#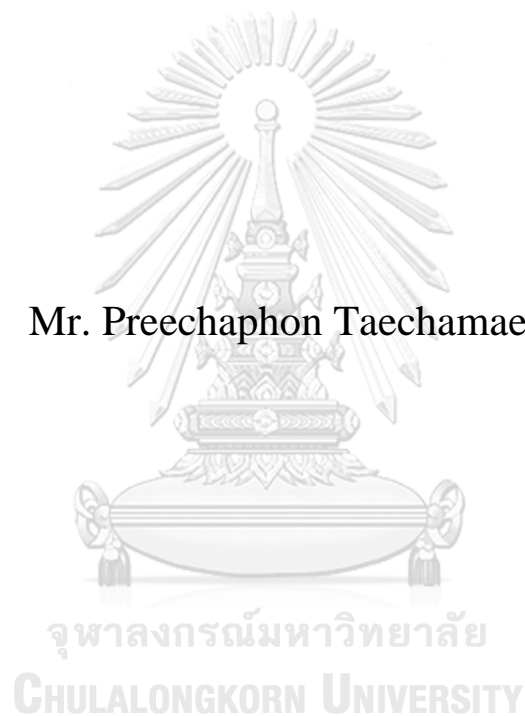 EFFECT OF A COMBINATION OF ALTRENOGEST AND DOUBLE PGF2alpha ADMINISTRATIONS ON FARROWING VARIATION, PIGLET'S PERFORMANCES AND COLOSTRUM IgG

Mr. Preechaphon Taechamaeteekul

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ผลของการใช้ฮอร์โมนอัลทรีโนเจสร่วมกับการฉีดโพสตาแกลนดินเอฟทูแอลฟาสองครั้งต่อความแปรปรวนของการคลอด สมรรถภาพของลูกสุกรและอิมมูโนกลอบูลินจีในน้ำนมเหลือง

นายปรีชาพล เตชะเมธีกุล

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรมหาบัณฑิต
สาขาวิชาวิทยาการสืบพันธุ์สัตว์ ภาควิชาสูติศาสตร์-เธนุเวชวิทยาและวิทยาการสืบพันธุ์
คณะสัตวแพทยศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย
ปีการศึกษา 2564

Thesis Title	EFFECT OF A COMBINATION OF ALTRENOGEST AND DOUBLE PGF2alpha ADMINISTRATIONS ON FARROWING VARIATION, PIGLET'S PERFORMANCES AND COLOSTRUM IgG
By	Mr. Preechaphon Taechamaeteekul
Field of Study	Theriogenology
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Accepted by the FACULTY OF VETERINARY SCIENCE, Chulalongkorn University in Partial Fulfillment of the Requirement for the Master of Science

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ปรีชาพล เตชะเมธีกุล : ผลของการใช้ฮอร์โมนอัลทรีโนเจสร่วมกับการฉีดโพสตาแกลนดินเอฟทูแอลฟาสองครั้งต่อความแปรปรวนของการคลอด สมรรถภาพของลูกสุกรและอิมมูโนกลอบูลินจีในน้ำนมเหลือง. (EFFECT OF A COMBINATION OF ALTRENOGEST AND DOUBLE PGF2alpha ADMINISTRATIONS ON FARROWING VARIATION, PIGLET'S PERFORMANCES AND COLOSTRUM IgG)
อ.ที่ปรึกษาหลัก : ศ. นสพ. ดร.เผด็จ ธรรมรักษ์

วัตถุประสงค์ของการศึกษาครั้งนี้เพื่อตรวจสอบผลของการใช้ฮอร์โมนอัลทรีโนเจสตั้งแต่วันที่ 109 ถึงวันที่ 112 ของการตั้งท้องร่วมกับการฉีดสารโพสตาแกลนดินเอฟทูแอลฟาที่บริเวณกล้ามเนื้อคอจำนวนสองครั้ง ณ วันที่ 113 ของการตั้งท้องต่อความแปรปรวนของวันในการคลอดของแม่สุกร รวมถึงศึกษาผลข้างเคียงของการทดลอง อาทิ น้ำนมเหลืองของแม่สุกร ปริมาณสารอิมมูโนโกลบูลินจีในน้ำนมเหลือง ลักษณะต่างๆ ของลูกสุกรแรกเกิด เป็นต้น การทดลองในครั้งนี้ใช้แม่สุกรจำนวน 193 ตัว โดยแม่สุกรทั้งหมดได้รับการจัดกลุ่มของแม่สุกรโดยแบ่งตามลำดับท้อง ได้แก่ กลุ่มควบคุมจำนวน 95 ตัว และกลุ่มทดลองจำนวน 98 ตัว แม่สุกรกลุ่มควบคุมจะปล่อยให้คลอดตามธรรมชาติ ส่วนแม่สุกรกลุ่มทดลองจะได้รับฮอร์โมนอัลทรีโนเจสปริมาณ 20 มิลลิกรัมต่อวันเป็นเวลา 4 วัน นับตั้งแต่วันที่ 109 ถึงวันที่ 112 ของการตั้งท้องและฉีดสารโพสตาแกลนดินเอฟทูแอลฟาที่กล้ามเนื้อบริเวณสันคอจำนวนสองเข็ม ณ วันที่ 113 ของการตั้งท้อง ข้อมูลต่างๆถูกบันทึก ได้แก่ น้ำหนักตัวของลูกสุกรแรกเกิดและเมื่อเวลาผ่านไป 24 ชั่วโมงหลังคลอดลูกสุกร จำนวนลูกสุกรทั้งหมดในกลุ่มควบคุมมีจำนวน 1,609 ตัว และกลุ่มทดลองจำนวน 1,707 ตัว ปริมาณการบริโภคน้ำนมเหลืองของลูกสุกร ปริมาณน้ำนมเหลืองที่ผลิตได้ของแม่สุกร ปริมาณสารอิมมูโนโกลบูลินจีในน้ำนมเหลือง ณ เวลา 0, 6 และ 24 ชั่วโมงหลังคลอด ปริมาณฮอร์โมนโปรเจสเตอโรนในซีรัมของแม่สุกรก่อนและหลังคลอด อัตราการรอดชีวิตของลูกสุกร ณ วันที่ 3 และ 7 หลังคลอด ผลของการศึกษาพบว่าค่าเฉลี่ยจำนวนลูกสุกรที่เกิดและจำนวนลูกสุกรที่มีชีวิตแรกคลอดเท่ากับ 17.0 ± 3.1 ตัว และ 15.4 ± 3.0 ตัว ตามลำดับ สัดส่วนของแม่สุกรที่คลอดก่อนกำหนด(ก่อนวันที่ 114 ของการตั้งท้อง)ในกลุ่มควบคุมสูงกว่ากลุ่มทดลอง (8.4% และ 2.0% ตามลำดับ, $P = 0.05$) และ สัดส่วนของแม่สุกรในกลุ่มทดลองจะคลอดในวันที่ 114 ของการตั้งท้องถึง 92.8% โดยสัดส่วนของแม่สุกรคลอดระหว่างเวลาทำงานในกลุ่มควบคุมต่ำกว่ากลุ่มทดลอง (50.5% และ 65.3% ตามลำดับ, $P = 0.038$) เปอร์เซ็นต์ของลูกสุกรตายแรกคลอดระหว่างกลุ่มควบคุมและกลุ่มทดลองไม่แตกต่างกันอย่างมีนัยสำคัญ (4.5% และ 4.6% ตามลำดับ, $P = 0.93$) ผลผลิตน้ำนมเหลืองของแม่สุกรระหว่างกลุ่มทดลองและกลุ่มควบคุมไม่แตกต่างกัน (5.28 ± 0.12 กิโลกรัม และ 5.52 ± 0.13 กิโลกรัม ตามลำดับ, $P = 0.174$) อย่างไรก็ตาม ปริมาณน้ำนมเหลืองที่ลูกสุกรกินได้ในกลุ่มทดลองต่ำกว่ากลุ่มควบคุม (357.0 ± 6.6 กรัม และ 381.2 ± 7.0 กรัม ตามลำดับ, $P = 0.012$) ปริมาณสารอิมมูโนโกลบูลินจีในน้ำนมเหลืองในกลุ่มควบคุมสูงกว่ากลุ่มทดลอง (41.2 ± 1.1 มิลลิกรัมต่อมิลลิลิตร และ 37.3 ± 1.0 มิลลิกรัมต่อมิลลิลิตร ตามลำดับ, $P = 0.013$) จากการศึกษาสามารถสรุปได้ว่า การใช้ฮอร์โมนอัลทรีโนเจสตั้งแต่วันที่ 109 ถึงวันที่ 112 ของการตั้งท้องร่วมกับการฉีดสารโพสตาแกลนดินเอฟทูแอลฟาที่กล้ามเนื้อบริเวณสันคอจำนวนสองเข็ม ณ วันที่ 113 ของการตั้งท้องสามารถลดอุบัติการณ์การคลอดก่อนกำหนดและสามารถลดความแปรปรวนของวันในการคลอดของแม่สุกรได้ โดยวิธีการดังกล่าวไม่ส่งผลต่อการเพิ่มอุบัติการณ์การตายแรกคลอดของลูกสุกร แต่อย่างไรก็ตาม ปริมาณการกินน้ำนมเหลืองของลูกสุกรและปริมาณสารอิมมูโนโกลบูลินจีในน้ำนมเหลืองของกลุ่มทดลองต่ำกว่ากลุ่มควบคุม ดังนั้นการพิจารณาการใช้ฮอร์โมนอัลทรีโนเจสตั้งแต่วันที่ 109 ถึงวันที่ 112 ของการตั้งท้องร่วมกับการฉีดสารโพสตาแกลนดินเอฟทูแอลฟาจำนวนสองเข็ม ณ วันที่ 113 ของการตั้งท้อง ควรพิจารณาถึงผลเสียที่อาจเกิดขึ้นกับผลผลิตโดยเฉพาะผลกระทบต่อคุณภาพและปริมาณของน้ำนมเหลือง รวมไปถึงการประยุกต์ใช้และเพิ่มการจัดการที่เหมาะสมเพื่อช่วยเหลือลูกสุกรอย่างใกล้ชิดเพื่อเลี่ยงผลเสียที่อาจเกิดขึ้นกับแม่และลูกสุกร

สาขาวิชา	วิทยาการสืบพันธุ์สัตว์	ลายมือชื่อนิสิต ....
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6370005831 : MAJOR THERIOGENOLOGY
KEYWORD: altrenogest, gestation length, progesterone, prostaglandin F2alpha, sows

Preechaphon Taechamaeteekul : EFFECT OF A COMBINATION OF ALTRENOGEST AND DOUBLE PGF2alpha ADMINISTRATIONS ON FARROWING VARIATION, PIGLET'S PERFORMANCES AND COLOSTRUM IgG. Advisor: Prof. Dr. PADET TUMMARUK

The aims of the present study were to investigate the effect of altrenogest treatment from 109 to 112 days of gestation in combination with double intramuscularly of PGF2alpha administrations at 113 days of gestation on the variation of farrowing in sows and its side effects on the sow colostrum yield, colostrum IgG, newborn piglet characteristics and piglet survival rate until seven days of postnatal life. In total, 193 sows were randomly allocated according to parity number into two groups, i.e. control (n = 95) and treatment (n = 98). The control sows were allowed to farrow naturally. The treatment sows were orally administered 20 mg per day of altrenogest for 4 days from 109 to 112 days of gestation and were administered PGF2alpha twice on day 113 of gestation. Individual body weight at birth and at 24 h after birth of piglets in all the litters were determined in both control (n = 1,609) and treatment (n = 1,707) groups. Colostrum consumption of all the piglets and colostrum yield of sows were estimated. Colostrum IgG at 0, 6 and 24 h postpartum and serum progesterone before and after farrowing were determined. Piglet survival rate until 3 days and 7 days of postnatal life were evaluated. On average, total number of piglets born and number of piglets born alive per litter were 17.0 ± 3.1 and 15.4 ± 3.0, respectively. The proportion of sows farrowed before 114 days of gestation in control was higher than treatment groups (8.4% and 2.0%, respectively, $P = 0.05$) and 92.8% of sows in the treatment group farrow on day 114 of gestation. The proportion of sows farrowed during working hours in control was lower than treatment groups (50.5% and 65.3%, respectively, $P = 0.038$). The percentage of stillborn piglets per litter did not differ significantly between in control and treatment groups (4.5% and 4.6%, respectively). Colostrum yield of sows did not differ between treatment and control group (5.28 ± 0.12 kg and 5.52 ± 0.13 kg, respectively, $P = 0.174$). However, colostrum intake of piglets in the treatment was lower than control groups (357.0 ± 6.6 g and 381.2 ± 7.0 g, respectively, $P = 0.012$). Colostrum IgG in the control was higher than treatment groups (41.2 ± 1.1 and 37.3 ± 1.0 mg per ml, respectively, $P = 0.013$). In conclusion, altrenogest treatment from 109 to 112 days and double PGF2alpha administrations on day 113 of gestation can reduce early parturition and can control gestation length in sows. No deleterious effect of this protocol on either the incidence of stillbirths or sow colostrum yield were detected. However, the piglet colostrum intake and colostrum IgG in the treatment groups were lower than control. Thus, intensive care of newborn piglets in the treatment group should be considered.

Field of Study:	Theriogenology	Student's Signature	
Academic Year:	2021	Advisor's Signature	

ACKNOWLEDGEMENTS

I would like to state my sincere gratitude to the following persons:

Asst. Prof. Dr. Suppawiwat Ponglowhapan, Head of the Department of Obstetrics, Gynaecology and Reproduction, Faculty of Veterinary Science, Chulalongkorn University for allowing me to gain such a great experience of my master's degree study in this warm and special place.

I would like to thank my respectful scientific advisor, Prof. Dr. Padet Tummaruk, who supported me in everything. He also scrutinized many versions of my scientific papers as well as thesis. He gave me an opportunity to make all the possibilities and introduce me to surpass my limit. Honestly, I really appreciate his guidance during my education.

My co-author, Dr. Kridtasak Sang-gassnee, my product specialist supervisor, for supporting me and offering encouragement to deal with pig production as well as giving a lot of clinical research idea. Thanks for being such a kind and enthusiastic person. All the research ideas have led me to gain such a great knowledge and experience.

My colleague, Dr. Natchanon Dumneim, thanks for helping me to prepare a professional manuscript draft and increase clarity of the manuscript for the readers. Moreover, he taught me to use many research tools such as Brix refractometer, ultrasonography, as well as a professional way to collect samples from sows and piglets.

The author also would like to thanks Chanchai Jamjang and Amornrat Tunboonjit who allowed me to perform experiment in the pig farm and permit to use a total of 193 sows being under their responsibility. Moreover, they provide me such a great food and a fantastic bedroom during my experimental period.

Special thanks to my great colleague, Alisa Pramul and her staffs at the barn, for being

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ABBREVIATIONS

°C	degree Celsius
µg	microgram
µl	microliter
BA	number of piglets born alive per litter
CL	corpus luteum
cm	centimeter
CORR	correlation
CV	coefficient of variation
ELISA	enzyme-linked immunosorbent assay
FSH	follicle stimulating hormone
g	gram
GLIMMIX	generalized linear mixed model
GLM	generalized linear model
h	hour
IU	international unit
kg	kilogram
LH	luteinizing hormone
LSD	least significant difference
M	molar
Mcal	megacalories
MF	number of mummified fetuses per litter
mg	milligram
min	minute
MIXED	mixed effect model
ml	milliliter
nm	nanometer
pg per ml	picogram per milliliter
PGF2alpha	prostaglandin F2alpha
SAS	statistical analysis system
SB	number of stillborn piglets per litter
SEM	standard error of the mean
TB	total number of piglets born per litter
USA	United States of America

CHAPTER I

INTRODUCTION

Importance and rationale

In the current swine production farming, advanced genetic selection, nutritional management, housing and disease prevention have improved dramatically in sows industry today (Kraeling and Webel, 2015; Thongkhuy et al., 2020). To increase the efficiency of management in modern genetic pigs, improvement of parturition control program have been developed for decades (Kirkwood et al., 1985; Vanderhaeghe et al., 2011; Gaggini et al., 2013; Taechamaeteekul et al., 2022). Generally, the average gestation length in sows varied among herds from 114-117 days and can vary among individual sows from 106 to 125 days (Sasaki and Koketsu, 2007; Tospitakkul et al., 2019; Pietruszka et al., 2020). Vanderhaeghe et al. (2011) found that 10% of sows farrowed before 114 days of gestation and 25% of sows were farrowed after 116 days of gestation. A previous study found that early parturition sows involve with an increase of the incidence of stillbirth rate (Rydhmer et al., 2008) and a decrease of piglet birth weight (Vanderhaeghe et al., 2011). Moreover, a previous study also found that the early parturition sows were correlated with the decreasing of milk production and changing in milk quality (Jackson et al., 1995). This negative effect of early parturition can lead to increase the proportion of the pre-weaning mortality rate in piglet (Canario et al., 2006; Wolf et al., 2008). Thus, to avoid these effects, control of parturition time in swine herd can improve the efficacy of farrowing supervision, cross-fostering, and care of newborn piglets. In addition, it may also reduce the difference in age and body weight at weaning of piglets and, hence, promote management and feeding strategies (Martel et al., 2008).

To perform synchronized farrowing in sow, altrenogest have been applied in previous studies (Kirkwood et al., 1985; Guthrie et al., 1987). Prevention of early parturition has been demonstrated by using altrenogest for 3 consecutive days during

the last period of gestation (Vanderhaeghe et al., 2011). Vanderhaeghe et al. (2011) reported that the administration of altrenogest in late gestation is an effective and safe method for avoiding early parturition. Moreover, altrenogest treatment does not affect the piglet birth weight and neonatal piglet survival (Gaggini et al., 2013).

Prostaglandin F2alpha (PGF2alpha) is widely used for induction of parturition in sows (Boonraungrod et al., 2018; Tospitakkul et al., 2019). For more effective to reduces variability in gestation length, double administrations of PGF2alpha were applied to induce farrowing (Tospitakkul et al., 2019). A previous study has shown that 100% of sows with double administration of PGF2alpha farrowed at day 115 of gestation, while 71.9% of sows with single administration of PGF2alpha farrowed at day 115 of gestation (Tospitakkul et al., 2019). Moreover, in herds with natural farrowing were farrowed only 8.3% (Tospitakkul et al., 2019). The number of dead born piglets, birth interval, piglet birth weight and colostrum yield did not affect by the induction of farrowing by using double administration of PGF2alpha (Tospitakkul et al., 2019). However, no study investigated the effect of using altrenogest administration during late gestation in combination with double administration of PGF2alpha in a large number of sows to synchronize the onset of farrowing before. Thus, the present study intends to investigate whether orally altrenogest administration and double administration of PGF2alpha could minimize the variation of gestation length in sows. Additionally, the effects of synchronized farrowing on the colostrum yield and piglet performances were also investigated.

Objectives of the study

1. To investigate the effect of altrenogest treatment during late gestation in combination with double administrations of PGF2alpha on the variation of farrowing in sows
2. To investigate the effect of altrenogest in combination with double administrations of PGF2alpha on the sow colostrum yield and newborn piglet characteristics

Expected output

1. Altrenogest treatment for prolonging gestation length combine with the induction of parturition by using double administrations of PGF2alpha can reduce the variation of gestation length and increase the proportion of sows that farrowed between 114 and 116 days of gestation

2. A combination of altrenogest and double administrations of PG2alpha treatment will not affect the piglet's performances and colostrum yield

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CHAPTER II

LITERATURE REVIEW

Gestation length in sow

Normal gestation length of sow averages 114 to 117 days. However, individual variation of the gestation length among sows within herd can be varied from 106-125 days (Sasaki and Koketsu, 2007; Tospitakkul et al., 2019; Pietruszka et al., 2020). Likewise, Vanderhaeghe et al. (2011) found that 10% of parturition sows were farrowed before 114 days and 25% of sows farrowed after 116 days of gestation. In Thailand, the gestation length of sows in a commercial herd averages 114.8 ± 1.8 days and 35.1% of sows had gestation length more than 116 days, while 22.5% farrowed before 114 days of gestation (Tospitakkul et al., 2019). In our previous study, Taechamaeteekul et al. (2022) found that 17.9% of sows farrowed naturally do not farrow within an optimal gestation length (i.e. between 114-117 days of gestation). These data indicated that the incidence of sows farrowed outside an optimal period can be detected in one from every five sows that farrow naturally. The variation of gestation length depends on many factors, including parity number of sows, litter size, season, and genetics (Rydhmer et al., 2008).

Furthermore, problems with colostrum milk composition and colostrum intake can be found in sows that had early parturition (Jackson et al., 1995). Average birth weight of the piglets, pre-weaning mortality and piglet growth rate during suckling are also associated with the gestation length in sows (Knol et al., 2002; Rydhmer et al., 2008). Rydhmer et al. (2008) found that sows with early parturition had a higher number of stillbirths and lower piglet birth weight compared to sow with a normal gestation length (i.e. 114-117 days). Sows that farrowed naturally did not farrow during the working hours. Thus, this event led to difficulty to perform farrowing supervision effectively (Tospitakkul et al., 2019). The previous study demonstrated

that 47.5% of sows without induction were farrowed during working time (i.e. 0700–1700 h) under commercial swine (Boonraungrod et al., 2018).

Physiology of hormone in non-pregnant and pregnant sows

In early pregnancy gilts, peripheral progesterone concentration averaged 24.87 ± 4.7 ng per ml at day 11 and slightly decline to 13.70 ± 3.04 ng per ml around day 21 of gestation (Haen et al., 2020). The existence of accessory corpus luteum on the ovaries increase progesterone concentration for pregnancy maintenance (Haen et al., 2020). In late gestation, progesterone concentration was stable around 8-10 ng per ml at day 90-112 of gestation (Killian et al., 1973). Until day 113-115 of gestation, the progesterone concentration decline to 5.5 ng per ml and decrease rapidly to less than 1 ng per ml at prepartum period (Killian et al., 1973).

In pigs, progesterone from the corpus luteum is important to maintain term of pregnancy. Moreover, when fetal cortisol is increased, parturition has not occurred (Randall, 1990). Parturition is occurred by cortisol which increased levels in the fetal plasma, but the pattern concentrations of fetal cortisol is different in each piglet (Langendijk and Plush, 2019). This can be assumed that the increase of fetal cortisol results in an increase maternal blood estradiol and PGF2alpha metabolites and a reduction in progesterone. The prepartum decrease in serum progesterone happens together with the first increase in PGF2alpha metabolites.

Altrenogest

Altrenogest is a synthetic progesterone which produced from the C19-steroid nortestosterone (Machnik et al., 2007). Altrenogest has ability to bind with progesterone receptors which located in the hypothalamus and pituitary gland. Thus, this binding effect can inhibit the releasing of luteinizing hormone (LH) and follicle-stimulating hormone (FSH) (dos Santos et al., 2004). This mechanism led to poor

development of oxytocin receptors because of lack of steroid hormones (Grazzini et al., 1998). But this blocking of the oxytocin receptor does not prevent luteolysis, while only the extension of gestation length affected by altrenogest. (Guthrie et al., 1987).

Altrenogest was permitted for use in gilts and sows by the U.S. Food and Drug Administration in 2003. Xiao et al. (2019) found that the mean peak time is 1.96 ± 1.45 h with the mean concentration of 66.16 ± 19.94 ng per ml. The elimination half-life and mean residence time are 7.24h and 9.47h, respectively (Xiao et al., 2019). After 24 h, the mean plasma altrenogest concentrations decreased to 5.01 ng per ml (Xiao et al., 2019).

Effects of altrenogest in controlling of parturition

In previous study, the using altrenogest to extend gestation length is an interesting method to prevent early parturition in modern swine herds (Foisnet et al., 2010; Vanderhaeghe et al., 2011; Gaggini et al., 2013). Gaggini et al. (2013) demonstrated that altrenogest treatment is an effective method to prevent early parturition in multiparous sows and resulted in heavier piglets at birth. Moreover, altrenogest orally in delays gestation does not affect litter weight gain and quantity of colostrum (Foisnet et al., 2010). Vanderhaeghe et al. (2011) investigated that the administration of altrenogest from 110-112 days of gestation is an effective and safe method for avoiding early parturition in sows. Moreover, altrenogest treatment from 111-113 days of gestation does not affect the piglet birth weight and neonatal piglet survival (Gaggini et al., 2013). However, altrenogest treatment until 113, 114 and 115 days of gestation has been found to increase the incidence of stillbirths (Taechamaeteekul et al., 2022). Moreover, progesterone withdrawal time is necessary because its effect involves with delayed prepartum peaks of prolactin (Foisnet et al., 2010).

The role of PGF2alpha in controlling parturition in pig

In sows, a significant regulator of corpora luteal (CL) function, uterine contractility, embryo attachment, and ovulation is PGF2alpha. PGF2alpha is substances that well known to use for the induction of farrowing (De Rensis et al., 2012). Besides, PGF2alpha stimulate smooth muscle to contraction, myometrial contractions and uterine expulsion of remaining products from parturition (Maneetong et al., 2021).

In general, PGF2alpha is commonly known as the inducing parturition substance in sows by administration of single dose of PGF2alpha via intramuscular route (De Rensis et al., 2012). Most studies found that 80-90% of sow farrow within 36 h after intramuscular injection of PGF2alpha (De Rensis et al., 2012; Tospitakkul et al., 2019). But sometimes failure of a single administration of PGF2alpha can be found due to the non-terminal luteolysis effect (Tospitakkul et al., 2019). Thus, the idea of administered of PGF2alpha twice with a 6 h interval ("double-dose") has been raised (Tospitakkul et al., 2019). A previous study has shown that sows treated with double PGF2alpha administered farrowed at day 115 of gestation up to 100%, while this evidence could occur in only 71.9% of the sows treated with a single administration of PGF2alpha (Tospitakkul et al., 2019). Moreover, reproductive performance (i.e. the incidence of low piglet birth weight, stillbirth, and mummified fetus) and colostrum yield are not compromised by the induction of farrowing after 114 days of gestation (Tospitakkul et al., 2019). The sows farrowed after double administration of PGF2alpha within 32 h (i.e. 24 h after the first injection of PGF2alpha and 8 h of the working hour, i.e. 0700 to 1700 h) (Tospitakkul et al., 2019).

Colostrum quantity and quality

Prolactin, estrogen and relaxin were important hormones to produce colostrum during pregnancy, especially three days before parturition (Geisert et al., 2020). In

swine, onset of lactogenesis is involved with preparturient decline in circulating progesterone (Geisert et al., 2020). Actually, mammogenesis in swine started at 85–109 days of gestation (Ji et al., 2006). Colostrum is significantly affecting to the survival rate of suckling piglets by giving energy for growth, thermoregulation and immunoglobins for disease resistance (Muns et al., 2016; Nuntapaitoon et al., 2019). Immunoglobulins such as IgA, IgG and IgM are important for piglets to prevent disease and reduce mortality (Nuntapaitoon, 2022). IgG concentration in colostrum could be varied from 20.0-176.0 mg per ml (Foisnet et al., 2010; Bovey et al., 2014). Moreover, IgG can decrease rapidly up to 80% at first 6 h after the onset of parturition (Markowska et al., 2010).

CHAPTER III

MATERIALS AND METHODS

Ethical permission

The study protocol and all experimental procedure in the current study followed the guidelines of the Ethical Principles and Guidelines for the Use of Animals for Scientific Purposes by the National Research Council of Thailand. Experimental design was approved by the Institutional Animal care and Use Committee (IACUC) in accordance with the university regulations and policies governing the care and use of experimental animals (Approval number 2131015).

Experimental design

The experiment was conducted in a commercial swine herd in the north-eastern part of Thailand to investigate the effect of altrenogest treatment during late gestation in combination with double administrations of PGF2alpha on the variation of farrowing in sows, colostrum milk, progesterone profiles before parturition and newborn piglet characteristics. Almost 193 crossbred Landrace × Yorkshire sows and 3,316 piglets were included in the experiment. Sows were classified into two group, i.e. control and treatment group. Sows in treatment group were orally administered 20 mg per day of altrenogest (Regumate®, Merck Animal Health, NJ, USA) for four days, from 109-112 days of gestation. After that, sows were intramuscularly administered PGF2alpha (185 µg cloprostenol sodium, Planate®, Merck Animal Health, NJ, USA) twice within a 6 h interval at 0800 h and 1400 h at 113 days of gestation. Blood samples (7-10 ml) were collected from sows via external jugular vein or ear vein at 113 days of gestation and at 1 h after the onset of parturition. The blood samples were centrifuged for 10 min at 2600×g to extract serum. The serum was collected and kept in micropipette tube at -20 °C until analyses. Colostrum samples

were pool collected manually from functional teats at 0, 6 and 24 h after the onset of farrowing. Colostrum samples at 0 h were kept in a clean bottle (10 ml) and were stored on ice in a Styrofoam box (4.0 °C) during the collection process and the samples were kept at -20 °C until IgG analyses using ELISA method. Moreover, colostrum IgG were repeated measurements at 0, 6 and 24 hours after onset parturition by using Brix refractometer (Pocket PAL-1 refractometer, Atago, Tokyo, Japan). Other piglets' characteristics including the total number of piglets born per litter (TB), number of piglets born alive per litter (BA), number of stillborn piglets per litter (SB), number of mummified fetuses per litter (MF), individual body weight at birth and 24 h after birth, piglet survival at 3 and 7 days after farrowed. Moreover, farrowing duration, duration of the first administration of PGF2alpha to farrowing and backfat thickness at 109 days of gestation were recorded and compared between groups.

Animals

The present study was conducted in a commercial swine herd in the north-eastern part of Thailand from September to November 2021. In total, 193 Landrace x Yorkshire crossbred sows with parity numbers 3.8 ± 2.4 (range: 1-8) were included in the experiment (Table 1). Gestation length was defined as the interval from the first insemination performed at the onset of estrus until farrowing. Sows were classified according to their parity number into three groups: 1 (n = 57), 2–4 (n = 64) and 5–8 (n = 72). The sows were randomly allocated according to parity number into two groups, i.e. control (n = 95) and treatment (n = 98). The control sows were allowed to farrow naturally. Sows in the treatment group were orally administered 20 mg per day of altrenogest (Regumate®, Merck Animal Health, NJ, USA) for four days, starting one day after the animal entered the farrowing house from 109 to 112 days of gestation. The altrenogest was orally administered to each individual sow using a drenching gun before the morning meal (0830 h). Additionally, the sows were intramuscularly administered PGF2alpha (185 µg cloprostenol sodium, Planate®, Merck Animal Health, NJ, USA) twice within a 6-hour interval at 0800 h and 1400 h at 113 days of

gestation. Individual body weight at birth and 24 h after birth of piglets in all litters were determined in both control (n = 1,609) and treatment (n = 1,707) groups. Colostrum consumption of all piglets and colostrum yield of sows were estimated according to an equation formulated by Theil et al. (2014). An estimated colostrum IgG at 0, 6 and 24 h postpartum was determined using Brix refractometer and colostrum IgG at 0 h postpartum was also determined by using ELISA. Serum progesterone before and after farrowing was also determined. Piglet survival rate at three and seven days of postnatal life was evaluated.

General management

The gestating sows were kept in an evaporative cooling system. The temperatures and humidity inside the barn during the experimental period were 27.7 ± 0.5 °C (range: 26.8–28.5 °C) and 77.3 ± 3.5% (range: 73–84%), respectively. The sows were kept in 0.5 × 2.0-m stalls with a concrete slatted floor. Gestating sows were fed 3.8–4.2 kg daily in two meals (3.2 Mcal of net energy and 15.0% crude protein), while gestating gilts were fed 3.0–3.2 kg per day. Gestating sows and gilts entered the farrowing house on the same weekday (Tuesday) at about seven days before the expected date of farrowing. During lactation, sows and their piglets were housed in individual farrowing pens and the sows were kept in a farrowing crate in the middle of the pen. The lactating sows were fed twice daily (0800 h and 1500 h) with a total amount of feed of 5.0–6.0 kg per day. The lactation diet contained 3.2 Mcal of net energy and 18.0% crude protein. Water was provided *ad libitum* via a drinking nipple. The lactation length averaged 29.5 ± 2.6 days (range: 24–35 days). The backfat thickness of sows was measured via A-mode ultrasonography (Renco Lean-Meater®, Minneapolis, MN, USA) at 109 days of gestation. Measurements were taken at the level of the last rib at 6–8 cm from the midline, on both sides of the sows. The average of the left and the right sides was calculated. The farrowing process was carefully monitored for 24 h daily by the research team and stock persons. Farrowing assistance was performed only when dystocia was clearly identified. Farrowing assistance was performed when an interval of 60 min elapsed from the birth of the

previous piglet, or when the sow showed intermittent straining accompanied by paddling of the legs or when the sow expelled small quantities of fetal fluid together with marked tail switching for more than 60 min without any piglet being born. Birth assistance included manual extraction of the piglets and intramuscular administration of 20 IU oxytocin (CP-CIN20, L.B.S. Laboratory Ltd., Bangkok, Thailand). The incidence of birth assistance was 8.4% (n = 8) and 11.2% (n = 11) in control and treatment groups, respectively. At the end of the farrowing process, all sows were treated with antibiotics (10 mg per kg of enrofloxacin, 100 mg per ml, BIC Chemical Co., Ltd., Nakhon Pathom, Thailand) and an antipyretic drug (2 mg per kg of tolfenamic acid, 40 mg per ml, Tolfedine® CS, Vetoquinol S.A., France). The first administration of tolfenamic acid and antibiotic drug was given at 1 h after farrowing and repeated once daily for three consecutive days. During lactation, sows were fed twice daily with a lactation diet to meet or exceed their nutritional requirements (NRC 2012). After farrowing, the amount of feed offered to sows increased daily, until 7 kg was reached after one week of lactation. Sows and piglets had *ad libitum* access to water by one nipple for the sow and one nipple for the piglets. Routine procedures performed on piglets included weighing, tail docking and 1 ml (200 mg) iron supplement administered intramuscularly (Ferron®, TP-drug Laboratories Co. Ltd., Bangkok, Thailand) on the third day of life. Piglets were orally administered a coccidiocide (Toltrazuril, 50 mg per ml, 20 mg per kg, Baycox 5%®, Bayer Animal Health GmbH, Leverkusen, Germany) on the third day of life.

Data collections

Data on the date when the sow entered the farrowing house and started altrenogest supplementation, the last day of altrenogest treatment, date and time when sows were administered PGF2alpha, and the farrowing date were recorded for each individual sow. The time when the first piglet was delivered was recorded and defined as the onset of parturition. The onset of parturition was classified into two groups according to working hours and defined as '1' when the sows farrowed from 0700 h

to 1700 h and as '0' when the sows farrowed from 1701 h to 0659 h. The parturition process of each sow was observed for 24 h by the research team. Sows were disturbed as little as possible during parturition. The time intervals (h) from the last altrenogest treatment to the onset of farrowing and from the first PGF2alpha treatment to the onset of farrowing were calculated. Reproductive data collected included the total number of piglets born per litter, the number of piglets born alive per litter, the percentage of mummified fetuses, and the stillborn piglets per litter. Body weight at birth and at 24 h after birth of all piglets in the litters in both control (95 litters, 1,609 piglets) and treatment (98 litters, 1,707 piglets) groups were measured using a digital scale (SDS® IDS701-CSERIES, SDS Digital Scale Co. Ltd., Yangzhou, China). Litter birth weight was calculated by summing the individual piglet birth weights. The variation in birth weight within the litter was defined as the coefficient of variation (CV) of the body weight at birth of the piglets within the litter. The proportion of live-born piglets with a body weight at birth of <1.0 kg was calculated. The colostrum intake of the piglets was estimated (Theil et al., 2014). Colostrum yield of sows was calculated by summing the colostrum intake of all piglets within the litter. A Brix refractometer (Pocket PAL-1 refractometer, Atago, Tokyo, Japan) was used to estimate immunoglobulin G (IgG) concentration in the sow colostrum at 0, 6 and 24 h after the onset of parturition (Hasan et al., 2016). The Brix refractometer analyses were determined in triplicate samples. The colostrum sample was manually collected within 5 min after the first piglet was delivered, immediately placed in the prism well of the refractometer, and the result recorded.

Blood collection and serum progesterone assay

Serum concentrations of progesterone were analysed from blood samples which were collected from sows at 113 days of gestation and at 1 h after the onset of parturition. Blood samples (7-10 ml) were collected from sows via external jugular vein or ear vein and kept in plain tubes. The samples were kept in Styrofoam box with an ice pack (4 °C) during the blood collection process. Thereafter, the blood samples were centrifuged for 10 min at 2,600×g to extract serum. The serum was collected and

kept in a micropipette tube at -20 °C until analyses. The progesterone concentrations were analysed by using ELISA (ARBOR assays Inc., Ann Arbor, MI, USA) according to Tummaruk et al. (2018). Briefly, the ELISA materials consisted of a reagent and a solid phase high-binding clear microplate. The microplate was coated with goat anti-mouse IgG 0.01 mg per ml (cat. #A008 10 mg, ARBOR assays Inc., MI, USA). The standard progesterone hormone (4.0 ng per ml) was added into the well. Two-fold dilution was performed to obtain standard progesterone concentrations of 200.0, 100.0, 50.0, 25.0, 12.5, 6.25, 3.12, 1.56 and 0.78 pg per well. A 50 µl of standard and samples (dilute 1:30) were pipetted into the microplate, in duplicate. Progesterone-HRP (horseradish peroxidase) (25 µl) and progesterone antibody (25 µl) (kindly provided by J.L. Brown, Smithsonian Conservation Biology Institute, VA, USA.) were added to all tubes. The progesterone antibody was added to all tubes except the blank well. The plate was covered with plastic sheet and shake for 2 h at room temperature (25 °C). The plate was washed 5 times before TMB peroxidase substrate (3,3´,5,5´-tetramethylbenzidine, 100 µl) was added. After 15 min, 50 µl stop solution (1N HCl) was added. Optical density was determined by using ELISA reader at 450 nm. Assay sensitivity, intra- and inter-assay coefficient of variance were 0.06 ng per ml, 1.7% and 2.1%, respectively.

Colostrum collection and determination of IgG concentrations

In total, 193 colostrum samples were collected. Pool colostrum samples were collected manually from functional teats at 0, 6 and 24 h after the onset of farrowing. Colostrum samples at 0 h were kept in a clean bottle (10 ml) and were stored on ice in a Styrofoam box (4 °C) during the collection process and the samples were kept at -20 °C until analyses. Moreover, colostrum samples were also collected at 6 and 24 hours after parturition to determine IgG concentration using Brix refractometer. In some sows, oxytocin (0.3 ml, 10 IU per ml, Bimeda-MTC Animal health Inc./Sante Animale Inc., Ontario, Canada) was administered intramuscularly for colostrum

sampling. The colostrum samples were centrifuged at 15,000xg for 20 min at 4 °C (Centrifuge 5810 R, Eppendor AG, Hamburg, Germany). Thereafter, the fat part was removed, and the remaining liquid collected. After that, the liquid part was diluted 1:500,000 with a sample conjugate diluent (50 mM Tris buffer, 0.14 M NaCl, 1% BSA and 0.05% Tween 20). The concentration of IgG was determined using an enzyme linked immunosorbent assays (ELISA) quantitation kit (Bethyl Laboratories Inc. Texas, USA). Briefly, 100 µl of anti-lgG antibody was added into each well and incubated at room temperature (25 °C) for 60 min and washed five times with washing buffer (50 mM Tris buffer, 0.14 M NaCl and 0.05% Tween 20) in washing machine (Tecan Sunrise™, Männedorf, Switzerland). Next, a 200 ul of blocking solution (50 mM Tris buffer, 0.14 M NaCl and 196BSA) was added into each well and incubated at room temperature (25 °C) for 30 min and washed five times with the washing buffer. Thereafter, a 100 µl, of standard solution of colostrum sample was added into each well and incubated at room temperature (25 °C) for 60 min and washed five times with washing buffer. The concentrations of lgG in the standard solutions were 500.0, 250.0, 125.0, 62.5, 31.25, 15.6 and 7.8 mg per ml. All the samples were analysed in duplicates. After that, a 100 µl of horseradish peroxidase and antibody were added. The plates were incubated for 60 min at room temperature and washed five times with the washing buffer. A 100 µl of TMB substrate solution was added into each well and incubated in the dark at room temperature. After 15 min, the colorimetric reaction produced a blue product, which turned yellow when the reaction was terminated by adding 100 µl of 0.18 M sulfuric acid. The absorbance was recorded at 450 nm using an ELISA plate reader (Tecan Sunrise™, Männedorf, Switzerland). The IgG concentrations in the colostrum samples were quantified by interpolating their absorbance from the standard curve generated in parallel with the colostrum samples. The inter- and intra-assay coefficients of variation were 2.2% and 2.7%, respectively.

Statistical analysis

The data were analysed using SAS, version 9.4 (SAS Inst. Cary, NC, USA). Descriptive statistics on reproductive traits and neonatal piglet characteristics were analysed using the MEANS procedure of SAS. The continuous data were presented as means, standard deviation (SD) and range, and categorical data were presented as percentages. Frequency analyses were carried out to determine the frequency distribution of gestation length and the onset of parturition in control and treatment groups. The proportion of sows farrowing earlier than 114 days and sows farrowing later than 116 days were compared between control and treatment groups using Fisher's exact test. In the treatment groups, the interval from the last altrenogest treatment (day 112) to the onset of farrowing and the interval from the first PGF2alpha (day 113) to the onset of farrowing were calculated in hours. The frequency distribution of the onset of parturition was analysed via frequency analysis. The onset of parturition was classified into two groups: working hours (0700–1700 h) and non-working hours (1701–0659 h). The proportion of sows farrowing during working hours was compared between control and treatment group using the Chi-square test. In addition, Pearson's correlation was determined to analyse the association among continuous traits including farrowing duration, TB, BA, MF, SB, backfat thickness, gestation length, Brix value at 0, 6 and 24 h postpartum, colostrum IgG and colostrum yield of sows.

Continuous data of sows including gestation length, backfat thickness at 109 days of gestation, TB, BA, MF, SB, Brix value at 0, 6 and 24 h postpartum, colostrum IgG and colostrum yield were analysed by using the general linear model (GLM) procedure of SAS. The statistical models included the effect of groups, parity number (1, 2–4 and 5–7), and interaction between group and parity. The least-square mean and standard error (SEM) were obtained from each class of factors and compared using the least significant difference (LSD) test.

Continuous piglet data, including body weight at birth, body weight 24 h after birth and colostrum intake were analysed using the general linear mixed model (MIXED) procedure of SAS. The statistical models included the fixed effect of

groups, parity number (1, 2–4 and 5–8), and interaction between group and parity. The TB was included in the statistical models as a co-variance. Sow identity was included in the model as a random effect. The proportion of piglets with a body weight at birth of less than 1.0 kg and the proportion of piglets that had inadequate colostrum intake (i.e. <300 g, Juthamanee and Tummaruk (2021)) were defined as a binomial trait (0, 1) and analysed using the generalised linear mixed model (GLIMMIX) procedure of SAS. Factors included in the statistical models were the fixed effect of groups, parity number (1, 2–4 and 5–8), and interaction between group and parity. TB was included in the statistical models as a co-variance. LSD and SEM were obtained from each class of factors and compared using the LSD test. For all analyses, a P value of less than 0.05 indicated statistical significance.

CHAPTER IV

RESULTS

Descriptive data

Descriptive statistics on reproductive traits of sows (n = 193) and their offspring (n = 3316) are presented in Table 1. Across groups, TB, BA, MF and SB were 17.0 ± 3.1 piglets per litter, 15.4 ± 3.0 piglets per litter, 4.7% and 4.6%, respectively (Table 1). The variation of gestation length in control and treatment groups are demonstrated in Figure 1. In the control group, gestation length varied from 112 to 118 days, while in the treatment group, the gestation length varied from 112 to 116 days (Figure 1). The proportion of sows farrowing before 114 days of gestation in the control group was higher than treatment group (8.4% and 2.0%, respectively, $P = 0.05$). Similarly, the proportion of sows farrowing after 116 days of gestation in the control group was higher than treatment group (8.4% and 0%, respectively, $P = 0.003$) (Figure 1). Indeed, 92.8% of sows in the treatment group farrowed at 114 days of gestation (Figure 1). On average, farrowing duration was 273.8 ± 131.8 min. Colostrum yield of sows averaged 5.44 ± 1.22 kg and varied among individual from 0.79 to 8.02 kg (Table 1). Gestation length of sows was positively correlated with the Brix value at 0 (r = 0.142, $P = 0.049$) and 6 hours (r = 0.277, $P < 0.001$) postpartum. Sow backfat thickness at 109 days of gestation was positively correlated with the Brix value at 0 h postpartum (r = 0.165, $P = 0.021$). The Brix value at 0 h postpartum was positively correlated with brix value at 6 h postpartum (r = 0.496, $P < 0.001$).

Table 1 Descriptive statistics on reproductive traits and piglet characteristics in crossbred Landrace × Yorkshire sows (n = 193) and their offspring (n = 3,316).

Variables	Mean ± SD	Range
Sows (n = 193)		
Parity number	3.8 ± 2.4	1–8
Gestation length (days)	114.6 ± 1.2	112–122
Total number of piglets born per litter (piglets)	17.0 ± 3.1	7–27
Number of piglets born alive per litter (piglets)	15.4 ± 3.0	3–23
Stillbirths (%)	4.6 ± 6.5	0–31.8
Mummified fetuses (%)	4.7 ± 7.5	0–57.1
Sows having ≥ 3 mummified fetuses per litter (%)	8.3	-
Backfat thickness at 109 days of gestation (mm)	20.8 ± 3.1	14–33.5
Farrowing duration (min)	273.8 ± 131.8	45–704
Colostrum yield (kg)	5.44 ± 1.22	0.79–8.02
IgG at 0 h postpartum (mg per ml)	39.1 ± 10.4	9.2 – 75.2
Brix index at 0 h (%)	27.9 ± 3.6	17.8–39.6
Brix index at 6 h (%)	24.1 ± 3.2	15.4–34.5
Brix index at 24 h (%)	18.5 ± 4.1	12.1–33.4
Number of piglets born alive at day 3 (piglets)	14.5 ± 2.8	2–22
Number of piglets born alive at day 7 (piglets)	14.4 ± 2.9	2–21
Live-born piglets (n = 3,316)		
Body weight at birth (kg)	1.28 ± 0.33	0.16–2.42
Body weight at 24 h after birth (kg)	1.35 ± 0.34	0.44–2.46
Piglets with body weight at birth of <1.0 kg (%)	21.5	-
Litter birth weight (kg)	19.7 ± 4.1	3.4–29.8
Variation in birth weight within litters (%)	21.2 ± 5.0	6.9–32.8
Colostrum intake (g)	371.2 ± 136.0	10.9–871.4

a.) Control (n = 95)

b.) Treatment (n = 98)
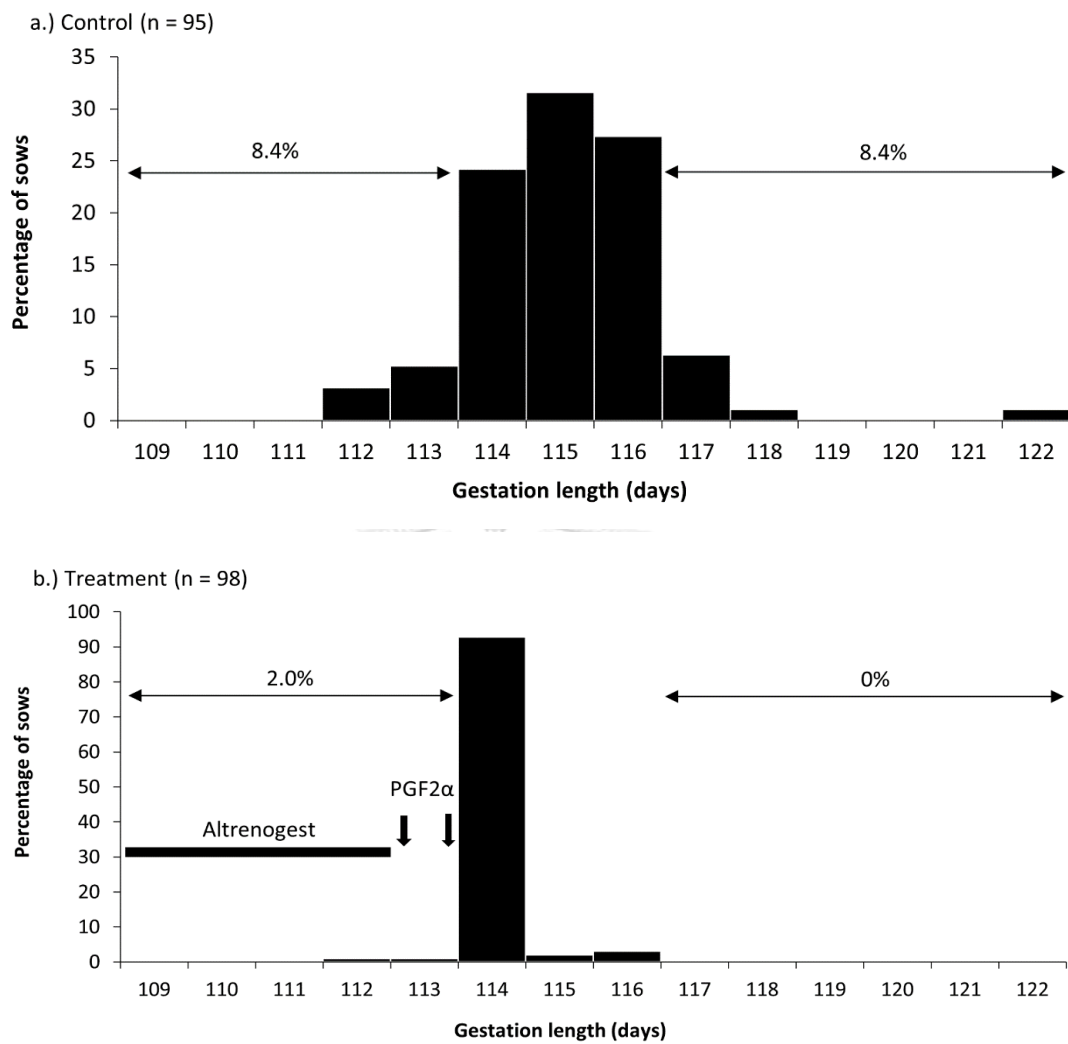
Figure 1 Frequency distribution of gestation length in sows that (a) farrowed naturally (control) compared with sows (b) treated with altrenogest from 109 to 112 days of gestation and double administration of PGF2alpha at 113 days of gestation (treatment).

Timing of parturition

The proportion of sows farrowed during working hours in the control group was lower than the treatment group (50.5% and 65.3%, respectively, $P = 0.038$) (Figure 2). In the treatment group, the interval from the last altrenogest treatment to the onset of farrowing was 51.6 ± 11.2 h (range: 6.4–101.9 h). The interval from the first PGF2alpha administration to the onset of farrowing were 28.1 ± 10.2 h (range: 7.9–78.0 h). One sow in the treatment group farrowed at 6.4 h after withdrawal of altrenogest and was not treated with PGF2alpha.
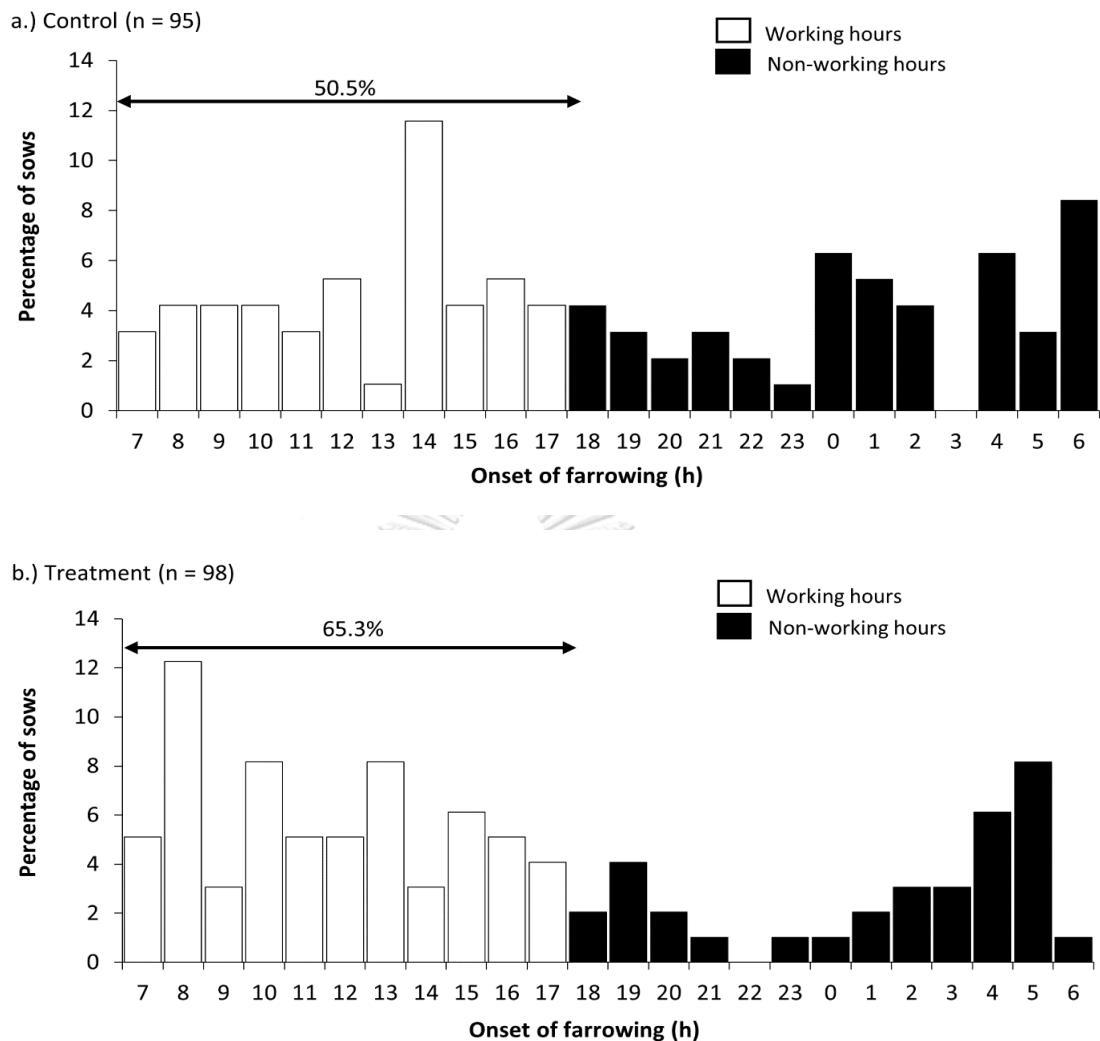
Figure 2 Frequency distribution of the onset of farrowing and the percentage of sows that farrowed during working hours (i.e. between 0700–1700 h) in (a) sows that farrowed naturally (control) and in (b) sows treated with altrenogest from 109 to 112 days of gestation and double administration of PGF2alpha at 113 days of gestation (treatment).

Sow reproductive performance

Reproductive performance of sows in the control group compared with the treatment group are presented in Table 2. On average, the gestation length of sows in the treatment group was 1.1 days shorter than the control (114.0 ± 0.1 days and 115.1 ± 0.1 days, respectively, $P < 0.001$) (Table 2). The TB, BA and MF did not differ significantly between control and treatment groups (Table 2).

Table 2 Reproductive performances and piglets (n = 3,316) characteristics in sows farrowed naturally (control) and sows synchronized farrowing by using altrenogest in combination with double administration of PGF2alpha (treatment) (least-square means ± SEM).

Variables	Control	Treatment	P value
Number of sows	**95**	**98**	
Parity number	3.5 ± 0.07	3.6 ± 0.07	0.129
Backfat thickness at day 109 (mm)	20.9 ± 0.33	20.6 ± 0.31	0.565
Farrowing duration (min)	264.9 ± 14.39	286.4 ± 13.59	0.277
Gestation length (d)			
Least-square mean ± SEM	115.1 ± 0.11	114.0 ± 0.10	<0.001
Range	112 – 122	112 – 116	-
Reproductive performances			
Total number of piglets born per litter	16.7 ± 0.33	17.3 ± 0.32	0.225
Number of piglets born alive per litter	15.1 ± 0.32	15.7 ± 0.31	0.197
Stillbirth (%)	4.5	4.6	0.963
Mummified fetuses (%)	4.8	4.6	0.744
Number of piglets at day 3 of lactation	14.3 ± 0.31	14.7 ± 0.29	0.352
Number of piglets at day 7 of lactation	14.2 ± 0.31	14.5 ± 0.30	0.552
Piglet mortality at days 3 (%)	5.8	7.3	0.087
Piglet mortality at days 7 (%)	6.1	8.0	0.035
Colostrum			
Colostrum yield (kg)	5.52 ± 0.13	5.28 ± 0.12	0.174
IgG at 0 h postpartum (mg per ml)	41.2 ± 1.1	37.3 ± 1.0	0.013
Brix at 0 h postpartum (%)	28.6 ± 0.39	27.4 ± 0.37	0.020
Brix at 6 h postpartum (%)	25.3 ± 0.33	23.3 ± 0.31	<0.001
Brix at 24 h postpartum (%)	19.1 ± 0.44	18.2 ± 0.41	0.152
Hormone			
Serum progesterone at 113 days of gestation (ng per ml)	17.4 ± 1.2	11.9 ± 1.3	0.003
Serum progesterone at 24 h postpartum (ng per ml)	4.7 ± 1.2	6.8 ± 1.2	0.224
Number of live-born piglets	**1,609**	**1,707**	
Birth weight (kg)	1.30 ± 0.02	1.25 ± 0.02	0.048
Litter birth weight (kg)	19.9 ± 0.4	19.5 ± 0.3	0.393
Within-litter variation of piglet birth weight (%)	21.7 ± 0.5	21.0 ± 0.5	0.345
Piglets with birth weight <1.0 kg (%)	19.1	23.8	0.099
Body weight at 24 h postpartum (kg)	1.37 ± 0.02	1.32 ± 0.02	0.017
Colostrum intake (g)	381.2 ± 7.0	357.0 ± 6.6	0.012
Piglets that had colostrum intake <300 g (%)	26.3	35.2	<0.001

Interestingly, the percentage of stillborn piglets per litter did not differ significantly between control and treatment groups (4.5% and 4.6%, respectively). Similarly, the frequency of sows that had 0, 1, 2 and ≥3 stillborn piglets per litter did not differ significantly between control and treatment groups (Figure 3). The number of live piglets at 3 and 7 days of lactation did not differ significantly between groups (Table 2). However, the piglet mortality during the first seven days of postnatal life in the treatment group was higher than in the control (8.0% and 6.1%, respectively, $P = 0.035$).
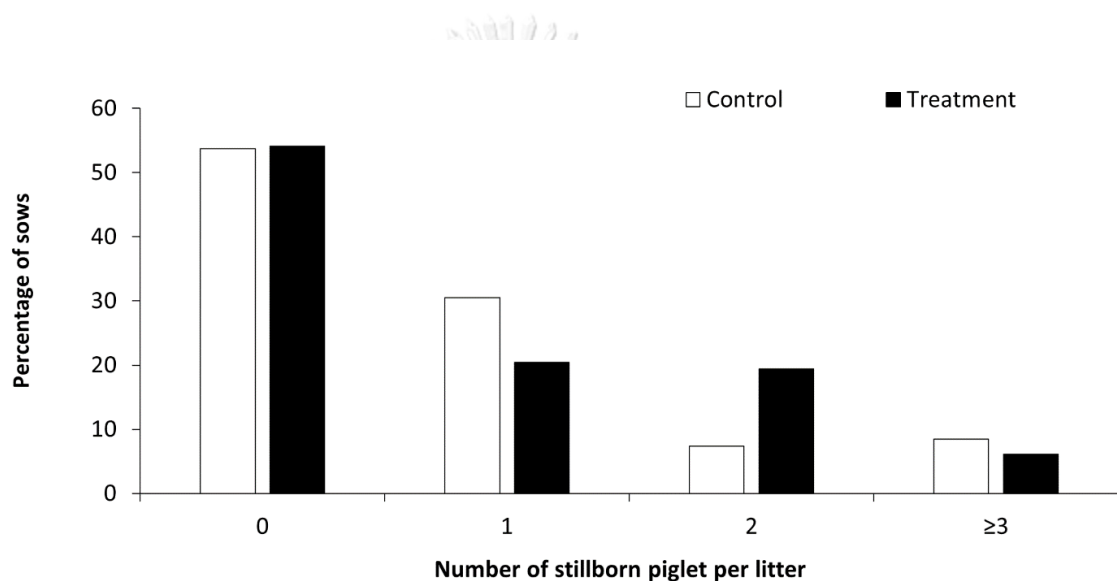
Figure 3 Frequency distribution on the number of stillborn piglets per litter in sows naturally farrowing (control) compared with sows treated with altrenogest from 109 to 112 days of gestation and double administration of PGF2alpha at 113 days of gestation (treatment).

Piglet characteristics and colostrum intake

Across groups, body weight at birth and 24 h after birth of the piglets were 1.28 ± 0.33 kg and 1.34 ± 0.34 kg, respectively (Table 1). Body weight at birth and 24 h after birth of the piglets in the control group was higher than the treatment group ($P < 0.05$, Table 2). However, litter birth weight of the piglets and the variation in birth weight within the litter did not differ significantly between groups ($P > 0.05$, Table 2). The proportion of live-born piglets with a body weight at birth of < 1.0 kg was 19.1% and 23.8% in control and treatment groups, respectively ($P = 0.099$). On average, the colostrum intake of the piglets was 371.2 ± 136.0 g (Table 1). Colostrum intake of piglets in the treatment group was lower than the control (357.0 ± 6.6 g and 381.2 ± 7.0 g, respectively, $P = 0.012$).

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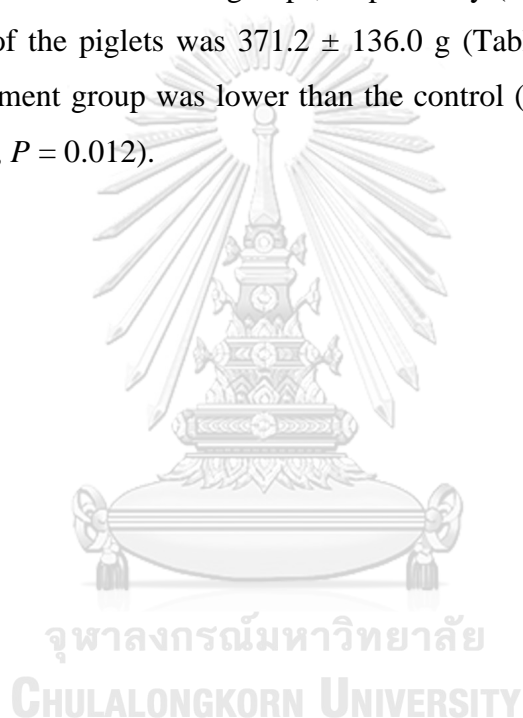
Figure 4 demonstrates the frequency distribution of colostrum intake of piglets in control and treatment groups. As can be seen, the proportion of piglets that had inadequate colostrum intake in the treatment group was higher than in the control (35.2% and 26.3%, respectively, $P < 0.001$).

a.) Control (n = 1,375 piglets)
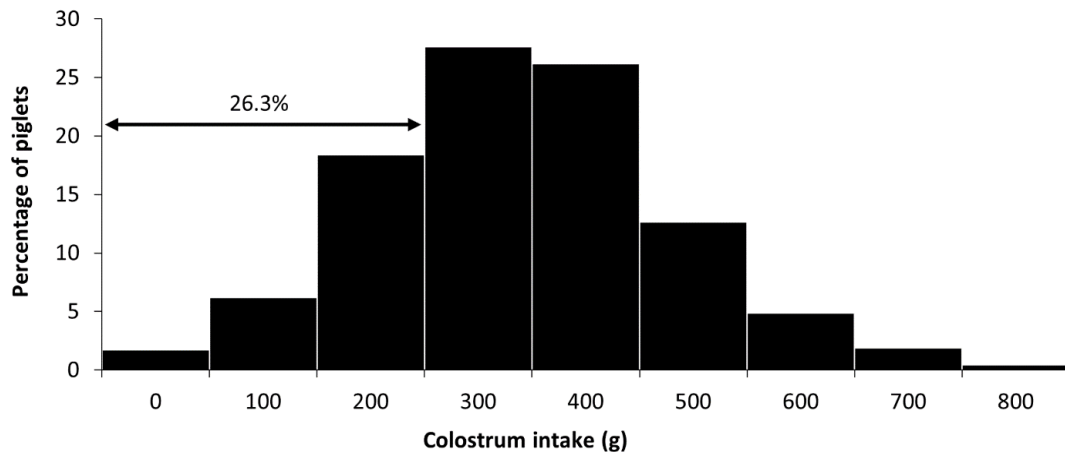
b.) Treatment (n = 1,453 piglets)

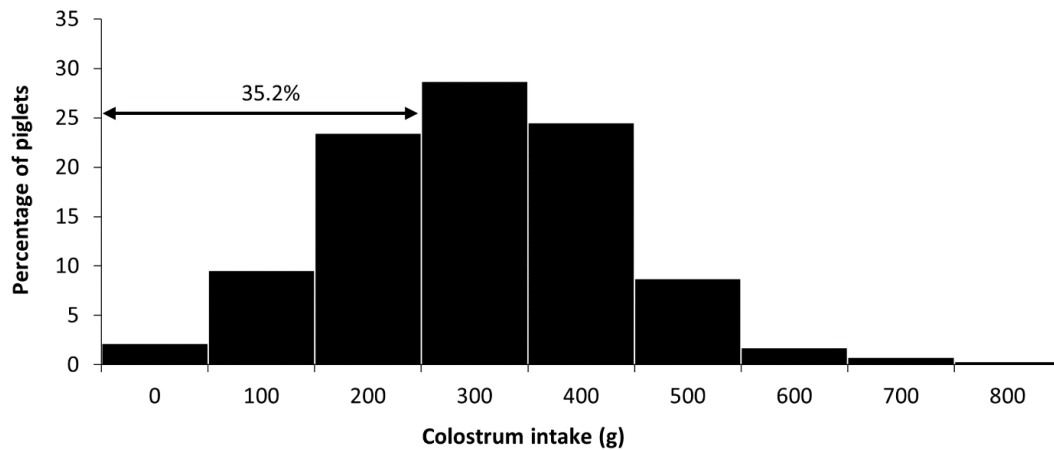**Figure 4** Frequency distribution of colostrum intake (g) of neonatal piglets and the proportion of piglets that had inadequate colostrum intake (<300 g) in (a) sows that farrowed naturally (control) and (b) sows treated with altrenogest from 109 to 112 days of gestation and double administration of PGF2alpha at 113 days of gestation (treatment).

Sow colostrum yield and IgG

The colostrum yield of sows did not differ significantly between treatment and control groups (5.28 ± 0.12 kg and 5.52 ± 0.13 kg, respectively, $P = 0.174$) (Table 2). The Brix value at 0 and 6 h postpartum in the treatment group was lower than in the control ($P < 0.05$), but the Brix value at 24 h postpartum did not differ significantly between groups (Table 2). The colostrum IgG in the control group was higher than treatment group (41.2 ± 1.1 mg per ml and 37.3 mg per ml, respectively, $P = 0.013$). Colostrum IgG did not correlate with serum progesterone concentration either before or after parturition (Table 3).

Serum progesterone

On average, serum progesterone concentrations of sows before and after parturition were 14.7 ± 7.3 ng per ml and 5.7 ± 6.7 ng per ml, respectively ($P < 0.001$). The serum progesterone at day 113 of gestation in the control group was higher than the treatment group (17.4 ± 1.2 ng per ml and 11.9 ± 1.3 ng per ml, respectively, $P = 0.003$) (Table 2). However, serum progesterone of sows at 24 h postpartum did not differ significantly between groups (4.7 ± 1.2 ng per ml and 6.8 ± 1.2 ng per ml, respectively, $P = 0.224$). The serum progesterone of sows at day 113 of gestation was positively correlated with gestation length (r = 0.459, $P < 0.001$) and negatively correlated with sow colostrum yield (r = -0.263, $P < 0.05$) (Table 3).

Table 3 Pearson's correlation between serum progesterone at 113 days of gestation and at one hour after the onset of expulsion stage and colostrum yield, farrowing duration, and litter characteristics in Landrace × Yorkshire sows (n = 60)

Variables	Serum progesterone (ng per ml)	
	Before farrowing	**After farrowing**
	14.7 ± 7.3	5.7 ± 6.7
Colostrum yield (kg)	-0.263*	NS
Colostrum IgG (mg per ml)	NS	NS
Farrowing duration (min)	NS	NS
Gestation length (d)	0.459***	NS
Total number of piglets born per litter	NS	NS
Number of piglets born alive per litter	NS	NS
Stillbirth (%)	NS	NS
Mummified fetuses (%)	NS	NS

*** $P < 0.001$, * $P < 0.05$, NS = not significant

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The association between serum progesterone at 113 days of gestation and sow colostrum yield in control and treatment groups are presented in Figure 5. In both groups, the sow colostrum yield declined when the serum progesterone concentrations of sows at 113 days of gestation increased (Figure 5).
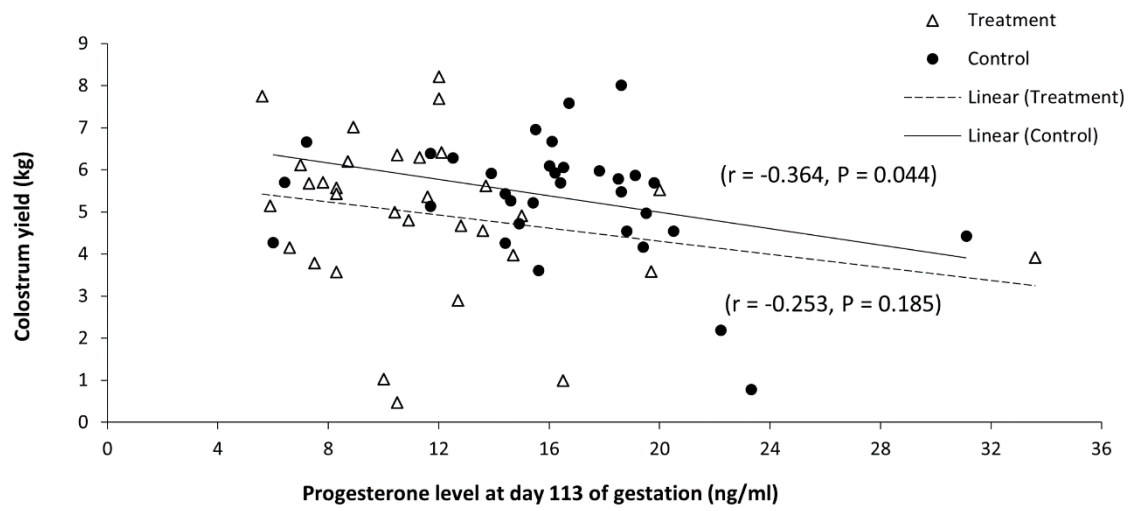

Figure 5 Relation between serum progesterone concentration at 113 days of gestation and colostrum yield in sows naturally farrowing (control) compared with sows treated with altrenogest from 109 to 112 days of gestation and double administration of PGF2alpha at 113 days of gestation (treatment).

CHAPTER V

Discussion

Gestation length and onset of parturition

In the present study, the efficacy of controlling parturition with altrenogest treatment for four consecutive days (i.e. from 109 to 112 days of gestation) in combination with double administration of PGF2alpha on day 113 of gestation is demonstrated. It was found that up to 92.8% of sows in the treatment group farrowed on day 114 of gestation. Therefore, this protocol has the potential to improve the proportion of sows that can farrow within optimal periods of gestation (i.e. between 114 and 116 days). We found that the proportion of sows that did not farrow during the optimal time frame was 16.8% in sows that farrowed naturally, while this proportion was only 2.0% of sows in the treatment group. Moreover, the incidence of early parturition was 8.4% in sows farrowed naturally and 2.0% in the altrenogest treated sows. On the other hand, the incidence of sows that had delayed gestation length (i.e. > 116 days) was 8.4% in sows that farrowed naturally, while none was detected in the treatment group. Previous study, Taechamaeteekul et al. (2022) found that 17.9% of sows that farrowed naturally do not farrow within an optimal gestation length. These data indicate that the incidence of sows farrowing outside an optimal period can be one from every five sows that farrow naturally. Thus, the control of parturition protocol can reduce this problem and improve the efficacy of farrowing assistance as well as care of newborn piglets. Additionally, we found that treating sows with altrenogest and PGF2alpha can increase the proportion of sows that farrow during working hours (i.e. from 0700h–1700h) by 14.8% (i.e. from 50.5% to 65.3%). Similarly, Taechamaeteekul et al. (2022) demonstrated that control of parturition using a similar protocol can increase the proportion of sows farrow during working hours from 46.4% to 72.3%. Indeed, the onset of parturition can be manipulated further by adjusting the time of PGF2α administration. In the present study, the first PGF2α administration was performed at 0800 h and the interval from the first PGF2α to the onset of

farrowing was 28.1 h. Therefore, to improve the proportion of sows that farrow during working hours, the administration of PGF2α should be done 4 h earlier, i.e. at 0400h. However, this is not during working hours and thus maybe difficult to implement under field condition. Moreover, the onset of parturition may be associated with the interval from the last feeding of altrenogest. Taechamaeteekul et al. (2022) found that feeding of altrenogest until 115 days of gestation can reduce the proportion of sows farrowing during working hours from 46.4% to 38.9%. This indicates that altrenogest treatment for too long a period of time may reduce the proportion of sows farrowing during working hours. Thus, in the present study, treatment with altrenogest can be recommended to finish at 112 days of gestation. Similarly, Vanderhaeghe et al. (2011) recommended administrating altrenogest to sows from 110 to 112 of gestation to reduce the incidence of early parturition. Moreover, the proportion of sows farrowing during working hours can be associated with the number of PGF2alpha administrations. Tospitakkul et al. (2019) demonstrated that double administration of PGF2alpha at 114 days of gestation can improve the proportion of sows farrowing during working hours from 84.4% to 100%, compared with a single administration of PGF2alpha. However, the number of sows in the previous study was only 23 in the treatment group (Tospitakkul et al., 2019). Additionally, Boonraungrod et al. (2018) demonstrated that the proportion of sows farrowing during working hours can be improved from 70.0% to 98.1% when using PGF2alpha in combination with carbetocin, compared with the use of PGF2alpha alone. Furthermore, the response to PGF2alpha in sows can vary between individuals (De Rensis et al., 2012). Thus, the use of PGF2alpha to induce parturition should be adjusted by considering the herd and genetic background of the animals. These findings indicated that using altrenogest and PGF2alpha to control parturition in sows can be an effective tool to reduce the variation in gestation length and improve the proportion of sows that farrow during the desired periods of time to enhance the efficacy of farrowing supervision and neonatal care.

Colostrum yield and IgG

Colostrum IgG in sows treated with altrenogest until 112 days of gestation in this study was reduced by 9.5% (i.e. from 41.2 to 37.3 mg per ml in control and treatment groups, respectively). Similarly, the Brix value at 0 h postpartum also declined from 28.6% to 27.4%. This agrees with our previous study which showed that sows treated with altrenogest until 115 days of gestation had a higher proportion of colostrum with inadequate IgG than sows that farrowed naturally (61.1% vs 27.1%) (Taechamaeteekul et al., 2022). The underlying cause of the reduced colostrum IgG is not known but could be associated with a shorter gestation length of sows in the treatment compared to control group. In general, the transfer of IgG from sow plasma to colostrum begins slowly from 10 days before parturition, increases 3-4 days before parturition and reaches its maximal on the day of parturition (Huang et al., 1992). Quesnel and Farmer (2019) suggested that the IgG transfer is not entirely finished before parturition in sows. This indicated that the supplementation of altrenogest, carried out in the same period as the transfer of IgG from plasma to colostrum, may influence the mechanism of IgG transfer. Another reason could be that sows in the control group had a longer gestation length than the treatment group and thus, they may have a longer duration of IgG transfer from plasma to colostrum than the treatment group. This is confirmed by our finding that gestation length of sows was positively correlated with the Brix value at 0 and 6 h postpartum. If this is the underlying cause of the reduced colostrum IgG in the treatment group, the induction of parturition with PGF2alpha should be extended from 113 to 114 days of gestation. However, the current parturition control protocol did not compromise the colostrum yield of sows.

Progesterone concentration

Progesterone concentration in sows both before and after parturition significantly influence colostrum production of sows (Foisnet et al., 2010; Quesnel and Farmer, 2019). In general, a serum progesterone concentration during late

gestation of 15 ng per ml is sufficient to maintain pregnancy. Serum progesterone declines rapidly to 1.3–3.5 ng per ml within 2-3 days before parturition (Baldwin and Stabenfeldt, 1975). In the present study, the serum progesterone concentration was determined at day 113 of gestation and at 24 h postpartum. We found that the serum progesterone concentration of sows at day 113 of gestation in the control group was higher than the treatment group (17.4 vs 11.9 ng per ml, respectively). This indicated that altrenogest treated sows had a lower progesterone level than the non-altrenogest treated group. The high serum progesterone concentration in late gestating sows can be associated with stress in pre-partum sows (Quesnel and Farmer, 2019). Brandt et al. (2007) demonstrated a strong positive correlation between cortisol and progesterone levels in sows after induced stress using ACTH administration. Moreover, the lower progesterone level in treatment group could be because to the clearance of altrenogest occurs rapidly after double administration of PGF2alpha. A previous study demonstrated that the elimination half-lives of altrenogest in gilts is 7.2–9.8 h (Xiao et al., 2019). Indeed, in our study, the induction of parturition by using PGF2alpha was started at 24 h after the withdrawal of altrenogest, far from the clearance time of altrenogest. Therefore, this finding confirms that the current parturition control protocol do not influence serum progesterone either before and after parturition.

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Incidence of stillbirth

In the current study, the stillbirth rate was similar between the altrenogest treated sows and sows farrowing naturally, i.e. 4.6% and 4.5%, respectively. Therefore, altrenogest supplementation for a four day period and not beyond 112 days of gestation did not affect the incidence of stillbirth in sows. However, in the previous study, the using altrenogest until 113, 114 and 115 days of gestation were increased in the percentage of stillbirths reach to 11.8–17.2% (Taechamaeteekul et al., 2022). The adverse effect of altrenogest on the incidence of stillbirth could be due to a too long period of altrenogest treatment in pre-partum sows (i.e. from 106 to 115 days of gestation (Taechamaeteekul et al., 2022)) or the treatment of altrenogest beyond

normal pregnancy term of sows (i.e. >114 days). The adverse effect of altrenogest on the incidence of stillbirth might be associated with a decreased of myometrium contraction (Kirkwood et al., 1985), which can lead to a delayed birth interval and, hence increase the incidence of hypoxia in piglets (Udomchanya et al., 2019). One reason to make the difference of percentage of stillbirth between these studies may be the current control of parturition protocol can allow workers to assist the newborn piglets closely during the birth period because parturition time is more predictable. Thus, sows in both control and treatment groups have been carefully supervised for 24 hours by the research team. Therefore, the stillbirth rate in the control groups is not high. Moreover, our results indicated that even though farrowing supervision has been performed for 24 h daily, approximately 4-5% of stillbirths still occurred. In the present study, the average total number of piglets born per litter was 17.0 piglets. Similarly, in a previous study, the incidence of stillborn piglets is 7.4% when the total number of piglets born per litter averaged 17.5 piglets per litter (Udomchanya et al., 2019). Additionally, the farrowing duration of sows without any stillborn piglets was shorter than sows with ≥ 3 stillborn piglets per litter (Udomchanya et al., 2019). These findings indicates that high incidence of stillbirth is an important issue in hyperprolific sow genetics and control of parturition time to be more predictable might help practitioners to improve the efficiency of farrowing supervision.

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