglets with a Hb ≤ 8 g/dl was 0, 0, 0, 0 and 7.1 % in the control and treatments 1-4, respectively (no significance, $p > 0.05$).

In spite of the iron dextran injection given to piglets, the Hct and Hb levels of sows and piglets were found to be significantly correlated (Table 3). Additionally, the correlations were stronger and more significant among the groups of piglets that had been injected with iron dextran (age > 3 days old) compared with piglets that had not yet been injected with iron dextran (age 1-2 days old) (Table 3). The Hct and Hb levels of the 2 piglets within a litter were also significantly correlated ($r = 0.50$, $p < 0.001$ and $r = 0.49$, $p < 0.001$, respectively).

Reproductive factors

Some reproductive traits measured are presented in Table 4. BA, piglet birth weights and the number of piglets at weaning did not differ significantly between the groups ($p > 0.05$). The control group had a larger TB than treatment 1, 3 and 4 ($p < 0.05$). The proportions of stillborn and mummified fetuses per litter were highest in the control group. All treatment groups had a significantly

Table 1 Concentration of iron glycine chelate supplement in feed and the time interval for iron chelate supplement in each group

Groups	Iron glycine chelate supplement (g/ton) ¹	Estimated dose of iron per sow per day during treatment(g/d) ²	The time for iron chelate supplementation before farrowing (weeks)	Approximate time for iron chelate supplement before blood samplings (weeks)
Control	0	0, 0	0	0
Treatment 1	62.5	0.1, 0.25	2	≥3
Treatment 2	62.5	0.1, 0.25	4	≥5
Treatment 3	62.5	0.1, 0.25	6	≥7
Treatment 4	62.5	0.1, 0.25	8	≥9

¹Concentration of ferrous iron from 500 ppm of Iron-G100®, which contained 12.5% ferrous iron and 16% glycine,

²doses of iron consumption per sow per day is based on a daily feed intake of 1.6 kg during gestation and 4 kg during lactation

Table 2 Number of sows and mean standard deviation of haematocrit (Hct) (%) and haemoglobin (Hb) (g/dl) values in sows and piglets, by groups

Groups	Sows			Piglets		
	N	Hct ¹	Hb ²	N	Hct	Hb
Control	21	35.0±2.1	11.7±0.7	21	33.9±2.5	11.3±0.9
Treatment 1	26	34.7±2.4	11.6±0.8	23	34.2±2.9	11.5±0.9
Treatment 2	13	33.0±2.0	11.1±0.6	16	29.1±3.2	9.8±1.1
Treatment 3	10	32.5±2.9	10.9±1.0	10	31.0±2.5	10.3±0.8
Treatment 4	27	32.5±2.7	10.8±0.9	28	31.7±4.8	10.6±1.5

¹Haematocrit (pack cell volume) normal range 32-50% (Fraser et al., 1991)

²Haemoglobin (g/dl) normal range 10-16 g/dl (Fraser et al., 1991)

Table 3 Correlations in haematocrit (Hct) and haemoglobin (Hb) between sows and piglets before and after iron injection

Sows	All piglets		Before iron injection		After iron injection	
	Hct	Hb	Hct	Hb	Hct	Hb
Hct	r=0.33*	r=0.34*	r=0.14 ^{ns}	r=0.14 ^{ns}	r=0.51**	r=0.51**
	(n=47)	(n=47)	(n=16)	(n=16)	(n=31)	(n=31)
Hb	r=0.32*	r=0.33*	r=0.13 ^{ns}	r=0.12 ^{ns}	r=0.52**	r=0.52**
	(n=47)	(n=47)	(n=16)	(n=16)	(n=31)	(n=31)

r = Pearson's correlation coefficient, n= number of observation, ns = no significance, * = significant difference at $p<0.05$,

** = significant difference at $p<0.01$

Table 4 Means \pm standard deviation and percentage of some reproductive traits by group

Reproductive performances	Control	Treatments			
		1	2	3	4
Number of litters	21	26	14	10	27
Total piglets born/litter	12.2 \pm 2.0 ^a	10.5 \pm 2.5 ^b	10.9 \pm 2.9	9.9 \pm 2.3 ^b	10.7 \pm 2.1 ^b
Piglets born alive/litter	11.3 \pm 2.0	10.1 \pm 2.1	10.3 \pm 2.5	9.8 \pm 2.5	10.7 \pm 2.1
Stillborn (%)	5.0 ^a	3.4 ^{ab}	4.4 ^{ab}	1.4 ^b	0 ^c
Mummified (%)	2.3 ^a	0.3 ^b	0.5 ^b	0 ^b	0 ^b
Individual birth weight (kg)	1.4 \pm 0.2	1.4 \pm 0.2	1.4 \pm 0.1	1.5 \pm 0.1	1.5 \pm 0.2
Lactation length (day)	36.8 \pm 3.8	29.7 \pm 7.3	32.0 \pm 2.5	33.6 \pm 2.3	28.5 \pm 1.2
Piglets weaned/litter	9.6 \pm 1.8	8.9 \pm 2.3	9.3 \pm 1.6	8.8 \pm 1.8	9.8 \pm 1.3
Weaning weight/piglet	5.5 \pm 0.6	4.8 \pm 0.5 ^a	5.6 \pm 0.5 ^b	5.6 \pm 0.3 ^b	5.3 \pm 0.6

Different letters within row indicated significant difference ($p < 0.05$)

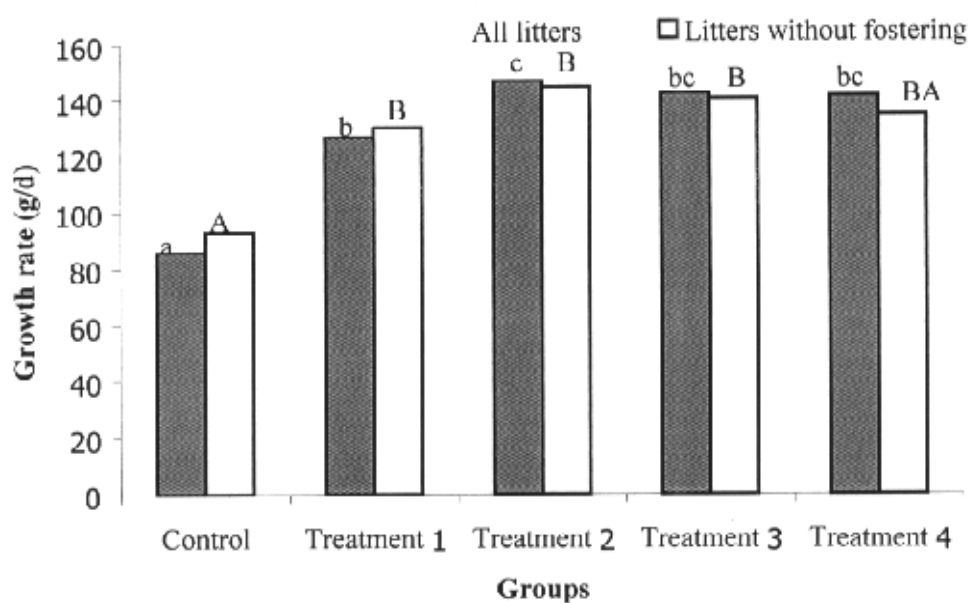


Fig. 1 A comparison of the growth rate (g/day) of suckling piglets (least-square means) between groups in all litters (93 litters, dark bar) and in litters without cross fostering (81 litters, white bar). One letter in common indicates no significant difference ($p > 0.05$) between bars of the same color.

lower percentage of mummified fetuses per litter compared with the control group ($p < 0.05$). Treatment 4 had a lower percentage of stillborn piglets per litter than the controls and treatments 1 and 2 ($p < 0.05$). The growth rate of suckling piglets in all the treatment groups was significantly faster than the control group (Fig. 1). Excluding the litters where cross fostering had occurred (14%), the piglets in treatments 1 to 3 still had a significantly faster growth rate than the control group (Fig. 1). Treatments 2 and 3 had a higher weaning weight than treatment 1 ($p < 0.05$).

Discussion

The present study was performed to investigate whether or not, iron glycine chelate given to sows in late pregnancy could enhance the reproductive performance of sows as well as benefit their piglets. Earlier studies had been performed for this purpose but the results are still equivocal (Brady et al., 1978; Guise and Penny, 1990; Egeli et al., 1998; Vallet et al., 2001). We demonstrated that both Hb and Hct were not affected by adding a 62.5 g/ton of iron glycine chelate to the sow's diet during late pregnancy. In herds with evidence of eperythrozoonosis, Virakul et al. (2002) reported that an iron chelate supplement given for 2 months before farrowing, resulted in a significant reduction in the proportion of sows suffering from anemia. In herds where the present study was conducted, no evidence of Eperythrozoonosis was observed and the sows in the control group had a relatively good reproductive performance (Table 4). Guise and Penny (1990) found that iron injection (1600 mg) given 3 weeks before farrowing gave a small, but not significant, improvement in some reproductive traits, such as an increase of 0.2 piglets born alive/ litter, a decrease in number of dead piglets/litter, an increase of 0.13 kg body weight at weaning and a decrease in the weaning to service interval of 0.28 days. Brady et al. (1978) found that a supplement of 8.5 g of amino acid chelate iron given daily, for 3 weeks before farrowing failed to improve the birth weights of the piglets nor the Hb value which

did not differ significantly between sows, with and without, iron supplementation. However, sows with an iron supplement had a significantly higher milk iron concentration during the 2nd and 3rd weeks of lactation, than sows without iron supplementation. It was proposed that iron chelate in a sow's diet might effectively prevent anemia in the offspring that can develop after the first week of lactation.

Earlier studies had indicated that overcrowding in the sow's uterine horn, negatively influences erythropoiesis and that iron is an essential element for efficient erythropoiesis (Vallet, 2000). A decrease in fetal erythropoiesis influences fetal health and survivability. An increase in iron delivery to the swine conceptus might therefore improve erythropoiesis and might have some beneficial effects on the offspring. In the present study, the Hct and Hb levels of sows did not increase after iron glycine chelate supplementation. This might be due to the homeostatic mechanisms that regulate plasma iron levels in relation to their control by the metabolism of the liver and other tissues (Huebers and Finch, 1987; Theil, 1987; Calvo et al., 1989). It has been shown that, in sows, there is mobilization of iron from its storage sites up to the second month of gestation, no appreciable decrease during the second half of pregnancy and no appreciable mobilization of the iron stores during the lactation period (Calvo et al., 1989). Furthermore, it was found that there is a positive correlation between the mean values of plasma ferritin concentration in piglets and the levels of plasma ferritin in their mothers (Calvo et al., 1989). In the present study, significant correlation of both Hb and Hct between piglets and their mothers was also observed. Apart of these mechanisms, the transfer of iron to the fetus is also limited by gut uptake and the secretion rate of uteroferrin by the uterus (Vallet et al., 1996, 1998). Vallet et al. (2001) found that increased plasma levels of iron during the early stages of pregnancy did not influence uterine secretion of uteroferrin.

In humans, iron chelate has been used in many countries that have a problem with iron deficiency (Gibson,

1997). It has been well established that ferrous iron in chelate form had a higher absorption rate than ferrous sulfate (Brady et al., 1978; Szarfarc et al., 2001; Pizarro et al., 2002). Supplements of iron chelate in pig feed might provide benefits for pig farms with evidence of iron deficiency. Under tropical climates, *eperythrozoön* is an importance parasite that causes anemia in sows. It should also be noted that the suckling piglets in the present study had a relatively slow growth rate, which may indicate poor management, subclinical health problems or poor milk production by the sows. Repeated experiments in well managed herds might be performed in further studies.

Supplemental iron chelate in the sow's diet increases the concentration of iron in the sow's milk, particularly after the first week of lactation (Brady et al., 1978). In humans, it has been shown that low hemoglobin concentrations in young children can be improved by daily consumption of milk fortified with 3 mg/litter of iron glycine chelate (Iost et al., 1998). The present study demonstrated that although iron dextran was given to the piglets, a significantly positive correlation of both Hb and Hct levels of sows and piglets was still observed, particularly in piglets older than 3 days. This supports the proposition that a supplement of iron chelate in the sow's diet might have reduced the number of piglets suffering from anemia, reducing pre-weaning mortality and enhancing growth rate.

Acknowledgements

We would like to thank Mr. Wirat, the herd owner, who provided the animals, feed, stock men and the many facilities used in this study. The study was aided by Grand Siam Co., Ltd and we wish to thank Mr. Ninnart, Mr. Chanit and Mr. Kreatirat for their great contributions in handling animals during blood sampling and for taking care of the data. That was Recorded.

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