รายงานฉบับสมบูรณ์

โครงการวิจัยเรื่อง

ปัจจัยที่มีอิทธิพลต่อผลผลิตน้ำนมเหลืองในแม่สุกร (ปีที่ ๒)

(Factors influencing colostrum yield in sows)

โดย

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ภาควิชาสูติศาสตร์-เธนุเวชวิทยา และวิทยาการสืบพันธุ์ คณะสัตวแพทยศาสตร์
จุฬาลงกรณ์มหาวิทยาลัย

พฤษภาคม ๒๕๖๒

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โครงการนี้ได้รับทุนอุดหนุนการวิจัยจาก “ทุนอุดหนุนโครงการวิจัย เงินอุดหนุนทั่วไปจากรัฐบาล ประจำปี พ.ศ. ๒๕๖๑ (งบประมาณแผ่นดิน)” สัญญาเลขที่ GB-B_๖๑_๐๘๗_๓๑_๑๐ ระยะเวลาดำเนินโครงการตั้งแต่วันที่ ๑ ตุลาคม พ.ศ. ๒๕๖๐ ถึงวันที่ ๓๐ กันยายน ๒๕๖๑ เป็นจำนวนเงิน ๙๙๐,๐๐๐ บาท

บทคัดย่อ
(ภาษาไทย)

ในช่วงทศวรรษที่ผ่านมา การผลิตสุกรในประเทศไทยกลายเป็นอุตสาหกรรมและจำนวนของลูกสุกรต่อครอกมีแนวโน้มเพิ่มขึ้นอย่างรวดเร็ว หนึ่งในปัจจัยสำคัญที่จะนำไปสู่ความสำเร็จใน *"อุตสาหกรรมฟาร์มสุกร"* คือ การจัดการการคลอดที่เหมาะสม โดยปัจจัยสำคัญที่จะนำไปสู่ความสำเร็จของการจัดการการคลอดประกอบด้วย การจัดการกระบวนการคลอดของแม่สุกรอย่างเหมาะสม การช่วยเหลือแม่สุกรที่ต้องการความช่วยเหลือ และ การย้ายฝากลูกสุกรอย่างเหมาะสม แนวทางการจัดการเหล่านี้ได้รับความสนใจมากขึ้นในวงการวิจัยสุกร เนื่องจากจำนวนลูกสุกรที่มีชีวิตต่อครอกเพิ่มขึ้นในกลุ่มแม่สุกรสายพันธุ์สมัยใหม่ *"น้ำนมเหลือง"* เป็นสิ่งคัดหลั่งสิ่งแรกที่ถูกผลิตออกมาจากต่อมสร้างน้ำนม และมีการหลั่งอย่างต่อเนื่องในช่วงคลอดนานถึง 12-24 ชั่วโมง ก่อนที่การหลั่งจะเปลี่ยนเป็นวงจรและต้องใช้การดูดของลูกสุกรเป็นตัวกระตุ้น น้ำนมเหลืองเป็นแหล่งอาหารที่ประกอบด้วยสารอาหารที่ย่อยง่ายและมีสารออกฤทธิ์ทางชีวภาพต่างๆ เช่น อิมมูโนโกลบูลลิน เอนไซม์ไฮโดรไลติก ฮอร์โมน และปัจจัยที่ช่วยในการเจริญเติบโต ดังนั้นน้ำนมเหลืองจึงมีบทบาทสำคัญในการควบคุมอุณหภูมิร่างกายลูกสุกร การส่งต่อภูมิคุ้มกันถ่ายทอด และการพัฒนาของลำไส้ของลูกสุกร น้ำนมเหลืองเป็นแหล่งพลังงาน ที่สามารถเผาผลาญได้สูงในลูกสุกรแรกคลอด และมีปริมาณไขมันและแลคโต๊สสูง เพื่อให้ลูกสุกรสามารถรับมือกับความเครียดจากความหนาวเย็นได้ โดยการเพิ่มอัตราการเผาผลาญและรักษาสมดุลของร่างกายในวันแรกหลังคลอด อุณหภูมิทางทวารหนักของลูกสุกรที่ 24 ชั่วโมง หลังคลอดมีความสัมพันธ์ในเชิงบวกกับปริมาณน้ำนมเหลืองที่ลูกสุกรได้รับ และมีความสัมพันธ์เชิงลบกับระยะเวลาตั้งแต่คลอดจนกระทั่งลูกสุกรสามารถดูดนมได้ครั้งแรก โปรตีนในน้ำนมเหลือง ประกอบด้วย อิมมูโนโกลบูลลิน ได้แก่ อิมมูโนโกลบูลลินจี (IgG) อิมมูโนโกลบูลลินเอ็ม (IgM) และ อิมมูโนโกลบูลลินเอ (IgA) IgG เป็นสารออกฤทธิ์ทางชีวภาพที่พบมากที่สุดในน้ำนมเหลืองและมีความเข้มข้นสูงที่สุดในช่วงหลังคลอดไม่กี่ชั่วโมงแรกและลดลงอย่างรวดเร็วภายใน 24 ชั่วโมง ลูกสุกรแรกคลอดจำเป็นต้องได้รับภูมิคุ้มกันถ่ายทอดจากการกิน IgG ในน้ำนมเหลือง เพื่อลดความไวต่อการติดเชื้อหลังคลอดและหลังหย่านม การดูดซึม IgG ในลูกสุกรแรกคลอดจะต้องเกิดขึ้นเกิดขึ้นก่อนที่กระบวนการการดูดซึมโปรตีนในลำไส้จะสิ้นสุดลง ซึ่งเกิดขึ้นเมื่อลูกสุกรมีอายุประมาณ 24 ชั่วโมง ความเข้มข้นของ IgG ในพลาสมาของลูกสุกรที่อายุ 24 ชั่วโมง มีความสัมพันธ์เชิงบวกกับปริมาณน้ำนมเหลืองที่ลูกสุกรได้รับ การเสริมน้ำนมเหลือง ให้แก่ลูกสุกรที่มีน้ำหนักแรกคลอดต่ำ ตัวละ 15 มิลลิลิตร สามารถเพิ่มความเข้มข้นของ IgG ในพลาสมาของลูกสุกรที่อายุ 4 วัน ได้ น้ำนมเหลืองของสุกรยังประกอบด้วยสารที่ช่วยในเจริญเติบโต (growth factor) ที่แตกต่างกัน เช่น insulin-like growth factor (IGF) I และ II epidermal growth factor insulin และ transforming growth factor-beta ส่วนประกอบที่ช่วยในการเจริญเติบโตที่ผ่านมาทางน้ำนมเหลือง เป็นกลไกในการกระตุ้นการเจริญเติบโตของและพัฒนาการทำงานของเนื้อเยื่อระบบทางเดินอาหารของลูกสุกร นอกจากนี้น้ำนมเหลืองยังช่วยเพิ่มการดูดซึมในลำไส้ การเริ่มต้นของการปิดตัวของลำไส้ และช่วยในการซ่อมแซมผิวเยื่อเมือกที่เสียหายอีกด้วย ซึ่งกระบวนการทั้งหมดนี้เป็นสิ่งจำเป็นสำหรับการเปลี่ยนแปลงของระบบทางเดินอาหารในช่วงหลังคลอด

คำสำคัญ น้ำหนักแรกคลอด น้ำนมเหลือง อิมมูโนโกลบูลิน ลูกสุกร

บทคัดย่อ
(ภาษาอังกฤษ)

Over the past decade, swine production in Thailand has become more industrialised, and the number of total piglets born per litter has increased rapidly. One of the most important factors to achieve a successful "*swine farming industry*" is to optimise farrowing management. The key factors for successful intensive farrowing management include, among other factors, proper farrowing supervision, intervention for sows that need birth assistance, care of newborn piglets and optimisation of cross-fostering management. These management practices are gaining increasing interest in the swine research field, mainly due to the increased number of piglets born alive per litter in modern genetic sows. "*Colostrum*" is the first milk secreted by the mammary gland, which sows continuously secrete from around farrowing up to 12–24 h, before its secretion becomes cyclic and nursery bouts start. Colostrum is a rich source of digestible nutrients and various bioactive compounds such as immunoglobulins, hydrolytic enzymes, hormones, and growth factors, thus, it plays a key role in piglet thermoregulation, the acquisition of passive immunity and intestinal development. Colostrum provides the newborn pig with highly metabolisable energy and its high content of fat and lactose is efficiently used by the newborn pig to cope with cold stress by increasing its metabolic rate and maintaining its homeothermic balance during the first day after birth. Accordingly, rectal piglet temperature at 24 h of age is positively correlated with colostrum intake and is negatively correlated with the time interval between birth and first suckling. The primary protein component of colostrum consists of immunoglobulins, including IgG, IgM, and IgA isotypes. Immunoglobulin G is the most common bioactive compound in colostrum and is at its highest concentration in the first few hours postpartum and decreases rapidly within 24 h. As has been previously mentioned, piglets need to receive passive immunity from IgGs in colostrum to reduce susceptibility to infection in the immediate postnatal period and also after weaning. The absorption of IgG by newborn piglets occurs before gut closure, which occurs at approximately 24 h of age. The IgG plasma concentration in piglets at 24 h of age is positively correlated with colostrum intake. Administration of 15 mL of colostrum after farrowing to small piglets increased their IgG plasma concentration at 4 days of age. Porcine colostrum also contains different types of milk-borne growth factors, e.g., the insulin-like growth factors IGF-I and IGF-II, epidermal growth factor, insulin and transforming growth factor-beta. Milk-borne growth factors via colostrum feeding play a regulatory role in the stimulation of gastrointestinal tissue growth, and the maturation of its function. Colostrum feeding also enhances intestinal macromolecule absorption, the onset of gut closure, and enhances the repair of damaged mucosa. All these process are required for the adaptive changes of the gastrointestinal tract during the postnatal period.

Keywords Birth weight, Colostrum, Immunoglobulin, Piglet

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คำย่อที่ใช้ในการวิจัย (List of Abbreviations)

CI	Colostrum intake
BWB	Body weight at birth
RT24h	Rectal temperature at 24 h after birth
BA	Number of piglets born alive per litter
IgG	Immunoglobulin G
IgA	Immunoglobulin A
VEGFA	Vascular endothelial growth factor
PIGF1	Placenta growth factor 1
NO	nitric oxide
eNOS	endometrial Nitric Oxide Synthetes
IACUC	Institutional Animal Care and Use Committee
BW	birth weight (kg)
BW24h	body weight at 24 h after birth (kg)
t	time elapsed between the first and the second weighting (min)
tFS	the interval between birth and first sucking (min)
h	hour
min	minute
TB	total number of piglets born per litter
BA	number of piglets born alive per litter
SatO2	blood oxygen saturation
M	movement capacity
U	udder stimulation
NCC	number of completed circles around the enclosure
SC	screaming
°C	degree celcius
ANOVA	Analysis of Variance
GLM	General linear model
LSD	least square mean
PWM	preweaning mortality

บทนำ
(Introduction)

ความสำคัญ และที่มาของปัญหาที่ทำการวิจัย

การที่ลูกสุกรจะสามารถต่อสู้กับโรคต่างๆ ได้นั้นขึ้นอยู่กับปริมาณภูมิคุ้มกันที่ลูกสุกรจะได้รับจากแม่สุกรหลังคลอด ลูกสุกรต่างจากมนุษย์และสัตว์เลี้ยงลูกด้วยนมอีกหลายชนิด ตรงที่ **ภูมิคุ้มกันต่างๆ ที่จะถ่ายทอดจากแม่มายังลูกจะต้องส่งผ่านมาทางน้ำนมเหลือง (colostrum) เท่านั้น** ทันทีที่ลูกสุกรคลอดออกมา ลูกสุกรก็จะได้สัมผัสกับเชื้อโรคต่างๆ ที่อยู่ในสิ่งแวดล้อม การตอบสนองทางภูมิคุ้มกันแบบไม่จำเพาะของลูกสุกรต่อเชื้อโรคต่างๆ เหล่านี้ยังทำได้ไม่ดี เนื่องจากลูกสุกรแรกคลอดยังไม่มีการพัฒนาของระบบภูมิคุ้มกันที่ดีพอ ดังนั้นภูมิคุ้มกันที่ได้รับการถ่ายทอดจากแม่สุกรผ่านทางนมน้ำเหลืองจึงมีความจำเป็นอย่างยิ่ง มีปัจจัยหลายอย่างที่มีผลต่อปริมาณของอิมมูโนโกลบูลินในน้ำนมของแม่สุกร เช่น สายพันธุ์ ลำดับท้อง และสิ่งแวดล้อม

น้ำนมเหลือง ของแม่สุกรอุดมไปด้วยภูมิคุ้มกันชนิดต่างๆ (immunoglobulin) และเซลล์เม็ดเลือดขาวชนิดลิมโฟไซต์ (lymphocyte) ไซโตไคน์ (cytokines) นิวคลีโอไทด์ (nucleotides) และสารเร่งการเจริญเติบโตชนิดต่างๆ (growth factor) ซึ่งมีผลต่อระบบภูมิคุ้มกันของลูกสุกรหลังคลอด อิมมูโนโกลบูลินที่ถ่ายทอดจากแม่สุกรสู่ลูกสุกรเป็นภูมิคุ้มกันที่ถูกสร้างขึ้นมาแบบจำเพาะต่อโรคบางโรค โดยความคุ้มกันนี้ขึ้นกับประสบการณ์ของแม่สุกรในการสัมผัสโรคต่างๆ มาก่อน ดังนั้นลูกสุกรที่ได้รับการถ่ายทอดอิมมูโนโกลบูลินมาจากแม่สุกรก็จะมีภูมิคุ้มกันเฉพาะต่อโรคที่แม่สุกรเคยสัมผัสมาแล้วเท่านั้น อิมมูโนโกลบูลินจากนมน้ำเหลืองของแม่สุกรจะถูกดูดซึมผ่านทางผนังลำไส้ของลูกสุกรด้วยกระบวนการเอ็นโดไซโตซิสแบบไม่จำเพาะ (non-specific endocytosis) กระบวนการดูดซึมนี้จะสิ้นสุดลงภายใน 24-36 ชั่วโมง หลังสัมผัสกับนมน้ำเหลือง จากการวิจัยพบว่า**อัตราการรอดชีวิตของลูกสุกรขึ้นกับปริมาณนมน้ำเหลืองที่ลูกสุกรได้รับ**

ปัจจุบันการตายของลูกสุกรก่อนหย่านม เป็นปัญหาสำคัญในอุตสาหกรรมการเลี้ยงสุกรทั่วโลก การศึกษาก่อนหน้านี้พบว่า ค่าเฉลี่ยของการตายของลูกสุกรก่อนหย่านมในฟาร์มสุกรทั่วโลกอยู่ในช่วง 10% ถึง 20% (KilBride et al. 2012; Kirkden et al. 2013; Nuntapaitoon and Tummaruk 2015) การตายของลูกสุกรก่อนหย่านมมีผลกระทบต่อทั้งการสูญเสียทางเศรษฐกิจและสวัสดิภาพของสัตว์ (animal welfare) โดยเฉลี่ย 50% ถึง 80% ของการตายของลูกสุกรก่อนหย่านมเกิดขึ้นในช่วงสัปดาห์แรกหลังคลอดโดยเฉพาะอย่างยิ่ง ภายในสามวันแรกเป็นช่วงเวลาที่วิกฤตที่สุด (Koketsu et al. 2006) ปัจจัยที่เกี่ยวข้องประกอบด้วย ลำดับท้องของแม่ ระยะเวลาคลอด ลำดับคลอด สุขภาพ พฤติกรรมของแม่และความสามารถในการรอดชีวิตของลูกสุกร ทั้งหมดเป็นปัจจัยสำคัญในการกำหนดการตายของลูกสุกรก่อนหย่านมในฟาร์ม (Baxter et al. 2008; Panzardi et al. 2013)

วัตถุประสงค์ของโครงการวิจัย

1. เพื่อตรวจวัดความแปรปรวนและค่าเฉลี่ยของปริมาณน้ำนมเหลืองที่แม่สุกรแต่ละตัวผลิตได้ในฟาร์มสุกรเชิงพาณิชย์ในประเทศไทย

2. เพื่อศึกษาปัจจัยที่มีอิทธิพลต่อปริมาณน้ำนมเหลืองที่แม่สุกรแต่ละตัวผลิตได้ ได้แก่ ลำดับท้องของแม่สุกร น้ำหนักแรกคลอดของลูกสุกร ฤดูกาล จำนวนลูกสุกรมีชีวิต/ครอก และอื่นๆ

3. เพื่อศึกษาผลของการให้อาหารเสริมประเภทไขมันคุณภาพสูง ในอาหารแม่สุกรอุ้มท้อง ต่อปริมาณและคุณภาพของน้ำนมเหลืองที่แม่สุกรแต่ละตัวผลิตได้

ขอบเขตของโครงการวิจัย

การศึกษานี้ครอบคลุมทั้งการวิจัยโดยการเก็บข้อมูล (observational study) ของปริมาณน้ำนมเหลืองที่แม่สุกรแต่ละตัวผลิตได้ในฟาร์สุกรเชิงพาณิชย์ในประเทศไทย ตลอดจนวิเคราะห์ปัจจัยต่างๆ ที่มีผลกระทบต่อปริมาณน้ำนมเหลืองที่แม่สุกรแต่ละตัวผลิตได้ และ การศึกษาทดลอง (experimental study) เพื่อศึกษาความเป็นไปได้ของการให้อาหารเสริมประเภทไขมันในอาหารแม่สุกรอุ้มท้องต่อปริมาณและส่วนประกอบของน้ำนมเหลืองที่แม่สุกรแต่ละตัวผลิตได้

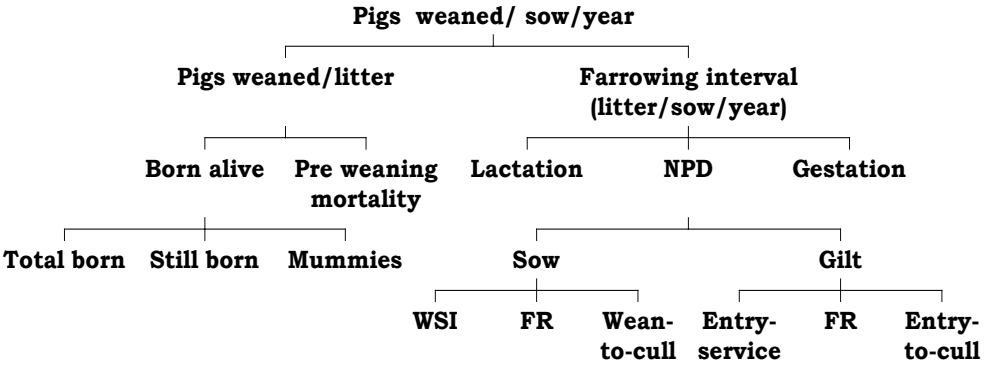
โครงการวิจัย แบ่งเป็น 2 โครงการย่อย ดังนี้

การทดลองที่ 1 ปัจจัยที่มีอิทธิพลต่อปริมาณน้ำนมเหลืองที่ลูกสุกรกินได้และความสัมพันธ์ของมันกับอัตราการรอดชีวิตและการเจริญเติบโตภายใต้ภูมิอากาศแบบร้อนชื้น (Factors influencing colostrum consumption by piglets and their relationship with survival and growth in tropical climates)

การทดลองที่ 2 ผลของการเสริมไขมันและหางนมต่อองค์ประกอบของน้ำนม การสูญเสียไขมันสันหลัง และสมรรถภาพการสืบพันธุ์ในแม่สุกรเลี้ยงลูก (Effect of fat and whey supplementation on milk composition, backfat loss and reproductive performance in lactating sows)

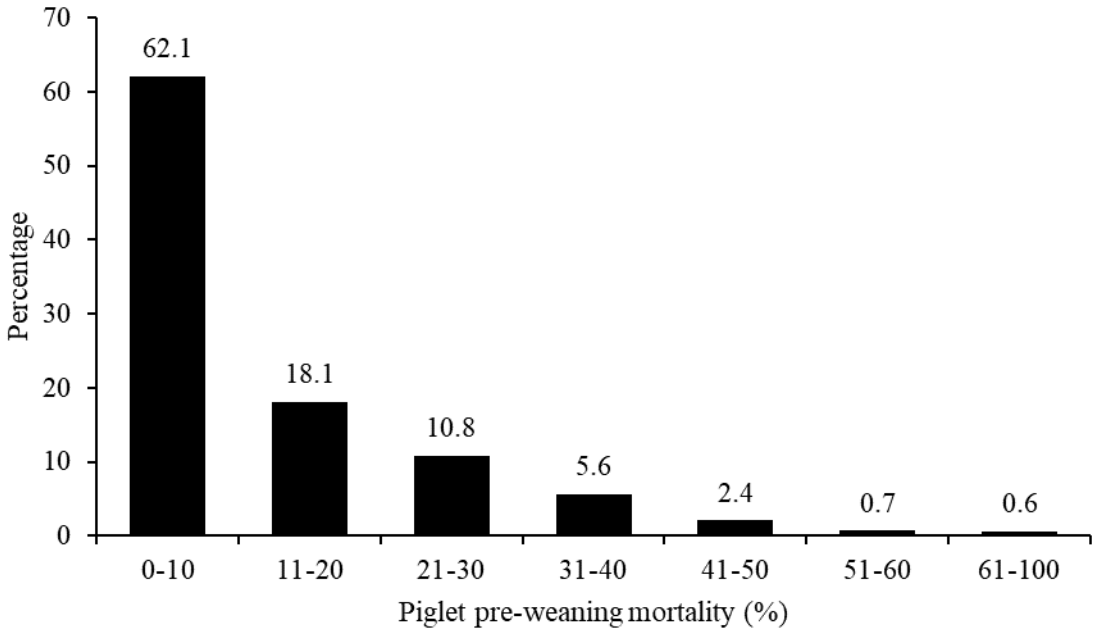
การทบทวนวรรณกรรมที่เกี่ยวข้อง (Literature review)

ปัจจุบันเป้าหมายในการผลิตลูกสุกรในฟาร์มสุกรเชิงพาณิชย์ คือ การผลิตให้ได้จำนวนลูกสุกรหย่านม 30 ตัวต่อแม่ต่อปี เป้าหมายนี้จะสามารถประสบความสำเร็จได้โดย 2 กระบวนการ คือ การเพิ่มจำนวนลูกสุกรหย่านมต่อครอก และการลดระยะเวลาในการผลิตลูกสุกร 1 ครอก (farrowing interval) (รูปที่ 1) ขนาดครอกของแม่สุกร (litter size) มีการเปลี่ยนแปลงอย่างมากในช่วงทศวรรษที่ผ่านมา เนื่องมาจากการปรับปรุงพันธุกรรมของแม่สุกรแม่สุกรให้มีลูกดกขึ้น (high prolificacy sow)



รูปที่ 1 โครงสร้างสมรรถภาพการสืบพันธุ์ในสุกร (NPD: non-productive days; WSI: weaned-to-service interval; FR: farrowing rate)

ถึงแม้ว่าการเพิ่มขนาดครอกแรกคลอดของแม่สุกรโดยการปรับปรุงพันธุ์จะได้รับการพัฒนาอย่างก้าวกระโดด โดยการคัดเลือกยีนส์ที่ทำให้สุกรคลอดลูกดกขึ้น แต่จากการวิจัยในช่วงหลายปีที่ผ่านมากลับพบว่า “**การตายของลูกสุกรก่อนหย่านม** (piglet pre-weaning mortality)” ในอุตสาหกรรมการเลี้ยงสุกรทั่วโลกมีแนวโน้มเพิ่มสูงขึ้น โดยจากการศึกษาวิจัยในหลายประเทศพบว่ามีการตายของลูกสุกรอยู่ระหว่าง 10-20% ในกลุ่มประเทศที่ผลิตสุกรเชิงพาณิชย์ (Koketsu et al., 2006; Nuntapaitoon and Tummaruk 2015; Nuntapaitoon and Tummaruk 2018a) โดยจากข้อมูลเมื่อไม่นานมานี้พบว่าอัตราการตายของลูกสุกรก่อนหย่านมเฉลี่ย เท่ากับ 12.9% ในกลุ่มประเทศในสหภาพยุโรป 9.4% ในประเทศฟิลิปปินส์ และ 12.2% ในประเทศไทย (Nuntapaitoon and Tummaruk, 2015) (รูปที่ 2) ในขณะที่อัตราการตายในลูกสุกรอนุบาลและสุกรขุนเฉลี่ยที่ 2.6% และ 2.5% ตามลำดับ (Muns et al., 2016) เมื่อคำนวนเป็นมูลค่าของการสูญเสียเหล่านี้พบว่า ถ้าเกษตรกรสามารถลดอัตราการตายของลูกสุกรก่อนหย่านมภายในฟาร์มจาก 11.5% ลงเหลือ 9.0% โดยคำนวนจากจำนวนลูกสุกรแรกคลอดมีชีวิตต่อครอกเฉลี่ย 13 ตัว จะสามารถเพิ่มค่าเฉลี่ยของน้ำหนักสุกรมีชีวิตที่จะเข้าโรงเชือดได้ 65 กิโลกรัมต่อแม่ต่อปี (โดยคำนวนจาก 2.30 ท้องต่อแม่ต่อปี) (Muns et al., 2016) ดังนั้น การตายของลูกสุกรก่อนหย่านมจึงถือได้ว่าเป็นปัญหาใหญ่ทั้งในด้านของจริยธรรมในการเลี้ยงดูสัตว์ (animal welfare) และในด้านการสูญเสียทางเศรษฐกิจ (economic loss) ที่สำคัญในอุตสาหกรรมการเลี้ยงสุกรซึ่งคงต้องหาทางแก้ไขอย่างถูกต้องและเหมาะสมอย่างรวดเร็วและมีประสิทธิภาพ



รูปที่ 2 ความถี่ของการกระจายของอัตราการตายของลูกสุกรก่อนหย่านมจากการศึกษาในแม่สุกรพันธุ์แลนด์เรซ x ยอร์เชียร์ จำนวน 199,918 ครอก จากแม่สุกร 74,088 ตัว ในฟาร์มสุกรเชิงพาณิชย์จำนวน 47 ฟาร์ม ในประเทศไทย ระหว่างปี ค.ศ. 2007–2013 (Nuntapaitoon and Tummaruk 2018a) (ค่าเฉลี่ย = 11.2%)

การตายของลูกสุกรก่อนหย่านม มีความแตกต่างจากการตายแรกคลอดของลูกสุกร (stillborn piglet) โดยลูกสุกรตายแรกคลอด คือ ลูกสุกรที่ไม่หายใจ (เนื้อเยื่อปอดจะจมน้ำ) และยังคงพบกีบอ่อน (periople) บนเนื้อกีบ ในบทความนี้จะกล่าวถึงการตายของลูกสุกรที่เกิดมามีชีวิตแล้วเท่านั้น โดยเรียกว่า “**การตายของลูกสุกรก่อนหย่านม**” โดยทั่วไป “การตายของลูกสุกรก่อนหย่านม” จะถูกคำนวณจากการใช้จำนวนลูกสุกรแรกคลอดที่มีชีวิตเป็นฐานในการคำนวณเท่านั้น สาเหตุของการตายของลูกสุกรก่อนหย่านมนั้นเกิดได้ทั้งจากสาเหตุจากการติดเชื้อ (infectious cause) และสาเหตุที่ไม่ได้เกิดจากการติดเชื้อ (non-infectious cause) สาเหตุจากการติดเชื้อส่วนใหญ่เป็นปัญหาเกี่ยวกับระบบทางเดินหายใจและอาการท้องเสีย อย่างไรก็ตามในบทความนี้ จะมุ่งเน้นไปที่สาเหตุการตายที่ไม่ได้เกิดจากการติดเชื้อของลูกสุกรก่อนหย่านมเป็นหลัก ซึ่งเป็นสาเหตุที่พบได้บ่อยกว่า

โดยเฉลี่ย 50-80% ของการตายของลูกสุกรจะเกิดขึ้นในช่วงสัปดาห์แรกหลังคลอด โดยช่วงที่สำคัญที่สุดคือ 72 ชั่วโมงแรกของชีวิต (Koketsu et al., 2006) ปัจจัยที่มีผลต่อการตายของลูกสุกรก่อนหย่านมภายในฟาร์ม ประกอบด้วย น้ำหนักแรกคลอดของลูกสุกร ขนาดครอก ลำดับการคลอด (birth order) เพศ ลำดับท้องของแม่สุกร ระยะเวลาคลอด (farrowing duration) พฤติกรรมของแม่สุกร ภาวะโภชนาการของแม่สุกร และอุณหภูมิสิ่งแวดล้อม (Muns et al., 2016; Nuntapaitoon and Tummaruk 2018b) นับว่าเป็นสิ่งสำคัญสำหรับสัตวแพทย์และสัตวบาลประจำฟาร์ม ที่จำเป็นต้องทำความเข้าใจถึงที่มาของการตายของลูกสุกรก่อนหย่านมในแต่ละฟาร์ม และประยุกต์ใช้วิธีการจัดการกับการตายของลูกสุกรก่อนหย่านมในฟาร์มให้ตรงกับสาเหตุให้มากที่สุด เพื่อเพิ่มจำนวนลูกสุกรหย่านมที่มีคุณภาพดี ดังนั้นการศึกษาวิจัยต่างๆ ในช่วงหลายปีที่ฟผ่านมา จึงเริ่มให้ความสนใจในการทบทวนความรู้ในปัจจุบันเกี่ยวกับสาเหตุการตายของลูกสุกรก่อนหย่านมมากขึ้น โดยพยายามศึกษาภายใต้สภาวะการเลี้ยงภายในฟาร์ม นอกจากนี้ยังเน้นการศึกษาเพื่อหาแนวทางการ

จัดการที่ในระหว่างการคลอดและผลกระทบของการจัดการต่อการตายของลูกสุกรก่อนหย่านม (Muns and Tummaruk 2016)

ตารางที่ 1 ตัวบ่งชี้ที่สำคัญต่อการตายของลูกสุกรก่อนหย่านม (ค่าเฉลี่ย ± SEM) เปรียบเทียบระหว่างลูกสุกรที่รอดชีวิตในช่วง 7 วัน หลังคลอด (n = 631) กับลูกสุกรที่ตายภายใน 7 วัน หลังคลอด (n = 59)

ตัวแปร	รอดชีวิต	ตาย	*P* value
จำนวนลูกสุกรแรกคลอดทั้งหมด/ ครอก	14.9 ± 0.14	15.6 ± 0.43	0.171
จำนวนลูกสุกรแรกคลอดมีชีวิต/ ครอก	13.0 ± 0.12	13.3 ± 0.45	0.491
ขนาดครอกภายหลังการย้ายฝาก	13.2 ± 0.07	13.7 ± 0.22	0.038
ระยะเวลาในการคลอด (นาที)	14.9 ± 0.80	9.5 ± 1.72	0.005
น้ำหนักแรกคลอด (กิโลกรัม)	1.52 ± 0.01	1.11 ± 0.05	< 0.001
ลำดับการคลอด	7.5 ± 0.18	8.5 ± 0.59	0.130
อัตราการเต้นของหัวใจ (ครั้ง/นาที)	66.5 ± 1.34	62.5 ± 3.68	0.381
กลูโคส (มิลลิกรัม/เดซิลิตร)	49.3 ± 0.70	47.8 ± 2.69	0.605
ปริมาณออกซิเจนอิ่มตัว (%)	91.3 ± 0.36	90.4 ± 0.99	0.458
อุณหภูมิทางทวารหนักที่ 24 ชั่วโมงหลังคลอด (°C)	38.7 ± 0.02	38.2 ± 0.14	< 0.001

ที่มา: Nuntapaitoon et al. (2018) Asian-Australasian Journal of Animal Science 31: 237-244.

สาเหตุของการตายก่อนหย่านมของลูกสุกร

"แม่สุกรทับลูกตาย" เป็นสาเหตุสำคัญของการตายก่อนหย่านมลูกสุกรที่พบเป็นส่วนใหญ่ นอกจากนี้ยังพบว่าเกิดจาก ความหนาวเย็น และการขาดอาหาร ร่วมด้วย มีการศึกษาวิจัยพบว่าสาเหตุการตายของลูกสุกรก่อนหย่านมในประเทศสหรัฐอเมริกา เกิดจากแม่ทับ 33.8% อ่อนแอ (low viability) 29.7% ท้องเสีย 12.2% การติดเชื้อ 8.1% ความผิดปกติแต่กำเนิด 5.5% และสาเหตุอื่นๆ 10.7% (Vaillancourt et al. 1990) ในประเทศญี่ปุ่น Koketsu et al. (2006) พบว่า "แม่ทับ" และ "อ่อนแอ" เป็นสาเหตุหลักของการตายของลูกสุกรก่อนหย่านมในฝูงสุกรของประเทศญี่ปุ่น ในประเทศสหราชอาณาจักร มีรายงานสาเหตุการตายของลูกสุกรในฟาร์มสุกรจำนวน 458 ฟาร์ม พบว่า "แม่ทับ" เป็นสาเหตุสำคัญของการตายที่พบได้มากที่สุด โดยสาเหตุอื่นๆ เช่น "ความผิดปกติแต่กำเนิด" หรือ "ถูกแม่สุกรทำร้าย" ก็สามารถพบได้เช่นกัน (Easicare 1995)

ทันทีที่คลอดลูกสุกรจะต้องฟื้นตัวจากความเครียดที่เกิดขึ้นระหว่างกระบวนการคลอดให้ได้โดยเร็วที่สุด เพื่อรับมือกับอุณหภูมิโดยรอบที่ลดลงอย่างรวดเร็วเมื่อเปรียบเทียบกับอุณหภูมิในถุงน้ำคร่ำ และยังต้องแข่งขันกันกับลูกสุกรในครอกเดียวกันอีกด้วย นอกจากนี้ลูกสุกรแรกคลอดยังมีสภาพทางสรีรวิทยาและภูมิคุ้มกันที่ไม่สมบูรณ์ อันเนื่องมาจากลักษณะทางจุลกายวิภาคของรกสุกร ที่มีลักษณะแบบ "epitheliochorial" ทำให้ไม่มีการส่งผ่านภูมิคุ้มกันผ่านรกเลย ดังนั้นลูกสุกรจึงจำเป็นต้องได้รับภูมิคุ้มกันถ่ายทอดจากแม่สุกร (passive immunity) ซึ่งประกอบไปด้วยอิมมูโนโกลบูลิน จี (immunoglobulin G หรือ IgG) ผ่านทางน้ำนมเหลือง (colostrum) นอกจากนี้ยังมีการวิจัยพบอีกว่าลูกสุกรแรกคลอดไม่มีเนื่อเยื่อไขมันสีน้ำตาล (brown fat adipose tissue) ซึ่งมีความจำเป็นต่อการควบคุมอุณหภูมิร่างกาย (thermoregulation) เหมือนกับลูกสัตว์เลี้ยงลูกด้วยนมชนิดอื่นๆ ประกอบกับการที่ร่างกายของลูกแรกคลอดสุกรมักจะเปียกมากอันเนื่องมาจากการสัมผัสกับของเหลวจากรก นอกจากนี้ยังพบว่าลูกสุกรแรกคลอดมีสัดส่วนระหว่างพื้นที่ผิวต่อ

ปริมาตรร่างกายสูงมากทำให้สูญเสียความร้อนได้ง่าย โดยเฉพาะในในลูกสุกรที่มีขนาดเล็กมาก สิ่งเหล่านี้ส่งผลให้ลูกสุกรแรกคลอดมีแนวโน้มที่จะหนาวและขาดอาหารตายได้โดยไม่ยากนัก

ภาวะอุณหภูมิร่างกายต่ำ (hypothermia) และ “การไม่ได้รับพลังงานที่เพียงพอ” เป็นสาเหตุโน้มนำที่สำคัญที่ทำให้ลูกสุกร “อ่อนแอ” และเสี่ยงต่อการถูก “แม่ทับ” มากขึ้น ทำให้การตายของลูกสุกรก่อนหย่านมมักจะพบได้มากในช่วงวันแรกๆ หลังคลอด กล่าวโดยสรุป การตายของลูกสุกรก่อนหย่านม นับว่าเป็นผลมาจากกลไกที่ซับซ้อนระหว่างตัวแปร 3 กลุ่ม ได้แก่ ลูกสุกร แม่สุกร และสิ่งแวดล้อม และผลดังกล่าวนำไปสู่การถูกแม่สุกรทับตายในที่สุด จากกลไกดังกล่าวทำให้เป็นการยากที่จะบ่งชี้ได้ชัดเจนว่า สาเหตุใดสาเหตุหนึ่ง เป็นสาเหตุที่ทำให้ลูกสุกรตายก่อนหย่านม แต่อย่างไรก็ดี **การได้รับน้ำนมเหลืองที่ไม่เพียงพอ** อาจจะเป็นปัจจัยหลักที่ทำให้เกิดการตายของลูกสุกรในช่วงต้นเนื่องจากการขาดสารอาหารและอิมมูโนโกลบูลิน ในสภาพการเลี้ยงสุกรในฟาร์ม การประเมินสาเหตุของการตายของลูกสุกรก่อนหย่านมขึ้นอยู่กับทักษะความชำนาญของผู้เลี้ยง และการหมั่นสังเกตของเกษตรกรอย่างใกล้ชิด อย่างไรก็ตาม ประสิทธิภาพของแรงงาน (ผู้ปฏิบัติ) และการชันสูตรลักษณะทางกายภาพของลูกสุกรก่อนที่ตายก่อนหย่านมอย่างครบถ้วน นับว่าเป็นข้อจำกัดในภาคสนามที่ทำให้การระบุสาเหตุที่แท้จริงของการตายของลูกสุกรก่อนหย่านมยังทำได้ไม่มีประสิทธิภาพนัก เกษตรกร สัตวแพทย์ และ สัตวบาล ตลอดจนผู้ที่เกี่ยวข้องอื่นๆ จึงควรหันมาให้ความสนในการศึกษาสาเหตุและแนวทางแก้ไขปัญหาการตายของลูกสุกรก่อนหย่านมให้มากขึ้น และลึกซึ้งขึ้น เพื่อช่วยลดการสูญเสียลูกสุกรในเล้าคลอด และลดต้นทุนการผลิตสุกร

ปัจจัยที่มีอิทธิพลต่อการตายก่อนหย่านมของลูกสุกร

สาเหตุของการตายก่อนหย่านมของลูกสุกรได้รับอิทธิพลมาจากหลายปัจจัย โดยทั่วไปปัจจัยที่มีอิทธิพลต่อการตายของลูกสุกรก่อนหย่านมสามารถจำแนกออกเป็นสามกลุ่มใหญ่ๆ ได้แก่ ปัจจัยที่เกี่ยวข้องกับตัวลูกสุกรเอง ปัจจัยที่เกี่ยวข้องกับแม่สุกร และ ปัจจัยที่เกี่ยวข้องกับสิ่งแวดล้อม (Muns et al., 2016) ในบทความนี้จะขอกล่าวถึงปัจจัยที่เกี่ยวข้องกับลูกสุกรที่นำไปสู่การตายก่อนหย่านมเป็นหลัก โดยปัจจัยเหล่านี้สามารถจำแนกได้เป็นหัวข้อย่อยๆ ได้อีก 3 ประเด็นสำคัญ ได้แก่ น้ำหนักแรกคลอด ความแข็งแรง และ เพศของลูกสุกร

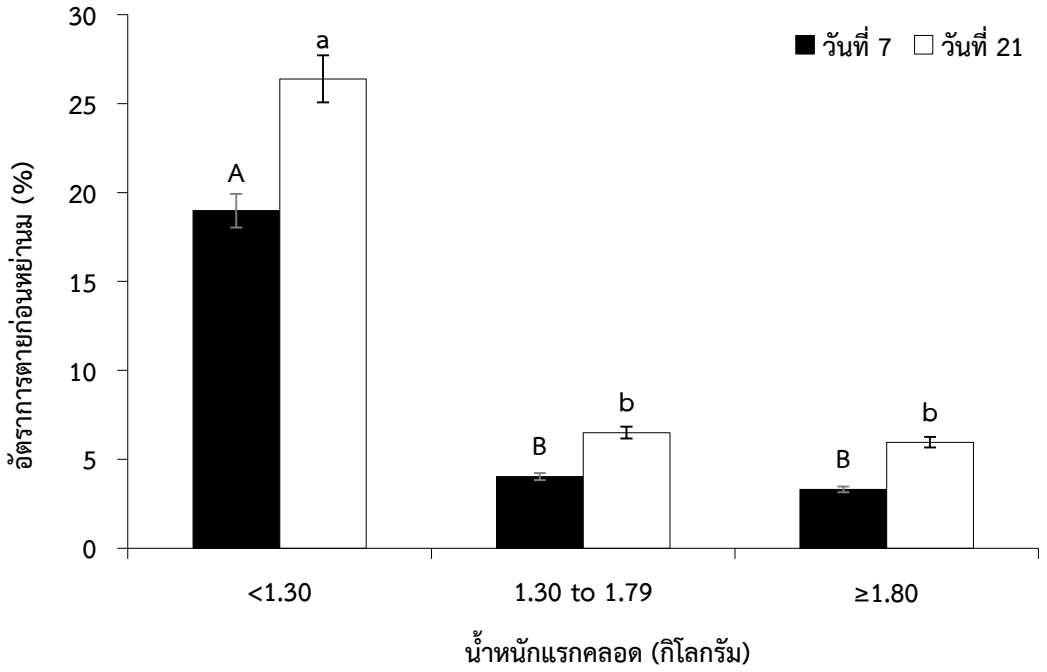
น้ำหนักแรกคลอด

น้ำหนักแรกคลอดเป็นปัจจัยที่สำคัญที่สุดต่อการรอดชีวิตและการเจริญเติบโตของลูกสุกร (Muns et al., 2013; Nuntapaitoon and Tummaruk 2015) (ตารางที่ 2) ลูกสุกรขนาดเล็กจะมีความสามารถในการรักษาอุณหภูมิของร่างกายต่ำลง (Theil et al., 2012) โดยมีการวิจัยพบว่าลูกสุกรที่มีน้ำหนักตัวน้อยกว่า 1.80 กิโลกรัม จะมีอัตราการรอดชีวิตมากกว่า 90% ในขณะที่ลูกสุกรที่มีน้ำหนักตัว 700 กรัม จะมีอัตราการรอดชีวิตเพียง 33% (Chris et al., 2012) Roehe and Kalm (2000) พบว่า น้ำหนักลูกสุกรแรกคลอดที่ลดลงเพิ่มโอกาสในการตายก่อนหย่านมมากขึ้น (รูปที่ 3) และ Fix et al. (2010) พบว่าลูกสุกรน้ำหนักแรกคลอดต่ำจะมีความสัมพันธ์กับอัตราการรอดชีวิตที่ต่ำตลอดวงจรการผลิต นอกจากนี้น้ำหนักแรกคลอดยังมีความสัมพันธ์ในเชิงบวกกับปริมาณน้ำนมเหลืองที่ลูกสุกรได้รับอีกด้วย (Ferrari et al., 2014)

ตารางที่ 2 อัตราการตายของลูกสุกรก่อนหย่านมในฟาร์มสุกรเชิงพาณิชย์แห่งหนึ่งในประเทศไทย จำแนกตามค่าเฉลี่ยของน้ำหนักแรกคลอดของลูกสุกร (*ที่มา:* Nuntapaitoon and Tummaruk 2015)

น้ำหนักแรกคลอด (กิโลกรัม)	จำนวนของแม่สุกร	อัตราการตายก่อนหย่านม (%)
≤ 1.30	642	18.8 ± 0.8[a]
1.30 – 1.79	8,284	15.7 ± 0.3[b]
≥ 1.80	2,228	12.1 ± 0.5[c]

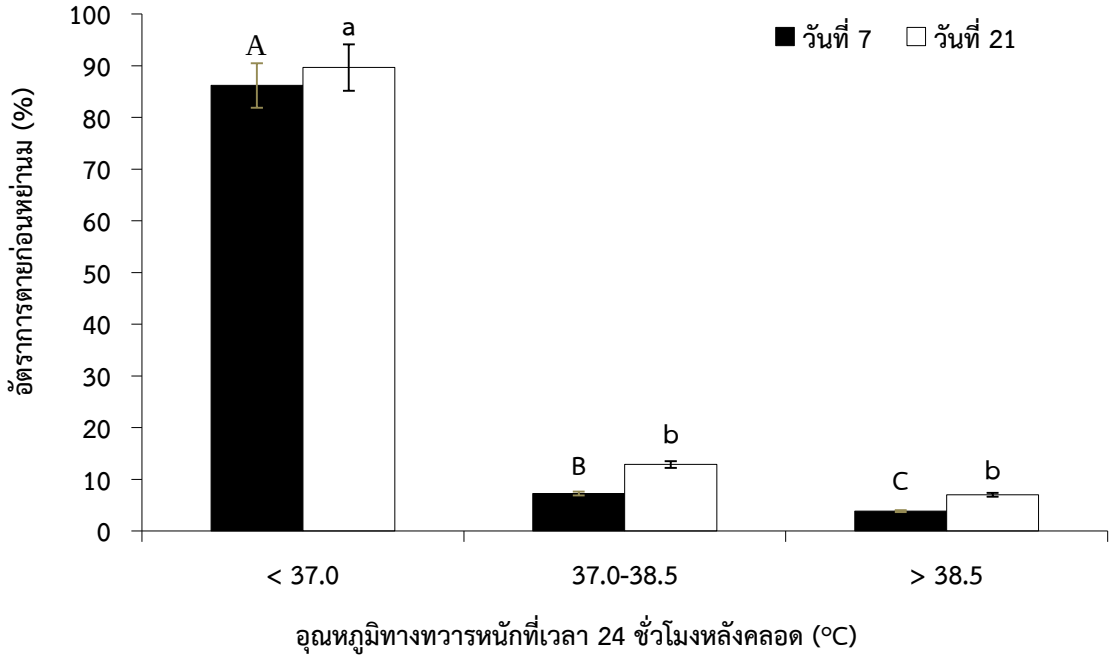
[a, b, c] ตัวอักษรยกที่แตกต่างกันมีความแตกต่างอย่างมีนัยสำคัญทางสถิติ (P<0.05)



รูปที่ 3 เปอร์เซ็นต์ของการตายของลูกสุกรในวันที่ 7 และ 21 หลังคลอด จำแนกตามน้ำหนักตัวแรกคลอดออกเป็น <1.30 กิโลกรัม (216 ตัว) 1.30 - 1.79 กิโลกรัม (323 ตัว) และ ≥1.80 กิโลกรัม (151 ตัว) ตัวอักษรยกที่ต่างกันมีความแตกต่างอย่างมีนัยสำคัญ (P<0.05) (*ที่มา:* Nuntapaitoon et al., 2018)

การมีพลังงานสำรองน้อย ในลูกสุกรที่มีน้ำหนักแรกคลอดต่ำ เป็นสาเหตุหนึ่งที่เพิ่มความเสี่ยงต่อการตายก่อนหย่านมในลูกสุกร ลูกสุกรน้ำหนักแรกคลอดต่ำจะมีดัชนีมวลกายต่ำ ดัชนีมวลกายมีความสัมพันธ์เชิงบวกกับกล้ามเนื้อของร่างกาย ปริมาณไกลโคเจน และอัตราการรอดชีวิตของลูกสุกร (Amdi et al., 2013) นอกจากนี้ น้ำหนักแรกคลอดมีความสำคัญอย่างมากต่อการบ่งชี้การอยู่รอดของลูกสุกรและความสามารถในการควบคุมอุณหภูมิร่างกาย (thermoregulation) ภายในชั่วโมงแรกหลังคลอด การควบคุมอุณหภูมิร่างกายของลูกสุกรจะได้รับผลกระทบจากการระเหยของของเหลวจากรกและทำให้ลูกสุกรมีความรู้สึกหนาวเย็นมาก ลูกสุกรที่อ่อนแอจะไม่สามารถฟื้นตัวได้จากอุณหภูมิที่ลดลงนี้ และภาวะอุณหภูมิร่างกายที่ต่ำลงจะส่งผลกระทบต่อความสามารถในการดูดนม นำไปสู่การขาดอาหาร อ่อนแรง (lethargy) และถูกแม่ทับตายในที่สุด มีการศึกษาวิจัยจำนวนมากที่แสดงให้เห็นว่าอุณหภูมิทางทวารหนักที่วัดภายใน 24 ชั่วโมงหลังคลอด มีความเกี่ยวข้องกับการตายของลูกสุกรก่อนหย่านม (Muns et al., 2013; Panzardi et al., 2013; Nuntapaitoon

et al., 2018) และชี้ให้เห็นว่าลูกสุกรที่มีอุณหภูมิทางทวารหนักต่ำอาจมีความสามารถในการควบคุมอุณหภูมิของร่างกายที่ต่ำ (รูปที่ 4) ลูกสุกรที่มีขนาดเล็กจะมีอัตราส่วนระหว่างพื้นที่ผิวของร่างกายต่อปริมาตรของร่างกายที่สูงขึ้น ส่งผลให้เกิดความเสี่ยงต่อการสูญเสียความร้อน และทำให้อุณหภูมิร่างกายต่ำลงเร็วขึ้น นอกจากนี้ลูกสุกรที่มีน้ำหนักแรกคลอดต่ำจำเป็นต้องใช้เวลานานกว่าในการเข้าถึงเต้านมแม่ และมีความสามารถต่ำกว่าในการแข่งขันกับลูกสุกรที่มีน้ำหนักตัวมากกว่าในครอกเดียวกัน จึงทำให้ได้รับปริมาณน้ำนมเหลืองลดน้อยลง (Tuchscherer et al., 2000) ผลการวิจัยโดย Vallet and Miles (2012) พบว่าลูกสุกรที่มีน้ำหนักแรกคลอดต่ำ จะมีความสามารถในการเคลื่อนไหวต่ำลง เนื่องจากมีเซลล์ประสาทภายในสมองที่มีประสิทธิภาพต่ำ ส่งผลกระทบต่อความสามารถในการส่งแรงกระตุ้นของเส้นประสาท ทำให้ลดประสิทธิภาพการดูดนมและเพิ่มโอกาสในการถูกแม่ทับตายมากขึ้น



รูปที่ 4 อัตราการตายก่อนหย่านมในวันที่ 7 และ 21 หลังคลอด ในลูกสุกร จำแนกกลุ่มตามอุณหภูมิทางทวารหนักที่วัดที่เวลา 24 ชั่วโมงหลังคลอด ออกเป็น <37.0 °C (29 ตัว) 37.0–38.5 °C (248 ตัว) และ >38.5 °C (413 ตัว) (*ที่มา:* Nuntapaitoon et al., 2018)

นอกจากนี้ความแปรปรวนภายในครอกของน้ำหนักลูกสุกรแรกคลอด ก็มีผลกระทบต่ออัตราการตายของลูกสุกรก่อนหย่านมเช่นกัน เนื่องจากลูกสุกรขนาดเล็กไม่สามารถแข่งขันกับลูกสุกรที่มีขนาดใหญ่ได้ ทำให้ลูกสุกรที่มีน้ำหนักแรกคลอดต่ำ มีระดับโภชนาการและระดับภูมิคุ้มกันต่ำลง ในช่วง 2 ทศวรรษที่ผ่านมา การปรับปรุงพันธุกรรมของแม่สุกรส่งผลให้แม่สุกรในปัจจุบันมีจำนวนลูกสุกรแรกคลอดเพิ่มมากขึ้น ในทางกลับกันก็ส่งผลให้น้ำหนักของลูกสุกรแรกคลอดมีแนวโน้มต่ำลง ซึ่งเกิดจากการลดลงของขนาดพื้นที่ของมดลูกสำหรับให้ลูกสุกรฝังตัวและลดปริมาณสารอาหารที่ลูกสุกรได้รับต่อตัว Quiniou et al. (2002) พบว่าแม่สุกรที่มีจำนวนลูกสุกรแรกคลอดทั้งหมดเพิ่มขึ้นจาก 9 ตัวต่อครอก เป็น 17 ตัวต่อครอก (เพิ่มขึ้น 88%) จะมีน้ำหนักรวมทั้งครอก (litter weight) เพิ่มขึ้นเพียง 55% เท่านั้น นอกจากนี้เมื่อมีการปรับปรุงพันธุกรรมสุกรให้มีขนาดครอก (litter size) ที่ใหญ่ขึ้นจะทำให้เกิดความแปรปรวนของน้ำหนักลูกสุกรแรกคลอดเพิ่มขึ้นด้วย เนื่องจากขนาด

ของรก การเจริญเติบโตของลูกสุกรจะแตกต่างกันไปตามความแตกต่างของประสิทธิภาพและการสร้างหลอดเลือดภายในรก Roehe and Kalm (2000) พบว่ารกขนาดเล็กจะมีประสิทธภาพในการส่งน้ำตาลกลูโคสและฟรุกโตสให้ลูกสุกรในมดลูกต่ำลง ส่งผลให้ลูกสุกรในมดลูกมีอัตราการเติบโตที่ลดลงและมีน้ำหนักแรกคลอดต่ำ การที่แม่สุกรมีขนาดของรกที่ไม่เพียงพอเป็นสาเหตุหลักของการเกิดปัญหาการเจริญเติบโตของตัวอ่อนภายในมดลูกอย่างจำกัด (intra-uterine growth restriction) ซึ่งมีผลในทางลบต่อน้ำหนักตัวของลูกสุกรแรกคลอด และทำให้ลูกสุกรมีความสามารถในการควบคุมอุณหภูมิ (thermoregulation) ต่ำลง

ความแข็งแรงของลูกสุกร (piglet vitality)

ความแข็งแรงของลูกสุกร (piglet vitality) เป็นสิ่งที่กำหนดความสามารถในการแข่งขันเพื่อเข้าหาเต้านมและดูดนม (Trujillo-Ortega et al., 2007) ลูกสุกรที่แข็งแรงจะมีอัตราการรอดชีวิตที่สูงขึ้นที่อายุ 7 วัน และ 10 วัน (Vasdal et al., 2011) และมีการเจริญเติบโตดีกว่าในช่วงหย่านม (Muns et al., 2013) ตัวแปรทางสรีรวิทยาของลูกสุกรที่ถูกนำมาใช้ในการประเมินความแข็งแรงของลูกสุกรแรกคลอด และแปรผลเป็นคะแนนความแข็งแรงของลูกสุกร ได้แก่ อัตราการเต้นของหัวใจ (heart rate) การบีบตัวของกล้ามเนื้อ การเริ่มหายใจ และความพยายามในการยืนหลังคลอด ตัวแปรเหล่านี้ให้ผลในเชิงบวกต่ออัตราการรอดและอุณหภูมิทางทวารหนักหลังคลอดหนึ่งชั่วโมงในลูกสุกร นอกจากนี้ *“ความสามารถในการเข้าดูดนมได้ครั้งแรกหลังคลอด”* และ *“ความสามารถในการควบคุมอุณหภูมิร่างกายในช่วง 24 ชั่วโมงแรกของชีวิต”* ก็ถูกนำมาใช้บ่งชี้ความแข็งแรงของลูกสุกรเช่นกัน นอกจากนี้ยังมีการวิจัยพบว่าตัวแปรเหล่านี้ส่งผลในเชิงบวกกับปริมาณน้ำนมเหลืองที่ลูกสุกรได้รับอีกด้วย (Tuchscherer et al., 2000) ความแข็งแรงของลูกสุกร มีความสัมพันธ์กับพฤติกรรมและการตอบสนอง จากการทดสอบทางประสาทวิทยา (neuro-behavior) หรือ การทดสอบการตอบสนอง ลูกสุกรที่มีโอกาสรอดจะแสดงพฤติกรรมและการตอบสนองที่ดี เมื่อเร็วๆ นี้ มีความพยายามในการศึกษาพฤติกรรมของลูกสุกรหลังคลอด เช่น การกระตุ้นเต้านม ความสามารถในการเคลื่อนตัวภายในคอกวงกลม (รูปที่ 5) เพื่อแสดงถึงความสามารถในการอยู่รอดของพบว่าลูกสุกรที่แสดงพฤติกรรมเหล่านี้มีอัตราการรอดชีวิตและการเจริญเติบโตที่สูงขึ้น (Muns et al., 2013) การประเมินความแข็งแรงของลูกสุกรทางสรีรวิทยาและพฤติกรรมดังกล่าว ต้องทำในช่วงแรกคลอดและบางอย่างต้องใช้อุปกรณ์ด้วย (Muns et al., 2013)

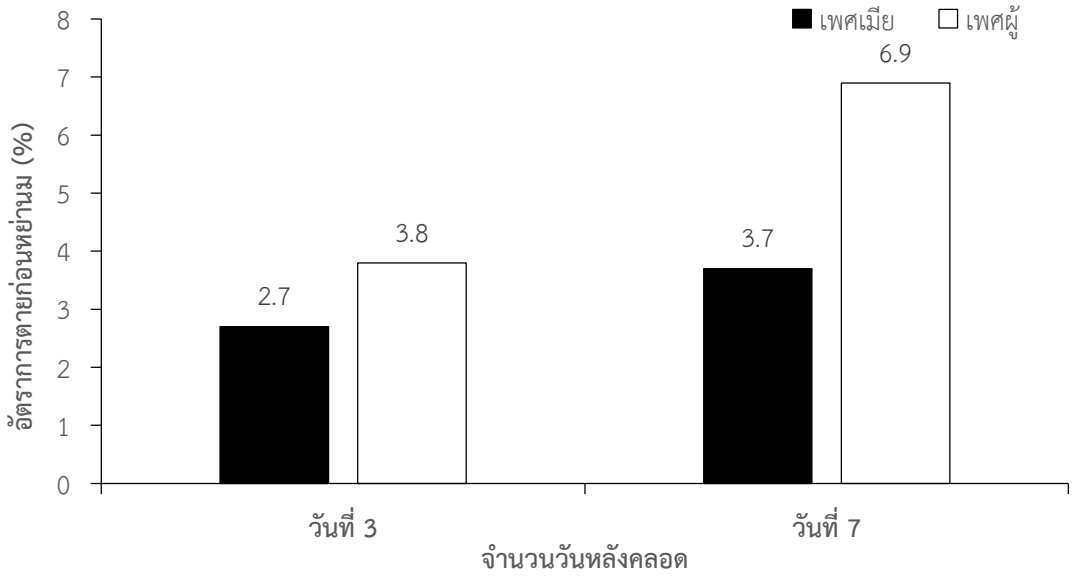
รูปที่ 5 การทดสอบการเคลื่อนไหวของลูกสุกรเป็นวงกลมในภาชนะทรงกระบอก

ความแข็งแรงของลูกสุกรแรกคลอด มีความเกี่ยวข้องกับภาวะการขาดออกซิเจนของลูกสุกรขณะที่อยู่ในช่องคลอด (หรือภาวะขาดอากาศหายใจในระหว่างคลอด) ซึ่งเกิดกับลูกสุกรเมื่อคลอด (Trujillo-Ortega et al., 2007) และเป็นสาเหตุสำคัญที่สุดของการตายแรกคลอด (stillbirth) และการตายของลูกสุกรก่อนหย่านมในช่วงต้น *"ความสมบูรณ์ของสายสะดือ"* มีความเกี่ยวข้องกับความแข็งแรงของลูกสุกร การแตกของสายสะดือจะลดการส่งเลือดไปเลี้ยงลูกสุกรและเสี่ยงที่จะทำให้เกิดภาวะโลหิตจางและหรือภาวะขาดออกซิเจน (hypoxia) ลดความแข็งแรงของลูกสุกร และเพิ่มความเสี่ยงต่อการตายในช่วงต้น ร่างกายที่ผิดปกติ เช่น อาการขากางแต่กำเนิด (splay-leg) เป็นอุปสรรคต่อการเคลื่อนไหวของลูกสุกร หรือความเสียหายของระบบประสาทส่วนกลางของลูกสุกรซึ่งเกิดจากการขาดออกซิเจน ความผิดปกติแต่กำเนิด หรือ ความเครียดของแม่สุกร จะลดความแข็งแรงของลูกสุกรและเพิ่มโอกาสในการถูกแม่ทับตายได้มากขึ้น นอกจากนี้ความแข็งแรงของลูกสุกรยังมีความเกี่ยวข้องกับระดับน้ำตาลในเลือดอีกด้วย แต่ผลการวิจัยยังไม่เป็นไปในแนวทางเดียวกัน โดยพบว่าระดับความเข้มข้นของกลูโคสในเลือดที่สูง (45-162 มิลลิกรัมต่อเดซิลิตร) เป็นผลมาจากความทรมานระหว่างการคลอด และ กลูโคสความเข้มข้นต่ำ (24-30 มิลลิกรัมต่อเดซิลิตร) เป็นสัญญาณบ่งชี้ว่าร่างกายมีปริมาณน้ำตาลที่สะสมต่ำ (Panzardi et al., 2013; Trujillo-Ortega et al., 2007)

"การขาดออกซิเจนของลูกสุกรขณะที่อยู่ในช่องคลอด" เป็นปัจจัยหลักที่มีอิทธิพลต่อความแข็งแรงของลูกสุกรแรกคลอด โดยการขาดออกซิเจนจะทำให้เกิดการเสียหายของระบบประสาทส่วนกลางของลูกสุกรในท้อง และลดความสามารถในการเข้าหาเต้านม เพิ่มระยะเวลาตั้งแต่เกิดจนกระทั่งดูดนมครั้งแรก ซึ่งนำไปสู่ปัญหาอุณหภูมิของร่างกายต่ำและการขาดอาหาร คะแนนความแข็งแรงของลูกสุกรที่ต่ำมีความสัมพันธ์กับระดับแลคเตตในเลือดที่เพิ่มขึ้น CO_2 ที่เพิ่มขึ้น และความเป็นกรดในเลือดที่ลดลง ลำดับการคลอด (birth order) และการคลอดโดยเอาขาออก (posterior presentation) เป็นปัจจัยที่สัมพันธ์กับการขาดออกซิเจนของลูกสุกรขณะที่อยู่ในช่องคลอด การบีบตัวของมดลูกในแม่สุกรที่มีระยะเวลาในการคลอดนานเกินไป จะลดปริมาณออกซิเจนของลูกสุกรก่อนคลอด ทำให้ความแข็งแรงของลูกสุกรลดลง (Alonso-Spilsbury et al., 2005) และจะทำให้มีความเสี่ยงสูงมากขึ้นในลูกสุกรที่คลอดหลังๆ การใช้ฮอร์โมนออกซิโตซินที่มากเกินไป เช่น การใช้ฮอร์โมนออกซิโตซินเป็นประจำหลังคลอดลูกสุกรตัวแรกหรือการให้ยาเกินขนาด อาจทำให้ความแข็งแรงของลูกสุกรลดลง โดยเกิดจากความรุนแรงและความถี่ในการหดตัวของมดลูกเพิ่มมากขึ้น

เพศของลูกสุกร

การตายของลูกสุกรก่อนหย่านมมีแนวโน้มที่จะพบได้สูงกว่าในลูกสุกรเพศผู้ ถึงแม้ว่าลูกสุกรเพศผู้จะมีน้ำหนักแรกคลอดโดยเฉลี่ยสูงกว่าเพศเมียก็ตาม (Baxter et al., 2012) โดย Baxter et al. (2012) วิจัยพบว่าลูกสุกรเพศเมียใช้พลังงานไปกับระบบทางสรีรวิทยาจำเพาะ (เช่น การควบคุมอุณหภูมิและระบบภูมิคุ้มกัน) ในขณะที่ลูกสุกรเพศผู้ใช้พลังงานไปกับการเพิ่มขนาดและองค์ประกอบของร่างกาย (ได้แก่ กระบวนการที่เชื่อมโยงกับสมรรถภาพการสืบพันธุ์ในระยะโตเต็มวัย) ส่งผลให้ลูกสุกรเพศผู้มีแนวโน้มมีความเสี่ยงต่อการตายที่เกี่ยวข้องกับการใช้พลังงาน (เช่น ความหนาวเย็น การขาดอาหาร ถูกแม่ทับ และ โรค) เช่นเดียวกัน Panzardi et al. (2013) วิจัยพบว่าลูกสุกรเพศเมียมีความสามารถในการอยู่รอดสูงกว่าลูกสุกรเพศผู้อย่างมีนัยสำคัญ (รูปที่ 6) อย่างไรก็ดีงานวิจัยบางชิ้นก็ไม่พบว่าเพศของลูกสุกรมีผลต่ออัตราการตายของลูกสุกรก่อนหย่านมแต่อย่างใด (Li et al., 2012)



รูปที่ 6 อัตราการตายของลูกสุกรในวันที่ 3 และ 7 หลังคลอด จำแนกตามเพศของลูกสุกร (ที่มา: ดัดแปลงจากข้อมูลของ Panzardi *et al.* 2013)

น้ำนมเหลือง

น้ำนมเหลือง (colostrum) เป็นสิ่งคัดหลั่งสิ่งแรกที่ผลิตออกมาจากต่อมสร้างน้ำนมและมีการหลั่งอย่างต่อเนื่องในช่วงคลอดนานถึง 12-24 ชั่วโมง (Quesnel et al., 2012) (ตารางที่ 3) ก่อนที่การหลั่งจะเปลี่ยนเป็นวงจรและต้องใช้การดูดของลูกสุกรเป็นตัวกระตุ้น น้ำนมเหลืองเป็นแหล่งอาหารที่ประกอบด้วยสารอาหารที่ย่อยง่ายและมีสารออกฤทธิ์ทางชีวภาพต่างๆ เช่น อิมมูโนโกลบูลลิน เอนไซม์ไฮโดรไลติก ฮอร์โมน และปัจจัยที่ช่วยในการเจริญเติบโต (Wu et al., 2010) ดังนั้นน้ำนมเหลืองจึงมีบทบาทสำคัญในการควบคุมอุณหภูมิร่างกายลูกสุกร การส่งต่อภูมิคุ้มกันถ่ายทอด และการพัฒนาของลำไส้ของลูกสุกร (Devillers et al., 2007)

ตารางที่ 3 องค์ประกอบของไขมัน โปรตีน แลคโต๊ส ของแข็งทั้งหมด และพลังงานในน้ำนมเหลือง น้ำนมในช่วงเปลี่ยนผ่าน และน้ำนมปกติ (ที่มา: Theil *el al.* 2014)

	น้ำนมเหลือง			น้ำนมในช่วงเปลี่ยนผ่าน		น้ำนมปกติ	
	ช่วงต้น	ช่วงกลาง	ช่วงท้าย				
ระยะเวลาหลังคลอด	0 h	12 h	24 h	36 h	3 d	17 d	SEM
องค์ประกอบทางเคมี (กรัม/100 กรัม)							
ไขมัน	5.1	5.3	6.9	9.1	9.8	8.2	0.5
โปรตีน	17.7	12.2	8.6	7.3	6.1	4.7	0.5
แลคโต๊ส	3.5	4.0	4.4	4.6	4.8	5.1	0.1
ของแข็ง (dry mater)	27.3	22.4	20.6	21.4	21.2	18.9	0.6
พลังงาน (kg/100g)	260	276	346	435	468	409	21

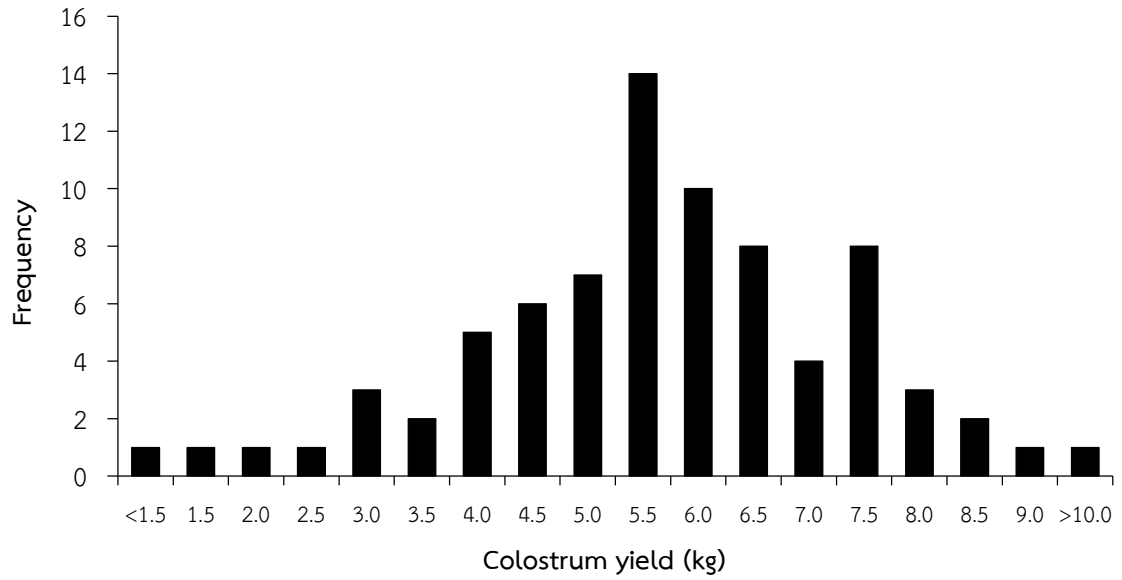
น้ำนมเหลืองเป็นแหล่งพลังงาน ที่สามารถเผาผลาญได้สูงในลูกสุกรแรกคลอด และมีปริมาณไขมันและแลคโต๊สสูง (ตารางที่ 3) เพื่อให้ลูกสุกรสามารถรับมือกับความเครียดจากความหนาวเย็นได้ โดยการเพิ่มอัตราการเผาผลาญและรักษาสมดุลของร่างกายในวันแรกหลังคลอด มีการวิจัยพบว่าอุณหภูมิทางทวารหนักของลูกสุกรที่ 24 ชั่วโมงหลังคลอดมีความสัมพันธ์ในเชิงบวกกับปริมาณน้ำนมเหลืองที่ลูกสุกรได้รับ (Devillers et al., 2011) และมีความสัมพันธ์เชิงลบกับระยะเวลาตั้งแต่คลอดจนกระทั่งลูกสุกรสามารถดูดนมได้ครั้งแรก (Tuchscherer et al., 2000) **โปรตีนในน้ำนมเหลือง** ประกอบด้วย อิมมูโนโกลบูลลิน ได้แก่ อิมมูโนโกลบูลลินจี (IgG) อิมมูโนโกลบูลลินเอ็ม (IgM) และ อิมมูโนโกลบูลลินเอ (IgA) IgG เป็นสารออกฤทธิ์ทางชีวภาพที่พบมากที่สุดในน้ำนมเหลืองและมีความเข้มข้นสูงที่สุดในช่วงหลังคลอดไม่กี่ชั่วโมงแรกและลดลงอย่างรวดเร็วภายใน 24 ชั่วโมง ลูกสุกรแรกคลอดจำเป็นต้องได้รับภูมิคุ้มกันถ่ายทอดจากการกิน IgG ในน้ำนมเหลือง เพื่อลดความไวต่อการติดเชื้อหลังคลอดและหลังหย่านม (Rooke and Bland, 2002) การดูดซึม IgG ในลูกสุกรแรกคลอดจะต้องเกิดขึ้นเกิดขึ้นก่อนที่กระบวนการการดูดซึมโปรตีนในลำไส้จะสิ้นสุดลง (gut closer) ซึ่งเกิดขึ้นเมื่อลูกสุกรมีอายุประมาณ 24 ชั่วโมง (Quesnel et al., 2012) ความเข้มข้นของ IgG ในพลาสมาของลูกสุกรที่อายุ 24 ชั่วโมงมีความสัมพันธ์เชิงบวกกับปริมาณน้ำนมเหลืองที่ลูกสุกรได้รับ (Devillers et al., 2011) Muns et al. (2014) วิจัยพบว่าการเสริมน้ำนมเหลือง ให้แก่ลูกสุกรที่มีน้ำหนักแรกคลอดต่ำ ตัวละ 15 มิลลิลิตร สามารถเพิ่มความเข้มข้นของ IgG ในพลาสมาของลูกสุกรที่อายุ 4 วัน ได้ น้ำนมเหลืองของสุกรยังประกอบด้วยสารที่ช่วยในเจริญเติบโต (growth factor) ที่แตกต่างกัน เช่น insulin-like growth factor (IGF) I และ II epidermal growth factor insulin และ transforming growth factor-beta) Xu et al. (2000) พบว่าส่วนประกอบที่ช่วยในเจริญเติบโตที่ผ่านมาทางน้ำนมเหลือง เป็นกลไกในการกระตุ้นการเจริญเติบโตของและพัฒนาการทำงานของเนื้อเยื่อระบบทางเดินอาหารของลูกสุกร นอกจากนี้น้ำนมเหลืองยังช่วยเพิ่มการดูดซึมในลำไส้ การเริ่มต้นของการปิดตัวของลำไส้ และช่วยในการซ่อมแซมผิวเยื่อเมือกที่เสียหายอีกด้วย (Rooke and Bland, 2002) ซึ่งกระบวนการทั้งหมดนี้เป็นสิ่งจำเป็นสำหรับการเปลี่ยนแปลงของระบบทางเดินอาหารในช่วงหลังคลอด

Quesnel *et al.* (2012) พบว่าน้ำนมเหลืองที่ลูกสุกรได้รับในปริมาณไม่น้อยกว่า 250 กรัมต่อตัวสามารถทำให้ลูกสุกรมีการเจริญเติบโตและได้รับภูมิคุ้มกันถ่ายทอดที่เพียงพอ Pierzynowski et al. (2014) พบว่าน้ำนมเหลืองที่ลูกสุกรได้รับสามารถกระตุ้นพัฒนาการของสมองส่วนฮิพโปแคมปัสโดยการกระตุ้นการสังเคราะห์โปรตีนในสมองและการพัฒนาสมองในช่วงแรกหลังคลอด น้ำนมเหลืองที่ลูกสุกรได้รับยังสามารถเพิ่มน้ำหนักหย่านมและเพิ่มน้ำหนักลูกสุกรที่ 6 สัปดาห์ด้วย (Decaluwé *et al*., 2014) บ่งชี้ว่าน้ำนมเหลืองที่ลูกสุกรได้รับส่งผลในระยะยาวต่อการเจริญเติบโตของลูกสุกร (Devillers *et al.,* 2011) ปริมาณน้ำนมเหลืองที่ลูกสุกรได้รับยังมีความสัมพันธ์ในเชิงบวกกับอัตราการรอดชีวิตของลูกสุกรก่อนหย่านมอีกด้วย (Decaluwé *et al.*, 2014) ดังนั้นสภาวะใดๆ ที่ทำให้ความสามารถในการได้รับน้ำนมเหลืองของลูกสุกรลดลงจะเพิ่มความเสี่ยงต่อการตายหรือทำให้ความสามารถในการเจริญเติบโตลดลง

ปัจจัยที่มีอิทธิพลต่อปริมาณน้ำนมเหลืองที่ลูกสุกรได้รับ ประกอบด้วย ความแข็งแรงของลูกสุกร ลำดับการคลอด (birth order) จำนวนลูกสุกรแรกคลอดมีชีวิตต่อครอก และโภชนาการของแม่สุกร (Quesnel et al., 2012) ความสามารถของลูกสุกรในการเข้าถึงเต้านม และการดูดนมมีความเกี่ยวข้องกับการเพิ่มขึ้นของปริมาณน้ำนมเหลืองที่ลูกสุกรได้รับ ในขณะที่ความแข็งแรงของลูกสุกรที่ลดลงหลังคลอดหรือปัจจัยอื่นๆ ที่มีผลกระทบต่อช่วงเวลาตั้งแต่คลอดจนกระทั่งลูกสุกรสามารถดูดนมครั้งแรกมีความสัมพันธ์เชิงลบกับปริมาณน้ำนมเหลืองที่ลูกสุกรได้รับ การแข่งขันระหว่างลูกสุกรในครอกเดียวกันส่งผลกระทบในเชิงลบต่อปริมาณน้ำนมเหลืองที่ลูกสุกรได้รับโดยเฉพาะอย่างยิ่งในครอกที่มีลูกสุกรน้ำหนักแรกคลอดต่ำ เนื่องจากครอกขนาดใหญ่

(large litter) จะมีการต่อสู้ในการดูดนมมากขึ้น มีความเสี่ยงต่อการขาดอาหาร และการถูกแม่สุกรทับตายมากขึ้น

ปริมาณน้ำนมเหลืองที่แม่สุกรผลิตได้ (colostrum yield) มีความแตกต่างกันอย่างมากระหว่างแม่สุกรแต่ละตัว (รูปที่ 7) ถึงแม้จะอยู่ในสายพันธุ์และในสภาพที่อยู่อาศัยและการจัดการเดียวกัน (Devillers et al., 2007) การกระตุ้นเต้านมโดยลูกสุกรอย่างเหมาะสมสามารถกระตุ้นให้เกิดผลผลิตน้ำนมเหลืองได้สูงสุด จากการวิจัยพบว่าปริมาณน้ำนมเหลืองที่แม่สุกรผลิตได้ทั้งหมดอยู่ระหว่าง 2.5 ถึง 5.0 กิโลกรัม ในครอกที่มีลูกสุกร 8 ถึง 12 ตัว ปริมาณน้ำนมเหลืองที่แม่สุกรผลิตได้ขึ้นกับน้ำหนักครอก (litter weight) และความแปรปรวนของน้ำหนักลูกสุกรในครอก (Devillers et al., 2007) ความล้มเหลวในการผลิตน้ำนมเหลืองจากแม่สุกรจะส่งผลเสียต่อการอยู่รอดและการเจริญเติบโตของลูกสุกร การผลิตน้ำนมไม่เพียงพอในแม่สุกรมีส่วนทำให้อัตราการตายก่อนหย่านมสูงถึง 6 ถึง 17% ปริมาณน้ำนมเหลืองที่แม่สุกรสามารถผลิตได้ขึ้นอยู่กับ พันธุ์ อาหาร ปริมาณน้ำดื่มที่แม่สุกรได้รับ ระดับพลังงาน ความสะอาด ลำดับท้องของแม่สุกร และอื่น ๆ เช่น การเหนี่ยวนำคลอด สิ่งแวดล้อม และ ฮอร์โมน (Devillers et al., 2007) นอกจากนี้กลุ่มอาการ post-partum dysgalactia syndrome (PDS) หรือ mastitis-metritis-agalactia (MMA) ทำให้เกิดความล้มเหลวในการให้นมลูกในช่วง 3 วันแรกหลังคลอดได้ การย้ายแม่สุกรไปยังเล้าคลอดช้าเกินไป การให้อาหารแบบไม่จำกัดในวันแรกหลังคลอด การคลอดยาก ท้องผูก สุขอนามัยที่พื้นคอกไม่ดี และอุณหภูมิสิ่งแวดล้อมสูง เป็นปัจจัยที่มีเพิ่มโอกาสการเกิด PDS ได้ (Muns et al., 2016)

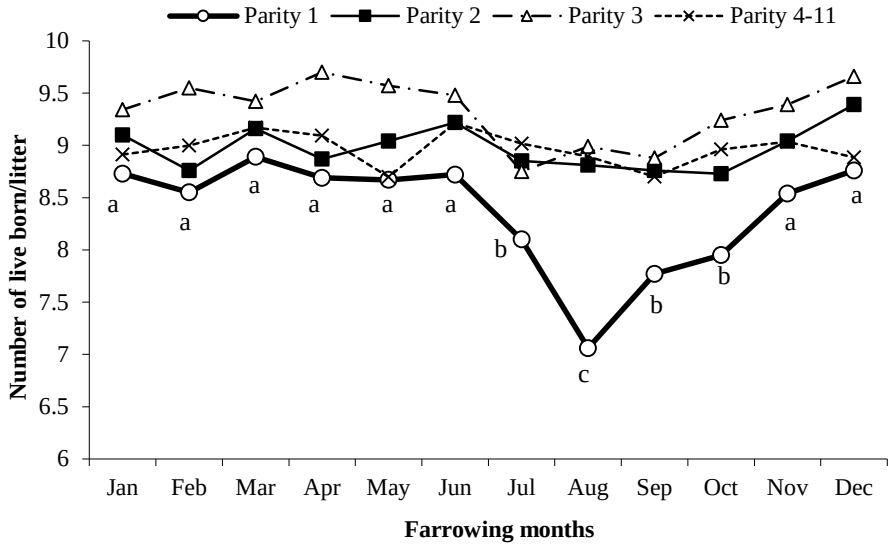


รูปที่ 7 ปริมาณน้ำนมเหลืองที่แม่สุกรแม่สุกรผลิตได้ภายใน 24 ชั่วโมงหลังคลอด จากการศึกษาในแม่สุกรพันธุ์ผสมแลนด์เรซ x ยอร์กเชียร์ จำนวน 78 ตัว ในฟาร์มสุกรเชิงพาณิชย์แห่งหนึ่งในประเทศไทย

ลำดับท้อง

ผลของลำดับท้องของแม่สุกรต่ออัตราการตายของลูกสุกรก่อนหย่านมมีความขัดแย้งกันในหลายรายงาน เช่น Knol et al. (2002) และ Carney-Hinkle et al. (2013) พบว่าลำดับท้องไม่มีผลต่ออัตราการตายของลูกสุกร แต่ Muns et al. (2015) พบว่าอัตราการตายของลูกสุกรก่อนหย่านมในแม่สุกรสาวต่ำกว่าในแม่สุกรนาง นอกจากนี้ ยังมีการศึกษาพบว่าลำดับท้องมีความสัมพันธ์เชิงลบกับการตายของลูกสุกรก่อนหย่านม (Koketsu et al., 2006) เป็นที่ทราบกันดีว่า แม่สุกรลำดับท้องที่ 2 และ 3 มีแนวโน้มที่จะผลิตน้ำนมเหลืองสูง

กว่าแม่สุกรในกลุ่มอื่นๆ (Devillers et al., 2007) และแม่สุกรลำดับท้องที่ 4-6 สามารถผลิตน้ำนมเหลืองได้สูงกว่าแม่สุกรท้องแรก (Ferrari et al., 2014) เนื่องจากแม่สุกรท้องแรกผลิตน้ำนมเหลืองได้น้อยจึงทำให้เกิดการตายของลูกสุกรก่อนหย่านมสูงขึ้นในงานวิจัยบางฉบับ ลูกสุกรที่เกิดจากแม่สุกรท้องแรกจะได้รับปริมาณน้ำนมเหลืองน้อยกว่าลูกสุกรที่เกิดจากแม่สุกรท้อง 4-6 ในการวิจัยของ Ferrari et al. (2014) ดังนั้นภูมิคุ้มกันในลูกสุกรจากแม่สุกรนางจะมีมากกว่าลูกสุกรจากแม่สุกรสาว ทำให้มีอัตราการตายก่อนหย่านมของลูกสุกรจากแม่สุกรนางน้อยกว่าและอัตราการเจริญเติบโตมากกว่าลูกสุกรจากแม่สุกรสาว (Ferrari et al., 2014) นอกจากนี้ลูกสุกรที่เกิดจากแม่สุกรสาว มักจะมีน้ำหนักแรกคลอดต่ำและมีความเข้มข้นของ IgA และ IgG ต่ำกว่าลูกสุกรที่เกิดจากแม่สุกรนาง (Carney-Hinkle et al., 2013) นอกจากนี้สุกรสาวมีประสบการณ์ในการคลอดที่น้อยกว่าแม่สุกรนางซึ่งอาจส่งผลกระทบต่ออัตราการตายของลูกสุกรก่อนหย่านมเช่นกัน Ruediger and Schulze (2012) วิจัยพบว่าแม่สุกรสาวเกิดความเครียดหลังคลอดได้มากกว่าแม่สุกรนาง นอกจากนี้สุกรสาวยังมีประสิทธิภาพในการสืบพันธุ์ต่ำกว่าและมีความไวต่อปัจจัยทางสิ่งแวดล้อมมากกว่าแม่สุกรนางอีกด้วย (Tummaruk et al., 2004; Tummaruk et al., 2010) (รูปที่ 8)



รูปที่ 8 ผลกระทบของฤดูกาลต่อขนาดครอกในสุกรสาวเปรียบเทียบกับแม่สุกรนาง (ที่มา: Tummaruk et al., 2004)

ในทางตรงกันข้าม สำหรับการวิจัยที่ไม่พบความสัมพันธ์ระหว่างลำดับท้องและการตายของลูกสุกรก่อนหย่านม สามารถอธิบายได้ว่าขนาดครอกมักเพิ่มขึ้นตามลำดับท้องของแม่สุกรที่เพิ่มขึ้น น้ำหนักแรกคลอดต่ำมักเกิดขึ้นพร้อมกับการเพิ่มขนาดครอก ความแปรปรวนของน้ำหนักแรกคลอดภายในครอกยังมีการเพิ่มขึ้นตามขนาดครอก ลูกสุกรที่อายุ 0 ถึง 7 วัน มีความเสี่ยงต่อการตายเมื่อเลี้ยงกับแม่สุกรอายุมาก ระยะเวลาในการคลอดของแม่สุกรท้องแรกจะสั้นกว่าแม่สุกรที่มีลำดับท้องมากกว่า 2 (Tummaruk and Sang-Gassanee, 2013) นอกจากนี้แม่สุกรที่อายุมากยังมีระยะเวลาในการคลอดนานเนื่องจากมีไขมันมากเกินไปและการบีบตัวของกล้ามเนื้อมดลูกลดลงซึ่งจะเพิ่มความเสี่ยงในการเกิดปัญหาการขาดออกซิเจนในลูกสุกรขณะที่อยู่ในช่องคลอดได้มากขึ้น ในแม่สุกรที่อายุมากจะมีจำนวนเต้านมทำงานได้ลดลง 41% (Vasdal and Andersen, 2012)

ความเครียดของแม่สุกร

ในช่วงเวลาใกล้คลอดและหลังคลอด (peri-partum period) (ตั้งแต่ 4 วันก่อนคลอด ถึง 3 วันหลังคลอด) เป็นระยะเวลาที่สำคัญมากในการผลิตลูกสุกร กระบวนการคลอดเริ่มต้นขึ้นในช่วงไม่กี่วันก่อนคลอด ในระหว่างนี้แม่สุกรอาจถูกทำให้เครียดจากการถูกย้ายเข้าไปในคอกคลอดซึ่งเป็นสภาพแวดล้อมใหม่และความเครียดจากกระบวนการคลอด ความเครียดระหว่างคลอดจะทำให้ระยะเวลาในการคลอด (farrowing duration) เพิ่มขึ้น และการผลิตน้ำนมเหลืองลดลง ซึ่งทำให้พลังงานและปริมาณ IgG ที่ลูกสุกรควรจะได้รับลดลง ความเครียดจากการคลอดอาจส่งผลต่อพฤติกรรมของแม่สุกรและนำไปสู่ภาวะกระวนกระวายและการก้าวร้าวด้วยเช่นกัน ซึ่งจะเพิ่มความเสี่ยงในการทับลูกสุกรและไม่ให้ลูกสุกรดูดนม (Baxter et al., 2011) Muns et al. (2014) พบว่าแม่สุกรที่มีแนวโน้มว่ามีระดับคอร์ติซอลสูงขึ้นหลังจากเข้าเล้าคลอดจะมีการเคลื่อนไหวเพิ่มขึ้นในช่วงหนึ่งวันก่อนคลอด ความเครียดของแม่ก่อนคลอดส่งผลต่อพฤติกรรมและสรีรวิทยาของลูกสุกรโดยการเปลี่ยนแปลงการทำงานของไฮโปธารามัส (Muns et al., 2014) Muns et al. (2014) พบว่าลูกสุกรที่เกิดจากแม่สุกรที่เครียดจะมีอัตราการตายก่อนหย่านมที่สูงขึ้นและโตช้าลง ทั้งนี้อาจเป็นเพราะความสามารถในการควบคุมอุณหภูมิของลูกสุกรที่น้อยลง จากการยับยั้งการทำงานของต่อมไทรอยด์เนื่องจากความเครียดของแม่สุกรก่อนคลอด

โภชนาการในแม่สุกร

โภชนาการในแม่สุกร (sow nutrition) มีบทบาทสำคัญต่อการตายของลูกสุกรก่อนหย่านม เนื่องจากอาหารมีอิทธิพลต่อพัฒนาการของลูกสุกรในครรภ์ในระหว่างอุ้มท้องโดยมีผลกระทบโดยตรงต่อน้ำหนักแรกคลอดของลูกสุกรและความสามารถในการอยู่รอดของลูกสุกร (Campos et al., 2012) ดังนั้นการให้อาหารเสริมในแม่สุกรอุ้มท้องและเลี้ยงลูกเพื่อลดการตายของลูกสุกรก่อนหย่านมและเพิ่มการเจริญเติบโตของลูกสุกรจึงได้รับความสนใจจากนักวิจัยจำนวนมากในช่วงไม่กี่ปีที่ผ่านมา มีการวิจัยพบว่าน้ำหนักแรกคลอดของลูกสุกรมีความสัมพันธ์เชิงบวกกับปริมาณพลังงานที่แม่สุกรได้รับตลอดการอุ้มท้อง (Campos et al., 2012) นอกจากนี้มีการวิจัยพบว่าในแม่สุกรที่ให้ผลผลิตสูง การสูญเสียตัวอ่อนในระยะต้นไม่ได้รับผลกระทบจากการให้อาหารมากเกินไป (de Vos et al., 2014) อย่างไรก็ดีการให้โปรตีนเพื่อการเจริญเติบโตของลูกสุกรในครรภ์มีความสำคัญมากขึ้นในระหว่างอุ้มท้อง (de Vos et al., 2014) การจำกัดปริมาณของโปรตีนหรือการที่มีกรดอะมิโนที่ไม่สมดุลในอาหารแม่สุกรอุ้มท้อง อาจเพิ่มอุบัติการณ์การเกิดลูกสุกรที่มีน้ำหนักแรกคลอดต่ำ (Kim et al., 2009) การเจริญเติบโตของลูกสุกรในครรภ์ถูกควบคุมโดยกรดอะมิโนในตระกูลอาร์จีนีน (arginine) (Wu et al., 2011) การเสริม *L*-arginine หรือ *L*-glutamine ในอาหารแม่สุกรสามารถเพิ่มน้ำหนักแรกคลอดของลูกสุกรได้อย่างมีนัยสำคัญ (Gao et al., 2012; Wu et al., 2013) นอกจากนี้อาหารที่เสริมด้วย *L*-carnitine ในระหว่างอุ้มท้องยังสามารถเพิ่มน้ำหนักแรกคลอดได้อีกด้วย (Doberenz et al., 2006) เนื่องจากการเพิ่มปริมาณปริมาณน้ำตาลกลูโคส glucose transporter -1 และ IGF-I ในมดลูก (Doberenz et al., 2006) และการพัฒนาเส้นใยกล้ามเนื้อเพิ่มขึ้น ในทางกลับกันความสามารถในการอยู่รอดของลูกสุกรยังได้รับอิทธิพลทางอ้อมจากโภชนาการของแม่ โดยพบว่าลูกสุกรที่เกิดจากแม่สุกรที่เสริมด้วย *L*-carnitine มีพฤติกรรมการดูดนมที่ดีขึ้น การเสริมอาหารด้วยน้ำมันปลาทูน่าหรือแซลมอนทำให้ลูกสุกรมีพฤติกรรมการดูดนมที่ดีขึ้นและลดอัตราการเกิดการถูกแม่ทับตายถึงแม้ว่าน้ำหนักแรกคลอดจะลดลง ซึ่งเป็นที่ทราบกันดีว่า กรดไขมันไม่อิ่มตัวสายยาว (long-chain polyunsaturated fatty acids-PUFAs) เป็นส่วนประกอบสำคัญในการพัฒนาสมองและหน้าที่ทางสรีรวิทยาอื่นๆ (de Vos et al., 2014)

โภชนาการของแม่สุกรอุ้มท้องระยะท้ายส่งผลกระทบต่อปริมาณน้ำนมเหลืองและองค์ประกอบของน้ำนมเหลือง (Theil et al., 2014) ในช่วงอุ้มท้องระยะท้ายแม่สุกรมีความต้องการพลังงานสูงเพื่อใช้ในการพัฒนาเต้านม โภชนาการอาจส่งผลกระทบต่อการผลิตน้ำนมเหลืองทั้งจากการพัฒนาต่อมเต้านม (mammary gland) และผ่านทางกลไกที่ควบคุมการหลั่งน้ำนมเหลือง การให้อาหารแม่สุกรที่มากเกินไปในช่วงอุ้มท้องมีผลในทางลบต่อกระบวนการผลิตน้ำนม เนื่องจากการสะสมไขมันที่มากเกินไป แม่สุกรที่อ้วนจะมีความต้านทานต่ออินซูลินสูงซึ่งจะขัดขวางการขนส่งกลูโคสไปยังต่อมน้ำนมในการสังเคราะห์แลคโต๊ส ในทางกลับกัน การจำกัดอาหารในแม่สุกรอุ้มท้องระยะท้ายอาจมีผลกระทบเล็กน้อยต่อผลผลิตของน้ำนมเหลืองเนื่องจากแม่สุกรมีปริมาณพลังงานสำรองอยู่มาก อย่างไรก็ดีผลการวิจัยของ Decaluwé *et al.* (2013) ชี้ให้เห็นว่าการที่มีกระบวนการคาตาบอลิสม (catabolism) มากเกินไปก่อนคลอดอาจทำให้เกิดการลดปริมาณการสร้างน้ำนมเหลืองได้ นอกจากนี้การให้อาหารประเภทไขมันเสริมในช่วงอุ้มท้องและการให้กลูตามีนในระหว่างการให้นมสามารถเพิ่มการผลิตน้ำนมของแม่สุกร เพิ่มความแข็งแรงของลำไส้ของลูกสุกรและเพิ่มอัตราการเติบโตและเพิ่มอัตราการรอดของลูกสุกร นอกจากนี้ยังพบว่าการให้อาหารแม่สุกรที่มีเส้นใยอาหารในปริมาณสูงระหว่างอุ้มท้องมีผลดีต่อปริมาณน้ำนมเหลืองที่ลูกสุกรได้รับอีกด้วย (Theil *et al.*, 2014)

อิทธิพลของสิ่งแวดล้อมต่อการตายก่อนหย่านมในลูกสุกร

ฤดูกาลและอุณหภูมิ

ผลกระทบของฤดูกาลต่อการตายก่อนหย่านมของลูกสุกรยังคงเป็นที่ถกเถียงกัน Koketsu et al. (2006) พบว่า ในประเทศญี่ปุ่นการตายของลูกสุกรก่อนหย่านม ในฤดูร้อน (กรกฎาคม - กันยายน) สูงกว่าฤดูใบไม้ผลิ (เมษายน - มิถุนายน) (11.6% กับ 9.4% ตามลำดับ) ในขณะที่การวิจัยในอเมริกาพบว่าการตายของลูกสุกรก่อนหย่านมมีค่าสูงสุดในฤดูหนาวเนื่องจากอุณหภูมิของสิ่งแวดล้อมต่ำและสุกรได้รับความเครียดอันเนื่องมาจากอากาศเย็น (Dial et al., 1992) โดยทั่วไปลูกสุกรสามารถอยู่ในที่ที่ต่ำกว่าอุณหภูมิที่เหมาะสมได้ไม่เกิน 2 ชั่วโมง อุณหภูมิของสิ่งแวดล้อมที่เหมาะสมของลูกสุกรคือ 34 องศาเซลเซียส (Herpin et al., 2002) **ลูกสุกรแรกคลอดมีความรู้สึกไวต่อความหนาวเย็นมาก เนื่องจากระบบควบคุมอุณหภูมิของร่างกาย (thermoregulation) ยังไม่สมบูรณ์** ลูกสุกรเกิดมาพร้อมกับการมีไขมันใต้ผิวหนังเพียงเล็กน้อยและไม่มีฉนวนป้องกันการสูญเสียความร้อนที่ดี ลูกสุกรจึงจำเป็นต้องได้รับการดูแลในสภาพแวดล้อมที่อบอุ่นและแห้งเพื่อความอยู่รอด โดยเฉพาะอย่างยิ่งในช่วงวันแรกหลังคลอด ความเครียดจากความหนาวเย็น (cold stress) เป็นตัวก่อให้เกิดความเครียดที่สำคัญที่สุดในลูกสุกรแรกเกิด (Baxter et al., 2009) ในสภาพแวดล้อมที่มีอุณหภูมิต่ำลูกสุกรมีความเสี่ยงต่อการถูกทับตายเนื่องจาก ลูกสุกรต้องการอยู่ใกล้ๆ กับเต้านมเพื่อเพิ่มความอบอุ่น นอกจากนี้ Pedersen et al. (2013) พบว่า**ปริมาณน้ำนมเหลืองที่ลูกสุกรได้รับจะลดลงในช่วงที่มีการสัมผัสกับความเย็น**ทำให้เกิดการขาดอาหารและลดความเข้มข้นของอิมมูโนโกลบูลินในลูกสุกร ในทางกลับกันแม่สุกรที่อยู่ในเขตร้อนที่มีอุณหภูมิตั้งแต่ 18 ถึง 20 องศาเซลเซียส ขึ้นไป **อุณหภูมิแวดล้อมสูงขึ้นสามารถลดปริมาณการกินอาหารของแม่สุกรลง ทำให้น้ำนมลดลงด้วยเนื่องจากความเครียดจากความร้อน** (Malmkvist et al., 2012) ดังนั้นความเครียดจากความร้อนจึงทำให้การผลิตน้ำนมเหลืองและการผลิตน้ำนมของแม่สุกรและการเจริญเติบโตของลูกสุกรลดลง (Farmer et al., 2010) นอกจากนี้ ความเครียดจากความร้อนยังอาจทำให้เกิดการเปลี่ยนแปลงของแม่สุกรในลักษณะอื่นๆ ด้วย เช่น ลดความถี่และระยะเวลาในการเลี้ยงลูก เพิ่มเวลาในการถ่ายปัสสาวะหรืออุจจาระและเพิ่มอัตราการตายของลูกสุกรเนื่องจากการถูกแม่สุกรทับ (Silva et al., 2006) มีการวิจัยพบว่าการให้ความร้อนบนพื้นของห้องคลอดสามารถกระตุ้นให้การเกิด

ความเครียดระหว่างใกล้คลอดและหลังคลอดในสุกรที่มีความสามารถในการควบคุมอุณหภูมิได้น้อย (Malmkvist et al. 2012)

โรงเรือน

ขนาดของฟาร์มมีบทบาทสำคัญในการลดความสูญเสียของลูกสุกรแรกเกิด (Oliviero et al., 2010) โดยเฉลี่ยการตายของลูกสุกรก่อนหย่านมในฟาร์มขนาดใหญ่จะต่ำกว่าฟาร์มขนาดเล็ก (Friendship et al., 1986; Hoshino et al., 2009) ผลกระทบของขนาดฟาร์มต่อการตายของลูกสุกรก่อนหย่านมเกี่ยวข้องกับการจัดการหลังคลอดและคุณภาพของคนงานซึ่งโดยปกติจะดีกว่าในฟาร์มขนาดใหญ่ Hoshino et al. (2009) พบว่าฟาร์มที่มีประสิทธิภาพสูงในประเทศญี่ปุ่นมีจำนวนลูกสุกรตายแรกคลอดที่ลดลงเนื่องจากมีการจัดการในเล้าคลอดที่ดีกว่าฟาร์มที่มีประสิทธิภาพต่ำ ระบบโรงเรือนและการออกแบบมีผลกระทบอย่างมากต่อสวัสดิภาพและประสิทธิภาพ ของแม่สุกรและลูกสุกร ระบบคอกคลอดถูกออกแบบมาเพื่อป้องกันไม่ให้แม่สุกรทับลูกสุกรโดยการจำกัดการเคลื่อนไหวของแม่สุกรและมีพื้นที่สำหรับลูกสุกร โดยเฉลี่ยแม่สุกรจะถูกจำกัดในคอกที่มีเนื้อที่ 1.26 ตารางเมตร ภายในพื้นที่คอกรวม 3.54 ตารางเมตร (Vosough Ahmadi et al., 2011) มีการวิจัยพบว่าแม่สุกรที่ถูกเลี้ยงในคอกที่ถูกจำกัดแสดงอาการที่ผิดปกติ เช่น อัตราการเต้นของหัวใจและการตอบสนองต่อฮอร์โมนความเครียด พฤติกรรมเชิงลบหรือผิดปกติ (Baxter et al., 2011a) ด้วยเหตุนี้การออกแบบที่แตกต่างกันในการเลี้ยงแบบกลุ่มและแบบเดี่ยว หรือเลี้ยงปล่อยจึงได้รับการพัฒนาเพื่อเป็นทางเลือกให้แก่เกษตรกร (Baxter et al., 2012; Wechsler and Weber 2007) อย่างไรก็ตามยังไม่มีทางเลือกที่เหมาะสม ดังนั้นการใช้งานในเชิงพาณิชย์ยังคงมีข้อจำกัด การเลี้ยงแบบกลุ่มสามารถแยกได้เป็นสองลักษณะ คือ ตลอดการเลี้ยงลูกหรือเป็นบางช่วงระหว่างการเลี้ยงลูก แม่สุกรถูกแบ่งกลุ่มและถูกดูดนมด้วยลูกสุกรที่มาจากหลายๆ คอก หรือมีพื้นที่ส่วนกลางที่สามารถเข้าได้เฉพาะแม่สุกรตลอดช่วงการให้นม การเลี้ยงภายในโรงเรือนสามารถแบ่งเป็นคอกหรือคอกที่ได้รับการออกแบบ โดยเฉลี่ยคอกจะประกอบด้วยเนื้อที่ขนาด 10.48 ตารางเมตร รวมพื้นที่ขับถ่ายและนอน ลูกสุกรจะมีบริเวณแยกต่างหากพร้อมด้วยการเสริมความอบอุ่นด้วยโคมไฟหรือวัสดุรองพื้นคอก คอกถูกออกแบบมาหลากหลาย โดยปกติจะมีพื้นที่ทั้งหมดประมาณ 7.06 ตารางเมตรของพื้นที่โดยมีพื้นที่สำหรับทำรังหรือนอนประมาณ 2.90 ตารางเมตร ลูกสุกรจะมีบริเวณแยกต่างหากพร้อมด้วยการเสริมความอบอุ่นด้วยโคมไฟหรือวัสดุรองพื้นคอกเช่นเดียวกัน ในระบบการเลี้ยงแบบกลางแจ้ง แม่สุกรและลูกสุกรจะเลี้ยงในกระท่อมแยกแต่ละคอก (พื้นที่เฉลี่ย 377 ตารางเมตร) โดยสามารถเข้าถึงพื้นที่ส่วนตัวหรือกลุ่มได้

แม้ว่าระบบการเลี้ยงแบบกลุ่มจะมียุ่งยากมากขึ้นแต่แม่สุกรจะมีอิสระในการเคลื่อนไหวและมีความเป็นไปได้ในที่จะเลี้ยงลูกเป็นระยะเวลานาน แต่ก็มีความเสี่ยงเพิ่มขึ้นในการโดนทับและการเลิกเลี้ยงในช่วงต้นหรือการไม่ยอมเลี้ยงลูก Wechsler and Weber (2007) พบว่าแม่สุกรอุ้มท้องไม่ควรอยู่เป็นกลุ่มในขณะคลอดแต่ควรแยกเป็นรายตัวในคอกขนาดใหญ่ที่มีพื้นที่สำหรับทำรังหรือนอนและทำกิจกรรมแยกต่างหาก Baxter et al. (2012) อธิบายอัตราการตายของลูกสุกรทั้งหมด (โดยทุกครอกมีเลี้ยงลูกสุกร 11 ตัว) มีค่า 18.1% 19.3% 15.0% และ 17.1% ในซองบังคับ คอกทั่วไป คอกที่ออกแบบเฉพาะ และระบบการเลี้ยงกลางแจ้ง ตามลำดับ การตายของลูกสุกรก่อนหย่านมจะใกล้เคียงกันในแต่ละระบบการเลี้ยง ยกเว้นระบบการเลี้ยงแบบกลางแจ้ง ระบบซองบังคับถูกออกแบบเฉพาะเพื่อป้องกันการทับลูกสุกรในช่วงท้ายตัวแม่สุกร แม้ว่าจะไม่ได้มีประสิทธิผลในการป้องกันการทับบริเวณช่วงท้อง เมื่อแม่สุกรนอนลงจากท่านั่ง โดยเฉพาะอย่างยิ่งในการศึกษาการตายของลูกสุกรก่อนหย่านมในฟาร์ม 112 ฟาร์มในสหราชอาณาจักรโดย KilBride et al. (2010) พบว่าซองบังคับถูกเปรียบเทียบกับการเลี้ยงแบบปล่อยสามระบบที่แตกต่างกัน (รวมทั้งระบบในโรงเรือนและกลางแจ้ง) ผู้เขียนสรุปว่าความเสี่ยงของการตายของลูกสุกรก่อนหย่านมจากการถูกแม่ทับต่ำในซองบังคับ อย่างไรก็ตาม ความ

เสี่ยงต่อการตายจากสาเหตุอื่นๆ ในซองบังคับสูงกว่าในกลุ่มอื่นๆ ซึ่งส่งผลให้อัตราการตายของลูกสุกรก่อนหย่านมใกล้เคียงกัน แม่สุกรในซองบังคับทั่วไปยังมีโอกาสที่จะบาดเจ็บบริเวณหัวนมอย่างรุนแรงเมื่อเทียบกับระบบเลี้ยงปล่อย ซึ่งอาจทำให้ปริมาณน้ำนมเหลืองที่ลูกสุกรได้รับลดลง คล้ายคลึงกับในซองบังคับ Baxter et al. (2009) พบว่าน้ำหนักของลูกสุกรแรกเกิดและอุณหภูมิทางทวารหนักที่ 1 ชั่วโมงหลังคลอดเป็นตัวบ่งชี้ความอยู่รอดหลังคลอดที่สำคัญที่สุดในระบบการเลี้ยงแบบกลางแจ้ง อย่างไรก็ตาม การเข้าถึงเต้านม หัวนมและดูดนมแม่ได้ช้านั้น ไม่เป็นตัวชี้วัดความอยู่รอดในระบบการเลี้ยงแบบกลางแจ้ง แต่เป็นตัวชี้วัดที่สำคัญในระบบการเลี้ยงในโรงเรือน มีการศึกษาพบว่าแม่สุกรที่ถูกเลี้ยงในคอกตั้งแต่วันที่ 114 จนถึง 4 วันหลังคลอดสามารถลดการตายของลูกสุกรก่อนหย่านมเมื่อเทียบกับการเลี้ยงแบบปล่อย (Hales et al., 2015) ลักษณะพื้นคอกของคอกคลอดหรือเลี้ยงลูกอาจมีผลต่อการตายของลูกสุกรก่อนหย่านม พื้นคอกที่แข็ง (เช่น พื้นเหล็กหล่อ พื้นคอนกรีตบางส่วน และพื้นผิวเป็นตาข่ายบางส่วน) จะเพิ่มอุบัติการณ์การเกิดแผลที่ขาหน้าในลูกสุกร (Gu et al., 2010) ซึ่งมีผลเสียต่อการเจริญเติบโตก่อนหย่านมของลูกสุกร นอกจากนี้ การใช้แผ่นใยสังเคราะห์ที่วางอยู่บนพื้นเหล็กในบริเวณที่ลูกดูดนมลูกสุกรช่วยลดความเสี่ยงต่อการโดนทับและความเสี่ยงต่อการมีอุณหภูมิของลูกสุกรต่ำ โดยการลดการสูญเสียความร้อนระหว่างช่องอกของลูกสุกรกับผิวพื้นผิวสัมผัส (Gu et al., 2010) ในทำนองเดียวกันการใช้วัสดุเสริมในซองบังคับอาจช่วยลดอุบัติการณ์ของแผลที่หัวนม (Lewis et al., 2006)

การจัดการ

การจัดการเพื่อลดผลกระทบเชิงลบของปัจจัยที่มีอิทธิพลต่อการตายของลูกสุกรก่อนหย่านมดังที่นำเสนอข้างต้น ต้องมีการให้ลำดับความสำคัญและขั้นตอนในการจัดการเกี่ยวกับแม่สุกรและลูกสุกรในฟาร์มสุกรเชิงพาณิชย์ ซึ่งโดยทั่วไปผู้ผลิตมักให้ความสำคัญกับการจัดการในวันคลอดและในช่วงสองวันแรกหลังจากคลอดเท่านั้น **การเฝ้าคลอดพร้อมกับการช่วยคลอด** เป็นการจัดการขั้นพื้นฐานเพื่อลดจำนวนลูกสุกรตายแรกคลอดเป็นหลัก (Vanderhaeghe et al., 2013) อย่างไรก็ตามการเฝ้าคลอดและขั้นตอนการจัดการที่ดีมีส่วนช่วยลดการตายของลูกสุกรก่อนหย่านมได้ (Vanderhaeghe et al., 2013) การลดจำนวนลูกสุกรตายแรกคลอด การเพิ่มการรอดชีวิตในช่วงวันแรกและการเพิ่มน้ำหนักหย่านม **เกิดจากการมีขั้นตอนการเฝ้าคลอดที่ดี** ซึ่งประกอบด้วย

1. การทำให้ลูกสุกรแรกคลอดตัวแห้ง
2. การเสริมน้ำนมเหลืองหรือน้ำนมทดแทน และ
3. การให้ออกซิเจนเสริมผ่านหน้ากาก (White et al., 1996)

แต่อย่างไรก็ดีขั้นตอนต่างๆ ในการเฝ้าคลอดดังที่กล่าวมาข้างต้น บางครั้งอาจยากที่จะนำมาประยุกต์ใช้ในเชิงพาณิชย์เนื่องจากเพิ่มความยุ่งยากในการทำงาน อย่างไรก็ตามขั้นตอนที่ง่ายขึ้นยังเป็นสิ่งที่น่าสนใจ เช่น การทำให้ลูกสุกรแรกคลอดตัวแห้ง มีประโยชน์ในฝูงการเลี้ยงแบบอุตสาหกรรม Christison et al. (1997) สังเกตพบว่าลูกสุกรจะรอดตายมากขึ้นเมื่อลูกสุกรตัวแห้งหรืออยู่ภายใต้ไฟกกทันทีหลังคลอด Andersen et al. (2009) และ Vasdal et al. (2011) พบว่าลูกสุกรแรกที่ถูกทำให้ตัวแห้งและถูกวางไว้ที่เต้านมจัดการร่วมกัน สามารถลดอัตราการตายของลูกสุกรในแม่สุกรที่เลี้ยงแบบปล่อย มากกว่านั้น Andersen et al. (2007) เปรียบเทียบข้อมูลที่บันทึกจากฟาร์มเลี้ยงสุกรในประเทศนอร์เวย์ 39 ฟาร์ม พบว่าการวางลูกสุกรไว้ที่เต้านมทันทีหลังคลอดและช่วยลูกสุกรหาหัวนมสามารถลดอัตราการตายลง ในขณะที่การย้ายลูกสุกรไปอยู่ในกล่องกกในขณะให้อาหารแม่สุกรไม่ได้มีอิทธิพลต่อการรอดชีวิต

การจัดการหลังคลอดที่สำคัญ ได้แก่ การเพิ่มพลังงาน และ เพิ่มปริมาณน้ำนมเหลืองในลูกสุกร เพื่อลดความแปรปรวนของน้ำหนักของสุกรในครอก การย้ายลูกสุกรขนาดใหญ่ออกจากแม่เป็นระยะเวลาหนึ่งเพื่อให้

ลูกสุกรขนาดเล็กสามารถเข้าถึงเต้านมได้อย่างเหมาะสม (split nursing) ก็เป็นสิ่งที่ควรปฏิบัติในฟาร์มในช่วงวันคลอดเช่นกัน Muns et al. (2015) พบว่าอัตราการตายของลูกสุกรที่มีน้ำหนักแรกคลอดต่ำไม่มีการเปลี่ยนแปลงเมื่อทำการแยกเลี้ยง ในทางกลับกันการเสริมอาหารให้แก่ลูกสุกรด้วยน้ำนมเหลืองหรือสารเสริมพลังงานที่ขายในท้องตลาดมักทำเพื่อเพิ่มปริมาณน้ำนมเหลืองที่ลูกสุกรน้ำหนักแรกคลอดต่ำกินได้ และทำให้ลูกสุกรมีระดับ IgG ที่เหมาะสม อย่างไรก็ตามการรีดน้ำนมเหลืองมาป้อนเสริมให้กับลูกสุกรยังมีข้อจำกัดในการใช้ในฟาร์ม เป็นที่น่าสนใจว่า น้ำนมเหลืองจากวัว อาจใช้เป็นแหล่งภูมิคุ้มกันในการเลี้ยงลูกสุกรได้ นอกจากนี้ไตรกลีเซอไรด์สายกลางสามารถใช้เป็นแหล่งพลังงานให้แก่ลูกสุกรอายุ 22-35 ชั่วโมง ได้ อย่างไรก็ดีการใช้ไตรกลีเซอไรด์สายกลางที่มากเกินไปอาจทำให้ลูกสุกรโคม่าได้จากการเพิ่มความเข้มข้นของกรดไขมันหมุนเวียนจนทำให้เป็นพิษ อย่างไรก็ตามนักวิจัยบางกลุ่มได้ตั้งข้อสังเกตถึงอัตราการรอดตายและอัตราการเติบโตของลูกสุกรขนาดเล็กที่เพิ่มมากขึ้นเมื่อลูกสุกรได้รับการเสริมน้ำนมเหลืองในฟาร์ม Muns et al. (2014) พบว่าการให้อาหารเสริมในลูกสุกรขนาดเล็กด้วยน้ำนมเหลือง 15 มิลลิลิตร ในช่วงแรกหลังคลอดทำให้ระดับความเข้มข้นของ IgG ในซีรั่มอยู่ในระดับที่เหมาะสมเมื่ออายุ 4 วัน นอกเหนือจากการแยกเลี้ยงและการเสริมอาหาร การฝากเลี้ยงเป็นแนวทางการจัดการที่ใช้ในฟาร์มเชิงพาณิชย์เมื่อขนาดของครอกมีมากกว่าจำนวนเต้านมที่ใช้งานได้และหรือเพื่อจัดการความแปรปรวนของน้ำหนักลูกสุกรแรกคลอดภายในครอก ซึ่งสถานการณ์นี้อาจทำให้ปริมาณน้ำนมเหลืองที่ลูกสุกรได้รับลดลงและนำไปสู่การเพิ่มขึ้นของการตายในลูกสุกรก่อนหย่านม แม้ว่าการย้ายฝากจะมีผลต่อการอยู่รอดและประสิทธิภาพของลูกสุกร ยังคงมีข้อถกเถียงกันในงานวิจัยเกี่ยวกับกลยุทธ์การย้ายฝากที่ดีที่สุด ลูกสุกรที่มีน้ำหนักแรกคลอดต่ำจะมีอัตราการตายที่เพิ่มขึ้นเมื่อเลี้ยงอยู่กับลูกสุกรที่มีน้ำหนักแรกคลอดสูง คอกที่ทำการย้ายฝากจะมีความแปรปรวนของน้ำหนักเพิ่มเป็นสองเท่า Muns et al. (2014) แนะนำว่าสภาพความสะอาดและสถานภาพทางสุขภาพของฟาร์มสามารถส่งผลต่อผลกระทบของกลยุทธ์การย้ายฝากในฟาร์มได้

การใช้สุกรสายพันธุ์ให้ลูกสุกรแรกคลอดมีชีวิตจำนวนมากกว่า 14 ตัว และการขยายพันธุ์สุกรที่ให้ผลผลิตสูง นำไปสู่การมีจำนวนลูกสุกรมากกว่าจำนวนเต้านมที่สามารถใช้งานได้ในชุดเดียวกัน ในสถานการณ์เช่นนี้ฟาร์มอาจดำเนินการใช้ระบบแม่เลี้ยงตามขั้นตอนการจัดการ ได้แก่ ระบบขั้นตอนเดียว ประกอบด้วยระบบสุกรตัวเดียวและระบบสองขั้นตอนโดยใช้แม่สุกร 2 ตัว ใน **“ระบบขั้นตอนเดียว”** ประกอบด้วยการหย่านมแม่สุกรที่จะนำมาใช้เป็น **“แม่นม”** ที่ 21 วันนับหรือมากกว่า แม่สุกรที่ได้รับการคัดเลือกจะได้รับลูกสุกรส่วนเกินจากชุดแม่คลอดตัวใหม่และจะให้นมในช่วงการให้นมลูกชุดใหม่ **“ระบบสองขั้นตอน”** ได้แก่ การหย่านมจากแม่สุกรตัวที่ 1 ในวันที่ 28 วันของการให้นม เพื่อนำมาเลี้ยงลูกสุกรอายุ 4-7 วัน หลังจากนำแม่สุกรตัวที่ 2 ที่หย่านมลูกของตัวเองที่อายุ 4-7 วัน ไปเป็นแม่เลี้ยงเพื่อช่วยเลี้ยงลูกสุกรที่คลอดใหม่ การใช้ระบบแม่นมจะช่วยในการรักษาชีวิตของลูกสุกรส่วนเกินในฟาร์ม อย่างไรก็ตาม Baxter et al. (2013) พบความไม่ลงตัวระหว่างปริมาณน้ำนมที่ลูกสุกรต้องการกับปริมาณน้ำนมที่แม่นมผลิตได้ และความเสี่ยงต่อการเกิดโรคเนื่องจากการหยุดชะงักของระบบเข้าหมดออกหมด (all - in - out – out) ซึ่งเป็นความเสี่ยงที่เห็นได้ชัดมากขึ้นของระบบแม่นม จึงควรมีการศึกษาเพิ่มเติมเกี่ยวกับการใช้ระบบการเลี้ยงด้วยแม่นม อีกทางเลือกหนึ่งคืออาจใช้ระบบการเลี้ยงโดยให้นมทดแทนแก่ลูกสุกรส่วนเกินและลูกสุกรที่อ่อนแออยู่ในครอก คล้ายกับการให้อาหารเลียราง ลูกสุกรส่วนเกินและลูกสุกรที่อ่อนแอมักจะถูกแยกเลี้ยงหรืออยู่ในกล่องในบริเวณคอกคลอดสัตว์มักถูกย้ายไปยังระบบการเลี้ยงแบบนี้เมื่อมีอายุระหว่าง 3-7 วัน De Vos et al. (2014) พบว่า ลูกสุกรที่ถูกเลี้ยงด้วยนมทดแทนมีการเจริญเติบโตที่คล้ายคลึงกันและทำให้ลำไส้โตเต็มที่เมื่ออายุ 28 วัน แต่ไม่ได้รายงานถึงผลกระทบต่ออัตราการตาย De Vos et al. (2014) ยังชี้ให้เห็นว่าระบบการเลี้ยงด้วยนมทดแทนเป็นประโยชน์สำหรับลูกสุกรทุกประเภท ในทางตรงกันข้าม Widowski et al. (2005) พบความเสี่ยงที่สูงขึ้น

สำหรับพฤติกรรมการดูดนมที่เปลี่ยนไปในลูกสุกรที่เลี้ยงด้วยนมทดแทนที่เลี้ยงผ่านรางพลาสติกเมื่อเทียบกับลูกสุกรที่ป้อนผ่านหัวนมปลอม อย่างไรก็ตามมีความจำเป็นต้องมีการวิจัยทางวิทยาศาสตร์เกี่ยวกับการใช้การเลี้ยงลูกด้วยนมทดแทนต่อไปในอนาคต

วิธีการดำเนินการวิจัย (Materials and methods)

การทดลองที่ 1 (Observational study) ความแปรปรวนและค่าเฉลี่ยของปริมาณน้ำนมเหลืองที่แม่สุกรแต่ละตัวผลิตได้ในฟาร์สุกรเชิงพาณิชย์ในประเทศไทย

ฟาร์มทดลอง

การวิจัยครั้งนี้ทำในฟาร์มสุกรเอกชน 4 แห่ง (A B C และ D) ในประเทศไทยมีจำนวนแม่สุกรให้ผลผลิตจำนวน 1,500 2,600 3,000 และ 4,000 แม่ ตามลำดับ ฟาร์มทุกฟาร์มมีการผลิตสุกรสาวทดแทนในฝูง สุกรสาวเข้ารวมฝูงเมื่ออายุ 165 วัน (น้ำหนักตัว 90 กิโลกรัม) สุกรสาวอยู่รวมฝูงเป็นเวลา 50-60 วันก่อนจะถูกส่งไปยังโรงเรือนผสมพันธุ์ในฝูงสุกรสาวมีการให้น้ำจากจุ๊บน้ำอัตโนมัติและอาหารอย่างไม่จำกัดมีการให้อาหารวันละ 2 ครั้ง (ประมาณ 3 กิโลกรัมต่อวัน) ประกอบด้วยข้าวโพดถั่วเหลืองปลาป่นเป็นส่วนประกอบหลักมีปริมาณโปรตีนหยาบ 16-18% พลังงาน 3,000-3,400 กิโลแคลอรี่ต่อกิโลกรัม และไลซีน 0.85-1.00% สุกรสาวอยู่ในโรงเรือนแบบระบบเปิดซึ่งมีอุปกรณ์สเปร์ยน้ำและพัดลมระบายอากาศ สุกรอยู่ในคอกรวมประมาณ 6-15 ตัวต่อคอกและมีความหนาแน่น 1.5-2.0 ตารางเมตรต่อตัว

การตรวจวัดปริมาณน้ำนมเหลือง

ทำการชั่งน้ำหนักลูกสุกรแรกคลอดเป็นรายตัว จำนวน 5,000 ตัว จากแม่สุกร 400-500 แม่ ด้วยตาชั่งดิจิตอลที่มีความละเอียดเป็นกรัม (Universal weight enterprise co. ltd., New Taipei, Taiwan) โดยทำการชั่งน้ำหนักทันทีหลังคลอด และชั่งน้ำหนักซ้ำอีกครั้งที่เวลาประมาณ 24 ชั่วโมงหลังคลอด บันทึกข้อมูลลูกสุกรเป็นรายตัว ได้แก่ เบอร์แม่ เบอร์ลูก วันเกิด ลำดับการคลอด เวลาคลอด จำนวนลูกสุกรแรกคลอดทั้งหมด จำนวนลูกสุกรแรกคลอดมีชีวิต จำนวนลูกตายแรกคลอด มัมมี่ ทำการตรวจวัดปริมาณน้ำนมเหลืองที่ลูกสุกรได้รับเป็นรายตัวโดยคำนวณจากน้ำหนักที่เพิ่มขึ้นในช่วง 24 ชั่วโมงหลังคลอด และระยะเวลาตั้งแต่คลอดจนเริ่มกินนมตามสูตรที่ได้รับการศึกษาไว้ก่อนหน้านี้โดย Theil et al. (2014):

$$CC\ (g) = -106 + 2.26WG + 200BWB + 0.111D - 1414WG/D + 0.0182WG/BWB$$

WG is piglet weight gain (g)
BWB is birth weight (kg)
D is the duration of colostrum suckling (min)

การคำนวณผลผลิตน้ำนมเหลืองของแม่สุกร (colostrum yield of the sows)

ปริมาณของนมน้ำเหลืองที่ลูกแต่ละตัวกินได้รวมกันเท่ากับผลผลิตน้ำนมเหลืองของแม่สุกร

การตรวจคุณภาพน้ำนมเหลือง

เก็บน้ำนมเหลืองในแม่สุกรเพื่อตรวจคุณภาพของน้ำนมโดยตรวจปริมาณไขมัน โปรตีน และน้ำตาลแลคโตสในน้ำนม โดยสุ่มรีดเก็บน้ำนมจากเต้านมประมาณ 10-15 มิลลิลิตร ใส่สารกันบูด ใส่ขวดปราศจากเชื้อเก็บในที่เย็น 4 องศาเซลเซียส และส่งตรวจคุณภาพน้ำนมภายใน 24 ชั่วโมง นอกจากนี้ยังทำการแช่แข็งน้ำนม

บางส่วนและทำการตรวจองค์ประกอบไขมันในน้ำนมด้วยวิธีตรวจ Fatty acid profile ตามวิธีการของ AOAC 2005

การวัดความหนาไขมันสันหลัง

วัดความหนาไขมันสันหลังในแม่สุกรก่อนคลอดที่ตำแหน่ง P2 (ประมาณ 6-8 เซนติเมตร จากแนวกลางสันหลังในตำแหน่งซี่โครงซี่สุดท้าย) โดยใช้เครื่องอัลตราซาวน์ชนิด A-mode (Renco Lean-Meater®, Minneapolis, MN, USA) ความหนาไขมันสันหลังจะถูกวัดก่อนคลอด (การทดลองที่ 1) และในวันหย่านม (การทดลองที่ 2) ทำการประเมินการสูญเสียความหนาไขมันสันหลังโดยดูผลต่างของความหนาไขมันสันหลังทั้งสองครั้ง คำนวณเปอร์เซนต์การสูญเสียไขมันสันหลังโดยคำนวณจากไขมันสันหลังที่หายไปหารด้วยไขมันสันหลังก่อนคลอดคูณด้วย 100 (การทดลองที่ 2)

การจัดการทั่วไป

แม่สุกรถูกย้ายจากโรงเรือนอุ้มท้องขึ้นมาพักบนโรงเรือนคลอดก่อนครบกำหนดคลอดประมาณ 1 สัปดาห์ โดยก่อนการย้ายแม่สุกรขึ้นโรงเรือนคลอดทำการฉีดยาต้านปรสิตโดยใช้ Ivermectin ขนาด 300 ไมโครกรัม/กิโลกรัม ย้ายแม่สุกรในช่วงเช้า และอาบน้ำให้แม่สุกร แม่สุกรได้รับอาหาร 1.6 กิโลกรัม/วัน วันละ 2 ครั้ง และได้รับน้ำเต็มที่ เปิดระบบน้ำหยดในช่วงกลางวันเพื่อระบายความร้อนให้แม่สุกรบนโรงเรือนคลอด เมื่อใกล้ครบกำหนดคลอด มีการเตรียมคอกคลอด และเปิดไฟกกให้อุ่นเตรียมพร้อมก่อนการคลอด โดยปกติจะปล่อยให้แม่สุกรคลอดเองตามธรรมชาติ แต่หากพบว่ามีการคลอดยาก เช่น ใช้เวลาในการคลอดนานกว่า 2.5 ชั่วโมง หรือกรณีที่แม่สุกรมีอาการเบ่งคลอดแต่ไม่มีลูกสุกรออกมาเป็นเวลานานเกิน 1 ชั่วโมง จะทำการช่วยดึงลูกสุกรออกจากช่องคลอด เมื่อลูกสุกรคลอดออกมาแล้วทำการล้วงปากเพื่อกระตุ้นการหายใจ ทำให้อบอุ่นโดยเปิดไฟกก เช็ดตัวให้แห้งโดยเร็ว จากนั้นปล่อยให้ลูกสุกรดูดนมน้ำเหลืองจากแม่สุกร เมื่อแม่สุกรคลอดลูกตัวสุดท้าย สังเกตการขับรกระหว่าง 20 นาทีถึง 12 ชั่วโมงหลังคลอด ฉีดฮอร์โมนออกซิโตซิน ตัวละ 20 ยูนิต เข้ากล้ามเนื้อ แม่สุกรทุกตัวได้รับยาปฏิชีวนะ วัดอุณหภูมิร่างกายแม่สุกรทุกวันหลังคลอดเป็นเวลา 4 วัน หากแม่สุกรอุณหภูมิร่างกายสูงกว่า 103 องศาฟาเรนไฮต์ถือว่ามีไข้ ฉีดยาลดไข้และแก้อักเสบ แม่สุกรมีระยะเลี้ยงลูก 25-28 วัน ลูกสุกรวันแรกหลังคลอดจะถูกย้ายฝากหากแม่สุกรมีจำนวนลูกสุกรต่อครอกจำนวนมากและเพื่อคัดแยกขนาดลูกสุกรที่มีขนาดใกล้เคียงกันไว้ด้วยกัน โดยให้แม่สุกรเลี้ยงลูกประมาณ 10-12 ตัว/ครอก ลูกสุกรทุกตัวอยู่กับแม่สุกรในคอกที่มีไฟกกและกระสอบให้ความอบอุ่นและสามารถกินนมน้ำเหลืองจากแม่สุกรได้ตลอดเวลา ลูกสุกร ถูกชั่งน้ำหนัก เมื่ออายุ 1 วัน พร้อมกับตัดเขี้ยว ตัดหาง ป้อนยาป้องกันโรคบิดชนิดโทลทราซูริล (Toltrazuril) ในปริมาณ 20 มิลลิกรัม/กิโลกรัม เมื่อการจัดการหลังคลอดเสร็จ ทำการตัดเบอร์หูและแยกลูกสุกรแต่ครอกให้ธาตุเหล็ก เมื่อลูกสุกรหย่านม ทำการชั่งน้ำหนักจดบันทึกก่อนย้ายไปโรงเรือนสุกรอนุบาล สุขภาพของสุกรสาวและสุกรนางได้รับการเฝ้าระวังโดยสัตวแพทย์สุกรสาวได้รับวัคซีนป้องกันโรคปากและเท้าเปื่อย (FMDV) โรคอหิวาต์สุกร (CSFV) โรคพิษสุนัขบ้าเทียม (ADV) โรคพาร์โวไวรัสในสุกร (PPV) ที่อายุระหว่าง 22 และ 30 สัปดาห์ หลังจากที่สุกรเข้าฝูง 1 สัปดาห์สุกรนางจะถูกย้ายเข้ามาร่วมฝูงด้วยเป็นเวลาประมาณ 4 สัปดาห์เพื่อให้สุกรสาวได้คลุกโรค (acclimatization) ด้วยอัตราส่วนสุกรนาง 1 ตัวต่อสุกรสาว 6-10 ตัวซึ่งโดยทั่วไปแล้วสุกรนางที่นำเข้ามาให้สุกรสาวคลุกโรคนั้นจะมีการหมุนเวียนทุกสัปดาห์

การทดลองที่ 2 (Experimental study) ผลของการเสริมไขมันคุณภาพสูงในแม่สุกรอุ้มท้องต่อปริมาณน้ำนมเหลืองที่แม่สุกรผลิตได้

การออกแบบการทดลอง

ทำการศึกษาในแม่สุกรจำนวน 60 แม่ โดยแบ่งกลุ่มสุกรเป็น 2 กลุ่ม กลุ่มละ 30 แม่ ในกลุ่มที่ 1 กินอาหารปกติ (control) และกลุ่มที่ 2 ได้รับการเสริมไขมันคุณภาพสูง ผสมในอาหารแม่สุกรทดแทนไขมันในกลุ่มควบคุม โดยปรับให้ทั้งสองกลุ่ม %ไขมัน เท่ากัน (ตารางที่ 1) ตลอดระยะเวลาอุ้มท้อง ทำการติดตามสมรรถภาพการสืบพันธุ์ของแม่สุกรทั้ง 3 กลุ่ม ได้แก่ จำนวนลูกสุกรแรกคลอดทั้งหมด จำนวนลูกสุกรแรกคลอดมีชีวิต จำนวนลูกสุกรตายแรกคลอด จำนวนมัมมี่ น้ำหนักแรกคลอด และ ปริมาณนมน้ำเหลืองที่แม่สุกรผลิตได้ (colostrum yield of the sow) เปรียบเทียบไขมันสันหลังก่อนและหลังหย่านมระหว่างกลุ่มควบคุมและกลุ่มทดลอง เปรียบเทียบองค์ประกอบของน้ำนมโดยเน้นที่ปริมาณไขมันของน้ำนมจากแม่สุกรระหว่างกลุ่มควบคุมและกลุ่มทดลอง ลูกสุกรทุกตัวจะถูกทำสัญญลักษณ์ หรือ เบอร์หูเป็นรายตัว เปรียบเทียบอัตราการเจริญเติบโตของลูกสุกร โดยวัดจากน้ำหนักของลูกสุกรแรกคลอดเทียบกับน้ำหนักลูกสุกรหย่านมที่ 21 วัน และเปรียบเทียบอัตราการตายก่อนหย่านมของลูกสุกรจากแม่สุกรทั้งสองกลุ่ม

ตารางที่ 4 ส่วนประกอบของอาหารของแม่สุกรกลุ่มควบคุมและกลุ่มทดลอง

ส่วนประกอบ	กลุ่มควบคุม		กลุ่มทดลอง	
	กิโลกรัม/ตัน	ไขมัน (%)	กิโลกรัม/ตัน	ไขมัน (%)
ปลายข้าว	350	0.46	330	0.43
น้ำมันปาล์ม	40	4	15	1.5
น้ำมันรำข้าว	250	3.75	250	3.75
รำละเอียด	120	0	120	0
กากถั่วเหลืองแยกเปลือก	100	0.1	100	0.1
ถั่วเหลืองไขมันเต็ม	50	1	50	1
ไลซีน	3	0	3	0
เมธไทโอนีน	1.5	0	1.5	0
ทรีโอนีน	1.5	0	1.5	0
21% โมโนไดแคลเซียมฟอสเฟต	17	0.09	17	0.09
หินฝุ่น	8	0	8	0
เกลือ	5	0	5	0
ปลาป่น 70%	50	0.5	50	0.5
อิมัลซิไฟเออร์	-	-	0.2	-
โบนโมเฟต50®	-	-	50	2.5

สัตว์ทดลองและการจัดการทั่วไป

ทำการทดลองในฟาร์มสุกรในภาคตะวันตกของประเทศไทย ระหว่างเดือนสิงหาคมถึงเดือนกันยายน โดยใช้แม่สุกรพันธุ์ผสมแลนด์เรซและยอร์กเชียร์ (Landrace x Yorkshire) จำนวน 147 ตัว โดยมีลำดับท้องเฉลี่ย 1.8±0.4 (พิสัย 1-2) เลี้ยงในกรงตับในโรงเรือนควบคุมอุณหภูมิ (closed-housing system equipped with evaporative cooling system) เพื่อลดผลกระทบจากอุณหภูมิ ในช่วงนี้อุณหภูมิภายนอกโรงเรือนอยู่ระหว่าง 24.4-32.7 ℃ และมีความชื้นสัมพัทธ์ 85.1% (Thai meteorological department, Bangna, Bangkok, Thailand) ย้ายแม่สุกรมารอคลอดเป็นเวลา 7 วันก่อนคลอด ในคอกแยกมีพื้นที่ 4.5 ตารางเมตรต่อตัว สังเกตอาการของแม่สุกรโดยสัตวแพทย์ แม่สุกรทุกตัวมีการทำวัคซีนป้องกันโรคอหิวาต์สุกร (CSFV) วัคซีนป้องกันโรคพิษสุนัขบ้าเทียม (ADV) และวัคซีนป้องกันโรคเซอร์โคไวรัสในสุกร (PCV-2) ก่อนการคลอด และวัคซีนป้องกันโรคพาร์โวไวรัส (PPV) วัคซีนป้องกันโรคปากและเท้าเปื่อย (FMDV) หลังการคลอด ในช่วงเลี้ยงลูกให้อาหารวันละ 2-3 ครั้ง (ประมาณ 5-6 กิโลกรัมต่อตัวต่อวัน) ซึ่งประกอบไปด้วย ข้าวโพด การถั่วเหลือง และปลาป่น โดยอาหารมีโปรตีน 18.0% พลังงาน 3,150 กิโลแคลลอรี่ต่อกิโลกรัมและไลซีน 1.0% ในภาวะปกติสำหรับสุกรสาวทดแทนจะมีการผสมที่อายุมากกว่า 32 สัปดาห์ มีน้ำหนักตัวไม่ต่ำกว่า 130 กิโลกรัม อย่างน้อยต้องเป็นสัดที่ 2 ด้วย ใช้การผสมเทียมทั้งหมด ในวันคลอดทำการบันทึก จำนวนลูกสุกรแรก คลอดทั้งหมดต่อครอก (TB) จำนวนลูกสุกรแรกคลอดมีชีวิต (BA) ลูกสุกรตายคลอด (SB) และลูกกรอก (MM) ในวันหย่านมทำการบันทึกจำนวนวันจากหย่านมถึงวันผสมของแม่สุกร

ความหนาของไขมันสันหลัง

ทำการวัดความหนาไขมันสันหลัง (BF) โดยใช้เครื่องอัลตร้าซาวน์ชนิด A-mode (Renco Lean-Meater®, Minneapolis, MN, USA) ก่อนคลอด และเมื่อหย่านม (22.7±3.4 วัน) โดยทำการวัดที่บริเวณซี่โครงซี่สุดท้ายห่างจากสันหลัง 6-8 เซนติเมตร โดยวัดทั้งสองข้าง (Tummaruk et al., 2007) หาค่าเฉลี่ยจากความค่าที่วัดได้ การสูญเสียไขมันสันหลังหาได้จากความแตกต่างระหว่างความหนาของไขมันสันหลังก่อนคลอด และเมื่อหย่านม

การจัดกลุ่มแม่สุกร

แบ่งกลุ่มแม่สุกรตามความหนาไขมันสันหลัง ได้แก่ บาง (12.0–16.5 มิลลิเมตร จำนวน 33 ตัว) ปานกลาง (17.0–21.5 มิลลิเมตร จำนวน 78 ตัว) และหนา (22.0–24.5 มิลลิเมตร จำนวน 33 ตัว) หลังคลอดแบ่งแม่สุกรเป็น 3 กลุ่ม ตามชนิดของอาหารที่ให้ ได้แก่ อาหารควบคุม จำนวน 50 ตัว อาหารควบคุมเสริม micro encapsulated fat filled whey (Bormofett50®) จำนวน 48 ตัว และอาหาร ควบคุมเสริมเวย์โปรตีน จำนวน 50 ตัว Bormofett50® มีพลังงาน 5,920 แคลลอลี/กิโลกรัม โปรตีน 6.3% เถ้า 4.1% ไขมัน 50% แคลเซี่ยม 0.2% ฟอสฟอรัส 0.4% เกลือ 0.4% อาร์จีนีน 0.13% ไอโซลิวซีน 0.35% ลิวซีน 0.55% ไลซีน 0.49% เมทไธโอนีน+ซิสทีน 0.23% เมทไธโอนีน 0.1% ฟีนิลอะลานีน+ไทโลซีน 0.27% ฟีนิลอะลานีน 0.15% ทรีโอนีน 0.39% ทริปโตเฟน 0.1% วาลีน 0.33% และแลคโต๊ส 35.6% (Bormofett50®, Nutrifeed Co., Ltd., The Netherlands) เวย์โปรตีนประกอบด้วย ไขมันนม 1% โปรตีน 12% แลคโต๊ส 72% ความชื้น 1.7% และเถ้า 9% (Nutrifeed Co. Ltd., The Netherlands)

การสังเกตอาการของแม่สุกรหลังคลอด

การสังเกตอาการหลังคลอดของแม่สุกรประกอบด้วย อุณหภูมิ หนองจากช่องคลอด (>10 มิลลิลิตร) ความผิดปกติของเต้านม การกินอาหาร (เช่น กินอาหารลดลง จนกระทั่งไม่กินอาหาร) (Glock and Bilkei, 2005) ในวันที่ 0 1 และ 2 แม่ สุกรที่มีอุณหภูมิมากกว่า 103 องศาฟาเรนไฮ จัดว่ามีไข้ ไม่มีไข้ให้คะแนน 0 และมีไข้ให้คะแนน 1 หนองจากช่องคลอด มีหนองผิดปกติมากกว่า 10 มิลลิลิตรให้คะแนน 1 ปกติให้คะแนน 0 (Tummaruk, 2013) ความผิดปกติของ เต้านมดูจากการอักเสบ และไม่มีน้ำนม การอักเสบประกอบด้วยเต้านมบวมแดง หากมีเต้านมอย่างน้อย 1 เต้าแสดง อาการอักเสบให้คะแนน 1 หากไม่พบให้คะแนน 0 การกินอาหารให้คะแนน 0 หากกินอาหารปกติ (>80 % ของปริมาณที่กินปกติ) และให้คะแนน 1 หากกินอาหารลดลง ปกติหลังคลอดจะมีการฉีดยาต้านจุลชีพ (Amoxycillin Clavulanic acid, Synulox®, Zoetis, USA) ร่วมกับยาแก้อักเสบ (Tolfédine®, Vétoquinol, France) และไวตามินรวม (Fercobseang®, Vétoquinol, France) ในช่วง 3 วันหลังคลอดซึ่งปรับเปลี่ยนตามอาการของแม่สุกร

การเก็บตัวอย่างน้ำนม

ทำการเก็บตัวอย่างน้ำนมจากแม่สุกรในสัปดาห์ที่ 2 และ 3 ของการเลี้ยงลูก โดยรีดน้ำนมจากเต้านมคู่ที่ 4-6 ก่อนรีด ทำความสะอาดเต้านมและหัวนมด้วยน้ำอุ่น เช็ดด้วยผ้าแห้ง และนวดเต้านมก่อนการรีด ในบางกรณีอาจพิจารณาใช้ฮอร์โมนออกซิโตซิน 10-20 IU เก็บน้ำนมในขวดที่สะอาด เก็บรักษาตัวอย่างน้ำนมแม่ละ 10 มิลลิลิตร ที่อุณหภูมิ 4 องศาเซลเซียส ในกล่องโฟมและนำส่งห้องปฏิบัติการภายใน 24 ชั่วโมง ตัวอย่างน้ำนมจากกลุ่มควบคุมจำนวน 48 ตัวอย่าง กลุ่มเสริม Bormofett50® จำนวน 49 ตัวอย่าง และกลุ่มเสริมเวย์โปรตีนจำนวน 50 ตัวอย่าง ทำการตรวจตัวอย่างน้ำนมด้วย MilkoScan 133B (FOSS Electric, Hilleroed, Denmark) ตรวจส่วนปริมาณไขมัน โปรตีน แลคโต๊ส และของแข็งทั้งหมดโดยวิธี Infrared (IR) instrumental analysis

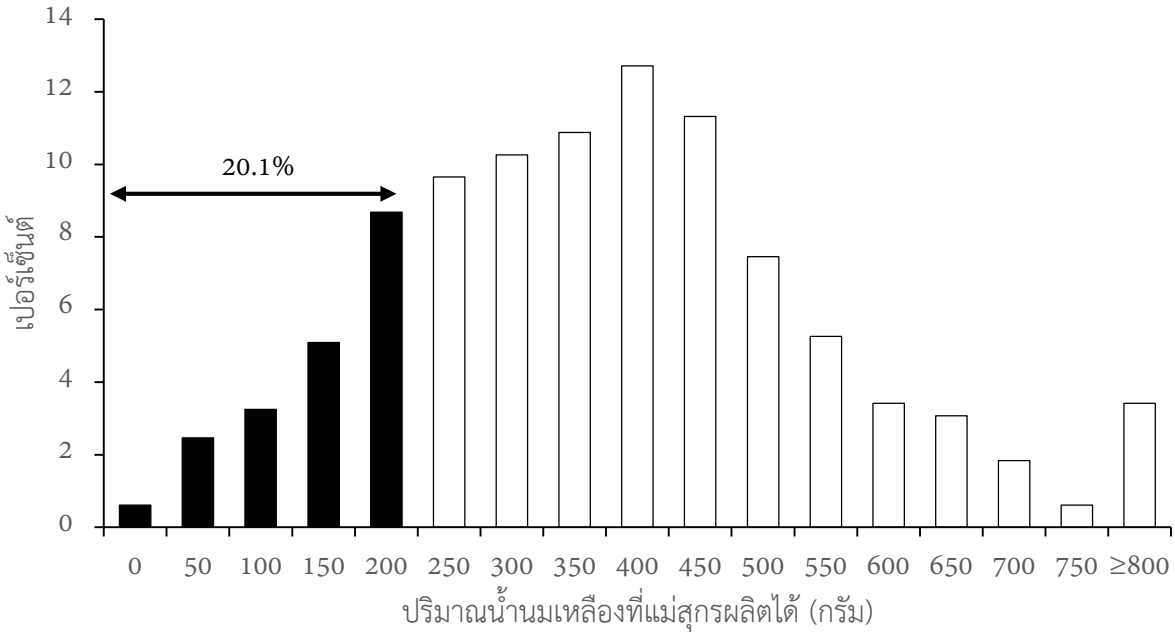
การวิเคราะห์ข้อมูลทางสถิติ

วิเคราะห์ข้อมูลทางสถิติโดยใช้โปรแกรม SAS (SAS 2002) คำนวณค่าสถิติเชิงพรรณา ได้แก่ ค่าเฉลี่ย ส่วนเบี่ยงแบนมาตรฐาน (SD) พิสัย และ ค่าความถี่ ข้อมูลเชิงปริมาณวิเคราะห์ด้วยวิธี Multiple Analysis of Variance (ANOVA) วิเคราะห์ปัจจัยที่มีผลต่อครอก TB BA MM SB น้ำหนักแรกเกิด อัตราการเจริญเติบโต จำนวนลูกสุกรหย่านม และน้ำหนักหย่านม และ ความหนาไขมันสันหลังในช่วงก่อนคลอด และหย่านม การสูญเสียไขมันสันหลัง ความสัมพันธ์ของการสูญเสียไขมันสันหลัง (%) ระยะเวลาเลี้ยงลูก และระยะเวลาจากหย่านมถึงผสม โดยใช้ General Linear Model (GLM) procedure of SAS โมเดลทางสถิติประกอบด้วยผลของความหนาไขมันขณะคลอด (บาง ปานกลาง หนา) ชนิดของอาหาร (กลุ่มควบคุม เสริม Bormrfett50® และเสริมเวย์) และความสัมพันธ์ระหว่าง ความหนาไขมันสันหลังกับชนิดอาหาร ใช้ Least–square means สำหรับเปรียบเทียบความแตกต่างของข้อมูล ชุดข้อมูลที่ประกอบด้วยการมีไข้ (0, 1) หนองไหล (0, 1) ผิดปกติของเต้านม (0, 1) การกินอาหาร (0, 1) ในวันที่1 และ 2 หลังคลอดทำการวิเคราะห์โดยใช้ Chi-squares test ที่ความเชื่อมั่น $P<0.05$

ผลการวิจัย (Results)

การทดลองที่ 1 (observational study) ความแปรปรวนและค่าเฉลี่ยของปริมาณน้ำนมเหลืองที่แม่สุกรแต่ละตัวผลิตได้ในฟาร์สุกรเชิงพาณิชย์ในประเทศไทย

ผลการทดลองพบว่าปริมาณน้ำนมเหลืองที่ลูกสุกรกินได้มีค่าเฉลี่ย เท่ากับ 405 ± 183 กรัม ความถี่ของการกระจายของปริมาณน้ำนมเหลืองที่ลูกสุกรกินได้แสดงในรูปที่ 7 จากรูปพบว่า 20.1% ของลูกสุกรได้รับน้ำนมเหลืองต่ำกว่าปริมาณที่ควรจะได้รับ (Quesnel et al., 2012) ดังนั้นสุกรเหล่านี้อาจมีความเสี่ยงต่อการตายก่อนหย่านม และอาจจะมีการเจริญเติบโตที่ไม่ดีเท่าที่ควร



รูปที่ 9 ความถี่ของการกระจายของปริมาณน้ำนมเหลืองที่ลูกสุกรกินได้ (colostrum consumption) ในฟาร์มสุกรเชิงพาณิชย์แห่งหนึ่งในประเทศไทย จำนวน 1,140 ตัว

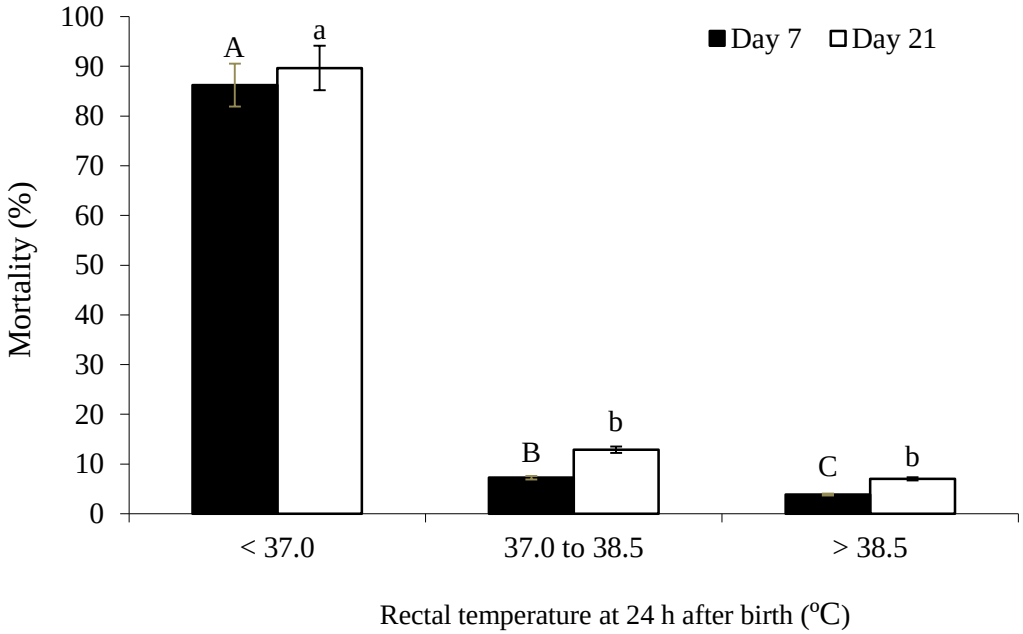
น้ำหนักแรกคลอดของลูกสุกร ลำดับการคลอด จำนวนลูกสุกรแรกคลอดทั้งหมด จำนวนลูกสุกรแรกคลอดมีชีวิต คะแนนรูปร่าง อัตราการเต้นของหัวใจ และอุณหภูมิทางทวารหนัก มีความสัมพันธ์กับปริมาณน้ำนมเหลืองที่ลูกสุกรกินได้อย่างมีนัยสำคัญ (ตารางที่ 5) อย่างไรก็ดี ระยะเลี้ยงลูก ระยะเวลาห่างระหว่างการคลอดลูกแต่ละตัว (birth interval) ปริมาณออกซิเจนในกระแสเลือด และลำดับท้องของแม่สุกร ไม่มีความสัมพันธ์กับปริมาณน้ำนมเหลืองที่ลูกสุกรกินได้

ในการวิจัยครั้งนี้ อุณหภูมิทางทวารหนักของลูกสุกรมีความเกี่ยวข้องกับการกินนมน้ำเหลืองของลูกสุกร เช่นเดียวกัน ผลการวิจัยก่อนหน้านี้พบว่าอุณหภูมิทางทวารหนักของลูกสุกรขึ้นกับปริมาณน้ำนมเหลืองที่ลูกสุกรกินได้อย่างมีนัยสำคัญ (Tuchscherer et al., 2000) การค้นพบเหล่านี้บ่งชี้ว่าลูกสุกรที่มีอุณภูมิทางทวารหนักต่ำ มีความสามารถในการปรับสมดุลย์อุณหภูมิร่างกายของสุกรต่ำด้วย (thermoregulation abilities) การปรับสมดุลย์อุณหภูมิร่างกาย เป็นขั้นตอนที่สำคัญทางสรีรวิทยาของลูกสุกรแรกคลอดที่จะทำให้สามารถดำรงชีวิตต่อไปได้ ลูกสุกรที่ตายภายใน 1 วันหลังจากที่คลอดออกมาพบว่าไม่มีความสามารถในการรักษาอุณหภูมิที่เหมาะสมของทวารหนักเอาไว้ได้ภายใน 24 ชั่วโมงหลังคลอด ผลการทดลองพบว่าอุณหภูมิทาง

ทวารหนักของลูกสุกรที่อายุ 24 ชั่วโมง มีความเกี่ยวข้องกับอัตราการตายของลูกสุกรก่อนหย่านมอย่างมีนัยสำคัญ (รูปที่ 8) ดังนั้น การเพิ่มปริมาณน้ำนมเหลืองที่ลูกสุกรกินได้ในช่วงวันแรกหลังคลอดจึงมีความสำคัญมากในฟาร์มสุกร

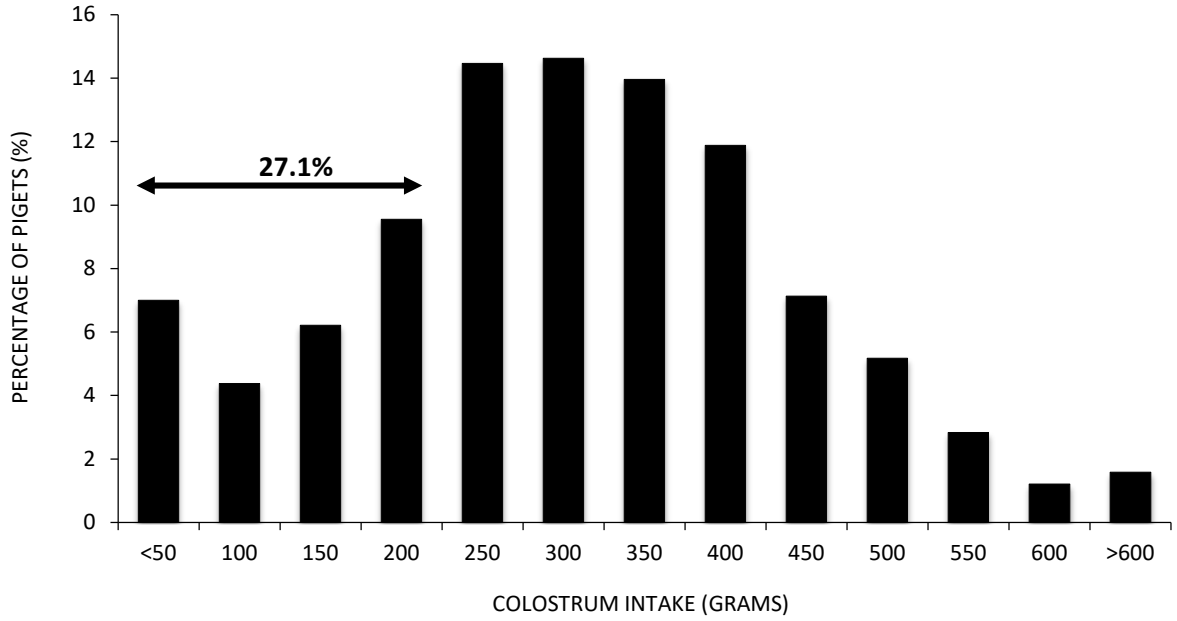
ตารางที่ 5 สหสัมพันธ์ (correlation) ระหว่างปริมาณน้ำนมเหลืองที่ลูกสุกรกินได้ (ค่าเฉลี่ย ± SD = 405 ± 183 กรัม) และคุณลักษณะของครอกและลูกสุกร

Variables	Colostrum consumption		
	n	r	*P* value
Gestation length (days)	1,140	0.01	*NS*
Total born	1,140	-0.21	***
Born alive	1,140	-0.19	***
Body conditions score	1,140	0.06	*
Birth weight (grams)	1,140	0.29	***
Birth order	1,140	-0.07	**
Birth interval (min)	1,140	-0.02	*NS*
Heart rate (beat/min)	872	0.11	**
Blood oxygen saturation (%)	872	0.05	*NS*
Rectal temperature (°C)	862	0.30	***

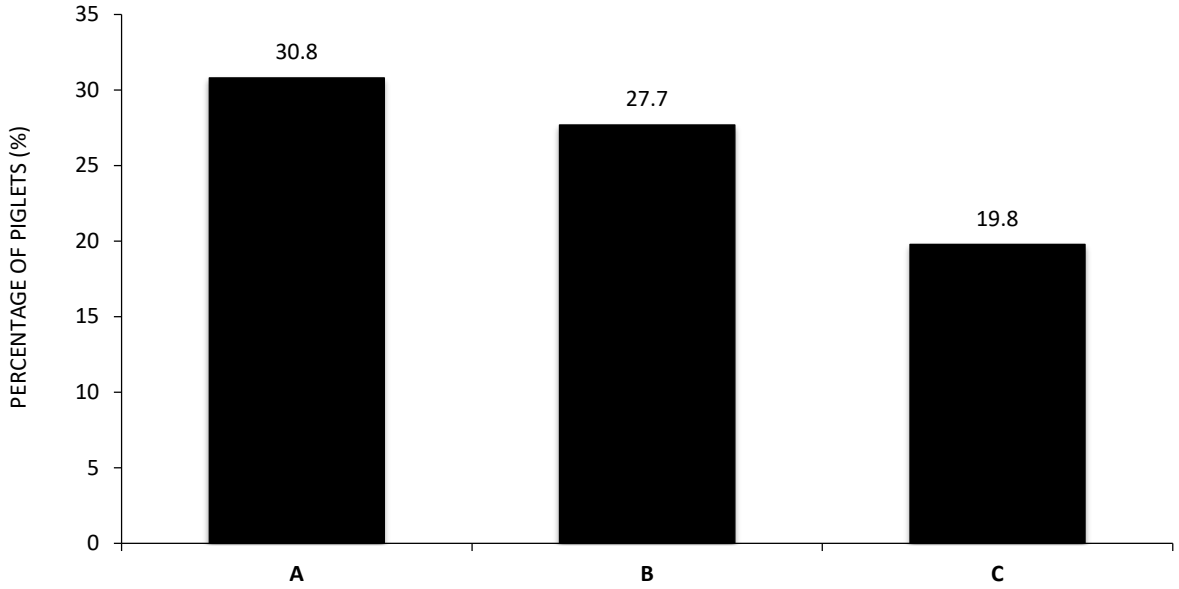


รูปที่ 10 อัตราการตายก่อนหย่านมของลูกสุกรในวันที่ 7 และ 21 หลังคลอด แบ่งกลุ่มตามอุณหภูมิทางทวารหนักของลูกสุกรที่ 24 ชั่วโมงหลังคลอด ได้แก่ ลูกสุกรที่มีอุณหภูมิทางทวารหนักระดับต่ำ (<37.0°C, n = 29) ปานกลาง (37.0°C to 38.5 °C, n = 248) และ สูง (>38.5°C, n = 413) ^{A,B,C,a,b,c} ค่าที่มีตัวอักษรยกที่แตกต่างกันมีความแตกต่างอย่างมีนัยสำคัญ ($P < 0.05$)

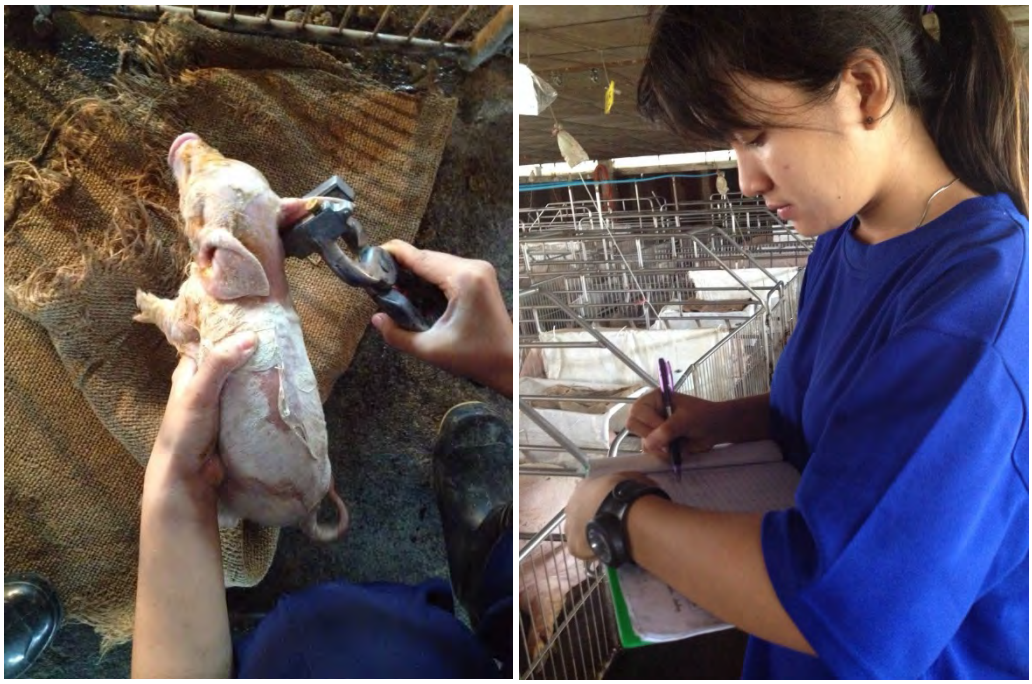
ผลการศึกษาในภาคสนามในฟาร์มสุกรจำนวน 3 ฟาร์ม พบว่าโดยเฉลี่ยลูกสุกรสามารถกินน้ำนมเหลืองได้ 279 ± 141 กรัม (พิสัย 0-940 กรัม) จากลูกสุกรทั้งหมด 2399 ตัวที่ทำการศึกษา ลูกสุกรจำนวน 93 ตัว (3.9%) ไม่ได้รับน้ำนมเหลืองเลย และ จำนวน 651 ตัว (27.1%) ได้รับน้ำนมเหลืองต่ำกว่า 200 กรัม ลูกสุกรที่กินน้ำนมเหลืองได้ 0-50, 51-100, 101-150, 151-200, 201-250, 251-300, 301-350, 351-400, 401-450, 451-500 และ ≥500 กรัม มีสัดส่วนเท่ากับ 7.0%, 4.4%, 6.2%, 9.5%, 14.5%, 14.6%, 14.0%, 11.9%, 7.1%, 5.2% และ 5.6% ตามลำดับ (รูปที่ 9) สัดส่วนของลูกสุกรที่กินน้ำนมเหลืองได้ต่ำกว่า 200 กรัม คิดเป็น 30.8, 27.7 และ 19.8% ในฟาร์ม A B และ C ตามลำดับ (P<0.001) (รูปที่ 11) โดยเฉลี่ย ปริมาณน้ำนมเหลืองที่ลูกสุกรได้รับเท่ากับ 267 277 และ 300 กรัม ในฟาร์ม A B และ C ตามลำดับ (P<0.001) ข้อมูลเหล่านี้บ่งชี้ว่า ในภาคสนามมีลูกสุกรจำนวนหนึ่งที่ได้รับน้ำนมเหลืองต่ำกว่าระดับมาตรฐาน และอาจเป็นสาเหตุหนึ่งที่ทำให้ลูกสุกรมีอัตราการตายก่อนหย่านมสูง



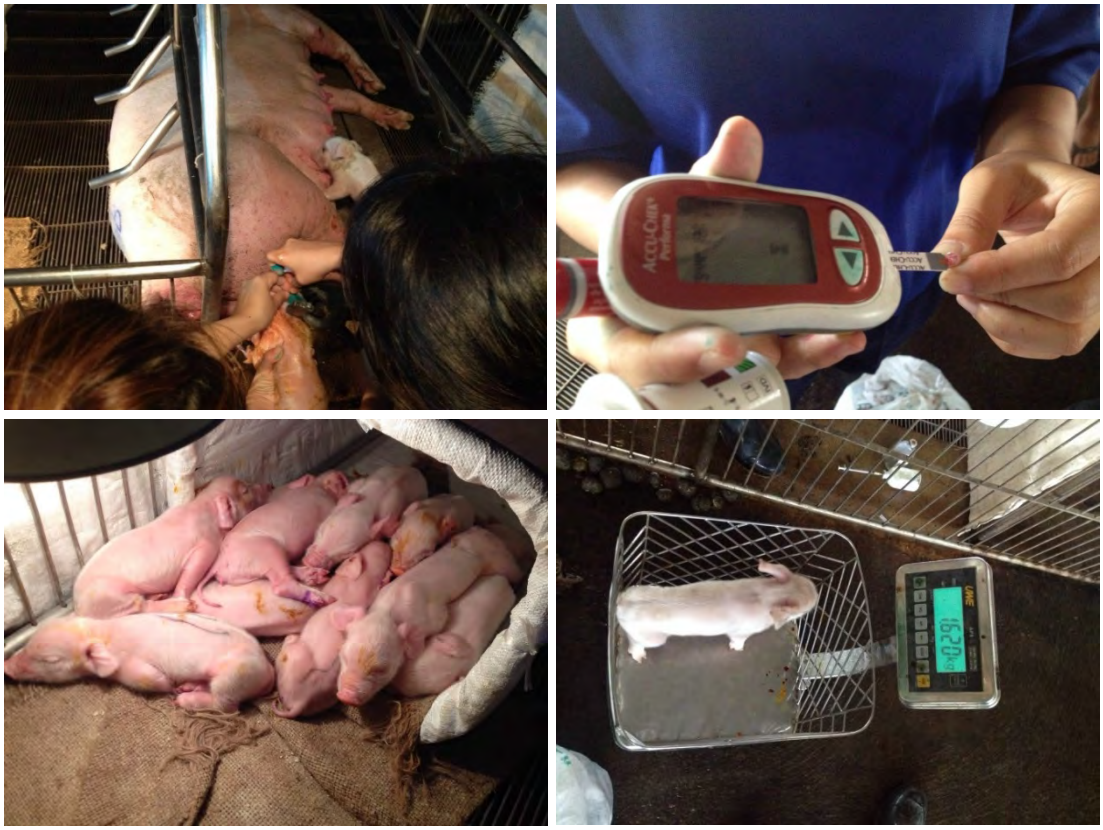
รูปที่ 11 ปริมาณน้ำนมเหลืองที่ลูกสุกรกินได้จากลูกสุกรจำนวน 2,399 ตัว ในฟาร์มสุกรเชิงพาณิชย์ในประเทศไทย จำนวน 3 ฟาร์ม



รูปที่ 12 สัดส่วนของลูกสุกรที่ได้รับน้ำนมเหลืองไม่ถึง 200 กรัม ในฟาร์ม A B และ C



รูปที่ 13 การเก็บข้อมูลน้ำหนักลูกสุกรเป็นรายตัวแรกคลอดเพื่อประเมินปริมาณน้ำนมเหลืองที่ลูกสุกรกินได้ในฟาร์ม A

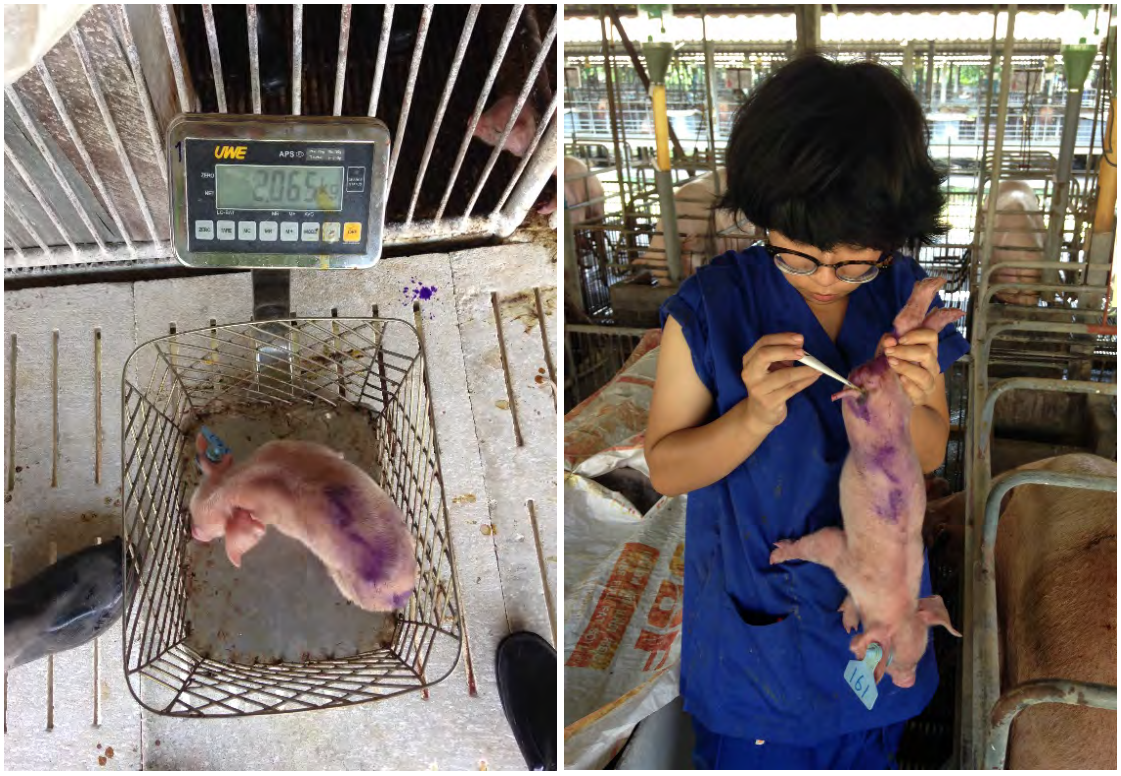


รูปที่ 14 การดำเนินการวิจัยกับลูกสุกรแรกคลอดเป็นรายตัวในฟาร์ม A ได้แก่ การเฝ้าคลอด การวัดปริมาณน้ำตาลในเลือด การนับจำนวนลูกสุกรแรกคลอดมีชีวิต และ การชั่งน้ำหนักลูกสุกรแต่ละตัวก่อนและหลังกินนม

รูปที่ 15 การตรวจวัดปริมาณออกซิเจนในกระแสเลือดของลูกสุกรแรกคลอด และการวัดความหนาไขมันสันหลังของแม่สุกรก่อนคลอด

รูปที่ 16 การทำวิจัยในฟาร์ม B ได้แก่ การเตรียมโกนขนแม่สุกรเพื่อวัดความหนาไขมันสันหลังก่อนคลอด การขับรกของแม่สุกร การเฝ้าคลอด และการตรวจวัดการกินนมน้ำเหลืองของลูกสุกรเป็นรายตัวโดยการเขียนเบอร์ไว้ที่บริเวณหลัง ตามลำดับการคลอด

รูปที่ 17 การรีดเก็บน้ำนมเหลืองในแม่สุกรหลังคลอด



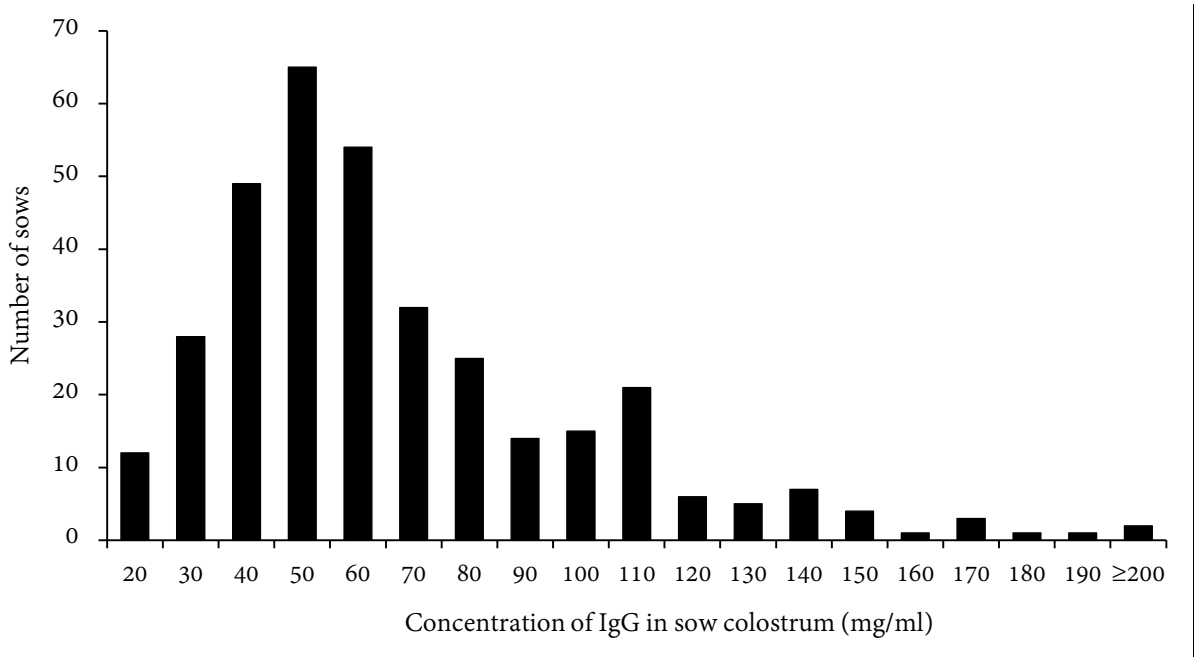
รูปที่ 18 การชั่งน้ำหนักและการวัดอุณหภูมิทางทวารหนักในลูกสุกรที่ 24 ชั่วโมงหลังคลอด

รูปที่ 19 การตรวจนับจำนวนลูกสุกรมีชีวิตแรกคลอด และการชั่งน้ำหนักลูกสุกรแรกคลอดเป็นรายตัว

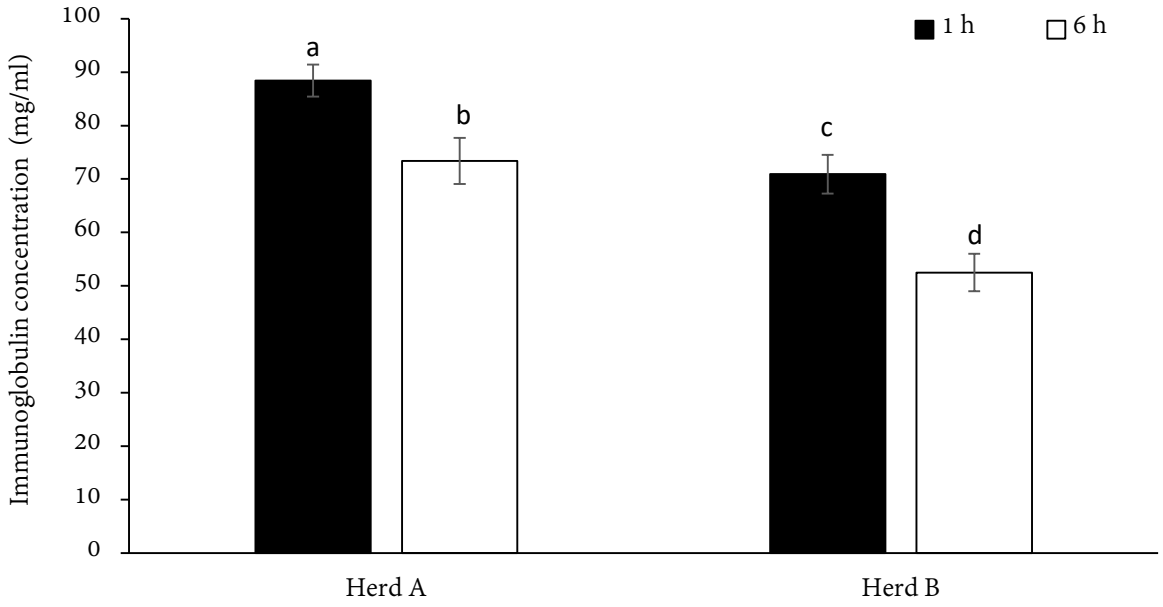
ตารางที่ 5 แสดงข้อมูลทางระบบสืบพันธุ์ ความหนาไขมันสันหลังก่อนคลอด และความเข้มข้นของอิมมูโนโกลบูลินจีในน้ำนมเหลืองของแม่สุกร โดยพบว่าความเข้มข้นของอิมมูโนโกลบูลินจีในน้ำนมเหลืองของแม่สุกรมีค่าเฉลี่ย 72.3 ± 34.1 มิลลิกรัม/มิลลิลิตร โดยมีความแปรปรวนระหว่างแม่สุกรแต่ละตัว ตั้งแต่ 21.8 – 242.9 มิลลิกรัม/มิลลิลิตร (ตารางที่ 6)

ตารางที่ 6 สถิติเชิงพรรณาแสดงข้อมูลทางระบบสืบพันธุ์ ความหนาไขมันสันหลังก่อนคลอด และความเข้มข้นของอิมมูโนโกลบูลินจีในน้ำนมเหลืองของแม่สุกร (n = 345)

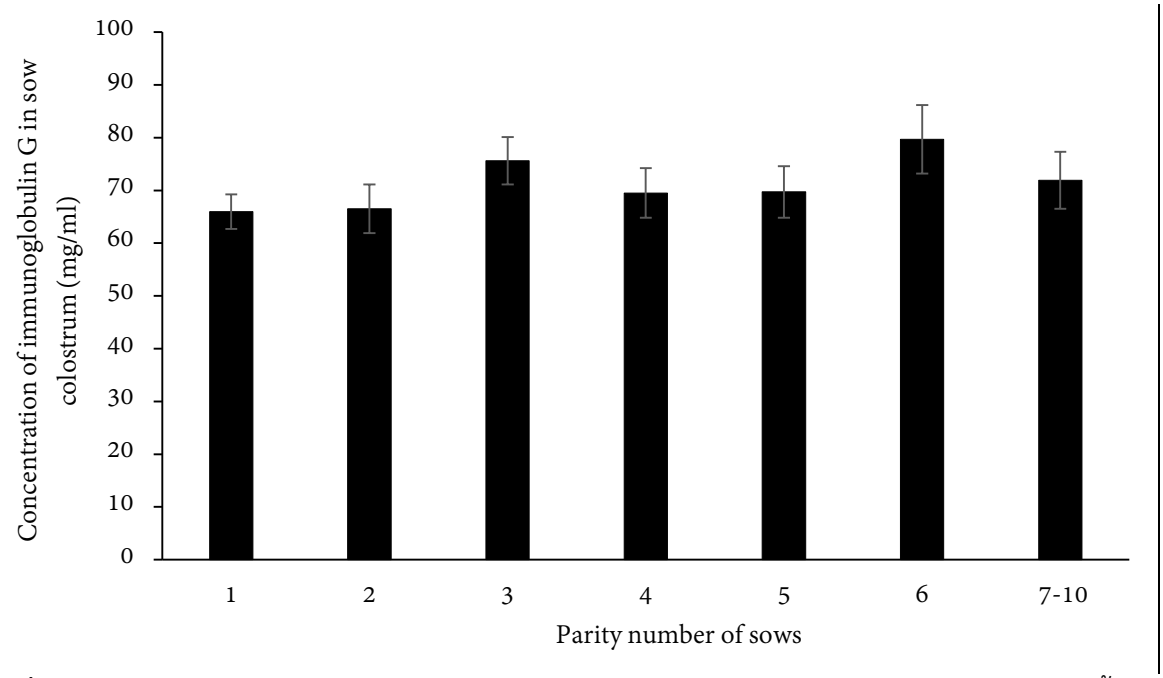
Variables	Means ± SD	Range
Parity number	3.4 ± 2.2	1 – 10
Total number of piglets born per litter	13.9 ± 3.5	3 – 23
Number of piglets born alive per litter	12.4 ± 3.0	3 – 20
Number of stillborn per litter	0.8 ± 1.4	0 – 6
Number of mummified fetuses per litter	0.3 ± 0.5	0 – 2
Backfat thickness (mm)	15.1 ± 1.7	9.0 – 24.5
Immunoglobulin G concentration (mg/ml)	72.3 ± 34.1	21.8 – 242.9



รูปที่ 20 การกระจายตัวของความเข้มข้นของอิมมูโนโกลบูลินจี ในน้ำนมเหลืองของแม่สุกร จำนวน 229 ตัว



รูปที่ 21 ความเข้มข้นโดยเฉลี่ยของอิมมูโนโกลบูลินจี (least-square means ± SEM, mg/ml) ในน้ำนมเหลืองของแม่สุกรที่ชั่วโมงแรกและชั่วโมงที่ 6 หลังคลอดในฟาร์ม A (n = 181) และ ฟาร์ม B (n = 160) [a,b,c,d] ตัวอักษรยกที่แตกต่างกันภายในฟาร์มเดียวกันแสดงถึงความแตกต่างอย่างมีนัยสำคัญ (P<0.01) ความแตกต่างระหว่างฟาร์ม ได้แก่ ที่ 1 ชั่วโมงหลังคลอด a กับ c (P<0.001) และ ที่ 6 ชั่วโมงหลังคลอด b กับ d (P<0.001)



รูปที่ 22 ความเข้มข้นของอิมมูโนโกลบูลินจี (least-square means ± SEM, มิลลิกรัม/ มิลลิลิตร) ในน้ำนมเหลืองของแม่สุกรซึ่งเก็บภายใน 6 ชั่วโมงหลังคลอด จำแนกตามลำดับท้องของแม่สุกร

การทดลองที่ 2 (experimental study) ผลของการเสริมไขมันคุณภาพสูงในแม่สุกรอุ้มท้องต่อปริมาณน้ำนมเหลืองที่แม่สุกรผลิตได้

ผลการทดลองพบว่าการเสริมอาหารที่มีไขมันคุณภาพสูงในแม่สุกรเลี้ยงลูกให้ผลในเชิงบวกทั้งในแม่และลูกสุกร ได้แก่ การเพิ่มขึ้นของระดับไขมันในน้ำนมแม่สุกร จาก 7.8% เป็น 9.8% (P=0.09) การเพิ่มขึ้นของกรดไขมัน 12 ชนิด ในน้ำนมแม่สุกร ได้แก่ caprylic acid, undecanoic acid, lauric acid, pentadecanoic acid, heptadecanoic acid, cis-10-heptadecanoic acid, elaidic acid, oleic acid, linolelaidic acid, heneicosanoic acid, eicosadienoic acid และ podocarpic acid นอกจากนี้ยังพบว่าการเสริมอาหารที่มีไขมันคุณภาพสูงในแม่สุกรเลี้ยงลูกช่วยลดการสูญเสียไขมันสันหลังในแม่สุกรท้องแรกอย่างมีนัยสำคัญ (7.5% และ 2.8% ในกลุ่มควบคุม และกลุ่มทดลอง ตามลำดับ P<0.05) สำหรับลูกสุกรพบว่าการเสริมอาหารที่มีไขมันคุณภาพสูงในแม่สุกรเลี้ยงลูกเพิ่มปริมาณการกินนมน้ำเหลืองได้ของลูกสุกร (302.1 กรัม และ 333.5 กรัม ในกลุ่มควบคุมและกลุ่มทดลอง ตามลำดับ P=0.013) ผลการตรวจวิเคราะห์ค่าองค์ประกอบทางเคมีของน้ำนมแม่สุกรในกลุ่มควบคุมเปรียบเทียบกับกลุ่มทดลองแสดงในตารางที่ 6

ตารางที่ 7 องค์ประกอบทางเคมีน้ำนม (mean±SD) ของแม่สุกรระยะให้นมของกลุ่มควบคุม (ได้รับอาหารปกติ) เปรียบเทียบกับกลุ่มทดลอง (ได้รับอาหารที่มีการเสริมไขมันที่มีขนาดโมเลกุลเล็ก)

องค์ประกอบน้ำนม	กลุ่มควบคุม (n=13)	กลุ่มทดลอง (n=14)	ค่าความแตกต่าง (P value)
ไขมัน (%)	7.8 ± 2.1	9.8 ± 3.8	+ 2.1 (P = 0.091)
โปรตีน (%)	5.3 ± 0.7	6.2 ± 2.0	+ 0.9 (P = 0.121)
น้ำตาลแลคโทส (%)	5.5 ± 0.3	5.1 ± 0.7	- 0.4 (P = 0.053)
ของแข็งทั้งหมด (%)	19.3 ± 2.5	21.9 ± 4.1	+ 2.6 (P = 0.062)

จากผลการทดลองพบว่าองค์ประกอบทางเคมีของน้ำนมมีความแตกต่างกันระหว่างกลุ่มควบคุมและกลุ่มทดลอง โดยพบว่าเปอร์เซ็นต์ของไขมัน โปรตีน และของแข็งทั้งหมดในน้ำนมในแม่สุกรกลุ่มทดลองมีแนวโน้มมากกว่ากลุ่มควบคุม (ตารางที่ 7) โดยเฉพาะไขมันนมของแม่สุกรในกลุ่มทดลองสูงกว่ากลุ่มควบคุม ถึง 2.1 % (P=0.09) บ่งชี้ว่าคุณภาพของอาหารแม่สุกรเลี้ยงลูกช่วยเพิ่มคุณภาพของน้ำนมได้

ตารางที่ 8 แสดงส่วนประกอบของกรดไขมัน (กรัม/100 กรัมของไขมันทั้งหมด) ในน้ำนมแม่สุกรกลุ่มควบคุมเปรียบเทียบกับกลุ่มทดลอง จากตารางพบว่ามีการเพิ่มขึ้นของปริมาณกรดไขมันในน้ำนมทั้งชนิดอิ่มตัวและไม่อิ่มตัวในแม่สุกรกลุ่มทดลอง โดยพบว่ากรดไขมันที่เพิ่มสูงขึ้น ได้แก่ C8:0 (Caprylic acid) C11:0 (Undecanoic acid) C15:0 (Pentadecanoic acid) C17:0 (Heptadecanoic acid) C17:1 (cis-10-Heptadecanoic acid) C17:1 (cis-10-Heptadecanoic acid) C18:1n9t (Elaidic acid) C18:1n9c (Oleic acid) C18:2n6t (Linolelaidic acid) C21:0 (Heneicosanoic acid) และ C20:3n6 (Podocarpic acid) (ตารางที่ 8)

ตางรางที่ 8 ส่วนประกอบของกรดไขมัน (กรัม/100 กรัมของไขมันทั้งหมด) ในน้ำนมแม่สุกรกลุ่มควบคุม เปรียบเทียบกับกลุ่มทดลอง

กรดไขมัน	กลุ่มควบคุม	กลุ่มทดลอง	ส่วนต่าง	*P* value
C 8:0 (Caprylic acid)	0.01±0.03	0.20±0.03	+0.19	<0.001
C 10:0 (Capric acid)	0.10±0.008	0.09±0.008	-0.01	0.558
C 11:0 (Undecanoic acid)	0.0002±0.02	0.13±0.02	+0.13	<0.001
C 12:0 (Lauric acid)	1.28±0.13	1.74±0.12	+0.46	0.009
C 13:0 (Tridecanoic acid)	0.003±0.001	0.005±0.001	+0.002	0.338
C 14:0 (Myristic acid)	4.46±0.21	4.92±0.20	+0.46	0.091
C 14:1 (Myristoleic acid)	0.19±0.02	0.21±0.02	+0.02	0.610
C 15:0 (Pentadecanoic acid)	0.09±0.007	0.11±0.007	+0.02	0.046
C 16:0 (Palmitic acid)	32.2±0.53	30.9±0.50	-1.30	0.068
C 16:1 (Palmitoleic acid)	9.02±0.53	7.78±0.50	-1.24	0.074
C 17:0 (Heptadecanoic acid)	0.17±0.01	0.21±0.01	+0.04	0.007
C 17:1 (cis-10-Heptadecanoic acid)	0.15±0.01	0.19±0.01	+0.04	0.014
C 18:0 (Stearic acid)	4.81±0.23	5.24±0.22	+0.43	0.151
C 18:1n9t (Elaidic acid)	0.06±0.01	0.09±0.01	+0.03	0.017
C 18:1n9c (Oleic acid)	28.6±0.87	32.5±0.82	+3.90	0.001
C 18:2n6t (Linolelaidic acid)	0.0006±0.01	0.07±0.01	+0.07	<0.001
C 18:2n6c (Linoleic acid)	16.7±0.55	13.6±0.51	-3.10	<0.001
C 18:3n6 (Pinolenic acid)	0.16±0.03	0.20±0.02	+0.04	0.221
C 18:3n3 (Linolenic acid)	1.17±0.05	0.77±0.05	-0.40	<0.001
C 20:0 (Arachidic acid)	0.09±0.006	0.11±0.005	+0.02	0.059
C 21:0 (Heneicosanoic acid)	0.0008±0.001	0.007±0.001	+0.01	0.016
C 20:2 (Eicosadienoic acid)	0.002±0.002	0.009±0.002	+0.007	0.025
C 22:0 (Docosanoic acid)	0.16±0.02	0.09±0.02	-0.07	0.013
C 20:3n6 (Podocarpic acid)	0.04±0.009	0.07±0.008	+0.03	0.020
C20:3n3 (cis-11,14,17-Eicosatrienoic acid)	0.012±0.004	0.017±0.004	+0.005	0.327
C 20:4n6 (Arachidonic acid)	0.63±0.05	0.73±0.05	+0.10	0.192
C 22:2	0.0007±0.001	0.002±0.001	+0.001	0.514

ตารางที่ 9 สมรรถภาพการสืบพันธุ์ของแม่สุกรในกลุ่มควบคุม เปรียบเทียบกับกลุ่มทดลอง

สมรรถภาพทางการสืบพันธุ์	กลุ่มควบคุม	กลุ่มทดลอง
ลำดับท้อง	5.9 ± 4.2	5.6 ± 4.3
ความหนาไขมันสันหลัง(มิลลิเมตร)	16.9 ± 4.9	17.2 ± 5.8
จำนวนลูกสุกรทั้งหมดต่อครอก	11.3 ± 3.4	10.8 ± 3.6
จำนวนลูกสุกรที่คลอดมีชีวิตต่อครอก	10.3 ± 3.4	10.0 ± 3.9
ลูกตายแรกคลอด(%)	6.5	7.3
ลูกกรอก(%)	2.1	1.4
น้ำหนักลูกสุกรแรกคลอด (กิโลกรัม)	1.31 ± 0.18	1.30 ± 0.24
ปริมาณนมน้ำเหลือง (กรัม)	2,999 ± 1,138	3,047 ± 1,153
น้ำหนักลูกสุกรอายุ 1 วัน(กรัม)	1.41 ± 0.19	1.44 ± 0.28
น้ำหนักลูกสุกรอายุ 14 วัน(กรัม)	3.85 ± 0.76	3.82 ± 0.79
น้ำหนักลูกสุกรอายุ 21 วัน(กรัม)	5.31 ± 0.91	5.38 ± 1.13
จำนวนลูกหย่านมต่อครอก	7.7 ± 3.3	7.0 ± 3.3

ตารางที่ 10 ลักษณะของลูกสุกรแรกคลอดและประสิทธิภาพของลูกสุกรในครอกซึ่งมาจากแม่สุกรกลุ่มควบคุม เปรียบเทียบกับแม่สุกรกลุ่มทดลอง

ลักษณะของลูกสุกร	กลุ่มควบคุม	กลุ่มทดลอง	ส่วนต่าง (*P* value)
จำนวนลูกสุกร	309	289	
น้ำหนักลูกสุกรแรกคลอด (กรัม)	1,295 ± 313	1,267 ± 321	-
กลูโคสในเลือดที่ 24 ชั่วโมง (มก./ดล.)	117.6 ± 23.4	117.2 ± 24.4	-
เวลาตั้งแต่เกิดถึงดูดนมครั้งแรก(นาที)	20.9 ± 16.2	24.2 ± 17.5	-
น้ำหนักลูกสุกรอายุ 24 ชั่วโมง (กรัม)	1,405 ± 316	1,403 ± 346	-
นมน้ำเหลืองที่กินได้ (กรัม)	302.1 ± 126.8	333.5 ± 165.4	+31.4 (*P* = 0.013)
น้ำหนักลูกสุกรอายุ 14 วัน(กรัม)	3,796 ± 1,095	3,789 ± 1,157	- 7.0 (*P* = 0.884)
น้ำหนักลูกสุกรอายุ 21 วัน(กรัม)	5,262 ± 1,391	5,303 ± 1,580	+41.0 (*P* = 0.774)
อัตราการตายก่อนหย่านม(%)	24.9%	29.4%	- 4.5% (*P* = 0.216)
อัตราการเจริญเติบโตต่อวัน(กรัม/วัน)	185.3 ± 60.9	189.0 ± 67.7	+ 4.0 (*P* = 0.737)

ตารางที่ 9 แสดงสมรรถภาพการสืบพันธุ์ของแม่สุกรในกลุ่มควบคุม เปรียบเทียบกับกลุ่มทดลอง และตารางที่ 10 แสดงลักษณะของลูกสุกรแรกคลอดและประสิทธิภาพของลูกสุกรในครอกซึ่งมาจากแม่สุกรกลุ่มควบคุม เปรียบเทียบกับแม่สุกรกลุ่มทดลอง จากตารางพบว่าปริมาณนมน้ำเหลืองที่กินได้ของลูกสุกรแต่ละตัวในกลุ่มทดลองสูงกว่ากลุ่มควบคุมย่างมีนัยสำคัญ (302.1 และ 333.5 กรัม ตามลำดับ *P*=0.013)

ตารางที่ 11 ความสัมพันธ์ระหว่างอัตราการตายก่อนหย่านมในลูกสุกรกับน้ำหนักลูกสุกรแรกคลอดในแม่สุกรกลุ่มควบคุมและกลุ่มทดลอง

น้ำหนักลูกสุกรแรกคลอด (กก.)	อัตราการตายก่อนหย่านมของลูกสุกร (%)		ส่วนต่าง (*P* value)
	กลุ่มควบคุม	กลุ่มทดลอง	
<1.0	25/49 (51%)[a]	29/55 (53%)[a]	+ 2% (0.861)
1.0-1.2	20/51 (39%)[a]	21/59 (36%)[ab]	- 3% (0.695)
1.2-1.4	18/85 (21%)[ab]	17/76 (22%)[b]	+ 1% (0.854)
1.4-1.6	8/76 (11%)[b]	13/58 (22%)[b]	+ 11 (0.060)
>1.6	6/48 (12%)[b]	5/41 (12%)[b]	0% (0.965)

[a,b] แสดงความความแตกต่างกันของข้อมูลภายในคอลัมป์เดียวกันอย่างมีนัยสำคัญทางสถิติ (*P* <0.05)

ตารางที่ 11 แสดงความสัมพันธ์ระหว่างอัตราการตายก่อนหย่านมในลูกสุกรกับน้ำหนักลูกสุกรแรกคลอดในแม่สุกรกลุ่มควบคุมและกลุ่มทดลอง จากตารางพบว่าอัตราการตายก่อนหย่านมของลูกสุกรไม่มีความแตกต่างกันระหว่างกลุ่มทดลองและกลุ่มควบคุม ตารางที่ 12 แสดงความสัมพันธ์ของอัตราการตายก่อนหย่านมในลูกสุกรกับลำดับท้องของแม่สุกรเปรียบเทียบในแม่สุกรกลุ่มควบคุมและกลุ่มทดลอง

ตารางที่ 12 ความสัมพันธ์ของอัตราการตายก่อนหย่านมในลูกสุกรกับลำดับท้องของแม่สุกรเปรียบเทียบในแม่สุกรกลุ่มควบคุมและกลุ่มทดลอง

ลำดับท้องของแม่สุกร	อัตราการตายก่อนหย่านมของลูกสุกร (%)		ส่วนต่าง (*P* value)
	กลุ่มควบคุม	กลุ่มทดลอง	
1	33/96 (34%)[a]	44/100 (44%)[a]	+ 10% (0.247)
2-5	11/57 (19%)[a]	18/70 (26%)[b]	+ 7% (0.999)
6-12	33/156 (21%)[a]	23/119 (19%)[b]	- 2% (0.982)

[a,b] แสดงความความแตกต่างกันของข้อมูลในภายในคอลัมป์เดียวกันอย่างมีนัยสำคัญทางสถิติ (*P* <0.05)

ตารางที่ 13 แสดงความสัมพันธ์ระหว่างอัตราการเติบโตต่อวันตั้งแต่แรกคลอดถึงอายุ 21 วัน กับน้ำหนักลูกสุกรแรกคลอดในแม่สุกรกลุ่มควบคุมและกลุ่มทดลอง จากตารางพบว่าลูกสุกรที่มีน้ำหนักแรกคลอด 1.4-1.6 กิโลกรัม ในกลุ่มทดลองมีแนวโน้มสูงกว่ากลุ่มควบคุม (182.8 และ 202.7 กรัม/วัน ตามลำดับ P=0.071)

ตารางที่ 13 ความสัมพันธ์ระหว่างอัตราการเติบโตต่อวันตั้งแต่แรกคลอดถึงอายุ 21 วัน กับน้ำหนักลูกสุกรแรกคลอดในแม่สุกรกลุ่มควบคุมและกลุ่มทดลอง

น้ำหนักลูกสุกรแรกคลอด (กก.)	อัตราการเติบโตต่อวัน (กรัม/วัน)		ส่วนต่าง (*P* value)
	กลุ่มควบคุม	กลุ่มทดลอง	
<1.0	130.5 ± 12.3[a]	120.0 ± 11.2[a]	- 10.5 (0.528)
1.0-1.2	157.6 ± 10.5[a]	161.4 ± 9.2[b]	+ 3.8 (0.787)
1.2-1.4	206.0 ± 7.0[b]	188.5 ± 7.6[c]	- 17.5 (0.090)
1.4-1.6	182.8± 7.0[c]	202.7 ± 8.4[c]	+ 19.9 (0.071)
>1.6	216.9 ± 9.2[b]	231.6 ± 9.9[d]	+ 14.7 (0.278)

[a,b,c,d] แสดงความแตกต่างกันของข้อมูลภายในคอลัมป์เดียวกันอย่างมีนัยสำคัญทางสถิติ ($P < 0.05$)

อภิปราย/ วิจารณ์ (Discussion)

ในช่วงหลายปีที่ผ่านมา นักวิจัยได้ศึกษาถึงปัจจัยที่มีอิทธิพลต่อความสามารถในการสร้างน้ำนมของแม่สุกรซึ่งมีผลต่อความสามารถในการเจริญเติบโตของลูกสุกรก่อนหย่านมอย่างสูง และลดอัตราการตายของลูกสุกรก่อนหย่านม (Papadopoulos et al., 2010; Panzardi et al., 2013; Tummaruk, 2013) ในเขตร้อนยังมีการศึกษาเรื่องดังกล่าวไม่มากนัก (Tummaruk, 2013; Tummaruk and Sang-Gassanee 2013) ดังนั้นจึงยังจำเป็นต้องมีการศึกษาถึงปัจจัยที่เกี่ยวข้องกับความผิดปกติของแม่สุกรหลังคลอดและการตายของลูกสุกร ในฟาร์มสุกรที่อยู่ในพื้นที่ที่มีอากาศร้อน เป็นที่ทราบกันดีว่าอากาศร้อนส่งผลกระทบต่อผลผลิตของสุกรทั้งในยุโรปและอเมริการเหนือ (Suriyasomboon et al., 2006; Tummaruk et al., 2010) เนื่องจากมีผลต่อการกินอาหารของสุกรในช่วงเลี้ยงลูกทำให้แม่สุกรได้รับพลังงานไม่เพียงพอ โดยเฉพาะอย่างยิ่งในช่วง 2-3 วันหลังคลอด และมีความสัมพันธ์กับการสูญเสียไขมันสันหลังของแม่สุกร มีการศึกษาพบว่า จำนวนลูกสุกรแรกเกิดและจำนวนลูกสุกรมีชีวิตในฟาร์มสุกรในประเทศไทยในปัจจุบันมีแนวโน้มสูงขึ้น (Tummaruk et al., 2010) การทำให้แม่สุกรมีความสามารถในการสร้างน้ำนมจึงมีความสำคัญเป็นอย่างยิ่ง

ปัจจุบันพบว่า แม่สุกรที่มีความหนาไขมันสันหลังมากก่อนคลอดจะกินอาหารได้น้อยลงในช่วงหลังคลอด และเกือบ 20% จะมีอาการเบื่ออาหารไปจนถึง 2 วันหลังคลอด จากข้อมูลนี้ทำให้ทราบว่าการเสริมเวย์โปรตีนหรือการเสริมไขมันคุณภาพสูง (Bormofett50®) จะไม่ประสบความสำเร็จหากแม่สุกรมีความหนาไขมันสันหลังมากก่อนเข้าคลอด ดังนั้นปัจจัยที่จำเป็นจะต้องควบคุมให้ได้คือความหนาไขมันสันหลังของแม่สุกร ในประเทศไทยมีอากาศร้อนชื้นทำให้ความอยากอาหารและการกินได้ของแม่สุกรเลี้ยงลูกลดลง ในระหว่างการศึกษา นี้อุณหภูมิเฉลี่ยในเวลากลางวันคือ 32.7 °C ความชื้นสัมพัทธ์ 85.1% อาจมีผลทำให้เกิดความเครียดจากอากาศร้อน (heat stress) ในแม่สุกรบางตัวได้ ผลของความชื้นต่อประสิทธิภาพของแม่สุกรในประเทศไทยมีการศึกษาอย่างกว้างขวาง (Suriyasomboon et al., 2006; Tummaruk et al., 2010) ความชื้นสัมพัทธ์ที่เพิ่มขึ้นมากกว่า 40% ทั้งในช่วงเลี้ยงลูกและหลังการผสมมีผลต่อขนาดครอก (Suriyasomboon et al., 2006) Tummaruk et al. (2010) พบว่าเมื่อความชื้นสัมพัทธ์เพิ่มจาก 50% เป็น 80% มีผลให้ขนาดครอกลดลง 0.8 ตัว ซึ่งเกิดจากความเครียดจากความร้อน และแม่สุกรรู้สึกไม่สบายตัวซึ่งส่งผลกระทบต่อการเจริญของไข่ ลดจำนวนการตกไข่ (ovulation rate) และเพิ่มอัตราการตายของตัวอ่อน (Suriyasomboon et al., 2006) ในการศึกษานี้แม่สุกรที่มีไขมันสันหลังบางขณะคลอดจะสูญเสียไขมันสันหลังในช่วงเลี้ยงลูกน้อยกว่าแม่สุกรที่เข้าคลอดด้วยไขมันสันหลังหนา จากข้อมูลนี้แสดงให้เห็นว่าภายใต้อุณหภูมิและความชื้นสูงเช่นในประเทศไทยแม่สุกรที่มีไขมันสันหลังบางขณะเข้าคลอดกินอาหารหลังคลอดได้ดีกว่า ซึ่งสอดคล้องกับการศึกษาในประเทศไทยก่อนหน้านี้ (Tummaruk, 2013) Einarsson and Rojkittikhun (1993) แสดงให้เห็นว่าแม่สุกรที่กินอาหารมากเกินไป และมีการเจริญเติบโตมากเกินไปในช่วงอุ้มท้องมีแนวโน้มสูญเสียน้ำหนักมากกว่าในช่วงเลี้ยงลูก ในภูมิอากาศร้อนชื้น แม่สุกรมีแนวโน้มกินอาหารได้น้อยส่งผลต่อการสูญเสียน้ำหนักในช่วงเลี้ยงลูก ดังนั้นจึงควรมีการประเมินความหนาไขมันสันหลังแม่สุกรก่อนคลอดอย่างระมัดระวัง ในการศึกษานี้แสดงให้เห็นว่าแม่สุกรที่มีความหนาไขมันสันหลังน้อยกว่าสามารถรับมือกับความเครียดจากความร้อนได้ดีกว่า และคุณภาพน้ำนมเกี่ยวข้องกับอาหารที่แม่สุกรได้รับ โดยพบว่าการเสริมไขมันในแม่สุกรก่อนคลอดช่วยเพิ่มไขมันในน้ำนมได้ซึ่งน้ำนมเป็นแหล่งพลังงานที่ สำคัญในลูกสุกร ลูกสุกรแรกเกิดต้องการน้ำนมอย่างน้อย 200 มิลลิลิตร ในวันแรก (ได้แก่ น้ำนมเหลือง) (Quesnel et al., 2012) ปัจจัยที่ส่งผลต่อการรอดชีวิตและการเจริญเติบโตของลูกสุกรมีหลายประการ เช่น ระดับน้ำตาลในกระแสเลือด อุณหภูมิร่างกาย ลำดับการคลอด (birth order) สีของผิวหนัง ความสมบูรณ์ของสายสะดือ และระยะเวลาจากเกิดจนยืนได้ (Panzardi et al., 2013) หากจะลดการตายของ

ลูกสุกรลง คุณภาพของน้ำนมแม่สุกนสำคัญมาก เราพบว่าการเสริมไขมันในอาหารแม่สุกรก่อนคลอดสามารถเพิ่มไขมันในน้ำนมแม่สุกรได้ถึง 0.7%

ในการศึกษานี้พบว่าความหนาไขมันสันหลังของแม่สุกรมีผลต่อการตายก่อนหย่านมของลูกสุกร การเสริมไขมันในอาหารแม่สุกรสามารถเพิ่มไขมันในน้ำนมแม่สุกรได้ โดยเฉพาะอย่างยิ่งแม่สุกรที่มีไขมันสันหลังบางกว่า โดยการศึกษานี้เป็นรายงานชิ้นแรกที่ศึกษาผลของการเสริมไขมันในอาหารแม่สุกรก่อนคลอดต่อน้ำนมแม่สุกรในสภาพการเลี้ยงจริง จำนวนลูกสุกรตายก่อนหย่านมลดลงอย่างมีนัยสำคัญ เนื่องจาก Bormofett50® มีส่วนประกอบของไขมันสูงถึง 50% ซึ่งใช้เป็นแหล่งพลังงานของแม่สุกรที่สำคัญ ช่วยเพิ่มไขมันในน้ำนม และลดการตายของลูกสุกรแรกเกิด ลูกสุกรที่กินน้ำนมเหลืองได้มากกว่าย่อมมีโอกาสรอดชีวิตมากกว่า (Quesnel et al., 2012) ในภูมิอากาศร้อนชื้น การเสริมไขมันในอาหารแม่สุกรก่อนคลอด จะช่วยแม่สุกรในการสร้างน้ำนมที่มีพลังงานสูง นั่นคือโอกาสรอดชีวิตของลูกสุกรที่เพิ่มมากขึ้นด้วย ความหนาของไขมันสันหลังของแม่สุกรก่อนคลอดมีผลต่อการสูญเสียไขมันสันหลังในช่วงเลี้ยงลูก การเสริมไขมันในอาหารแม่สุกรก่อนคลอดสามารถเพิ่มระดับไขมันในน้ำนมของแม่สุกรได้ ส่งผลต่อการเจริญเติบโตของลูกสุกร และลดอัตราการตายของลูกสุกรได้

น้ำนมเป็นปัจจัยสำคัญต่อการรอดและเจริญเติบโตของลูกสุกร (Panzadi et al. 2013; Renaudeau et al. 2013; Tummaruk et al. 2014) เพราะเป็นแหล่งพลังงานที่สำคัญที่ลูกสุกรจะได้รับ ทำให้ปัจจุบันมีงานวิจัยจำนวนมากพยายามศึกษาและหาปัจจัยที่มีผลต่อการสร้างน้ำนมและองค์ประกอบน้ำนมของแม่สุกร นอกจากนี้การปรับปรุงพันธุกรรมอย่างก้าวหน้าเพื่อให้ได้จำนวนลูกต่อครอกเพิ่มมากขึ้นจากอดีต ทำให้เมื่อเมื่อมีจำนวนลูกสุกรต่อครอกเพิ่มมากขึ้น แต่ความสามารถในการสร้างน้ำนมยังคงเท่าเดิม ด้านคุณภาพและองค์ประกอบของน้ำนมจึงเป็นสิ่งสำคัญอย่างยิ่ง ที่จะช่วยให้แม่สุกรมีน้ำนมเพียงพอต่อการเจริญเติบโตและรอดชีวิตของลูกสุกร

ปัจจัยหนึ่งที่มีผลต่อการสร้างน้ำนมของแม่สุกรคือ **“อาหารที่แม่สุกรได้รับ”** ทำให้มีการทดลองเสริมอาหารต่างๆ จำนวนมาก เพื่อเพิ่มคุณภาพของน้ำนม เช่นเดียวกับการศึกษาทดลองในครั้งนี้ ได้เสริมไขมันสกัดจากหางนมที่มีขนาดโมเลกุลเล็กในอาหารแม่สุกร ทำให้คุณภาพน้ำนมดีขึ้น สามารถเพิ่มอัตราการเจริญเติบโตของลูกสุกรและส่งผลต่อการเพิ่มผลผลิตตามมา โดยผลการศึกษาพบว่าองค์ประกอบของไขมันในน้ำนมในแม่สุกรกลุ่มที่ได้รับการเสริมไขมันสกัดจากหางนมที่มีขนาดโมเลกุลเล็กในอาหารมีค่ามากกว่าถึง 2.1% เมื่อเทียบกับกลุ่มควบคุม คือ 9.8% ในกลุ่มทดลอง 7.8 % ในกลุ่มควบคุม ซึ่งพบว่าสอดคล้องกับงานวิจัยก่อนหน้านี้ที่มีการทดลองเสริมน้ำมันมะพร้าว 8% ในช่วงสัปดาห์สุดท้ายของการตั้งท้อง ทำให้นมน้ำเหลืองมีระดับพลังงานเพิ่มขึ้นใน 24 ชั่วโมงแรกหลังคลอด (Hansen et al. 2012) และพบว่าการเสริมน้ำมันข้าวโพด 10% ในอาหารแม่สุกรช่วง 2 สัปดาห์ก่อนคลอดจนถึงระยะในนมสามารถเพิ่มไขมันในน้ำนมได้ถึง 1.2% เมื่อเปรียบเทียบกับกลุ่มที่ได้รับอาหารปกติ (Jackson et al. 1995) การศึกษาก่อนหน้านี้พบว่าปริมาณไขมันสูงสุดในน้ำนมของแม่สุกรมีค่าปกติอยู่ที่ 10.6% ภายใน 48 ชั่วโมงหลังคลอด (Jackson et al. 1995) ดังนั้นการเสริมสารอาหารเพื่อหวังผลในการเพิ่มคุณภาพของน้ำนมของแม่สุกรนั้น จึงควรเสริมตั้งแต่ช่วงก่อนคลอด เพื่อให้เกิดประโยชน์และสามารถเพิ่มปริมาณของสารอาหารในน้ำนมได้อย่างมีประสิทธิภาพ

“น้ำนมเหลือง” คือ แหล่งพลังงานที่สำคัญที่สุดในลูกสุกรดูดนม (suckling piglets) หากได้รับปริมาณนมน้ำเหลืองเพียงพอจะทำให้เพิ่มอัตราการคลอดชีวิตของลูกสุกรแรกคลอด (survival rate of neonatal piglets) Quesnel et al. (2012) **พบว่าภายใน 24 ชั่วโมงแรกหลังคลอดลูกสุกรควรได้รับนมน้ำเหลืองปริมาณ 200 กรัมต่อตัว** จึงจะเพียงพอและลดความเสี่ยงในการตายก่อนหย่านม โดยปัจจัยที่ส่งผลให้ลูกสุกรได้รับนมน้ำเหลืองเพียงพอนั้น ได้แก่ ความสามารถในการดูดนมของลูกสุกร การลดความแตกต่างของน้ำหนักลูกสุกรแรกคลอด เพื่อให้ลูกสุกรทุกตัวได้รับน้ำนมในปริมาณที่เท่ากัน ลดปัญหาการเกิดลูกสุกรที่มีน้ำหนักแรก

คลอดต่ำ อ่อนแอ และตายในช่วงแรกหลังการคลอด และสุดท้ายคือคุณภาพของนมน้ำเหลืองที่ดี โดยการศึกษาครั้งนี้พบว่า การเสริมไขมันในอาหารแม่สุกร สามารถช่วยเพิ่มปริมาณนมน้ำเหลืองที่ลูกสุกรกินได้มากกว่ากลุ่มควบคุมถึง 31.4 กรัมต่อตัว (335.5 กรัม และ 302.1 กรัม ในกลุ่มทดลองและกลุ่มควบคุม ตามลำดับ) ภายใน 24 ชั่วโมงแรกหลังคลอด ถ้าหากลูกสุกรได้รับนมน้ำเหลืองเพียงพอจะสามารถเพิ่มอัตราการเจริญเติบโตได้ ซึ่งสอดคล้องกับผลการศึกษาในครั้งนี้ที่พบว่า ลูกสุกรที่มีน้ำหนักแรกคลอดมากกว่า 1.4 กิโลกรัมในกลุ่มทดลอง มีอัตราการเจริญเติบโตต่อวันมากกว่ากลุ่มควบคุม

โดยสรุปการศึกษาในครั้งนี้ชี้ให้เห็นว่าการเสริมไขมันในช่วงระยะท้ายของการท้องและระยะให้นมนั้น แม่สุกรสามารถย่อย ดูดซึม และนำไขมันไปใช้ประโยชน์ได้ ทำให้องค์ประกอบของน้ำนมโดยเฉพาะไขมันเพิ่มขึ้น ซึ่งส่งผลต่อปริมาณนมน้ำเหลืองที่ลูกสุกรได้รับ และการเจริญเติบโตต่อวันของลูกสุกร

บทสรุปและข้อเสนอแนะ

การตายของลูกสุกรก่อนหย่านมเป็นปัญหาสวัสดิภาพสัตว์และเป็นปัญหาทางเศรษฐกิจ ที่สำคัญที่ยังคงต้องกังวลในอุตสาหกรรมการผลิตสุกร แม้ว่าจะเป็นที่ยอมรับกันดีว่า **น้ำหนักของลูกสุกรแรกคลอดเป็นปัจจัยหลักที่มีผลต่ออัตราการรอดชีวิตและการเจริญเติบโตของลูกสุกร** แต่การตายของลูกสุกรก่อนหย่านมเกิดจากหลายสาเหตุและมีอิทธิพลจากหลายปัจจัย ความเข้าใจและความรู้เกี่ยวกับสาเหตุและปัจจัยต่างๆ ที่มีผลต่อการตายของลูกสุกรก่อนหย่านม จะสามารถลดปริมาณการตายของลูกสุกรก่อนหย่านมได้ แนวทางหลักๆ ในการลดอัตราการตายของลูกสุกรก่อนหย่านม ได้แก่

1. การเสริมสร้างโภชนาการทั้งแม่และลูกสุกร
2. การศึกษากลยุทธ์ใหม่ๆ ในการจัดการฟาร์ม ซึ่งเป็นสิ่งสำคัญสำหรับสัตวแพทย์และผู้ผลิตที่ควรจะพยายามทำความเข้าใจและวิเคราะห์ปัจจัยที่มีผลต่อการตายของลูกสุกรก่อนหย่านมของลูกสุกรในฟาร์มแต่ละฟาร์มอย่างเหมาะสม
3. พัฒนากระบวนการเฝ้าคลอดที่มีประสิทธิภาพ ถึงแม้ความแข็งแรงของลูกสุกรจะมีความสำคัญ แต่ก็ยังไม่มีขั้นตอนหรือแนวทางที่เหมาะสมในการประเมินความแข็งแรงของลูกสุกร
4. ให้ความสำคัญกับน้ำนมเหลืองซึ่งเป็นแหล่งพลังงานเพียงอย่างเดียวและให้ภูมิคุ้มกันถ่ายทอดแก่ลูกสุกร ผู้ผลิตควรให้ความสำคัญกับการพยายามให้ลูกสุกรได้รับน้ำนมเหลืองในปริมาณที่เหมาะสมหลังคลอด
5. การจัดให้ลูกสุกรได้อยู่ในสภาพแวดล้อมที่เหมาะสม
6. ศึกษาเพิ่มเติมเกี่ยวกับปัจจัยที่ยังคงสับสน เช่น ผลกระทบของลำดับท้อง
7. ศึกษาปัจจัยที่มีผลต่อความแข็งแรงของลูกสุกรในสภาพอากาศที่หนาวเย็นและในสภาพอากาศร้อน เป็นสิ่งจำเป็นในการประเมินผลกระทบสุดท้ายของปัจจัยที่มีอิทธิพลต่อการตายของลูกสุกรก่อนหย่านม ซึ่งอาจมีการจัดการที่มีความแตกต่างกันเพื่อลดการตายของลูกสุกรก่อนหย่านม

จากการศึกษาวิจัยเหล่านี้ สามารถสรุปได้ว่าการคลอดในระบบการเลี้ยงปล่อยมีอัตราการตายของลูกสุกรก่อนหย่านมเท่ากับการเลี้ยงในซองบังคับ การออกแบบซองคลอดเพื่อให้เหมาะสมกับฟาร์มในอนาคต การควบคุมการเคลื่อนไหวของแม่สุกรภายในครอก การทำให้สภาพแวดล้อมในคอกคลอดเหมาะสม เพื่อตอบสนองความต้องการทางชีวภาพและเป้าหมายการผลิต อย่างไรก็ตาม จำเป็นต้องมีการศึกษาเพิ่มเติม ในท้ายที่สุด ขั้นตอนการเฝ้าคลอดเป็นประโยชน์สำหรับผู้ผลิตและ**ควรมีการศึกษาเพิ่มเติมเกี่ยวกับการเสริมอาหารให้แก่ลูกสุกรที่มีน้ำหนักแรกคลอดต่ำ (เช่น การให้น้ำนมเหลืองหรือการเสริมอาหารที่จำหน่ายเชิงพาณิชย์)** นอกจากนี้ ผลกระทบของการย้ายฝากต่อการตายของลูกสุกรก่อนหย่านม ยังจำเป็นต้องมีการทบทวนใหม่เพื่อทำความเข้าใจการใช้งานที่เหมาะสมในสถานการณ์ที่ต่างกัน (เช่น ในฟาร์มที่มีสถานะสุขภาพไม่ดี) เช่นเดียวกับการปฏิบัติในฝูงที่ให้ผลผลิตสูง แต่การวิจัยทางวิทยาศาสตร์เกี่ยวกับระบบแม่นมและการเลี้ยงลูกด้วยนมทดแทนยังเป็นสิ่งที่น่าสนใจอย่างยิ่ง

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ภาคผนวก (Appendix)

ผลงานวิจัยที่ตีพิมพ์ในวารสารระดับนานาชาติ

1. **Tummaruk, P.,** Sumransap, P., Jiebna, N., 2014. Fat and whey supplementation influence milk composition, backfat loss, and reproductive performance in lactating sows. Tropical Animal Health and Production 46: 753-758. **Q2**
2. Muns, R., Nuntapaitoon, M., **Tummaruk, P.,** 2016. Non-infectious causes of pre-weaning mortality in piglets. Livestock Science 184: 46–57. **Q1**
3. Muns, R., **Tummaruk, P.,** 2016. Management strategies in the farrowing house to improve piglet pre-weaning survival and growth. The Thai Journal of Veterinary Medicine 46: 347–354. **Q4**
4. Nuntapaitoon, M., Muns, R., **Tummaruk, P.,** 2018. Newborn traits associated with pre-weaning growth and survival in piglets. Asian-Australasian Journal of Animal Science 31: 237-244. **Q1**
5. Nuntapaitoon, M., Muns, R., Theil, P.K., **Tummaruk, P.,** 2018. *L*-arginine supplementation in sow diet during late gestation decrease stillborn piglet, increase piglet birth weight and increase immunoglobulin G concentration in colostrum. Theriogenology 121: 27 – 34. **Q1**
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ประวัตินักวิจัยและคณะ พร้อมหน่วยงานสังกัด

ประวัติผู้วิจัย

ชื่อหัวหน้าโครงการ

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- Swedish University of Agricultural Science (SLU), Uppsala, Sweden	โท	Master of Science in Veterinary Medicine	2542
- SLU, Uppsala, Sweden	เอก	Obstetrics and Gynaecology	2544

ผลงานวิจัยที่พิมพ์เผยแพร่ (5 ปี ย้อนหลัง ค.ศ. 2015-2019)

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ขอรับรองว่าข้อความที่ให้ไว้เป็นความจริงทุกประการ

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REGULAR ARTICLES

Fat and whey supplementation influence milk composition, backfat loss, and reproductive performance in lactating sows

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Abstract This study investigates the effects of microencapsulated fat (FAT) and whey protein (WHEY) supplementation on the milk composition, backfat loss, and reproductive performance in lactating sows. A total of 144 sows were divided according to their backfat thickness at farrowing into three groups, i.e., low (12.0–16.5 mm, n=33), moderate (17.0–21.5 mm, n=78), and high (22.0–24.5 mm, n=33). The lactation diet was divided into three types, i.e., a control diet (CONTROL, n=50), a diet supplemented with FAT (n=48), and a diet supplemented with WHEY (n=50). Pooled milk samples were collected at the second and third week of lactation. On average, the sows lost backfat 23.5 % during lactation. The backfat loss during lactation was 24.5, 22.7, and 22.8 % in sows fed with CONTROL, FAT, and WHEY diets, respectively (P>0.05). Supplementation of FAT increased the percentage of fat in the sow's milk compared to the CONTROL (9.1 and 8.4 %, P=0.022). For sows with low backfat, FAT and WHEY supplementation increased the average daily gain of piglets compared to the CONTROL (244, 236, and 205 g/days, respectively, P<0.05). For sows with high backfat, the sows receiving the CONTROL diet had a higher total piglet mortality than those that received FAT or WHEY (28.1, 14.1, and 13.0 %, respectively, P<0.05). It could be concluded that supplementation of FAT in the diet of sow during lactation significantly enhanced the fat content in the sow's milk, improved the piglet's daily weight gain, and reduced piglet mortality.

Keywords Backfat · Diet · Lactation · Milk · Pig

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Introduction

A sow's milk composition and milk yield are important factors in determining mortality rate and growth rate of the preweaning piglets (Farmer et al. 2012). For the modern genotype pig, as the number of nursing piglets per sows has increased, due to genetic improvement in the prolificacy traits, the milk quantity per piglet has decreased. This has led to a limitation in the growth rate and weaning weight of piglets. Therefore, much research is investigating factors that enhance a sow's milk composition and milk yield (Benzoni et al. 2012; Jang et al. 2013). Additionally, the health of postpartum sows, the physiological state and management strategies in relation to milk production is being intensively investigated (Quesnel et al. 2012; Tummaruk and Sang-Gassanee 2013).

In general, the inferior reproductive performance of the postweaning sows is largely dependent on body weight and/or backfat loss during lactation (Tummaruk 2013). Due to heat stress, sows kept in tropical climates have a relatively poor feed intake during lactation and have a high risk of backfat loss. Furthermore, in tropical climates, the appetite of lactating sows is generally too low to meet their nutrient requirements for milk production (Renaudeau and Noblet 2001). This issue is emphasized in tropical conditions due to the effect of heat stress on the reduction of feed intake. An earlier study found that giving alkyl-glycerol fatty acids to sows in late gestation and lactation can improve the passive immunity transfer to the piglets (Benzoni et al. 2012). Furthermore, the supplementation of live yeast in a sow's diet elevated immunoglobulin G

(IgG) concentration in the sow colostrum and subsequently enhanced the plasma IgG of the piglets (Jang et al. 2013). These findings indicate that the sow's diet composition influences the sow's milk quality and may also influence the piglet's growth and survival. The aim of the present study was to determine the effect of microencapsulated fat-filled whey (FAT) and whey protein (WHEY) supplementation to lactation diet on the milk composition, backfat loss, and reproductive performance in sows.

Materials and methods

Animal and general management

The experiment was carried out in a commercial swine breeding herd in eastern Thailand in August and September 2012, with 147 Landrace x Yorkshire F1 crossbred sows in the first or second parity (mean parity 1.8). One week before farrowing, the animals entered the farrowing house, which was equipped with evaporative cooling and individual farrowing crates. The health of the animals was supervised by the herd veterinarian and all sows received routine vaccinations. Most sows were treated with antibiotics (amoxicillin clavulanic acid), anti-inflammatory drugs (Tolfédine®), and vitamins (Fercobseang®) during the 3 days after farrowing, but treatment was modified according to clinical signs. During lactation, sows fed 2–3 times a day (about 5–6 kg of feed/day) with a corn–soybean–fish ration containing 18.0 % crude protein, 3,150 kcal/kg metabolisable energy, and 1.0 % lysine. Conventional artificial insemination was used. Replacement gilts were bred at ≥32 weeks of age with body weight of ≥130 kg and at the second or subsequent estrus.

Reproductive data

At farrowing, the date of farrowing, the total number of piglets born/litter (TB), the number of piglet born alive per litter (BA), the percentage of stillborn piglets per litter (SB) and the percentage of mummified fetuses per litter (MM), and the piglet's birth weight were recorded. Cross-fostering was performed within treatment groups between 24 and 48 h of birth. At weaning, the date of weaning, the number of piglets at weaning, and weaning weight were measured. Lactation length was the interval (days) between farrowing and weaning (22.7±3.5 days). Data on daily feed intake of sows in each group was recorded daily from farrowing until weaning. The average daily gain of the piglets from birth to weaning was calculated: average daily gain (gram/day)=[weaning weight (kg)−birth weight (kg)/lactation length (day)]×1,000. Preweaning mortality at the individual sow level was calculated: preweaning mortality (%)=[(number of lived born piglets after cross-fostering−number of piglets at weaning)/number of lived born piglets after cross-fostering]. After weaning, the weaning-to-service interval (WSI) was recorded. Two sows were culled after weaning, so 142 sows remained in the analyses on WSI.

Backfat thickness measurement

The backfat thickness of the sows was measured at the level of the last rib at about 6 to 8 cm from the midline using A-mode ultrasonography (Renco Lean-Meater®, Minneapolis, MN, USA.). The backfat measurement was performed in each sow at farrowing and at weaning. Backfat loss was defined as the difference between backfat thickness at farrowing and at weaning in each sow. The relative loss of backfat (%) was defined as the backfat loss (mm) divided by backfat thickness at farrowing and multiplied by 100.

Classification of sows

Of all the sows (n=147), backfat was not determined in three sows, therefore only 144 sows were included in the analyses of backfat loss. The sows were divided into three groups according to backfat at farrowing as low (12.0–16.5 mm, n=33), moderate (17.0–21.5 mm, n=78), and high (22.0–24.5 mm, n=33). After farrowing, they were categorized into three groups according to the type of diet as conventional lactation feed (CONTROL, n=50), controlled feed supplemented with microencapsulated fat-filled whey (FAT, n=48), and controlled feed supplemented with whey protein (WHEY, n=50). The FAT product contained an energy of 5,920 C/kg and high in encapsulated, spray dried fat (50.0 % fat and 35.6 % lactose, FrieslandCampina Nutrifeed, The Netherlands). The WHEY product contained milk protein 12 % and lactose 72 % (FrieslandCampina Nutrifeed, The Netherlands).

Milk sample

Milk samples were collected from the sows during the second and third week of lactation. The milk samples were collected manually from 4–6 mammary glands from each sow. The udder and teats were cleaned with warm water, wiped with a dry towel, and gently massaged before collection. In some cases, 10–20 IU of oxytocin was also applied. The milk samples from each sow were pooled and were kept in a clean bottle. The samples (10 ml) were stored at 4ºC on ice in a foam box and were sent to the laboratory within 24 h. In total, 48, 49, and 50 samples were obtained from the sows in the CONTROL, FAT, and WHEY groups, respectively. The analyses of milk contents were conducted using MilkoScan 133B (FOSS electric, Hilleroed, Denmark). The milk composition including fat, protein, lactose, and total solid contents were determined by infrared (IR) instrumental analysis. Briefly, the IR spectrophotometry is a measuring technique mainly used

for quantitative analysis. The presence of compound in the sample was determined on the basis of infrared spectra (Luinge et al. 1993).

Statistical analysis

Statistical analyses were performed using SAS (SAS Inst. Inc., Cary, NC). Descriptive statistics and frequency tables were employed for all reproductive parameters. Multiple analysis of variance was conducted to analyze continuous dependent variables including litter traits (i.e., TB, BA, MM, SB, piglet's birth weight, average daily gain, number of piglets at weaning, preweaning mortality, total piglet mortality [i.e., sum of MM, SB, and preweaning mortality], and weaning weight) and sow's performance (i.e., backfat, backfat loss, relative backfat loss, lactation length, and WSI) using the general linear model procedure. The statistical models included the effect of backfat at farrowing class (low, moderate, and high), the type of diet (CONTROL, FAT, WHEY), and the interaction between the backfat and the type of diet. For the piglet's mortality traits (MM, SB, preweaning mortality, and total piglet mortality), TB was also included in the statistical models as a covariance (regression). The means daily feed intake of sows in each week of lactation was calculated and compared between groups and between weeks of lactation by multiple ANOVA. Least squares means were obtained from each class of the factors and were compared using the least significant difference test. a $P<0.05$ was considered as statistically significant.

Results

Effect of backfat thickness

Descriptive statistics on litter traits, piglet mortality, and backfat thickness are presented in Table 1. The backfat of sows at farrowing influenced the backfat loss during lactation ($P<0.001$) and MM ($P=0.006$). On average, the relative backfat loss of the sows during lactation period was 23.5 % (Table 1). Of these sows ($n=144$), six sows (4.1 %) did not lose any backfat, while 13 sows (9.1 %), 32 sows (22.2 %), 46 sows (31.9 %), 32 sows (22.2 %), and 15 sows (10.4 %) lost backfat 1–10, 11–20, 21–30, 31–40, and >40 % during lactation, respectively. Sows with a high backfat at farrowing lost 29.6 % of backfat during lactation, while sows with a low backfat at farrowing lost 16.1 % of backfat during lactation ($P<0.001$). The total piglet mortality was 18.4 % in high backfat sows but it was 11.1 % in low backfat sows ($P=0.042$) (Table 2).

Table 1 Descriptive statistics ($n=147$)

Parameters	Mean±SD	Range
Litter performance		
Total number of piglets born/litter (TB)	14.0±3.1	6–23
Number of piglets born alive/litter (BA)	12.6±3.0	2–20
Piglet's birth weight (kg)	1.50±0.24	0.90–2.70
Piglet's weight at weaning (kg)	7.0±0.9	3.9–9.2
Average daily gain of piglets (g/day)	218±3.8	111–315
Number of piglets at weaning/litter	12.0±1.6	7–17
Piglet's mortality		
Mummified fetuses/litter (MM, %)	4.3±10.5	0–87.5
Stillborn piglets/litter (SB, %)	4.7±7.8	0–46.1
Pre-weaning mortality (%)	5.3±9.1	0–50
Total piglets mortality (%)	13.8±15.5	0–87.5
Sow		
Parity number	1.8±0.4	1–2
Backfat at farrowing (mm)	19.2±3.2	12.0–24.5
Backfat at weaning (mm)	14.6±3.1	8.0–23.0
Backfat loss (mm)	−4.7±3.1	−5.0–+14.0
Relative backfat loss (%)	−23.5±14.7	−34.5–+58.3
Lactation (day)	22.7±3.5	14–29
Average daily feed intake of sow (g/day)	4.4±1.1	2.9–6.8
Weaning-to-service interval (WSI, day)	4.6±0.8	4–8

Effect of diets and interaction between diets and backfat thickness

During lactation, the average daily feed intake of the sows was 4.4±1.1 kg/sow/day and was increased from the first (3.3 kg/sow/day) to the second (4.2 kg/sow/day, $P<0.001$) and the third week (5.5 kg/sow/day, $P<0.001$) of lactation. However, the average daily feed intake of sows in the CONTROL, FAT, and WHEY groups did not differ significantly. The relative backfat loss during lactation was 24.5, 22.7, and 22.8 % in sows fed with CONTROL, FAT, and WHEY diets, respectively ($P>0.05$). Likewise, all of the piglet's mortality traits and the piglet's average daily gain did not differ between the sows fed with CONTROL, FAT, and WHEY diets ($P>0.05$).

Interaction between backfat thickness at farrowing and type of diet influenced total piglet mortality ($P=0.048$). In sows with high backfat at farrowing, those receiving CONTROL diet had a higher total piglet mortality than those receiving FAT and WHEY diets (Table 3). In addition, low backfat sows fed with FAT supplementation yielded a significantly higher average daily gain of piglets than the CONTROL sows (Table 3). Nevertheless, the feed supplementation did not influence the average daily gain of piglets from sows with moderate and high backfat (Table 3).

The milk compositions of lactating sows are presented in Table 4. On average, the milk of sows contained 8.7 % fat,

Table 2 Reproductive performance of postpartum sows by backfat at farrowing (least squares means±SEM)

Items	Backfat thickness at farrowing		
	Low (n=33)	Moderate (n=78)	High (n=33)
Litter performance			
Total number of piglet born/litter (TB)	13.9±0.5a	13.5±0.3a	15.7±0.5b
Number of piglets born alive/litter (BA)	12.7±0.5a	12.5±0.3a	13.3±0.5a
Piglet's birth weight (kg)	1.55±0.04a	1.51±0.03ab	1.45±0.04b
Piglet's weight at weaning (kg)	7.0±0.2a	7.4±0.1a	7.3±0.2a
Average daily gain of piglets (g/day)	228±7.6a	240±5.0a	240±7.3a
Number of piglets at weaning/litter	12.7±0.3a	11.7±0.2b	11.9±0.3ab
Piglet's mortality			
Mummified fetuses/litter (MM, %)	1.2±1.8a	3.7±1.2a	9.4±1.9b
Stillborn piglets/litter (SB, %)	6.1±1.4a	4.4±0.9a	3.7±1.4a
Preweaning mortality (%)	4.1±1.4a	5.9±1.0a	5.8±1.5a
Total piglets mortality (%)	11.1±2.5a	13.5±1.6ab	18.4±2.5b
Sow			
Backfat thickness at farrowing (mm)	14.6±0.2a	19.6±0.1b	23.2±0.2c
Backfat thickness at weaning (mm)	12.2±0.5a	14.8±0.3b	16.3±0.5c
Backfat thickness loss (mm)	2.4±0.5a	4.8±0.3b	6.9±0.5c
Relative backfat loss (%)	16.1±2.5a	24.3±1.6b	29.6±2.5b
Lactation length (day)	22.8±0.6a	22.8±0.4a	22.3±0.6a
Weaning-to-service interval (WSI, day)	5.0±0.1a	4.5±0.1b	4.5±0.1b

Different letters within rows differ significantly (P<0.05)

5.7 % lactose, 5.0 % protein, and 20.0 % total solids. The supplementation of FAT during lactation significantly improved the percentage of fat from 8.4 to 9.1 % (+0.7 %, P= 0.022). The other contents of the sow's milk did not alter in sows supplemented with either FAT or WHEY (Table 4).

Discussion

During recent years, researchers have been trying to investigate factors affecting the sow's ability to produce adequate milk for their offspring in order to enhance piglet growth and reduce piglet preweaning mortality (Panzardi et al. 2013; Renaudeau et al. 2013; Tummaruk and Sang-Gassanee 2013). In tropical climates, lactating sows may not receive enough feed intake during lactation. Therefore, negative energy balance conditions, closely related to the sow's backfat loss, need to be carefully determined. In the present study, TB (14.0) and BA (12.6) are relatively high compared to a previous report in Thailand (11.3 TB and 10.2 BA, Tummaruk et al. 2010). This might be due to the introduction of a new genotype of sows with a high litter size to the Thai swine industry during recent years. Therefore, more attention on the sow's ability to produce milk and associated factors is an important issue to be addressed.

In the present study, the percentage of fat and other compositions in the sow milk are within the normal range and in agreement with earlier reports (Gourdine et al. 2006). The fat percentage in the milk of the normal sows peaked (10.6 %) at 48 h postpartum, lactose gradually increased during the first 168 h postpartum, and protein gradually decreased after 6 h postpartum (Jackson et al. 1995). This data indicates that the milk composition of the sows might play an important role in the growth and survival of piglets nearly immediately after birth. Thus, diets supplementation should be implemented before farrowing to achieve benefits through the improvement of milk compositions.

The milk composition of sows is associated with the sow diet. FAT supplementation significantly enhanced the fat content in the sow's milk (i.e., +0.7 %). Milk is the main energy source of suckling piglets. Newborn piglets are expected to consume at least 200 ml of milk during the first day of life to obtain enough energy to generate body growth (Quesnel et al. 2012). Risk factors associated with the piglet survival and growth included blood glucose, rectal temperature, birth order, skin color, and integrity of the umbilical cord (Panzardi et al. 2013). Beyond the piglet's vitality, the sow's ability to produce good milk is extremely important for the survival of the suckling piglets. FAT supplementation increased 0.7 % of the fat content in sow's milk. This may possibly be associated with the

Table 3 Piglet mortality, piglet's average daily gain, and backfat loss in sows with low, moderate, and high backfat at farrowing by groups of sows fed with control feed (CONTROL), microencapsulated fat-filled whey product supplementation (FAT), and whey protein supplementation (WHEY) (least squares means±SEM)

Parameters	CONTROL	FAT	WHEY
Low backfat sows			
Mummified fetuses/litter (MM, %)	1.2±3.1a	1.2±3.4a	1.3±2.9a
Stillborn piglets/litter (SB, %)	4.2±2.3a	5.6±2.6a	8.6±2.2a
Preweaning mortality (%)	3.5±2.7a	4.8±2.9a	3.9±2.5a
Total piglets mortality (%)	8.9±4.2a	10.8±4.7a	13.5±3.9a
Piglet's average daily gain (g/day)	196±12.5a	248±14.6b	236±11.8b
Backfat loss (mm)	3.4±0.8a	1.8±0.9a	2.0±0.7a
Moderate backfat sows			
Mummified fetuses/litter (MM, %)	2.0±2.0a	3.1±2.0a	6.0±2.1a
Stillborn piglets/litter (SB, %)	3.7±1.5a	3.9±1.5a	5.6±1.6a
Preweaning mortality (%)	5.3±1.6a	7.2±1.6a	5.1±1.7a
Total piglets mortality (%)	10.5±2.8a	13.7±2.7a	16.3±2.9a
Piglet's average daily gain (g/day)	245±9.2a	229±8.2a	247±7.8a
Backfat loss (mm)	4.2±0.5a	4.6±0.5a	5.5±0.5a
High backfat sows			
Mummified fetuses/litter (MM, %)	12.8±3.3a	7.2±3.3a	8.3±3.0a
Stillborn piglets/litter (SB, %)	5.6±2.5a	1.2±2.5a	4.3±2.3a
Preweaning mortality (%)	10.8±2.6a	5.9±2.6ab	0.6±2.4b
Total piglets mortality (%)	28.1±4.5a	14.1±4.4b	13.0±4.1b
Piglet's average daily gain (g/day)	234±10.2a	246±11.9a	247±14.6a
Backfat loss (mm)	6.7±0.8a	7.6±0.8a	6.3±0.8a

Different letters within rows differ significantly ($P<0.05$)

reduction in piglet mortality in the sows with a high backfat at farrowing. Tummaruk (2013) indicates that high backfat sows may be at risk of getting ill and having a low appetite and this may subsequently lead to a negative energy balance. These conditions may lead to the poor milk production of sows and associated with high piglet mortality. The present study found that feed supplementation with either FAT or WHEY may not be completed in sows with a high backfat at farrowing, partly due to the low appetite during lactation. Hence, it is important that the backfat of sows be controlled before any feed supplementation protocol can be implemented.

Table 4 Milk composition of lactating sows fed with conventional feed (CONTROL) compared with those fed with microencapsulated fat-filled whey product (FAT), and whey supplementation (WHEY) diets (means± SD)

Milk composition	CONTROL (n=48)	FAT (n=49)	WHEY (n=50)
Fat (%)	8.4±1.5a	9.1±1.1b	8.5±1.4ab
Protein (%)	5.1±0.4a	4.9±0.3a	5.0±0.4a
Lactose (%)	5.7±0.2a	5.7±0.2a	5.7±0.3a
Total solid (%)	19.8±1.5a	20.4±1.2a	20.0±1.5a

Different letters within columns differ significantly ($P<0.05$)

During lactation, the increase of fat in the sow's milk may increase the energy of the piglets and enhance piglet growth. This effect is more pronounced in sows with a low backfat at farrowing than sows with a moderate or high backfat at farrowing. To our knowledge, this is the first report on the influence of FAT on sow milk contents and reproductive performance under field conditions. Interestingly, piglet mortality was also reduced in the FAT group compared to the CONTROL group. This is due to the fact that FAT supplementation provided extra energy to the sows and increased the fat concentration in the sow's milk and hence enhanced the vitality of the neonatal piglets. Therefore, FAT supplementation may help sows to produce high energy milk and enhance piglet growth and reduce piglet mortality.

Sows fed with lactation diet supplemented with 8.0 % coconut oil during the last week of gestation secreted more colostral energy during the first 24 h (Hansen et al. 2012). Likewise, the supplementation of 10.0 % corn oil in sow diet during the last 2 weeks of gestation throughout lactation increased the milk fat percentage of sows compared to the control diet. These findings indicate that sows are able to digest, absorb, and utilize some extra amounts of fat (8–10 %) during late gestation and during lactation. Jackson et al. (1995) found that supplemental dietary fat can overcome

the reduced fat percentage in sow milk caused by the induction of premature farrowing. This data implies that the supplementation of fat to the sow diets during late gestation and lactation may help to maintain high energy in newborn piglets, especially when induction of parturition has been implemented. A significant alteration of the sow's milk composition, especially the fat content, as found in the present study, may have an influence on piglet growth and survival.

In conclusion, the backfat of sows at farrowing influences their backfat loss during lactation. The supplementation of FAT in a sow's feed during lactation significantly increases fat concentration in the sow's milk, enhances growth rate of the piglets in sows with low backfat at farrowing, and reduces piglet mortality in sows with high backfat at farrowing.

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Conflict of interest

All of the authors have no conflict of interest.

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Review article

Non-infectious causes of pre-weaning mortality in piglets

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ABSTRACT

Piglet pre-weaning mortality (PWM) is one of the major reproductive components that affects herd productivity in the swine industry. Knowledge of factors that influence piglet PWM are important to improve animal welfare, to reduce production loss and to raise profits in commercial herds. The main objective of the present work was to review the most important non-infectious causes of piglet PWM and to present the main factors influencing them under commercial conditions. Piglet pre-weaning mortality is a multifactorial process, the small size of piglets at birth, together with their low body energy storage and their immature immune system, make them prone to chilling, starving, or being crushed by the sow. In general, factors causing piglet PWM are usually classified into three major groups: piglet (i.e., birth weight, vitality, and gender), sow (i.e., colostrum, parity, maternal stress, and sow nutrition), and environmental factors (i.e., season and temperature, housing, and management). Birth weight is the most determinant factor for piglet survival with direct impact on thermoregulatory capacity and growth; piglet vitality is also correlated with survival and growth and is strongly influenced by the degree of intra-partum hypoxia suffered by the piglet; additionally, piglet PWM appears to be sex-biased, with males showing greater susceptibility to causal mortality factors. Newborn piglets are highly dependent on colostrum to use it as energy substrate for thermoregulation and growth, and also to acquire passive immunity crucial for their future survival; however, sows' parity is a factor with contradictory effect on PWM which requires further research; a proper sows' comfort is also important for maternal stress around farrowing might have a negative impact on offsprings development and also increases the risk of crushing; sows' nutrition will influence foetal development and piglet birth weight, and is determinant to ensure a proper colostrum/milk production. Finally, ambient temperature has an important impact on piglet survival because piglets are very sensitive to cold stress. The housing system used in the farrowing room seems to influence the incidence of crushing. Promising results have been obtained using recent designs that combine initial confinement of the sow with the subsequent ability to move within the same pen. Different management strategies to deal with PWM are usually performed by producers around farrowing. However, there is a lack of scientific evidence on techniques, such as oral supplementation of piglets, cross-fostering, nurse sow systems, or artificial rearing of piglets, and further research should be of interest.

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1. Introduction

The production target in modern commercial swine herds nowadays is close to 30 pigs weaned per sow per year (Knox, 2005). This target has been achieved in two ways: by improving the number of piglets born alive and reducing the farrowing interval (Fig. 1). Litter size in sows has been dramatically improved in recent decades by genetic selection for highly prolific sows (Marantidis et al., 2013).

Despite the improvements in litter size acquired through genetic selection, the mean piglet pre-weaning mortality (PWM) rate in commercial swine herds ranges between 10% and 20% in major pig-producing countries (KilBride et al., 2010; Kirkden et al., 2013a; Koketsu et al., 2006; Tuchscherer et al., 2000). Indeed, recent reports showed a mean piglet PWM rate of 12.9% in the European Union (EU), 9.4% in the Philippines, and 12.2% in Thailand (Interpigs reports, 2014; Bureau of Agricultural Statistical of Philippine, 2012; Nuntapaitoon and Tummaruk, 2013b, 2015). On the other hand, the mortality rate in the nursery and finishing phases usually reaches 2.6% and 2.5%, respectively (EU averages, Interpigs reports, 2014). Considering these mortality values, reducing the PWM from 11.5% to 9.0% in a farm with a mean of 13 live-born piglets per sow, would result in an increase of 65 kg of live body weight (BW) at slaughter per sow per year (assuming 2.30 farrowings per year). Therefore, mortality in the suckling period remains a major welfare and economic problem in swine industries, which still needs to be properly addressed.

To address PWM, it is essential to differentiate between prenatal and postnatal piglet mortality. A proper distinction between stillbirths and live-born piglets that died immediately after birth is needed to properly address PWM in farm conditions. A stillborn piglet did not breathe (lung tissue will not float in water) and has also the periople on the claws (Baxter et al., 2009). In the present review, only piglet PWM calculated from live-born piglets will be considered. The etiology of piglet PWM includes non-infectious and infectious causes. Infectious causes are mainly respiratory and diarrhea problems (Chrisensen and Svensmark, 1997). However, the present review will focus on the non-infectious causes of PWM.

On average, 50–80% of piglet deaths occur during the first week after birth, with the most critical period being the first 72 h of life (Koketsu et al., 2006; Shankar et al., 2009). Many factors determine the incidence of PWM under field conditions, including piglet birth BW, litter size, birth order, gender, parity, farrowing duration, maternal behaviour, sow nutritional status, and environmental temperature (Baxter et al., 2009; Muns et al., 2013; Panzardi et al., 2013). It is important for veterinarians to understand the possible causes underlying piglet PWM and to perform a multifactorial approach of PWM in farm situations, to increase the number of healthy piglets at weaning. Therefore, the aim of the present work was to review current knowledge concerning important non-infectious causes of piglet PWM focusing on the main factors found under commercial conditions. Furthermore, the review aims to highlight the most common management interventions performed around farrowing and their impact on piglet PWM.

2. Causes of pre-weaning mortality in piglets

There is a general agreement that crushing is the principal cause of piglet pre-weaning death, with chilling and starvation as underlying causes (Alonso-Spilsbury et al., 2007; Edwards, 2002; Herpin et al., 2002). Vaillancourt et al. (1990) found that the causes of death for pigs before weaning were crushing (33.8%), low viability (29.7%), scours (12.2%), infection (8.1%), deformity (5.5%), and others (10.7%) in the USA. Similarly, Koketsu et al. (2006) reported that crushing and a low viability of piglets at birth were the main

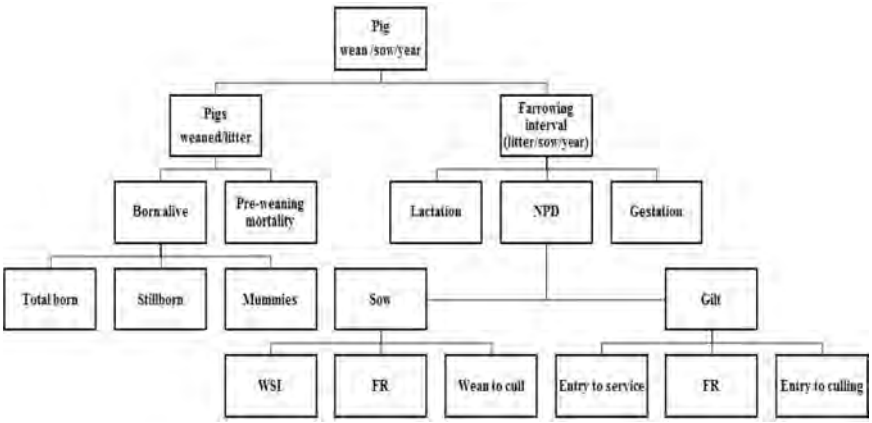

Fig. 1. Pig production diagram (NPD: non-productive days; WSI: weaned-to-service interval; FR: farrowing rate) (modified after Dial et al., 1992).

causes of PWM in Japanese herds. In England, the cause of mortality of live-born piglets in 458 commercial herds was recorded and the results suggested that crushing is by far the major cause of death (Easicare, 1995). Other minor non-infectious causes of death, such as congenital problems or savaging by the sow also exist.

At farrowing, piglets have to recover from the stress of birth, to cope with a decrease in ambient temperature, and to compete with their siblings. However, piglets are born physiologically and immunologically immature. Due to the epitheliochorial nature of the swine placenta, piglets need to receive a passive immunity supply, mainly from immunoglobulin G (IgG) in the colostrum (Herpin et al., 1996, 2002; Tuchscherer et al., 2000). Piglets are also born with no brown adipose tissue, which is used for thermoregulation (Berthon et al., 1993) and are born wet with placental fluids and with a high surface/volume ratio, due to their small size. As a consequence, newborn piglets are prone to chilling and starvation. Hypothermia and deficits in energy intake are factors that further weaken the piglet and thus increase the risk of crushing by sows. As a result, piglet PWM, especially at early stages, is considered to be the outcome of complex interactions between the piglet, the sow and its environment, with crushing being the final act in a complex chain of events (Alonso-Spilsbury et al., 2007; Edwards, 2002). The above-mentioned interactions make it difficult to establish single causes for piglet mortality, but inadequate colostrum intake might be the main factor that triggers early death in piglets due to undersupply of piglets with nutrients and immunoglobulins (Casellas et al., 2004; Edwards, 2002; Le Dividich et al., 2005; Quesnel et al., 2012). In farm conditions, the assessment of pre-weaning deaths strongly depends on the farmer's skills and observations. However, the practicalities of production and the multifactorial nature of PWM limit the accuracy of identifying the underlying cause of death.

3. Factors influencing pre-weaning mortality in piglets

As previously suggested, the cause of death can be influenced by many factors. In general, factors that cause piglet PWM are usually classified into three major groups, involving the piglet, the sow, and environmental factors (Fig. 2).

3.1. Piglet factors

3.1.1. Birth weight

Many studies have reported that piglet birth BW is the most important factor for survival and performance (Baxter et al., 2008; Fix et al., 2010; Muns et al., 2013; Rootwelt et al., 2013). Smaller piglets also have a reduced ability to maintain body temperature (Theil et al., 2012). It has been shown that piglets with an individual birth BW of >1.8 kg had a survival rate of over 90%, whereas piglets with a BW of 700 g had a survival rate of only 33% (Chris et al., 2012). Roehe and Kalm (2000) found that decreasing BW were associated with a rapid increase in odds ratios of PWM, and Fix et al. (2010) associated low BW piglets with lower survival during the complete production chain. Body weight is also positively correlated with colostrum intake (CI) (Amdi et al., 2013; Ferrari et al., 2014; Nuntapaitoon et al., 2014a).

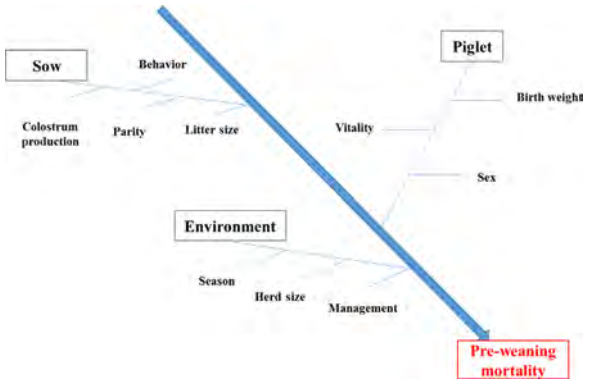

Fig. 2. Risk factors associated with pre-weaning mortality in piglets.

A reduced energy reserve in low birth BW piglets is one factor that explains the higher risk of death. Piglets with a low BW have a low body-mass index. Body-mass index is positively correlated with body muscle, glycogen storage and survival rate (Amdi et al., 2013). Body weight strongly influences an important piglet survival indicator – thermoregulation ability. Within the first hours after birth, thermoregulation is compromised in piglets because of evaporation of the placental fluids and consequent cooling. Susceptible piglets fail to recover from this initial temperature drop, and hypothermia affects the latency to suckle, leading to starvation, lethargy and, ultimately, to crushing by the sow (Weary et al., 1996). Several studies indicated that rectal temperature measured within 24 h after birth was associated with PWM (Tuchscherer et al., 2000; Baxter et al., 2008, 2009; Muns et al., 2013; Panzardi et al., 2013) and suggested that piglets with a low rectal temperature might have a lower thermoregulation ability. Smaller piglets have a higher surface area-to-volume ratio, resulting in a greater susceptibility to heat loss and hypothermia (Herpin et al., 2002). Moreover, low BW piglets require longer to reach the teat and suckle, and are less competitive for a teat than heavier littermates (Rooke and Bland, 2002; Le Dividich et al., 2005), thus reducing their CI (Tuchscherer et al., 2000). Vallet and Miles (2012) suggested that small piglets might move slowly due to brain myelination impairment, which affects the speed of nerve impulse transmission, thus compromising suckling and increasing the odds of crushing.

In addition, the within-litter BW variation is positively correlated with PWM (Milligan et al., 2002; Wolf et al., 2008), because small piglets cannot compete with their larger littermate pigs, resulting in low BW piglets with a low nutritional status and poor passive immunity (Quiniou et al., 2002). Genetic selection for sows with increased litter size has resulted in a reduction in piglets BW, mainly due to a decreased uterine space for foetus development and decreased amount of nutrients available per foetus (Campos et al. 2012). Quiniou et al. (2002) observed that between sows with 9 and 17 total born piglets (an 88% increase in litter size), there was only a 55% increase in total BW. Moreover, with genetic selection for litter size it has also been observed an increase in within-litter variation in piglet BW (Lund et al., 2002; Quesnel et al., 2008). Due to placenta size, foetal growth can vary with differences in placenta vascularisation and efficiency. Roehe and Kalm (2000) reported that a small placenta results in a low glucose and fructose supply to the foetus, resulting in a decreased growth rate and BW of piglets at birth. Placental insufficiency is a major cause of intra-uterine growth restriction that influences BW (Baxter et al., 2008; Rootwelt et al., 2013) and the thermoregulatory capabilities of newborn piglets (Mellor and Stafford, 2004).

3.1.2. Vitality

Piglet vitality determines the capacity of a piglet to compete for a teat and to suckle (Trujillo-Ortega et al., 2007). A high vitality piglet has been associated with an improved survival rate at 7 days and at 10 days of life (Baxter et al., 2008; Vasdal et al., 2011), and has also been positively correlated with piglet growth and survival at weaning (Muns et al., 2013). There is some confusion in the literature concerning the terminology used to evaluate piglet vitality, the terms “viability” and “vitality” are used interchangeably in different studies to designate the vigour or physical strength of

piglets. To avoid confusion, vitality is defined in the present review as vigour or physical strength.

Physiological variables of piglets have been measured at the moment of birth to assess piglet vitality. A vitality score obtained after recording piglets' heart rate, muscle tone, onset of respiration and attempts to stand at birth have been positively related to survival and rectal temperature one hour after birth (Baxter et al., 2009; Casellas et al., 2004; Randall, 1971; Zaleski and Hacker, 1993b). Likewise, the ability to first suckle after birth and thermoregulation ability during the first 24 h of life have been used to reflect piglet vitality and are positively correlated with CI (Herpin et al., 1996; Tuchscherer et al., 2000). Piglets' vitality has also been evaluated as the capacity to perform rooting behaviour (using a neurobehavioural test or rooting response test) with surviving piglets showing higher rooting capacity (Baxter et al., 2009). More recently, the behavioural traits of piglets after farrowing (e.g., the presence of an udder stimulation reflex, the capacity to move within a circular enclosure) have also been recorded to represent piglet vitality showing a positive correlation with piglet survival and growth (Muns et al., 2013). Most of the already mentioned physiological and behavioural vitality assessments are performed at very instant of birth and some of them require the use of electronic devices, only the vitality score performed by Muns et al. (2013) is performed at the end of farrowing only by visual assessment, thus easy to perform to all the piglets born in the litter on farm conditions.

Neonatal vitality is directly related to intra-partum hypoxia (or asphyxia during delivery) suffered by piglets at birth (Zaleski and Hacker, 1993b; Trujillo-Ortega et al., 2007), which is one of the most important causes of stillbirth and early PWM in piglets. The integrity of the umbilical cord is also related to piglet vitality. Alteration or rupture of the umbilical cord reduces blood perfusion to piglets, with the associated risk of causing anemia and/or hypoxia, reducing vitality and increasing the risk of early mortality (Rootwelt et al., 2012, 2013). Clearly, any congenital malformation and physical abnormality (e.g., splay-leg) that will impede piglet movements, or any damage to the foetal central nervous system, triggered either by intra-partum hypoxia, congenital causes or maternal stress (Herpin et al., 1996), will reduce piglet vitality and increase the odds of crushing. Finally, neonatal vitality has also been related to blood glucose levels at birth, but controversial results are found in the literature. High blood levels of glucose (45–162 mg/dL) at birth are considered to be a consequence of suffering during parturition, and low concentrations (24–30 mg/dL) are a sign of low glycogenic body reserves; both circumstances that might negatively influence piglet vitality and survival (Herpin et al., 1996; Mota-Rojas et al., 2011; Nuntapaitoon and Tummaruk, 2014a; Panzardi et al., 2013; Trujillo-Ortega et al., 2007). However, other studies failed to correlate blood glucose concentration at birth with piglet survival (Rootwelt et al., 2013, Tuchscherer et al., 2000).

Intra-partum hypoxia is the main factor that influences piglet vitality by damaging the foetal central nervous system and lowering the capacity to compete for a teat and increasing the time interval between birth and first suckling, which can lead to hypothermia and starvation (Randall, 1972; Trujillo-Ortega et al., 2007; Zaleski and Hacker, 1993b). Low piglet vitality score at birth has been associated to increased blood lactate level, blood partial pressure of CO_2, and reduced blood pH (Herpin et al., 1996). Birth order and posterior body presentation at birth are both factors that have been positively associated with intra-partum hypoxia and shown to be influencing piglets' vitality (Herpin et al., 1996; van Dijk et al., 2005). Uterine contractions in sows with a long farrowing duration also reduce the oxygenation of prenatal piglets, compromising their vitality (Alonso-Spilsbury et al., 2005; Rootwelt et al., 2013; Zaleski and Hacker, 1993a), with a higher risk for piglets born later during farrowing (van Rens and van der Lende, 2004; Motsi et al., 2006). Indeed, Nuntapaitoon and Tummaruk (2014b) observed that birth intervals of >30 min significantly increased the proportion of piglets suffering from hypoxia. The overuse of oxytocin (i.e., the routine administration of oxytocin immediately after the birth of the first piglet or overdosing) can also compromise piglet vitality by increasing the frequency, intensity and duration of uterine contractions (Mota-Rojas et al., 2005, 2006, 2007).

3.1.3. Gender

Piglet PWM is suggested to be sex-biased, with male piglets being at greater risk of death, despite being born with a higher BW (Herpin et al., 2002; Baxter et al., 2012a). Baxter et al. (2012a) suggested that females invest energy resources in specific physiological systems (e.g., thermoregulation and immunocompetence), whereas males invest energy resources in body size and body composition (processes linked with reproductive fitness in adulthood), consequently predisposing male piglets to causal mortality factors that are mainly associated with energetic demands (chilling, starvation, crushing or even disease). Similarly, Panzardi et al. (2013) found that female pigs had a higher early postnatal vitality than males; however, Li et al. (2012) found no gender effect on piglet mortality.

3.2. Sow factors

3.2.1. Colostrum

Colostrum is the first milk secreted by the mammary gland, which sows continuously secrete from around farrowing up to 12–24 h (Quesnel et al., 2012), before its secretion becomes cyclic and nursery bouts start (Auldist et al., 2000). Colostrum is a rich source of digestible nutrients and various bioactive compounds such as immunoglobulins, hydrolytic enzymes, hormones, and growth factors (Rooke and Bland, 2002; Wu et al., 2010), thus, it plays a key role in piglet thermoregulation, the acquisition of passive immunity and intestinal development (Devillers et al., 2007).

Colostrum provides the newborn pig with highly metabolisable energy (Le Dividich et al., 1994) and its high content of fat and lactose is efficiently used by the newborn pig to cope with cold stress by increasing its metabolic rate and maintaining its homeothermic balance during the first day after birth (Herpin et al., 2005; Le Dividich et al., 1994). Accordingly, rectal piglet temperature at 24 h of age is positively correlated with colostrum intake (Devillers et al., 2011) and is negatively correlated with the time interval between birth and first suckling (Tuchscherer et al., 2000). The primary protein component of colostrum consists of immunoglobulins, including IgG, IgM, and IgA isotypes. Immunoglobulin G is the most common bioactive compound in colostrum and is at its highest concentration in the first few hours postpartum and decreases rapidly within 24 h (Herpin et al., 2005; Markowska-Daniel and Pomorska-Mol, 2010; Vallet et al., 2013). As has been previously mentioned, piglets need to receive passive immunity from IgGs in colostrum to reduce susceptibility to infection in the immediate postnatal period and also after weaning (Rooke and Bland, 2002). The absorption of IgG by newborn piglets occurs before gut closure (Bland et al., 2003; Quesnel et al., 2012), which occurs at approximately 24 h of age (Rooke and Bland, 2002). The IgG plasma concentration in piglets at 24 h of age is positively correlated with colostrum intake (Devillers et al., 2011). Accordingly, Muns et al. (2014b) observed that administering 15 mL of sow colostrum after farrowing to small piglets increased their IgG plasma concentration at 4 days of age. Porcine colostrum also contains different types of milk-borne growth factors (e.g., the insulin-like growth factors IGF-I and IGF-II, epidermal growth factor, insulin and transforming growth factor-β). According to Xu et al. (2000), milk-borne growth factors via colostrum feeding play

a regulatory role in the stimulation of gastrointestinal tissue growth, and the maturation of its function. Colostrum feeding also enhances intestinal macromolecule absorption, the onset of gut closure, and enhances the repair of damaged mucosa (Rooke and Bland, 2002; Xu et al., 2000). All these process are required for the adaptive changes of the gastrointestinal tract during the postnatal period.

Quesnel et al. (2012) estimated that 250 g CI per piglet should ensure an optimal growth and passive immunity to the animals. Pierzynowski et al. (2014) also reported that CI stimulates the development of the hippocampus structure by the stimulation of brain protein synthesis and brain development during the early postnatal period. Colostrum intake also increases the piglet BW gain at weaning (Decaluwé et al., 2014; Devillers et al., 2004; Le Dividich et al., 2005) and up to 6 weeks of age, suggesting that it has a long-term effect on piglet growth (Devillers et al., 2011). Indeed, CI has been positively associated with piglet survival rate at weaning (Decaluwé et al., 2014; Devillers et al., 2011). Any circumstance that impairs piglet colostrum intake capacity will increase the risk of mortality or diminish its growth capacity. Factors that influence CI include piglet vitality at birth, birth order, the number of piglets born alive per litter, and sow nutrition (Quesnel et al., 2012; Nuntapaitoon et al., 2014a,b; Theil et al., 2014a). The ability of piglets to reach the udder and to suckle causes an increase in CI (Amdi et al., 2013). As has already been presented, reduced piglet vitality at birth or any other factor that affects the interval from piglet birth to first suckle and the ability of a piglet to stimulate a teat will negatively influence piglet CI. Competition between littermates has a negative effect especially on the piglets of the litter born with lower BW, because a high litter size increases the number of fights at suckling (Milligan et al., 2001) and increases the risk of starvation and crushing of the small piglets. However, colostrum yield is highly variable among sows, even within the same breed and in the same conditions of housing and management (Devillers et al., 2007; Farmer and Quesnel, 2009). Fraser (1984) suggested that the appropriate stimulation of the udder by piglets might be important to elicit a maximum colostrum yield by the sow. The total sow colostrum yield varies between 2.5 and 5.0 kg in a litter of 8–12 piglets (Farmer et al., 2006). Colostrum yield is independent of litter size, and is slightly influenced by litter weight and piglet BW variability (Devillers et al., 2007; Foisnet et al., 2010; Quesnel, 2011; Decaluwé et al., 2013). A reduction or failure to produce colostrum or milk by the sow would have a negative impact on piglet survival and growth. It is suggested that insufficient milk production or lactation failure in sows might account for 6–17% of PWM (Alonso-Spilsbury et al., 2007). Colostrum yield depends on the breed, feed and water intake, energy status, sanitary status, and parity of the sow, and on other factors such as farrowing induction; environment and hormone status can also influence colostrum production by the sow (Devillers et al., 2007; Quesnel, 2011; Decaluwé et al., 2013; Ferrari et al., 2014). Besides, post-partum dysgalactia syndrome (PDS) or mastitis-metritis-agalactia (MMA) is a multifactorial process with a considerable prevalence among herds, causing lactation failure usually during the first 3 days after farrowing. Late transferring of sows to farrowing facilities, *ad libitum* feeding during the first days of lactation, dystocia (Papadopoulos et al., 2010), constipation, poor floor hygiene, and high ambient temperature (Kirkden et al., 2013b) are factors that have been observed to increase the odds for PDS.

3.2.2. Parity

The effect of parity on piglet PWM can be contradictory: on one hand, Knol et al. (2002) and Carney-Hinkle et al. (2013) found no influence of parity on the survival rate of piglets, but Muns et al. (2015) observed a lower piglet PWM in primiparous sows than in multiparous sows. Moreover, different studies reported a negative correlation between parity and PWM (Koketsu et al., 2006; Li et al., 2010, 2012; Nuntapaitoon and Tummaruk, 2012, 2013a,b, 2015). It is known that second and third parity sows tend to have a higher colostrum yield than other parities (Devillers et al., 2007), and that sows from parity 4–6 have higher colostrum yield than primiparous sows (Ferrari et al., 2014). The apparent lower colostrum yield in primiparous sows might explain the negative correlation between parity and PWM observed by some authors. Accordingly, piglets from primiparous sows consumed less colostrum than piglets from sows with parity 4–6 in the experiment of Ferrari et al. (2014). Therefore, immune protection in the progeny of multiparous sows might be greater than in primiparous sows, resulting in a lower piglet mortality and increased daily gain before weaning (Ferrari et al., 2014). Moreover, piglets born from primiparous sows have a lower birth BW and lower serum concentration of IgA and IgG than piglets born from multiparous sows (Carney-Hinkle et al., 2013). Marchant et al. (2000) suggested that lower experience in primiparous sows at farrowing negatively affects piglet survival rate. Ruediger and Schulze (2012) reported that primiparous sows suffered greater post-farrowing stress, which declined in multiparous sows. Furthermore, primiparous sows show poorer reproductive performance and are more sensitive to environmental factors compared to multiparous sows (Tummaruk et al., 2010).

On the other hand, the absence of a relationship between parity and PWM or the lower PWM observed in primiparous sows in the experiments of Knol et al. (2002), Carney-Hinkle et al. (2013), and Muns et al. (2015), might be explained because litter size increases together with increases in parity (Roehe and Kalm, 2000). The number of low BW piglets increases together with an increase in litter size, although the mean piglet birth BW also increases. Therefore, the BW variability within a litter also increases with an increase in litter size. This situation is evident with older sows ($>$ 6th parity), as observed by Wientjes et al. (2012), who observed that 0- to 7-day-old piglets were particularly at risk of death when they were reared with old sows. The duration of farrowing in first parity sows is shorter than in sows with a parity $>$ two (Tummaruk and Sang-Gassanee, 2013). In addition, older sows have a longer farrowing duration, due to the presence of excessive fat and reduced uterine muscle tone, which increases the probability of intra-partum hypoxia (Zaleski and Hacker, 1993a). Finally, older sows usually have a reduced and more variable function and accessibility of teats. A 41% reduction in the number of functional teats was found in high-parity sows (Vasdal and Andersen, 2012). Further studies on the effect of parity on piglet PWM should be carried out.

3.2.3. Maternal stress

The peri-partum period (from 4 days before and up to 3 days after farrowing) is a sensitive period in piglet production. The parturition process starts a few days before farrowing. During this period, sows might be stressed due to the new environment in the farrowing pen and due to the parturition process (Baxter et al., 2011b; Muns et al., 2014a; Yun et al., 2015). Stress during the farrowing period increases the duration of farrowing and decreases colostrum production, thus reducing the energy and IgG supply to piglets (Edwards, 2002; Oliviero et al., 2008). The stress of farrowing can also affect the behaviour of the sow and lead to restlessness and even to aggressiveness (Kalantaridou et al., 2004), which increases the risk of crushing piglets and prevents suckling (Baxter et al., 2011a). Muns et al. (2014a) found that sows with a tendency for higher cortisol level after entering the farrowing stall showed an increase in activity one day before farrowing. Maternal pre-partal stress can affect behavioural and physiological aspects of the offspring by altering their hypothalamic activity (Kaiser and

Sacher, 2001; Kranendonk et al., 2007; Muns et al., 2014a). For example, Muns et al. (2014a) observed that piglets born from stressed sows had a higher mortality and reduced daily gain at weaning, probably due to a reduction in their thermoregulation ability caused by an inhibition of thyroid function due to maternal pre-partal stress (Berthon et al., 1993).

3.2.4. Sow nutrition

Maternal nutrient provision might play an important role in piglet PWM due to its influence in foetuses development during pregnancy, with direct impact on piglets' birth weight and vitality (see reviews of Campos et al. (2012), de Vos et al. (2014a), Yuan et al. (2015)). Therefore, dietary supplementation in pregnant and lactating sows to reduce piglet PWM and enhance piglet growth have been intensively investigated during recent years (Kalbe et al., 2013; Quesnel et al., 2014; Tummaruk and Sumransap, 2014). On one hand, birth BW of piglets is positively related to energy intake of sows throughout gestation (Campos et al., 2012). Besides, early embryonic loss seems not to be influenced by overfeeding in the modern hyperprolific sow (de Vos et al., 2014a). Nonetheless, protein availability for foetal growth is more important during gestation (de Vos et al., 2014a). Gestation diets with protein restriction or unbalanced amino acid profile might increase the incidence of piglets born with a low BW (Kim et al., 2009; Wu et al., 2006). Foetal growth is controlled by the amino acids in the arginine family (Wu et al., 2011). Indeed, supplementation of diets with L-arginine or L-glutamine significantly increased birth weight of piglets (Gao et al., 2012; Raghavan and Dikshit, 2004; Wu et al., 2013). In addition, diets supplemented with L-carnitine during pregnancy significantly increased BW of piglets (Doberenz et al., 2006). The reasons might be due to an increase in intrauterine nutrient supply of glucose, glucose transporter-1 and maternal IGF-I (Doberenz et al., 2006) and to an increased muscle fibre development (Musser et al., 2006). On the other hand, piglet vitality is also indirectly influenced by sow nutrition. Piglets born from sows supplemented with L-carnitine improved their suckling behaviour (Birkenfeld et al., 2006). Supplementing sows with tuna or salmon oil increased suckling behaviour of their piglets and reduced the crushing incidence despite also reducing their birth weight (Rooke et al., 2001a,b). It is known that long-chain polyunsaturated fatty acids (PUFAs) are important in the development of the brain and other physiological functions (de Vos et al., 2014a).

The nutrition of sows during late gestation can also influence colostrum yield or colostrum composition (see review of Theil et al. (2014b)). During late gestation, sows have a high energy demand for mammary development and nutrition might affect colostrum production both via mammary gland development and via mechanisms that control colostrum secretion during late gestation (Farmer and Quesnel, 2009). Overfeeding sows during gestation has a negative impact on mammogenesis, due to excessive fat deposition (Farmer and Sørensen, 2001). Fat sows have a high insulin resistance that disrupts glucose transport to the mammary gland for lactose synthesis (Shennan and Peaker, 2000; Père and Etienne, 2007). On the other hand, feed restriction at the end of gestation might only have a small detrimental effect on colostrum yield, because sows already have a large body energy reserve (Dourmad et al., 1999). However, the results of Decaluwé et al. (2013) and Loisel et al. (2014) suggest that an excessive catabolism before farrowing might be detrimental for colostrum yield. Furthermore, dietary-fat supplementation during gestation and dietary supplementation with glutamine during lactation increased milk production of sows, enhanced piglet's gut health and increased growth rate and survival rate of piglets (Laws et al., 2009; Jackson, 2004; Rooke et al., 2001a). In addition, it has been observed that feeding sows with a high amount of dietary fibre during gestation had a beneficial effect on the CI of piglets (Theil et al., 2014a).

3.3. Environmental factors

3.3.1. Season and temperature

The seasonal effect on PWM is controversial. Koketsu et al. (2006) found that PWM during the summer period (11.6%, July–September) was higher than in spring (9.4%, April–June). On the other hand, some reports observed that PWM was highest in the cold season because of a low ambient temperature and cold stress (Dial et al., 1992; Maderbacher et al., 1993). Piglets have a lower limit of the thermoneutral zone at 2 h of life close to 34 °C (Herpin et al., 2002). In general, newborn piglets are very sensitive to cold stress, due to incomplete thermoregulation at birth, few subcutaneous fat reserves and because they are poorly insulated. Piglets require a warm and dry environment for survival, especially during the first days after birth. It is well established that cold stress is the most important stressor in newborn piglets (Baxter et al., 2009; Shankar et al., 2009). Under low ambient temperature environments, piglets are at more risk of being crushed by the sow (Shankar et al., 2009), because the piglet stays close to the udder in search of a heat source. In addition, Pedersen et al. (2013) found that CI decreases during cold exposure, exacerbating the likelihood of starvation and reducing immunoglobulin concentrations in neonatal piglets. On the other hand, sows have a thermoneutral zone ranging from 18 °C to 20 °C (Silva et al., 2009). High ambient temperature can decrease the feed intake of lactating sows due to heat stress (Li et al., 2010; Malmkvist et al., 2012). Therefore, heat stress compromises colostrum and milk production in sows and growth performance in piglets (Farmer and Quesnel, 2009; Farmer et al., 2010). Moreover, heat stress can also cause alterations in sows, reduce the frequency and duration of nursing periods, increase the time spent urinating or defecating and finally, increase piglet mortality due to crushing (Silva et al., 2006). It has been observed that floor heating in farrowing pens can act as a stressor during the peri-parturient period in sows with limited ability to perform thermoregulatory behaviour (Damgaard et al., 2009; Malmkvist et al., 2009; Malmkvist et al., 2012). In farrowing pens, it has also been observed that maintaining the heat lamp in the side creep area instead of in the front creep area during the first days after farrowing, can reduce sow feed intake (Hrupka et al., 1998).

3.3.2. Housing

The size of the herd can play a significant role in minimizing neonatal losses (Oliviero et al., 2010). On average, PWM in large herds was lower than that in small herds (Friendship et al., 1986; Hoshino et al., 2009). The effect of herd size on PWM is related to post-partum management and the quality of stockpeople, which is usually better in large herds. Hoshino et al. (2009) found that high-performing herds in Japan had a lower number of stillbirths due to better farrowing management (farrowing supervision and assistance) than low-performing herds. The housing system and its design has a strong impact on different aspects of sow and piglet welfare and performance; however, it is out of the scope of the present paper to review the different existing farrowing systems or their designs and their welfare implications, but to highlight their main characteristics in relation to PWM. Conventional farrowing crates were designed to prevent crushing by restricting sow movements and to provide a zone of retreat for the piglets. On average, sows are restricted within a crate with 1.26 m^2 of available floor space, placed within a pen area of 3.54 m^2 (Vosough Ahmadi et al., 2011). It has been demonstrated that sows kept in conventional farrowing crates show signs of an impaired welfare state (e.g., heart rate and stress-hormone responses, negative or

abnormal behaviours) (see review of Baxter et al. (2011b)); for this reason, different designs of group- and individual loose-housing systems have been developed as alternatives to the conventional farrowing crate (Baxter et al., 2012b; Wechsler and Weber, 2007). Nonetheless, no commercially viable/feasible option has emerged, and therefore, their commercial use is limited (Van Nieuwamerongen et al., 2014; Vosough Ahmadi et al., 2011). Two main different group-housing systems can be identified for sows during lactation or part of lactation (see review of Van Nieuwamerongen et al. (2014). Sows can be grouped with their litters (multi-suckling system), or offered a communal area that is only accessible to sows for the whole lactation period (get-away systems). Indoor alternatives can be classified into pens and designed pens (see review of Vosough Ahmadi et al. (2011)). On average, pens consist of a uniform floor space of 10.48 m^2 with no distinction between excretory and lying areas. Piglets are provided with a separate creep area with supplementary heat via a lamp or mat. Designed pens contain different types of pens, but typically occupy a whole area or 7.06 m^2 of floor space, with a designated area for nesting/lying of approximately 2.90 m^2 of this space. Piglets are also provided with a separate creep area with supplementary heat via a lamp or mat. In outdoor systems, sows and piglets are usually kept individually in arks or huts (mean floor space of 377 m^2), with access to individual or group paddocks.

Although group housing systems provide more environmental complexity and freedom of movement for the sows and the possibility for extended lactation periods, they have an increased risk of crushing and early cessation or disruption of nursing (Van Nieuwamerongen et al., 2014). Indeed, Wechsler and Weber (2007) concluded that sows should not be group-housed at farrowing, but individually, in large pens with separate nesting/lying and activity areas. Vosough Ahmadi et al. (2011) observed similar total piglet mortality rates (including stillborn piglets) among 145 studies that included conventional crates (18.2%), pens (18.4%) and designed pens (16.5%). Accordingly, Baxter et al. (2012b) described a total piglet mortality rate (corrected for a standardised litter size of 11 piglets) of 18.1%, 19.3%, 15.0%, and 17.1% for conventional crates, pens, designed pens, and outdoor systems respectively. In their review, Baxter et al. (2012b) also observed a similar PWM (corrected for a standardised litter size of 11 piglets) among conventional crates (11.3%), pens (12.8%), designed pens (10.2%), and outdoor systems (14.3%). As presented, the PWM rate is similar among the different individual farrowing housing systems, except for outdoor systems. Crates were especially designed for preventing posterior crushing (beneath the sow's hind quarters), although they are not as effective in preventing ventral crushing when lying down from a sitting position (beneath the udder and rib cage) (Andersen et al., 2005; Pedersen et al., 2011; Wischner et al., 2010). More specifically, in a cohort study of PWM performed on 112 breeding farms in England by Kilbride et al. (2010), conventional farrowing crates were compared with three different loose-housing systems (including indoor and outdoor systems). These authors concluded that the risk of PWM due to crushing was lower in conventional farrowing crates. Nonetheless, the risk of death from other causes was higher in conventional farrowing crates, resulting in a similar level of PWM among the different farrowing systems. Sows in conventional farrowing crates also present higher number of teats with sever lesions in comparison to loose-housing systems (Verhovsek et al., 2007), which might be detrimental for piglets' CI. Similar to in conventional farrowing crates, Baxter et al. (2009) observed that piglet birth BW and rectal temperature 1 h after birth were the most significant postnatal survival indicators in outdoor systems. However, latency to reach the udder, a teat and to suckle, were not useful as survival indicators in outdoor systems, whereas they are important indicators in indoor conventional systems. Recent studies found that a pen design that allows for confinement of the sows from day 114 of gestation until 4 days after farrowing reduced PWM compared to gestation and lactation loose-housing systems (Hales et al., 2015; Moustsen et al., 2013). In the same studies, no alteration of the farrowing progress was observed.

More particularly, floor characteristics of the farrowing pen or the creep area might influence piglet PWM. Floors with rigid physical features (i.e. slatted iron floor, partial concrete and partial round-weld mesh floor) increase the incidence of foreleg skin lesions in lactating piglets (Gu et al., 2010; Mouttotou et al., 1999) with negative effect on piglet's pre-weaning growth (Johansen et al., 2004). Besides, the use of neoprene mats placed on the slatted iron floor of the piglet suckling area reduced the risk of crushing and the risk of piglet's hypothermia by reducing the temperature gradient between the piglet abdomen and the contact floor surface (Gu et al., 2010). Similarly, the use of enriching substrates in the farrowing crates might also help to reduce the incidence of teat lesion (Lewis et al., 2006).

3.3.3. *Management*

In order to minimize the negative impact of the most important factors influencing PWM presented above, there are some management priorities and procedures, concerning sows and piglets, commonly established in commercial swine herds. Producers usually try to concentrate their efforts on the farrowing day and during the first two days after farrowing.

Farrowing supervision together with manual birth assistance are management practices mainly oriented to reduce the number of stillbirths in swine herds (see review of Vanderhaeghe et al. (2013)). Nonetheless, good farrowing supervision and management protocols at birth also contribute to reduce piglet PWM (Holyoake et al., 1995; Vanderhaeghe et al., 2013). Reduction in number of stillbirth, improvements on survival during the first day, and increased weaning weight have been obtained with elaborated farrowing supervision protocols that included drying the newborn piglets, oral administration of 12 ml of bovine colostrum and oxygen administration through an oral mask (White et al., 1996). But such farrowing supervision protocols are hard to implement at commercial settings due to their complexity. Nonetheless, more simplified protocols have also been studied. Drying piglets at birth has been proved to be useful in commercial herds. Christison et al. (1997) observed that survival was improved when piglets were dried or placed under the heating lamp immediately after birth. Andersen et al. (2009) and Vasdal et al. (2011), after comparing different protocols around farrowing, also found that drying newborn piglets and placing them at the udder was the management combination with higher reduction in piglet mortality in loose-housed sows. Accordingly, Andersen et al. (2007), after comparing the records of an entire year from 39 Norwegian farms, observed that placing the piglets at the udder immediately after birth and assisting them to find a teat reduced mortality, whereas shunting the piglets inside the creep area while feeding the sow did not have any influence on survival.

The most important management strategies performed after farrowing are oriented to increase the energy status and CI by the piglet, and to reduce piglet BW variability within litter. On one hand, removing larger piglets in a litter from the dam for a set period of time to allow the smaller piglets adequately access to udder (split nursing) is a practice often practiced in commercial herds during the farrowing day. However, that does not seem to have a real impact on litter performance. Donovan and Dritz (2000) only observed a decrease in variation for piglet's average daily gain in large litters (>9 piglets born alive) with no effect on IgG plasma concentration or mortality rate when performing split nursing of the heaviest 50% of the piglets in the litter for 2 h. Additionally, Thorup (2006) and Muns et al. (2015) did not reduce

low BW piglets' mortality through split nursing. On the other hand, oral supplementation of piglets with colostrum or commercial energy boosters is commonly performed to increase low BW piglets CI and ensure a proper IgG level in commercial herds. However, limited studies performed under commercial conditions can be found in the literature. Gomez et al. (1998) observed that porcine immunoglobulins and bovine colostrum could be used as immunoglobulin sources in artificial rearing of colostrum-deprived newborn piglets. Emulsified medium-chain triglycerides have also been administrated as energy substrate to 22–35 h-old piglets with no clear effect on their growth and survival (Wieland et al., 1993a,b). Besides, administration of emulsified medium-chain triglycerides in excess could lead piglets to coma by increasing the concentration of circulating fatty acids to toxic levels (Wieland et al., 1993a). Nevertheless, a few authors have observed increased survival and growth rates in small piglets supplemented with colostrum under commercial conditions (Pinsumrit et al., 2004; Muns et al., 2014b, 2015). Indeed, Muns et al. (2014b) observed that supplementation of small piglets with extra 15 ml of colostrum early after birth ensured a proper level of serum IgG concentration at day 4 of life. In addition to split nursing and oral supplementation, cross-fostering is a management practice usually adopted in commercial farms when litter size outnumbers functional teats and/or to deal with BW variability within litters, situations that might limit CI by the piglet and lead to increased PWM. Although cross-fostering has a strong impact on piglet survival and performance (Muns et al., 2014b), there is some controversy in the literature concerning the best cross-fostering strategy. Heim et al. (2012) found no negative effects of fostering in adopted piglets after cross-fostering. However, Kilbride et al. (2014) showed that fostering piglets later than 24 h after birth increases the risk of mortality, and Deen and Bilkei (2004) found increased mortality of low BW piglets when cross-fostered with high BW piglets. Besides, Muns et al. (2014b) and Milligan et al., (2001) observed that litters cross-fostered to uniform litters doubled their BW coefficient of variation at the end of lactation. Nonetheless, Deen and Bilkei (2004) pointed out that low BW piglet survival is more related to litter size after cross-fostering than to the BW of their littermates. Finally, Muns et al. (2014b) suggested that farm's sanitary conditions/health status could strongly influence the impact of the cross-fostering strategy performed on farm.

The use of high prolific breeds delivering more than 14 live born piglets and the implementation of hyper-prolific breeding programs has led many farms to systematically produce greater number of piglets than the number of functional teats available in the same batch. In such situations, farms might implement the use of nurse sows systems following two main management procedures: one-step system, involving one sow, and two-step system or “cascade fostering”, involving two sows (see review of Baxter et al. (2013)). Briefly, the one-step system consists of weaning the litter from a sow (nurse sow) at 21 days of lactation or more. The selected nurse sow will then receive the surplus piglets from the newly farrowing batch and will nurse them for a new lactation period. The two-step system consists of weaning the litter from a sow (interim sow) at usually 28 days of lactation. In the second step, a 4–7 day old litter from a second sow is fostered to the interim sow. Finally, the second sow will receive the surplus piglets from the newly farrowing batch. The use of nurse sows systems clearly helps to maintain the surplus piglets in the farm. However, according to Baxter et al. (2013), the mismatch between piglets requirements with the milk supply of the nurse sow, and the risk of disease transmission due to the interruption of “all-in-all-out” systems are the more evident risks of nurse sows systems. More scientific studies should be done on the use of nurse sow systems. As an alternative to the use of nurse sows systems, producers in high prolific herds might implement artificial rearing systems using milk replacer to rear the surplus and weak piglets in a farrowing batch. Although milk replacer can be offered as a supplement feed in the litter (similar to creep feed), surplus and weak piglets are usually allocated separately in a different facility or in nest boxes (i.e., brooders) placed above the farrowing crates. The animals are usually moved to the artificial rearing systems between three and seven days of age. De Vos et al., (2014b) found that artificially reared piglets had similar growth and enhanced gut maturation at 28 days of age compared to sow reared piglets, but they did not report the effect on mortality. De Vos et al., (2014b) also suggested that artificially rearing systems are beneficial for piglets from all birth categories. On the other hand, Widowski et al. (2005) observed higher risk for redirected suckling behaviour in artificially reared piglets fed through a plastic trough compared to piglets fed through artificial nipples. However, there is a need for scientific research on the use of artificial rearing of piglets.

4. Conclusions

Piglet PWM is a serious and important welfare and economic problem of great concern in swine production. Although it is well established that piglet birth BW is the main factor that influences piglet survival and growth, PWM has a multifactorial aetiology and is influenced by different factors. Through understanding and knowledge of the different causes and factors that influence piglet PWM, we can therefore reduce PWM by nutritional intervention (see review of De Vos et al. (2014a)) or management strategies (see reviews of Baxter et al. (2013), Kirkden et al. (2013a,b)) of farm conditions. As observed, it is important for veterinarians and producers to understand and properly diagnose the factors that influence piglet PWM on their farms, in order to develop an efficient intervention protocol. However, despite the importance of piglet vitality there is a lack of vitality assessment protocols or strategies that can be performed by producers to a large number of piglets in sow commercial herds. Moreover, given the importance of colostrum as only energy source available and its role in providing passive immunity to piglets, producers should focus on ensuring a proper colostrum intake by the piglets after birth, as well as on providing a comfortable environment and proper nutrition to sows around farrowing. Besides, confusing factors such as the impact of sow parity need to be further studied. Furthermore, most of the studies on the factors that influence piglet survival are performed in temperate or cold climates and further research in hot or tropical climates is necessary to assess the final impact of factors that influence piglet PWM, which might be different and require different management approaches to piglet PWM. In addition, from the literature, we can conclude that individual loose-farrowing systems show similar PWM levels to those of conventional farrowing crates, with designed pens offering promising perspectives for future implementation at a commercial scale. Notably, recent studies suggested that an individual farrowing pen design, which combines the initial confinement of the sow with the subsequent ability to move within the pen, offers the potential to become a more suitable farrowing environment to meet biological needs and production goals; nonetheless, further studies are required. Finally, more feasible farrowing protocols should be of great interest for producers, and more studies on oral supplementation to low birth weight piglets are of great interest (e.g., colostrum supplementation or oral supplementation using commercial boosters). Besides, the impact cross-fostering on PWM also needs further reasearch to better understand its proper implementation in different situations (e.g., in farms with poor health status). Equally important, although their practice is mainly

limited to high prolific herds, scientific research on nurse sows systems and artificial rearing of piglets is of great interest.

Conflict of interest statement

All of the authors have no conflict of interest.

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Review Article

Management strategies in farrowing house to improve piglet pre-weaning survival and growth

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Abstract

Post-partum and lactation are the most complex periods in the swine production chain. Newborn pigs are highly vulnerable due to relatively low body weight at birth and physiological immaturity. Most of the management strategies performed in farrowing houses are oriented to ensure a proper level of colostrum intake by the piglets. Colostrum is essential as an energy source and to provide passive immunity to piglets. Different farrowing supervising protocols have been comprehensively investigated to reduce early mortality as well as to assist newborn piglets in obtaining an optimal amount of colostrum and milk. However, little is known of the benefits of oral supplementation in newborn piglets. Cross-fostering is also widely performed in general swine commercial herds to deal with highly prolific sows and has a strong impact on piglet survival. In order to prepare piglets for weaning, creep feeding is provided after the first week of lactation. Although the number of animals that actually consume the creep feed is not clear, creep feed consumption might influence feed intake after weaning. Finally, the attitude and skills of a stockperson might play an important role in the piglet's ability to cope with stressors. Positive and gentle human contact with newborn piglets might positively influence the piglets' emotional response to human handling and thus their welfare. The objective of this review was to present the most relevant management strategies performed in farrowing houses (i.e. oral supplementation, farrowing supervision, cross-fostering, creep feeding, and human-animal interaction) and their effect on piglet pre-weaning mortality and growth.

Keywords: colostrum, cross-fostering, lactation, mortality, oral supplementation, pig

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Introduction

With the use of highly prolific sows in commercial herds, high piglet pre-weaning mortality (PWM) remains an unsolved problem in pig production. Recent reports have shown average piglet PWM rates of 12.9%, 9.4%, and 12.2% in the European Union, the Philippines and Thailand, respectively (Bureau of Agricultural Statistical of Philippines, 2012; Interpig, 2014; Nuntapaitoon and Tummaruk, 2013). On the other hand, the mortality rate recorded during the rearing and finishing phases reached 3.3 and 2.8%, respectively (Interpig, 2014). Moreover, piglet PWM is one of the major reproductive components affecting herd productivity in the swine industry. It has been demonstrated that a 1% reduction in piglet mortality increased the sow annual output by €7.1 in a highly productive country such as the Netherlands (Chris et al., 2012). Therefore, the mortality of piglets in the suckling period is a major welfare and an economic problem in the swine industry which still needs to be addressed.

Neonatal piglets are very vulnerable at birth. They are characterised by a high surface to body mass ratio, limited reserves and poor immunity status. Among the different causes of early death, low colostrum intake is probably the most influential (Muns et al., 2016[b]). Colostrum intake is crucial for piglet growth since it provides piglets with the energy and passive immunity necessary at a very early stage (Quesnel et al., 2012). Moreover, piglets have to compete with littermates for a teat to suckle. Among other factors, alterations of piglet body weight (BW) at birth associated with an increased litter size might lead to high PWM. The use of highly prolific sows resulted in increased crowding in the uterine horns during gestation (Rutherford et al., 2013). Intra-uterine crowding may result in some piglets experiencing intra-uterine growth restriction or reduced BW at birth, therefore increasing litter birth weight variation (Yuan et al., 2015). Within-litter variation in birth weight strongly affects PWM, especially during the first 72 hours of life (Alonso-Spilsbury et al., 2007). In addition, a high ambient temperature around farrowing negatively affects the sow's welfare and performance, with a negative impact on piglet weaning weight (Muns et al., 2016[a]). Many management routines are performed in a farrowing house during the first two days post-partum to enhance piglet survival. In countries with a tropical climate such as Thailand such practices are of great importance for herd performance. In practice, during the peri-partum period, management is focused on helping piglets to minimise heat loss and maximise colostrum intake.

Colostrum: Colostrum is secreted by the mammary gland starting shortly before parturition and for a time interval of approximately 12-24 hours in most sows (Quesnel et al., 2012). Piglets obtain colostrum freely for 0-24 hours after farrowing. After 24-48 hours post-partum, the physiologic cyclical pattern of suckling and milk ejection is established (De Passillé and Rushen, 1989). Colostrum is a source of highly digestible nutrients and various forms of bioactive compounds such as immunoglobulins, hydrolytic enzymes, hormones, and growth factors (Rooke and Bland, 2002; Wu et al., 2010). Additionally, colostrum is the first and only food available for piglets after birth. Colostrum is crucial in providing energy for thermoregulation and body growth (Devillers et al., 2011; Herpin et al., 2005; Le Dividich et al., 2005). In addition, passive immunity supply in pigs mainly occurs from immunoglobulin G (IgG) in colostrum, providing newborn animals with passive humoral immune protection. Newborn piglet absorption of IgG happens before gut closure (Quesnel et al., 2012), which takes place at approximately 24 hours of age (Rooke and Bland, 2002). Therefore, the first 12-24 hours after birth are crucial for the piglet's colostrum intake.

However, colostrum yield is limited. Colostrum yield was shown to be independent of litter size, but moderately influenced by piglet BW and BW variability at birth (Devillers et al., 2007). Moreover, colostrum yield and IgG concentrations were shown to be highly variable among sows, even within sows from the same unit (Devillers et al., 2011; Quesnel, 2011). In addition, it was observed that the amount of colostrum ingestion during the first 24 hours after birth was highly variable among littermates. In one study, the average colostrum intake varied from 250-300 grams, but ranged from zero to 700 grams (Quesnel et al., 2012). Newborn piglets directly compete with their littermates for access to a mammary gland, preferably the anterior and middle glands. The posterior mammary glands may produce fewer beneficial proteins than the anterior glands (Wu et al., 2010). Additionally, piglets from the same litter indirectly compete for milk intake during lactation, and piglets that are better at draining, massaging and stimulating the teat will favour local blood flow together with hormonal and nutrient investment, thus increasing the teat's milk production (Algers, 1993). Therefore, management of the litter is important to ensure that all piglets have proper colostrum intake.

Farrowing supervision: Most of the management routines studied in literature consist of practices performed around farrowing, including farrowing supervision, and are oriented to cope with two main challenges: piglet thermoregulation capacity and piglet colostrum intake. Drying piglets at birth has proven useful in commercial herds. Christison et al. (1997) observed that survival was improved when piglets were dried or placed under a heating lamp immediately after birth. Vasdal et al. (2011) compared different protocols around farrowing in loose housed sows and found that drying newborn piglets and placing them at the udder were the winning management combination with greatest reduction in piglet mortality. Practices to ensure colostrum intake by piglets have also been studied. Andersen et al. (2007) compared records of an entire year from 39 farms in Norway. They observed that placing the piglets at the udder and assisting them to find a teat reduced mortality, but shutting the piglets inside the creep area while feeding the sow did not improve survival. Improved survival during the first day of life, reduction in the number of stillbirths at farrowing and increased weaning weights were obtained with more

complex protocols that included drying the newborn piglets, oral administration of 12 ml of bovine colostrum and oxygen administration through an oral mask (White et al., 1996). Good supervision when farrowing also improved pre-weaning survival (Holyoake et al., 1995). On the other hand, split nursing (i.e. removing the larger piglets in a litter for a set period of time, allowing the smaller piglets free access to the udder) is another practice performed on commercial farms to enhance colostrum intake in low birth BW piglets. Yet, this practice has little impact on litter performance. Donovan and Dritz (2000) found no effect on IgG plasma concentration or mortality rate when performing 2-hour split nursing of the heaviest 50% of the piglets in the litter. Donovan and Dritz (2000) only observed a decrease in the variation of piglet average daily gain in litters with more than nine pigs. Thorup (2006) did not obtain a drop in low birth BW piglet mortality through split nursing either. Dewey et al. (2008) observed an increase in pre-weaning growth and survival when combining oral administration of 12-20 ml of colostrum with split nursing in a 'maximal care treatment'. More recently, Muns et al. (2014) found that supplementing low birth BW piglets after birth with 15 ml of the sow's colostrum improved piglet IgG levels on day four compared to a control group. However, it only tended to improve growth and survival of small piglets at weaning in non-homogenised litters at the time of cross-fostering, but not in homogenised litters. In another study, Muns et al. (2015[a]) only observed improvement in BW at 24 hours of life in low birth BW piglets born from primiparous sows after being supplemented with 15 ml of the sow's colostrum. But such effect was not maintained at weaning. In the same study, they found no effect of colostrum supplementation on low birth BW piglets born from multiparous sows, suggesting that piglets born from primiparous sows might have a higher need for colostrum intake than piglets born from multiparous sows. More recently, Viehmann et al. (2015) observed that daily supplementation of piglets with bovine colostrum during the first three days after birth extended life in low birth BW piglets but did not influence pre-weaning survival. Similarly, Declerck et al. (2016) observed that providing direct energy (commercial energy booster) through oral supplementation to small neonatal piglets (< 1 kg of birth BW) reduced their mortality without improving colostrum intake.

Cross-fostering: Cross-fostering is an important and common management practice performed on commercial farms. Cross-fostering has become indispensable to deal with highly prolific sows delivering large litters at farrowing. There are many reasons to perform cross-fostering (Baxter et al., 2013) including to foster surplus piglets when a sow has more piglets than functional teats, to foster small piglets to create litters with similar birth weights or to create litters with low weight variation, death of a sow at farrowing, and when a sow attacks its own offspring. Concurrently, cross-fostering can be performed at a minimum extent (transferring as few piglets as possible), in order to adjust litters by the number of piglets according to the number of functional teats. On the contrary, cross-fostering can be performed at a greater extent (transferring a high number of piglets and involving most of the litters in the batch), adjusting litters by BW of the piglets, transferring animals based on parity of the dams (piglets from gilts transferred to middle-aged sows), etc.

Cross-fostering should be performed after piglets ingest colostrum from their biological dams, but before teat order is established in the litter (Heim et al., 2012). As previously stated, colostrum decreases after 12 hours post-partum. After the initial phase of continuous colostrum ejection, cyclical milk let-down instauration progressively occurs. Thereafter, within the first week after birth, a stable teat order among littermates is established (De Passillé and Rushen, 1989). Consequently, technical recommendations and routine farm procedures aim to perform cross-fostering between 12 and 24 hours after farrowing. Moreover, during the first day after farrowing, sows accept alien offspring without disrupting their litter suckling patterns, without impairing piglet or sow welfare and without becoming aggressive towards the adopted piglets (Robert and Martineau, 2001).

In literature, cross-fostering has been widely studied, with diverse results. Heim et al. (2012) observed that survival and growth were not impaired in fostered piglets. They also observed that litters composed exclusively of adopted piglets had no impairment of behaviour, survival or growth. Bierhals et al. (2011) found that piglets nursed by primiparous sows had lower BW at day 21 of lactation than piglets nursed by parity 5 sows. Akdag et al. (2009) and Milligan et al. (2002) associated increased birth weight variation with low survival rate, whereas other studies did not (Bierhals et al., 2011; Milligan et al., 2001). Deen and Bilkei (2004) found that mortality of low birth BW piglets increased when they were cross-fostered with high birth BW piglets. They also stated that low birth BW piglets had a higher chance of survival in small litters irrespective of the birth BW of their littermates. On the contrary, Muns et al. (2014) found that standardisation of litters at cross-fostering (adjusting litters by BW of the piglets) did not prevent them from having the same BW variability at weaning compared to non-standardised litters. They also found that non-standardised litters did not impair the growth or survival of small piglets compared to small piglets in standardised litters. On the other hand, Robert and Martineau (2001) observed that repeated cross-fostering through lactation reduced the weight gain of both adopted and resident piglets and increased the sow's aggression towards alien piglets.

It is a common practice on different farms to synchronise and induce farrowing, especially in multiparous sows, in order to concentrate and optimise tasks. With synchronised farrowing, cross-fostering becomes easier to perform. Nonetheless, the advantages and disadvantages of farrowing induction are outside the scope of this review and have recently been documented (Kirkden et al., 2013). Finally, cross-fostering might lead to transfer of pathogens from one litter to another; moreover, it can be critical for the success of immune transfer (humoral immunity and cell-mediated immunity) from a biological dam to newborn piglets if performed too early. However,

long-term impact of cross-fostering on piglet health and immunity has not been well examined (Bandrick et al., 2011).

Creep feeding: Once producers have focused on enhancing the early survival of newborn piglets by ensuring optimal colostrum intake, and once cross-fostering has been performed, all efforts are oriented to maximise piglet BW at the end of lactation and to prepare the animals for weaning (transition from milk consumption during the suckling period to a solid feed diet after weaning). For that purpose, after the first week or ten days of lactation, piglets are frequently given a highly palatable and highly digestible diet (creep feeding). The creep feed intake of piglets is usually not very high and it is inversely related to the sow's milk production. Consequently, creep feed offered during the lactation period does not have a high impact on sow performance or piglet growth at weaning (Bruininx et al., 2004; Sulabo et al., 2010[a]). It was observed that only a low proportion of piglets consumed feed during lactation (Sulabo et al., 2010[b]). It was also observed that creep feed intake was variable between and within litters (Bruininx et al., 2002; Wattanakul et al., 2005). Nevertheless, piglets that consume creep feed during lactation improved post-weaning performance through a shortened onset of feed consumption (Bruininx et al., 2002) and an increased feed intake and BW gain during the first days after weaning (Bruininx et al., 2004; Sulabo et al., 2010[a]; van den Brand et al., 2014). Early introduction of creep feeding influences the proportion of piglets eating creep feed. Sulabo et al. (2010[b]) observed a lower feed intake and lower number of eaters in litters offered creep feed for two days, and a lower feed intake in litters offered creep feed for six days, when compared to litters offered creep feed for 13 days. In addition, lactation length seems to influence creep feed intake. Callesen et al. (2007[b]) observed an increase in creep feed consumption of between 137 and 266% in piglets weaned at 33 days of age compared to piglets weaned at 27 days of age. Subsequently, they found that creep feed might benefit post-weaning growth of piglets after longer lactation. A number of researchers have studied strategies to improve creep feed consumption and the proportion of piglets eating creep feed. van den Brand et al. (2014) observed that piglets younger than 18 days of age preferred pellets with a large diameter (10-12 mm vs. 2 mm diameter pellet). Despite lowering the weaning BW, performance of intermittent suckling increased creep feed intake and improved growth in the first week after weaning in piglets that ate creep feed (Kuller et al., 2004, 2007). As suggested by Wattanakul et al. (2005), the method of creep feed presentation is very important in the initiation of feeding behaviour. Accordingly, offering creep feed with different flavours or using a feeder that stimulates piglet exploratory behaviour are strategies that might enhance creep feed intake during lactation (Adeleye et al., 2014, Kuller et al., 2010). A recent study has suggested that providing liquid milk replacement to piglets during lactation might have a positive influence on post-weaning survival (Park et al., 2014).

In addition to the management practices mentioned above (colostrum supplementation, cross-fostering and creep-feeding), weaning age is also an important factor determining future performance of the animals. In past experiments, lactation of 21 days increased wean-to-finish average daily gain and survival compared to shorter lactation (Main et al., 2004), and lactation of 33 days improved piglet growth after weaning compared to lactation of 27 days (Callesen et al., 2007[a]). It is known that longer lactation increases weight and physiologic maturity of piglets at weaning (Main et al., 2004). However, with the current multisite pig production system and its specific pig-flow, little decision capacity is left concerning weaning age.

Human-animal interaction: Intensive husbandry and housing practices in animal production also affect the nature and amount of human contact that the animals receive. Compared to other phases, lactation demands more human handling of sows and piglets. Implementation of good practices by trained employees and positive experiences with human interactions may have powerful influences. Good practices and positive experiences might have an effect not only on the productivity and welfare of the animal, but also on how the animal responds to aversive routine practices (Hemsworth and Coleman, 2011; Muns et al., 2015[b]). On one hand, the negative effects of negative emotional states such as fear on the welfare of animals are well known (Gonyou et al., 1986; Hemsworth et al., 1981, 1987, 1989). Routine interactions between stockpeople and their animals can result in farm animals becoming highly fearful of humans and, through stress, their productivity and welfare might be impaired (Hemsworth, 2003). The attitude and behaviour of stockpeople when handling and interacting with sows and piglets may have implications on both the productivity and stress physiology of the animals (Gonyou et al., 1986; Hemsworth and Coleman, 2011; Hemsworth et al., 1989). In addition, it was observed that handling pigs early in life might influence their subsequent behavioural responses to humans (Hemsworth and Barnett, 1992). On the other hand, there are limited data indicating the impact of positive emotional responses of farm animals in the presence of humans on subsequent experiences when in the presence of humans. Precisely, Muns et al. (2015[b]) observed that positive human contact after birth reduced piglet escape behaviour at subsequent stressful events. Early handling of piglets (tactile stimulation performed daily from day 5 to day 35 of age) resulted in piglets that were more active and less fearful in a novel environment, and less fearful of people in general (de Oliveira et al., 2015). Zupan et al. (2016) also observed that handling (tactile stimulation performed daily from day 5 to day 35 of age) increased piglet locomotor play and handling half of the litter increased social exploratory behaviour of the entire litter. They suggested that handling all or half of the piglets in the litter might be beneficial for the piglets' emotional state after weaning, thus increasing their welfare. However, the mechanisms underlying the influence of positive early contact are unclear. Additionally, secondary management practices commonly performed in farrowing facilities (e.g. castration, iron

administration, vaccination, ear clipping, tail docking, etc.) might have an impact on piglet and sow welfare and performance. Therefore, they should also be considered when planning or suggesting a protocol for management routines in the farrowing house. Finally, environmental factors (e.g. facility design, housing system, climatic conditions, etc.) also play an important role in the success of the management performed in the farrowing house.

Conclusion

Most of the management protocols studied so far are too complex and laborious, or they need to be performed too close to farrowing to be effective. Two of the simplest practices that have been studied, drying piglets at birth and placing them at the udder or under a heating lamp, successfully reduced mortality. While the importance of proper colostrum intake by piglets is completely assumed, very few studies have been performed under farm conditions regarding oral supplementation of piglets. Oral administration of colostrum (with manually milked sow colostrum obtained from the same herd) to low birth BW piglets guarantees a proper level of IgG, while direct energy supplementation reduces the mortality of low birth BW piglets. Therefore, a combination of oral supplementation using sow colostrum and a commercial energy booster might enhance both piglet energy and immunity status. Such management practices could reduce on-farm PWM and should be further studied. On the other hand, cross-fostering has been proven to strongly influence PWM. However, more conclusive studies are needed to clearly understand the effect of cross-fostering on piglet performance, especially on the reduction in litter weight variation. In addition, more studies of the effect of cross-fostering combined with other husbandry practices (e.g. oral supplementation) are necessary. Concerning the use of creep feeding, there is a lack of knowledge about whether the more vigorous or the smaller piglets are consuming creep feed during lactation. Recent studies have suggested that creep feed consumption can be enhanced by stimulating piglet exploratory behaviour and/or by modifying creep feed presentation. Further studies of the motivation that leads piglets to consume creep feed are of great interest and could help enhance post-weaning piglet adaptation. Furthermore, recent studies have suggested the benefits of positive human handling on piglet welfare, behaviour, and fear response. Given the amount of management and manipulation that piglets suffer during lactation, better understanding of the piglet emotional response to human handling could become an important tool to improve pig welfare and handling during lactation and after weaning. Indeed, improved knowledge of the piglet emotional response to human handling could strongly influence the producers' approach to the skills and attitudes of stockpeople, as well as lactation management planning. Finally, it would be of great interest to study the impact of the reviewed management strategies on farms differing in their sanitary status or on farms under different climatic conditions, thereby comparing the impact of similar management strategies in different countries or continents.

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บทคัดย่อ

กลยุทธ์การจัดการโรงเรือนคลอดเพื่อปรับปรุงการอยู่รอด และการเจริญเติบโตของลูกสุกรก่อนหย่านม

รามอน มุนส์ วิลา และ เผด็จ ธรรมรักษ์*

ระยะหลังคลอดและระยะการให้นมเป็นช่วงเวลาที่มีความซับซ้อนมากที่สุดช่วงหนึ่งในกระบวนการผลิตสุกร ลูกสุกรแรกคลอดมีความเปราะบางมากเนื่องจากมีน้ำหนักตัวแรกคลอดที่ค่อนข้างต่ำและระบบสรีระวิทยาของร่างกายยังเจริญไม่สมบูรณ์ กลยุทธ์ในการจัดการส่วนใหญ่ที่ทำในโรงเรือนคลอด มีวัตถุประสงค์เพื่อให้ลูกสุกรได้รับปริมาณน้ำนมเหลืองที่เพียงพอ น้ำนมเหลืองมีความจำเป็นเนื่องจากเป็นแหล่งพลังงานและส่งผ่านภูมิคุ้มกันจากแม่สุกรสู่ลูกสุกร กระบวนการในการเฝ้าคลอดในรูปแบบต่างๆถูกนำมาศึกษาค้นคว้าอย่างกว้างขวางเพื่อลดการตายของลูกสุกรในระยะแรกและช่วยเหลือลูกสุกรให้ได้รับน้ำนมเหลืองและน้ำนมแม่สุกรอย่างเพียงพอ อย่างไรก็ดีการศึกษาเกี่ยวกับผลของการป้อนสารอาหารเสริมให้กับลูกสุกรแรกคลอดยังมีน้อยมาก การย้ายฝากเป็นการจัดการที่ทำกันอย่างกว้างขวางในฟาร์มสุกรเชิงพาณิชย์ทั่วไปเพื่อรองรับแม่สุกรที่มีลูกดกซึ่งมีผลกระทบอย่างมากต่อการรอดชีวิตของลูกสุกร เพื่อเตรียมลูกสุกรสำหรับการหย่านม อาหารเลียรางจะถูกจัดเตรียมไว้ให้ลูกสุกรภายใน 1 สัปดาห์แรกหลังคลอด ถึงแม้ว่าจะไม่เป็นที่ทราบแน่ชัดว่าลูกสุกรมากน้อยเพียงใดที่ได้รับอาหารเลียราง ปริมาณอาหารเลียรางที่ลูกสุกรกินได้อาจมีอิทธิพลต่ออัตราการกินอาหารของลูกสุกรหลังหย่านม ท้ายที่สุดทัศนคติและทักษะของผู้เลี้ยงอาจมีบทบาทสำคัญต่อความสามารถของลูกสุกรในการทนต่อความเครียด การสัมผัสลูกสุกรแรกคลอดที่ดีและนุ่มนวลของคนเลี้ยงอาจมีอิทธิพลต่ออารมณ์ของลูกสุกรและพฤติกรรมการตอบสนองของลูกสุกรต่อคนเลี้ยง ซึ่งสอดคล้องกับหลักจริยธรรมในการเลี้ยงสัตว์ วัตถุประสงค์ของบทความปริทัศน์ฉบับนี้ เพื่อแสดงให้เห็นกลยุทธ์การจัดการที่สำคัญในโรงเรือนคลอด (ได้แก่ การป้อนอาหารเสริม การเฝ้าคลอด การย้ายฝาก การให้อาหารเลียราง และปฏิสัมพันธ์ระหว่างคนและสัตว์) และผลกระทบของสิ่งต่างๆเหล่านี้ต่ออัตราการตายของลูกสุกรก่อนหย่านมและการเจริญเติบโต โดยข้อมูลทั้งหมดได้จากศึกษาวิจัยอย่างเป็นวิทยาศาสตร์

คำสำคัญ: น้ำนมเหลือง การย้ายฝาก การให้นม การตาย การป้อนอาหารเสริม สุกร

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Newborn traits associated with pre-weaning growth and survival in piglets

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Objective: Piglet pre-weaning mortality is an important variable indicating the efficacy of farrowing management and animal well-being during lactation. The present study determined the association of newborn traits measured soon after birth with piglet pre-weaning mortality and growth.
Methods: In total, 805 piglets born from 57 multiparous sows were investigated. Their blood oxygen saturation, blood glucose and rectal temperature at 24 h after birth (RT24h) were monitored. Birth order, sex, skin color, integrity of the umbilical cord, attempts to stand and birth intervention were monitored. Piglets were weighed at day 0, 7, and 21 to evaluate average daily gain (ADG).
Results: Piglet pre-weaning mortality for lactation period was 12.6% and cumulative mortality during the first 7 days of age was 8.6%. A higher proportion of piglets with pale skin color died compared to piglets with normal skin color (26.7% vs 7.7%, p<0.001). A higher (p<0.001) proportion of piglets that attempted to stand after 5 min (38.5%) died compared to piglets that attempted to stand within 1 min (6.3%) after birth. Piglet body weight at birth (BW_B), blood glucose and the number of piglets born alive (BA) were correlated with ADG (p<0.05). Piglets with BW_B <1.30 kg had higher (p<0.001) mortality rate than piglets with BW_B≥1.80 kg (19.0% vs 3.3%) and piglets with BW_B 1.30 to 1.79 kg (4.0%). Piglet with RT24h <37.0°C had higher (p<0.001) mortality rate (86.2%) than piglets with RT24h >38.5°C (3.9%).
Conclusion: Low BW_B and low RT24h compromise piglet survival during the lactation period in the tropical conditions. Piglets in the litters with a high BA, low BW_B and low blood glucose have reduced ADG.

Keywords: Average Daily Gain; Birth Weight; Mortality; Newborn Traits; Pig

INTRODUCTION

In modern swine industry, producers expect up to 30 pigs weaned per sow per year [1]. However, in practice, a high proportion of piglet mortality occur during pre-weaning period [2]. Thus, factors associated with piglet pre-weaning mortality are becoming a major concern in swine industry worldwide [3]. One of main reason for a high proportion of piglet pre-weaning mortality is the use of high prolific sow genetics, which improved the number of piglets born alive per litter among swine commercial herds worldwide during the past 10 years [1]. Litter size (LS) is an important sow factor related to piglet survival and growth [2]. Nuntapaitoon and Tummaruk [2] demonstrated that piglet pre-weaning mortality in the litter with 13 to 15 littermate pigs (24.1%) was significantly higher than the litter with 1 to 7 (11.9%), 8 to 10 (11.8%), and 11 to 12 (14.6%) littermate pigs, respectively. Large LS also increases the body weight at birth (BW_B) variation among the piglets within litter [4]. Hence, the proportion of piglets with low BW_B is also increased [5]. Vallet and Miles [6] observed that low BW_B piglets had a higher risk of being crushed due to their slower speed of movement and reflexive actions. Intra-partum hypoxia is a main factor influenc-

ing piglet vitality as it damages the foetal central nervous system [7]. Thus, several indicators can be used in newborn piglets to evaluate the level of intra-partum hypoxia suffered during the birth process. In addition, piglet vitality determines their capacity to suckle and compete for a teat and is also positively correlated with piglet growth and survival until weaning [8]. One reason for reduced piglet vitality might be related to nutrients and oxygen supplies via umbilical cord from dam to fetus. Blood oxygen, blood glucose concentration, and time to stand after birth have been used as indirect measures of intra-partum hypoxia and neonatal piglet viability [9].

Factors influencing piglet pre-weaning mortality under field conditions include sow factors (e.g., breed, parity, nutritional status, farrowing duration, maternal behavior and LS), piglet factors (e.g., BW_B, birth order and sex) and environmental factors (e.g., ambient temperature and stocking density) [2,9]. To our knowledge, most of the studies on risk factors associated with piglet pre-weaning mortality were performed in cold or moderate climates [10-12]. Additional information in hot and humid climate countries is required to improve farrowing management and care of newborn piglets. The objective of the present study was to determine the effects of piglet neonatal traits and physiological characteristics measured soon after birth on their pre-weaning survival and growth.

MATERIALS AND METHODS

Animal care

The experiment followed the guidelines documented in The Ethical Principles and Guidelines for the Use of Animals for Scientific Purposes edited by the National Research Council of Thailand, and 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 no. 1431063).

Herd and management

The present study was carried out in a 3,500-sows commercial swine herd in the western part of Thailand between June and August 2013. The average ambient temperature during the experimental period ranged from 25.8°C to 30.0°C. The minimum and maximum temperature ranged from 21.1°C to 26.3°C and from 28.1°C to 37.6°C, respectively. The average relative humidity varied from 72.0% to 96.0%. Sows were kept in individual crates (1.2 m^2) during gestation in a conventional open-housing system and were provided with fans and individual water sprinklers to reduce the impact of high ambient temperature. During gestation, sows were fed a commercial gestation diet that met or exceed their nutritional requirement estimates (19.7% crude protein, 5.8% fat, 3.8% fibre, and 14.0 metabolizable energy, MJ/kg) [13]. Feed was provided twice a day following a standardised feeding pattern, resulting in an average of 2.5 kg per sow per day. During lactation, sows were fed twice a day with a commercial lactation diet, increasing the daily amount of feed offered, until *ad libitum* feed was reached after one week of lactation. The animals were received water *ad libitum* in a continuous water channel. Pregnant sows were moved to the farrowing house about one week before their expected farrowing date. Sows were kept in individual farrowing crates (1.2 m^2) placed at the centre of the pens with a space allowance of 4.2 m^2. The pens were fully slatted with concrete at the centre for sows and with steel slats at both sides of the farrowing crate for piglets. Each pen was provided with a creep area for piglets (0.60 m^2) placed on the floor on one side, covered by a plastic plate and heating lamp during the first week after farrowing. The heating lamp was usually turned on during the night or when the environment temperature fell below 30°C. The temperature in the creep area was between 30°C to 36°C.

Supervision of parturition process

The parturition process was carefully supervised by the first author (M. Nuntapaitoon). Briefly, sows were interfered with as little as possible during parturition, and birth intervention was performed only when dystocia was clearly identified. Dystocia was considered when an interval of >30 min elapsed from the birth of the last piglet, and when the sow showed intermittent straining accompanied by paddling of the legs or when the sow expelled small quantities of foetal fluid together with marked tail switching for >30 min without any piglet being born. Routine procedures performed on piglets included weighing, tail docking, tooth clipping and 1 mL (200 mg) iron supplement administered intramuscularly (Gleptosil, Alstoe Ltd. Animal Health, Leicestershire, England) on the day of birth. Piglets were orally administered a coccidiocide of 20 mg/kg body weight (Baycox [Toltrazuril 5.0% oral suspension], Bayer Inc., Mississauga, ON, Canada) to control neonatal coccidiosis at 3 days of age. In total, 805 piglets born from 57 Landrace×Yorkshire crossbred sows were included. The mean parity was 4.0±1.6 (ranged 2 to 7). Lactation length was on an average of 23.0±2.0 days.

Data collection

The following reproductive variables of the sows were recorded: farrowing duration (i.e., time between the first and last born piglets), total number of piglets born per litter (TB), number of piglets born alive per litter (BA), and mummified foetuses, stillbirths and number of piglets at weaning per litter. The piglets' heart rate and blood oxygen saturation ($SatO_2$) were monitored within 5 min after birth by using a veterinary pulse oximetry (EDAN VE-H100B Pulse Oximeter, Edan Instrument Inc., San Diego, CA, USA). Thereafter, blood samples for glucose analysis were collected from piglets within 5 to 10 min after birth (i.e., before first suckling). A small amount of blood sample (a mixture of venous and arterial blood) was obtained from the cut umbilical cord. Few drops of blood sample were used to determined blood glucose concentration by using a portable test kit of human

glucometer (Accu-Chek Performa, Roche, Mannheim, Germany). Birth order, birth interval (the time elapsed between each piglet born), sex, and time elapsed from birth until first attempts to stand (3 groups: <1 min, 1 to 5 min, and >5 min) were recorded for each piglet. Also, birth assistance was recorded (yes or no) if required by piglets. Skin color of the piglets was recorded at birth and was classified into 2 groups (normal or pale). Integrity of the umbilical cord of each piglet was examined and classified into two groups (intact or broken). Rectal temperature was measured at 24 h after birth (RT24h) with a digital thermometer (Microlife, Microlife AG Swiss Corporation, Widnau, Switzerland, with a display resolution of 0.01°C and ±0.1°C accuracy). All piglets were individually identified by an ear tattoo. Body weight of the piglets was measured immediately at birth. Litters were equalized to 13 or 14 piglets per litter after 24 h and within 48 h after birth. The LS was defined as the number of piglets after cross-fostering. Piglets were weighed again at day 7 and 21 after birth. Mortality rate of the piglets was also determined at day 7 and 21 of lactation. Creep feeding and drinking water were provided to the piglets from 7 days of age until weaning.

Statistical analysis

All statistical analyses were performed using SAS 9.0 (SAS Inst. Inc., Cary, NC, USA) [14]. Descriptive analysis (mean±standard deviation [SD] median and range) and frequency analysis were obtained for all reproductive parameters. To identify the potential indicators for piglet mortality and piglet average daily weight gain (ADG) at days 7 and 21 of lactation, each recorded factor was individually tested using univariate analyses. Continuous variables indicating the neonatal piglet characters (i.e., TB, BA, LS, birth order, BW_B, birth interval, heart rate, $SatO_2$ and blood glucose concentration) were compared between piglets dying and surviving at days 7 and 21 of lactation by using Student's *t* test (PROC TTEST). The association between categorical variables (i.e., sex, skin color, attempts to stand, umbilical cord integrity and birth assistance) and the piglet mortality (dead or alive) were analyzed using Chi-square test. The effect of these categorical variables on ADG at days 7 and 21 of lactation was analyzed using the PROC GLM of SAS. Pearson's correlation was performed to study collinearity among the continuous variables in the univariate models.

For multivariate analyses, generalised linear mixed models (GLMMIX macro) with the dependent variable (mortality) modeled as a binary outcome (dead or alive) was conducted. Factors with significant levels of $p<0.10$ were included in the final models. Highly correlated variables were not included in the same multivariate analyses models. Then, the final multivariate GLMMIX models for piglet mortality at days 7 and 21 of lactation included BW_B of the piglet classes (<1.30, 1.30 to 1.79, and ≥1.80 kg) and RT24h classes (<37.0°C, 37.0°C to 38.5°C, and >38.5°C). The classification of the independent variables was made according to frequency distribution with some minor adjustment based on biological reliability. Similarly, general linear mixed models (PROC MIXED) were conducted to analyze piglet ADG at days 7 and 21 of lactation. The final multivariate MIXED models for piglet ADG at day 7 and 21 included BW_B classes (<1.30, 1.30 to 1.79, and ≥1.80 kg), blood glucose concentration classes (≤24 and >24 mg/dL), BA classes (<12, 12 to 14, and ≥15 piglets), sex and attempts to stand (<1, 1 to 5, and >5 min). In all models, sow or litter were introduced as a random effect. Least squares means were obtained from each class of the variables and were compared using Tukey–Kramer adjustment for multiple comparisons. $p<0.05$ was regarded to be statistically significance and $0.05<p<0.10$ was considered as a tendency for statistically significance. Piglets were defined as experimental units.

RESULTS

Of the 805 piglets, 81 were stillborn (10.1%), 34 were mummified fetuses (4.2%) and 690 were BA (85.7%). Descriptive statistics of newborn piglet traits and piglet performance are presented in Table 1. On average (means±SD), TB, BA, and the number of piglets at weaning were 14.2±3.7, 12.1±3.4, and 11.7±1.7 piglets, respectively. The duration of farrowing averaged 217.8±83.7 min, and the average birth interval between piglets was 16.4±24.1 min. Overall, piglet pre-weaning mortality was 12.6% and cumulative mortality at day 7 was 8.6%.

Table 1. Descriptive statistics of 690 piglets evaluated at birth and during the lactation period

Variables	N	Mean±SD	Median	Range
Birth weight (kg)	690	1.49±0.38	1.48	0.46 to 2.71
Heart rate (bpm)	685	66.2±33.20	57.0	23.0 to 250
Glucose (mg/dL)	687	49.1±17.72	47.0	11.0 to 159
Oxygen saturation (%)	685	91.2±8.85	92.0	10.0 to 100
Rectal temperature at 24 h (°C)	670	38.7±0.57	38.7	35.5 to 40.3
Weight at day 7 (kg)	632	2.67±0.71	2.7	0.75 to 4.64
Weight at day 21 (kg)	602	6.09±1.51	6.1	1.88 to 10.07
ADG at day 7 (g/d)	632	163.7±67.32	164.6	–7.9 to 340.7
ADG at day 21 (g/d)	602	216.8±63.05	213.3	24.0 to 376.9

SD, standard deviation; ADG, average daily gain.

Univariate analyses

Factors associated with piglet pre-weaning mortality until day 7 after birth: Factors influencing piglet pre-weaning mortality rate until day 7 after birth are presented in Tables 2, 3. Both BW_B and RT24h influenced piglet mortality until day 7 after birth ($p<0.001$). Piglets that died before day 7 of life had a lower birth interval (9.5 vs 14.9 min, $p = 0.005$) and were reared in litters with a higher LS (13.7 vs 13.2 piglets, $p = 0.038$). The total number of piglets born per litter, BA, birth order, heart rate, $SatO_2$, and blood glucose concentration did not influence piglet survival ($p>0.05$, Table 2). A higher proportion of piglets with pale skin color died compared to piglets with normal skin color (26.7% vs 7.7%; $p<0.001$, Table 3). A higher proportion of piglets that attempted to stand after 5 min (38.5%) died compared to piglets that attempted to stand within 1 min (6.3%, $p<0.001$) and within 1 to 5 min (9.2%, $p<0.001$, Table 3). Birth intervention, sex and umbilical cord integrity had no effect on piglet mortality until day 7 after birth ($p>0.05$, Table 3).

Factors associated with piglet pre-weaning mortality until day 21 after birth: Factors influencing piglet pre-weaning mortality rate until day 21 after birth are presented in Table 3, 4. Both BW_B and RT24h influenced piglet mortality until day 21 after birth ($p<0.001$). Piglets that died before day 21 of life were born from sows with a higher TB, were reared in litters with a higher LS, and had lower birth intervals ($p<0.05$, Table 4). Birth order, heart rate, $SatO_2$ and blood glucose concentration did not influence piglet survival ($p>0.05$, Table 4). A higher proportion of piglets with pale skin color died compared to piglets with normal skin color (36.7% vs 11.5%; $p<0.001$, Table 3). A higher proportion of piglets that attempted to stand after 5 min (41.0%) died compared to piglets that attempted to stand within 1 min (10.8%, $p<0.001$) and within 1 to 5 min (10.8%, $p<0.001$, Table 3). Birth intervention, sex and umbilical cord integrity had no effect on piglet mortality until day 21 after birth ($p>0.05$, Table 3).

Factors associated with average daily gain until day 7 after birth: Piglet BW_B ($p<0.001$) and blood glucose concentration ($p<0.001$) positively influenced piglet ADG at day 7 ($r = 0.172$, $p<0.001$, Table 5). Piglets born from sows with higher TB and higher BA had a lower ADG at day 7 ($p<0.001$, Table 5). Piglets without birth intervention had lower growth than piglets with birth intervention (161.1±2.8 vs 182.4±7.7 g/d, $p = 0.010$, Table 6). Male piglets had higher growth than female piglets (169.1±3.7 vs 157.6±3.9 g/d, $p = 0.032$, Table 6). Piglets that attempted to stand after 5 min (127.1±13.6 g/d) had lower growth than piglets that attempted to stand within 1 min (165.9±2.9 g/d, $p = 0.006$) or within 1 to 5 min (156.3±13.6 g/d, $p = 0.071$, Table 6).

Factors associated with average daily gain until day 21 after birth: Piglet BW_B ($p<0.001$) and blood glucose concentration ($p = 0.009$) positively influenced piglet ADG at day 21 ($r = 0.106$, $p<0.01$, Table 5). Piglets born from sows with higher TB and BA had lower ADG at day 21 (Table 5, $p<0.001$). Piglets without birth intervention had lower growth than piglets with birth intervention (214.3±2.7 vs 235.1±7.3 g/d, $p = 0.008$, Table 6). Piglets that attempted to stand after 5 min (190.3±13.1 g/d) had lower growth

Table 3. Categorical variables influencing piglet pre-weaning mortality at day 7 and 21 after birth

Variables	Piglet pre-weaning mortality (%)	
	Day 7	Day 21
Skin color		
Normal	7.7[a]	11.5[a]
Pale	26.7[b]	36.7[b]
Time attempted to stand		
< 1 min	6.3[a]	10.8[a]
1 to 5 min	9.2[a]	10.8[a]
> 5 min	38.5[b]	41.0[b]
Birth intervention		
No	9.0[a]	13.4[a]
Yes	5.1[a]	6.3[a]
Sex		
Male	8.0[a]	13.6[a]
Female	9.1[a]	11.6[a]
Umbilical cord integrity		
Intact	8.9[a]	13.0[a]
Broken	7.8[a]	11.9[a]

[a,b] Values with different superscripts within the same column within variable differ significantly ($p < 0.05$).

Table 2. Potential indicators for piglet pre-weaning mortality (means±standard error of the mean) comparing surviving piglets from birth to day 7 of lactation (n = 631) with dying piglets (n = 59)

Variables	Surviving	Dying	p-value
Total number of piglets born per litter	14.9±0.14	15.6±0.43	0.171
Number of piglets born alive per litter	13.0±0.12	13.3±0.45	0.491
Litter size after cross-fostering	13.2±0.07	13.7±0.22	0.038
Birth interval (min)	14.9±0.80	9.5±1.72	0.005
Birth weight (kg)	1.52±0.01	1.11±0.05	<0.001
Birth order	7.5±0.18	8.5±0.59	0.130
Heart rate (bpm)	66.5±1.34	62.5±3.68	0.381
Glucose (mg/dL)	49.3±0.70	47.8±2.69	0.605
Oxygen saturation (%)	91.3±0.36	90.4±0.99	0.458
Rectal temperature at 24 h (°C)	38.7±0.02	38.2±0.14	<0.001

Table 4. Potential indicators for piglet pre-weaning mortality (means±standard error of the mean) comparing surviving piglets from birth to day 21 of lactation (n = 603) with dying piglets (n = 87)

Variables	Surviving	Dying	p-value
Total number of piglets born per litter	14.9±0.14	15.9±0.33	0.010
Number of piglets born alive per litter	12.9±0.12	13.7±0.32	0.028
Litter size after cross-fostering	13.2±0.07	13.6±0.18	0.042
Birth interval (min)	15.2±0.83	9.3±1.37	<0.001
Birth weight (kg)	1.53±0.01	1.16±0.05	<0.001
Birth order	7.5±0.19	8.1±0.45	0.319
Heart rate (bpm)	66.9±1.39	61.4±2.71	0.076
Glucose (mg/dL)	49.5±0.71	46.6±2.13	0.156
Oxygen saturation (%)	91.2±0.37	91.3±0.80	0.872
Rectal temperature at 24 h (°C)	38.7±0.02	38.3±0.10	<0.001

Table 5. Pearson's correlations among the most significant potential predictor measured during farrowing and soon after birth and average daily gain (ADG) of the piglets from birth until 7 and 21 days of age

	TB	BA	BI	BW_B	HR	GLU
BA	0.798***	-	-	-	-	-
BI	–0.138***	–0.128***	-	-	-	-
BW_B	–0.309***	–0.348***	0.180***	-	-	-
HR	–0.092*	–0.077*	-	-	-	-
$SatO_2$	-	-	-	-	–0.179***	-
GLU	–0.118**	–0.136***	0.146***	0.187***	-	-
RT24h	-	-	-	0.128***	-	-
ADG7	–0.272***	–0.283***	-	0.430***	-	0.172***
ADG21	–0.197***	–0.284***	-	0.431***	-	0.106**

TB, total number of piglets born per litter; BA, number of piglets born alive per litter; BI, birth interval; BW_B, birth weight; HR, heart rate; GLU, blood glucose concentration; $SatO_2$, blood oxygen saturation; RT24h, rectal temperature at 24 h after birth; ADG7, average daily gain from birth until day 7; ADG21, average daily gain from birth until day 21.
Significance levels: * p<0.05, ** p<0.01, *** p<0.001.

than piglets that attempted to stand within 1 min (218.0±2.8 g/d, p = 0.039, Table 6).

Table 6. Categorical variables influencing average daily gain (means±standard error of the mean) at day 7 and 21 after birth from univariate analyses

Variables	Average daily gain (g/d)	
	Day 7	Day 21
Skin color		
Normal	163.6±2.7[a]	217.0±2.6[a]
Pale	164.4±14.4[a]	210.6±14.5[a]
Time attempted to stand		
<1 min	165.9±2.8[a]	218.0±2.8[a]
1 to 5 min	156.3±8.7[ab]	215.9±8.3[ab]
>5 min	127.1±13.7[b]	190.3±13.1[b]
Birth intervention		
No	161.1±2.8[a]	214.3±2.7[a]
Yes	182.4±7.7[b]	235.1±7.3[b]
Sex		
Male	169.1±3.7[a]	219.1±3.6[a]
Female	157.6±3.9[b]	214.4±3.7[a]
Umbilical cord integrity		
Intact	160.4±3.2[a]	215.6±3.1[a]
Broken	170.6±4.7[a]	219.4±4.5[a]

[a,b] Values with different superscripts within the same column within variable differ significantly (p<0.05).

Multivariate analyses

Average daily gain: The final multi-covariate model for ADG at day 7 included BW_B (p<0.001), blood glucose concentration (p<0.001), BA (p = 0.025), sex (p = 0.087), and attempts to stand (p = 0.093) (Table 7). At day 7, the piglets with BW_B<1.30 kg had a lower ADG than the piglets with BW_B≥1.80 kg (p<0.001) and the piglets with BW_B 1.30 to 1.79 kg (p<0.001, Table 7). The piglets with a blood glucose concentration of ≤24 mg/dL had a lower ADG at day 7 than the piglets with a blood glucose concentration of >24 mg/dL (p<0.001, Table 7). Furthermore, the piglets with a low BA (<12 piglet) had a higher ADG at day 7 than the piglets with 12 to 14 BA (p = 0.087) and the piglets with ≥15 BA (p = 0.030, Table 7). The male piglets tended to have a higher ADG at day 7 than the female piglets (p = 0.087, Table 7). The piglets that stood within 1 min tended to have a higher ADG at day 7 than the piglets that stood after 5 min (p = 0.075, Table 7).

Based on a multivariate statistical model, factors significantly influencing ADG of the piglets at day 21 in the final model included BW_B (p<0.001), BA (p<0.001), and blood glucose concentration (p = 0.042). The statistical model revealed that, at day 21, the piglets with a BW_B of <1.30 kg had a lower ADG than the piglets with a BW_B of ≥1.80 kg (p<0.001) and the piglets with a BW_B 1.30 to 1.79 kg (p<0.001) (Table 7). The piglets from litters with a low

Table 7. Predictive factors included in the final models for average daily gain (least square means±standard error of the mean) from birth until 7 and 21 days of life from multivariate analyses

Variables	Average daily gain (g/d)	
	Day 7	Day 21
Number of piglets born alive per litter, piglets		
< 12	150.6 ± 11.09^{aA}	226.8 ± 9.88^{a}
12 to 14	126.4 ± 11.39^{abB}	190.6 ± 9.60^{b}
≥ 15	121.3 ± 11.16^{b}	192.8 ± 9.94^{b}
Birth weight (kg)		
< 1.30	88.9 ± 9.72^{c}	165.5 ± 9.01^{c}
1.30 to 1.79	145.3 ± 9.52^{b}	210.5 ± 8.45^{b}
≥ 1.80	164.2 ± 10.59^{a}	234.2 ± 9.40^{a}
Glucose (mg/dL)		
≤ 24	107.8 ± 15.32^{b}	190.3 ± 15.95^{b}
> 24	157.8 ± 6.16^{a}	220.6 ± 4.99^{a}
Sex		
Male	136.5 ± 9.45^{A}	NS
Female	129.1 ± 9.53^{B}	NS
Attempt to stand (min)		
< 1	141.8 ± 8.27^{A}	NS
1 to 5	140.2 ± 10.78^{AB}	NS
> 5	116.4 ± 13.87^{B}	NS

^{a,b,c} Values with different small superscripts within the same column differ significantly ($p < 0.001$).
^{A,B} Values with different capital superscripts within the same column tended to be differences ($0.05 < p < 0.10$).
NS, the variables were not significant ($p > 0.01$) and were not included in the final models.

BA (<12 piglets) had a higher ADG at day 21 than those from litters with a BA of 12 to 14 ($p<0.001$) and ≥15 ($p<0.001$). The piglets with a blood glucose concentration of ≤24 mg/dL had a lower ADG at day 21 than the piglets with a blood glucose concentration of >24 mg/dL ($p = 0.042$). Sex and attempts to stand did not influence ADG of the piglet at day 21 ($p>0.10$).

Piglet pre-weaning mortality: The final multivariate model for mortality at day 7 included BW_B and RT24h ($p<0.001$). At day 7, the piglets with BW_B<1.30 kg had a higher ($p<0.001$) mortality rate (19.0%) than the piglets with BW_B≥1.80 kg (3.3%) and piglets with BW_B 1.30 to 1.79 kg (4.0%, Figure 1). The piglets with RT24h < 37.0°C had a higher ($p<0.001$) mortality rate (86.2%) at day 7 than the piglets with RT24h 37.0°C to 38.5°C (7.3%) and RT24h >38.5°C (3.9%, Figure 2).

Based on a multivariate statistical model, factors influencing piglet mortality at day 21 included BW_B ($p<0.001$) and RT24h ($p<0.001$). At day 21, the piglets with BW_B<1.30 kg had a higher ($p<0.001$) mortality rate (26.4%) than the piglets with BW_B≥1.80 kg (6.0%) and the piglets with BW_B 1.30 to 1.79 kg (6.5%, Figure 1). The piglets with RT24h <37.0°C had a higher ($p<0.001$) mortality rate (89.7%) at day 21 than the piglets with RT24h 37.0°C to 38.5°C (12.9%) and RT24h >38.5°C (7.0%, Figure 2).

DISCUSSION

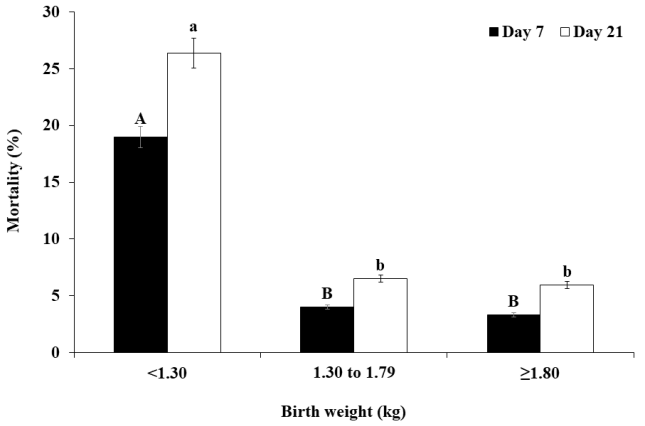

Figure 1. Percentage of mortality at days 7 and 21 for all piglets classified into low (<1.30 kg, n = 216), medium (1.30 to 1.79 kg, n = 323) and high (≥1.80 kg, n = 151) birth weight categories. ^{A,B,a,b} Values with different superscripts within the same day differ significantly ($p<0.05$).

The main objective of this study was to determine the effect of certain newborn piglet traits measured soon after birth on piglet pre-weaning mortality and growth. As expected, BW_B and RT24h were the most influential postnatal survival factors at both day 7 and at weaning. Furthermore, BW_B, BA and blood glucose concentration significantly influenced piglet growth during the whole lactation period, while sex and time spent attempting to stand had some impact on their growth up to day 7.

In agreement with our results, many studies have identified piglet BW_B as the main predictor for both survival and growth during lactation [9,15]. Piglet BW_B is positively associated with their physiological maturity and, in turn, correlates with different physical and physiological parameters such as colostrum intake capacity and thermoregulation ability [3]. Small piglets usually have decreased viability and a lower capacity to compete for a teat [16]. Johansen et al [17] found that piglets with a low BW_B often have lower ADG in the suckling period. In addition,

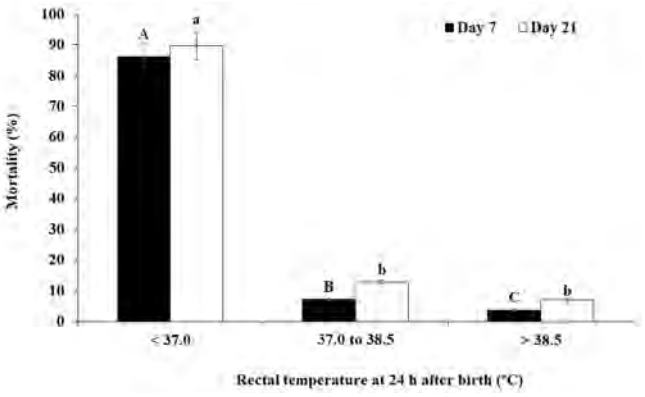

Figure 2. Percentage of mortality at days 7 and 21 for all piglets classified into low (<37.0°C, n = 29), medium (37.0°C to 38.5°C, n = 248) and high (>38.5°C, n = 413) rectal temperature categories at 24 h after birth. ^{A,B,C,a,b,c} Values with different superscripts within the same day differ significantly ($p<0.05$).

low BW_B piglets are less able to maintain body temperature [18] which leads to starvation, lethargy and increased risk of crushing by the sow. Therefore, lower BW_B piglets may also show a low nutritional status and poor passive immunity [19]. In agreement with our results, rectal temperature after birth was identified as an important indicator for piglet survival [9,16], indicating that piglets with low rectal temperature after 24 h might have lower thermoregulation abilities. Thermoregulation is a crucial physiological event for all newborn piglets. The piglets that die during the first days of life are not able to maintain optimal rectal temperature during the first 24 h of life [10]. In the present study, RT24h was significantly associated with mortality rate but was not related with ADG. In contrast, Panzardi et al [9] identified RT24h as an indicator for piglet growth at weaning. Likewise, Pedersen et al [20] found that piglets with low RT24h had low ADG from birth to weaning. One possible explanation might be due to that the piglets with low RT24h may consume less colostrum than the piglets with high RT24h. Thus, growth rate of these piglets might be compromise.

In the current study, BA was observed to influence piglet growth. Likewise, other studies found that BA negatively correlated with the piglet weaning weight [20]. This might be due to the fact that there is also an increase in the number of small piglets in the litter with an increased BA [21]. The present study also demonstrated that BW_B of the piglets was significantly decreased when TB increased (Table 5). Competition between littermates might have a negative impact on piglet colostrum intake, especially in the small piglets, resulting in reduced growth during lactation [3]. Moreover, BA was not related with mortality in the present study, whereas in the previous study, there was a positive relationship between the number of piglets in the litter and piglet mortality [2]. Nonetheless, Muns et al [8] and Pedersen et al [20] found a relationship between BA and piglet growth, but not between BA and mortality rate.

In the present study, blood glucose concentration at birth was a significant predictor for piglet ADG at 7 and 21 days of life but not for piglet mortality. Accordingly, studies failed to demonstrate a correlation between blood glucose concentration in newborn piglet and their survival [10,15,16]. However, Panzadi et al [9] found that either too low (24 to 30 mg/dL) or too high (45 to 162 mg/dL) levels of blood glucose in neonatal piglets were associated with an increased pre-weaning mortality. In the present study, piglets with high glucose concentrations at birth might have high energy reserves and, subsequently, enhanced capacity for suckling and growth. This implies that some source of glucose or energy supplementation in neonatal piglets maybe needed to improve the suckling capacity and growth performance in the neonatal piglets.

In the multivariate models for ADG at day 7, time from birth to first attempts to stand was also identified as a predictive factor. In the present study, piglets spending >5 min from birth to first attempts to stand had low ADG. Decaluwé et al [12] also found that piglets spending a long time from birth to suckling had a lower ADG during the lactation period than those spending a short time from birth to suckling. Moreover, neonatal piglets spending a short time from birth to first attempts to stand resulted in a low pre-weaning mortality [9,10]. However, Leenhouwers et al [22] found no relationship between time from birth to first attempts to stand and piglet mortality rate during the first week of lactation. Nonetheless, time elapsed from birth to first suckling significantly influences colostrum intake of the piglets [23]. Therefore, "the time elapsed from birth to first suckling" has been included in a formula for estimating colostrum consumption in piglets [23]. In the present study, piglets spending a short time period from birth to first attempts to stand are probably faster at first suckling, thus increasing their colostrum consumption. The colostrum consumption of the neonatal piglets significantly influence the piglet survival and passive immunity [24]. Therefore, in practice, newborn piglets spending more than 5 min to first attempt to stand need special cares.

In conclusion, low BW_B and low RT24h compromise piglet survival during the lactation period in the tropical conditions. In addition, piglets in the litters with a high number of BA and piglets with low BW_B and/or low blood glucose concentration have reduced body weight growth during lactation.

CONFLICT OF INTEREST

We certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

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Control of parturition in swine using $PGF_{2\alpha}$ in combination with carbetocin

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ABSTRACT

Carbetocin is an oxytocin-like molecule with long-acting properties. The present study determined the efficacy of prostaglandin F2alpha ($PGF_{2\alpha}$) combined with carbetocin compared to $PGF_{2\alpha}$ alone for the induction of parturition. A total of 2395 piglets born from 183 sows were included. Sows were randomly allocated into three groups: (1) control group ($n = 80$): sows farrowed naturally; (2) PGF group ($n = 50$): farrowing induced using $PGF_{2\alpha}$; and (3) carbetocin group ($n = 53$): farrowing induced using $PGF_{2\alpha}$ and carbetocin. At day 114 of gestation, sows in the PGF and carbetocin groups were administered 2 ml of a $PGF_{2\alpha}$ analogue. After 24 h, sows in the carbetocin group were injected with 0.6 μg/kg of carbetocin. Animals were monitored during the farrowing process. Farrowing duration, birth interval, rectal temperature and birth weight of the piglets were recorded. Colostrum intake of the piglets and colostrum yield of sows were estimated. The farrowing duration (274 ± 209 min) and birth interval (20.7 ± 55.8 min) did not differ among groups ($P > 0.05$). The percentage of sows that farrowed during working hours (0700 to 1700 h) were 51.3%, 70.0% and 98.1% in the control, PGF and carbetocin groups, respectively ($P < 0.001$). The proportion of stillborn piglets was 6.1%, 4.0% and 4.7% in the control, PGF and carbetocin groups, respectively ($P > 0.05$). The colostrum yield of sows in the carbetocin group (4050 ± 207 g) was lower than the control (4836 ± 148 g) and PGF (4896 ± 229 g) groups ($P < 0.05$). Farrowing induction using $PGF_{2\alpha}$ in combination with carbetocin successfully concentrated farrowings during working hours but reduced colostrum intake of the piglets. Thus, it should be performed along with proper neonatal care.

1. Introduction

Over the past decade, swine production in Thailand has become more industrialised, and the number of total piglets born per litter has increased rapidly. One of the most important factors to achieve a successful swine farming industry is to optimise farrowing management. The key factors for successful intensive farrowing management include, among other factors, proper farrowing supervision, intervention for sows that need birth assistance, care of newborn piglets and optimisation of cross-fostering management (Muns and Tummaruk, 2016). These management practices are gaining increasing interest in the swine research field, mainly due to the increased number of piglets born alive per litter in modern genetic sows (Muns et al., 2016b).

Intensive farrowing management requires well-educated workers to take care of both the postpartum sows and the newborn piglets. The gestation length and duration of farrowing varies among sows, and the majority of sows farrow at night, therefore, farrowing supervision is difficult under commercial conditions. Hence, natural and synthetic prostaglandin F2alpha ($PGF_{2\alpha}$) are commonly used in breeding herds worldwide to induce and control the onset of parturition in sows. Once the farrowing time can be synchronised and predicted, the peri- and postpartum management of sows becomes easier. Furthermore, cross-fostering and care of the newborn piglets can be performed properly and more efficiently, thereby reducing the risk of neonatal mortality.

One of the most common hormones used to induce parturition in sows is $PGF_{2\alpha}$ (De Rensis et al., 2012). In general, administration of $PGF_{2\alpha}$ to sows to induce farrowing is recommended via intramuscular injection and not any earlier than 2 days before the expected farrowing date. Additionally, oxytocin has been used together with $PGF_{2\alpha}$ to minimise variation in the onset of parturition among sows. It is recommended that oxytocin be administered 20–24 h after $PGF_{2\alpha}$ administration to induce uterine contractions (Cassar et al., 2005). Although oxytocin can reduce variation in the interval between $PGF_{2\alpha}$ administration and the onset of parturition, there is a concern regarding the adverse effect of oxytocin on the proportion of stillborn piglets and neonatal piglet vitality (Alonso-Spilsbury et al., 2004). Previous studies

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reported that the use of oxytocin in combination with $PGF_{2\alpha}$ increased the proportion of stillborn piglets in the litter (Alonso-Spilsbury et al., 2004; Mota-Rojas et al., 2005). Additionally, piglets born after oxytocin administration can show signs of slow or undetectable heart rate (Mota-Rojas et al., 2005). One of the limitations of oxytocin observed under field conditions is its very short-acting effect on uterine contractions (Kirkwood, 2015). Recently, carbetocin has been suggested as an alternative to oxytocin (Gheller et al., 2011).

Carbetocin is an oxytocin-like molecule with long-acting properties which targets the same receptors on the myometrium as oxytocin. The Society of Obstetricians and Gynaecologists of Canada recommended the use of carbetocin for the prevention of postpartum haemorrhage in humans (Schuurmans et al., 2005). Based on the literature, controlling parturition in swine through the combination of $PGF_{2\alpha}$ and carbetocin is an interesting and novel strategy with promising expectations for swine production (Kirkden et al., 2013). The aim of the present study was to determine the efficacy of the combination of $PGF_{2\alpha}$ and carbetocin to induce parturition compared to the use of $PGF_{2\alpha}$ alone. Additionally, the impact of carbetocin administration on sow reproductive performance (time of parturition during the day, farrowing duration, proportion of stillborn piglets and colostrum yield) and piglet characteristics (colostrum intake and body weight at 24 h of life) were also evaluated.

2. Materials and methods

This experiment followed the guidelines of The Ethical Principles and Guidelines for the Use of Animals for Scientific Purposes by the National Research Council of Thailand, and 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.

2.1. Animals, housing and general management

Sows were kept in a conventional open-housing system and were provided with fans and individual water sprinklers to control the temperature and reduce the impact of high ambient temperature. The ambient temperature inside the barn during the experimental period ranged from 25.8 to 30.0 °C. The minimum and maximum temperature ranged from 21.1 to 26.3 °C and from 28.1 to 37.6 °C, respectively. The relative humidity varied from 72.0 to 96.0%. In total, 2395 piglets born from 183 Landrace × Yorkshire crossbred sows were included. The parity of sows ranged from 1 to 5. The number of primiparous sows and sows with parity 2–5 were 57 and 126, respectively. During gestation, the sows were kept in individual stalls (1.2 m^2) and were fed a commercial gestation diet twice a day following a standardised feeding pattern. On average, the sows received 2.5 kg of feed per sow per day to meet or exceed their nutritional requirements (NRC, 2012).

Gestating sows were moved to the farrowing house approximately 1 week before the expected date of parturition. The sows were placed in individual crates (1.5 m^2) at the centre of the farrowing pens (4.2 m^2). The pens were fully slatted with a concrete base at the centre for sows and with steel slats at both sides of the farrowing crate for piglets. Each pen was provided with a warm creep area for piglets, which was placed on one side of the pen (0.60 m^2). A heating lamp was provided to piglets in the creep area during the first week after farrowing. The heating lamp was turned on during the night or when the environment temperature fell below 30 °C. Feed offered to sows was reduced to 2.0 kg for 2–3 days before farrowing. After farrowing, the amount of feed offered to sows increased daily according to the litter size and body condition of the sow until ad libitum feed was reached after 1 week of lactation. Sows and piglets had ad libitum access to water by one nipple drinker for the sow and one nipple drinker for the piglets. The parturition process was carefully monitored. The sows were interfered as little as possible during parturition. Birth assistance was performed only when an interval of 30–60 min had elapsed from the birth of the previous piglet. The birth assistance included the stimulation of uterine contraction by palpating dorsal wall of vagina (Ferguson reflex) and manual extraction of the piglets. All of the sows were treated with antibiotics and antipyretic drug after the end of the farrowing process. The sows were treated with an flunixin méglumine (50 mg/ml) 2.0 mg/kg (Fluxinic®, T.P. Drug Laboratories, Bangkok, Thailand) and amoxicillin 8.75 mg/kg i.m. (140 mg/ml amoxicillin trihydrate and 35 mg/ml clavulanic acid, Synulox™, Zoetis, USA) for 3 days postpartum. The routine procedures performed on piglets included weighing, tail docking, teeth clipping and 200 mg (1 mL) of iron dextran administered intramuscularly (Gleptosil®; Alstoe Ltd. Animal Health, Leicestershire, England) on the first day of life.

2.2. Experiment development

Sows were randomly allocated to one of the three treatment groups: (1) control group (n = 80): sows farrowed naturally; (2) PGF group (n = 50): farrowing induced using $PGF_{2\alpha}$; and (3) carbetocin group (n = 53): farrowing induced using $PGF_{2\alpha}$ combined with carbetocin. On day 114 of gestation, sows in the PGF and carbetocin groups were treated with 2 ml of a $PGF_{2\alpha}$ analogue (cloprostenol 175 μg; Planate®; MSD, Dublin, Ireland) injected intramuscularly in the cervical area. The sows were treated with $PGF_{2\alpha}$ analogue at 0800–0900 h on day 114 of gestation. After 24 h (at 0800 h on day 115 of gestation), sows in the carbetocin group were injected intramuscularly with 0.3 μg/kg of carbetocin (0.05 mg/ml Decomoton®; Laboratorios Calier, Barcelona, Spain) (1 ml for gilts and 1.5 ml for sows). The sows that farrowed within 24 h after $PGF_{2\alpha}$ administration were included in the PGF group (n = 17). The animals were individually monitored during the farrowing process. Sows that farrowed between 0700 and 1700 h were defined as sows that farrowed during working hours.

The sow parameters recorded during the experiment were backfat thickness (measured the day before parturition at the last rib and 6–8 cm from the midline using A-mode ultrasonography; Renco-Lean meter®; Minneapolis, MN, USA), gestation length (calculated from the date of first insemination to the date of farrowing), farrowing duration (defined as the time interval between the expulsion of the first and last piglets), total number of piglets born per litter (NTB), number of piglets born alive per litter (NBA), number of stillborn per litter and mummified foetuses per litter. The occurrence of birth assistance was also recorded.

Piglet parameters recorded during the experiment consisted of the birth interval (min), birth order and rectal temperature 24 h after birth measured using a digital thermometer (Verridian Dual Scale 9-Second Digital Thermometer Model 08-357; Verridian Healthcare Co. Ltd., IL, USA; display resolution of 0.01 °C and ± 0.1 °C accuracy). Piglets were weighed immediately after birth and again at 24 h using a digital scale (SDS® IDS701-CSERIES, SDS (Yangzhou) Digital Scale Co. Ltd., Yangzhou, China). All piglets were individually identified by an ear tattoo performed at birth.

Individual colostrum intake of the piglets was estimated by an equation published by Theil et al. (2014): Colostrum consumption (g) = -106 + 2.26WG + 200BWB + 0.111D–1414WG/D + 0.0182WG/BWB, where WG is piglet weight gain (g), BWB is birth weight (kg) and D is the duration of colostrum suckling (min). The colostrum yield of the sows was defined as the sum of individual colostrum consumption of all piglets in the litter.

2.3. Statistical analysis

The statistical analyses were carried out using SAS (version 9.0, SAS Institute Inc., Cary, NC, USA). Descriptive statistics were generated using the MEANS procedure of SAS for sow and piglet characteristics including the number of non-missing values, mean values and range. The distribution of the data was determined using the UNIVARIATE

procedure of SAS. Sow parameters (backfat thickness, gestation length, farrowing duration, NTB, NBA and colostrum yield) were analysed by general linear models using the GLM procedure of SAS. The statistical models included the treatment group (control, PGF and carbetocin) as the main effect and parity group (primiparous and multiparous) as a fixed effect, as well as the interaction between parity group and treatment group. The percentage of sows that farrowed during working hours (0700–1700 h) were compared between groups using a chi-square test. The incidence of birth assistance and the proportion of sows that farrowed after 115 days were regarded as binomial traits and were analysed by a generalised linear model using the GENMOD procedure of SAS. The statistical models included the treatment group as main effect. Parity groups (primiparous and multiparous) were introduced as a fixed effect and the interaction between parity groups and treatment groups were also introduced. Differences in least square means were compared by the least significant difference test.

Piglet parameters (birth interval, body weight, rectal temperature and colostrum intake) were analysed by general linear mixed models using the MIXED procedure of SAS. In all models, the sow was considered the experimental unit and was introduced as a random effect nested within treatment. In all models, the treatment group was introduced as the main effect. Parity groups (primiparous and multiparous), body weight of the piglet at birth (≤ 1.35, 1.36–1.60 and > 1.60 kg), birth order (1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15 and ≥ 16) were introduced as fixed effects, and the two-way interactions were also introduced. Difference of least square means were compared using the Tukey-Kramer test. A P-value < 0.05 was considered statistically significant.

3. Results

3.1. Sow parameters

The effect of treatment on sow reproductive parameters is presented in Table 1.

3.1.1. Farrowing duration

On average, the farrowing duration of the sows was 274 ± 209 min (4.6 h). Of all the sows (n = 183), 8.2% (n = 15), 49.2% (n = 90) and 42.6% (n = 78) had a farrowing duration of 30–119, 120–240 and > 240 min, respectively. The farrowing duration did not differ between primiparous (302 ± 32 min) and multiparous (259 ± 19 min) sows (P = 0.248). Likewise, the duration of farrowing did not differ between control (289 ± 24 min), PGF (294 ± 37 min) and carbetocin (259 ± 34 min) groups (P > 0.05). The proportion of sows that spent more than 240 min farrowing were 36.3% (n = 29), 54.0% (n = 27) and 41.5% (n = 22) in the control, PGF and carbetocin groups, respectively (P = 0.272).

3.1.2. Gestation length

On average, the gestation length of the sows was 114.9 ± 0.91 days (mean ± SD). Gestation length did not differ between primiparous and multiparous sows (114.8 ± 0.13 and 114.9 ± 0.08 days, respectively; P = 0.559). Fig. 1 shows the distribution of gestation length in the control (1a), PGF (1b) and carbetocin (1c) groups. As shown in the figure, the gestation length varied from 112–118, 114–117 and 115–116 days in the control, PGF and carbetocin groups, respectively. The proportion of sows that farrowed after 115 days in the control group (24/80 sows, 30.0%) was higher than in the PGF (3/50 sows, 6.0%, P = 0.002) and carbetocin (4/53 sows, 7.5%) groups (P = 0.003). Furthermore, the variability in gestation length was reduced in the carbetocin group with 92.5% of sows of this group farrowed at day 115 of gestation while 62.0% of sows in the PGF group farrowed at day 115 and 32.0% at day 114 and in the control group 35.0% of sows farrowed at day 115 and 21.3% at day 114 (Fig. 1).

3.1.3. Proportion of sows that farrowed during working hours

After the injection of $PFG_{2\alpha}$, the onset of parturition occurred at 39.9 ± 21.0 h and 39.0 ± 2.8 h in the PGF and carbetocin groups, respectively. In the carbetocin group, the interval from carbetocin injection to the onset of parturition was 3.3 ± 2.7 h. Fig. 2 shows the distribution of the onset of farrowing during the day in control (2a), PGF (2b) and carbetocin (2c) groups. The percentage of sows that farrowed during working hours in the control group (47.5%) was lower than in the PGF (66.0%, P < 0.05) and carbetocin (98.1%, P < 0.001) groups. The PGF and carbetocin groups had a higher proportion of sows farrowing during working hours than the control group (+ 18.5%, P = 0.039 and + 50.6%, P < 0.001; respectively). Furthermore, the proportion of sows farrowing during working hours in the carbetocin group was higher than in the PGF group (+ 32.1%, P < 0.001).

3.1.4. Colostrum yield

The average colostrum yield of sows was 4788 ± 1374 g. The maximum colostrum yield was 8610 g. Colostrum yield in the control, PGF and carbetocin groups was 4836 ± 148, 4896 ± 229 and 4050 ± 207 g, respectively (Fig. 3). The colostrum yield of sows in the

Table 1
Reproductive data of sows and piglets that farrowed naturally compared to those that were induced using prostaglandin $F_{2\alpha}$ ($PGF_{2\alpha}$) or $PGF_{2\alpha}$ in combination with carbetocin (least squares mean ± SEM).

Variables	Natural farrowing	Induced farrowing		P-value
		$PGF_{2\alpha}$	$PGF_{2\alpha}$ + carbetocin	
Sows	n = 80	n = 50	n = 53	
Gestation length, days	114.8 ± 0.1[a]	114.7 ± 0.2[a]	115.1 ± 0.1[a]	0.175
Parity number	2.2 ± 0.1[a]	2.0 ± 0.2[a]	2.1 ± 0.2[a]	0.707
Backfat thickness, mm	14.7 ± 0.3[a]	15.6 ± 0.5[a]	15.7 ± 0.5[a]	0.150
Farrowing duration, min	289 ± 24[a]	294 ± 37[a]	259 ± 34[a]	0.723
Total number of piglet born/litter	13.5 ± 0.4[a]	13.5 ± 0.6[a]	13.3 ± 0.5[a]	0.909
Number of piglets born alive/litter	12.3 ± 0.3[a]	12.7 ± 0.5[a]	12.1 ± 0.5[a]	0.769
Stillborn, %	6.1 ± 0.87[a]	4.0 ± 1.36[a]	4.7 ± 1.23[a]	0.396
Colostrum yield, g	4836 ± 148[a]	4896 ± 229[a]	4050 ± 207[b]	< 0.001
Birth assistance, %	33.8[a]	50.0[a]	73.6[b]	< 0.001
Piglets	n = 1058	n = 652	n = 685	
Birth interval, min	17.1 ± 1.2[a]	20.7 ± 1.9[a]	19.3 ± 1.7[a]	0.238
Rectal temperature at 24 h, °C	38.5 ± 0.1[a]	38.1 ± 0.1[b]	37.9 ± 0.1[b]	< 0.001
Body weight at 24 h, kg	1.52 ± 0.01[a]	1.51 ± 0.02[ab]	1.46 ± 0.02[b]	0.007
Colostrum intake, g	423.7 ± 10.0[a]	409.2 ± 15.2[a]	355.2 ± 12.9[b]	< 0.001

[a,b] Different superscript letters within the same row differ significantly (P < 0.05).

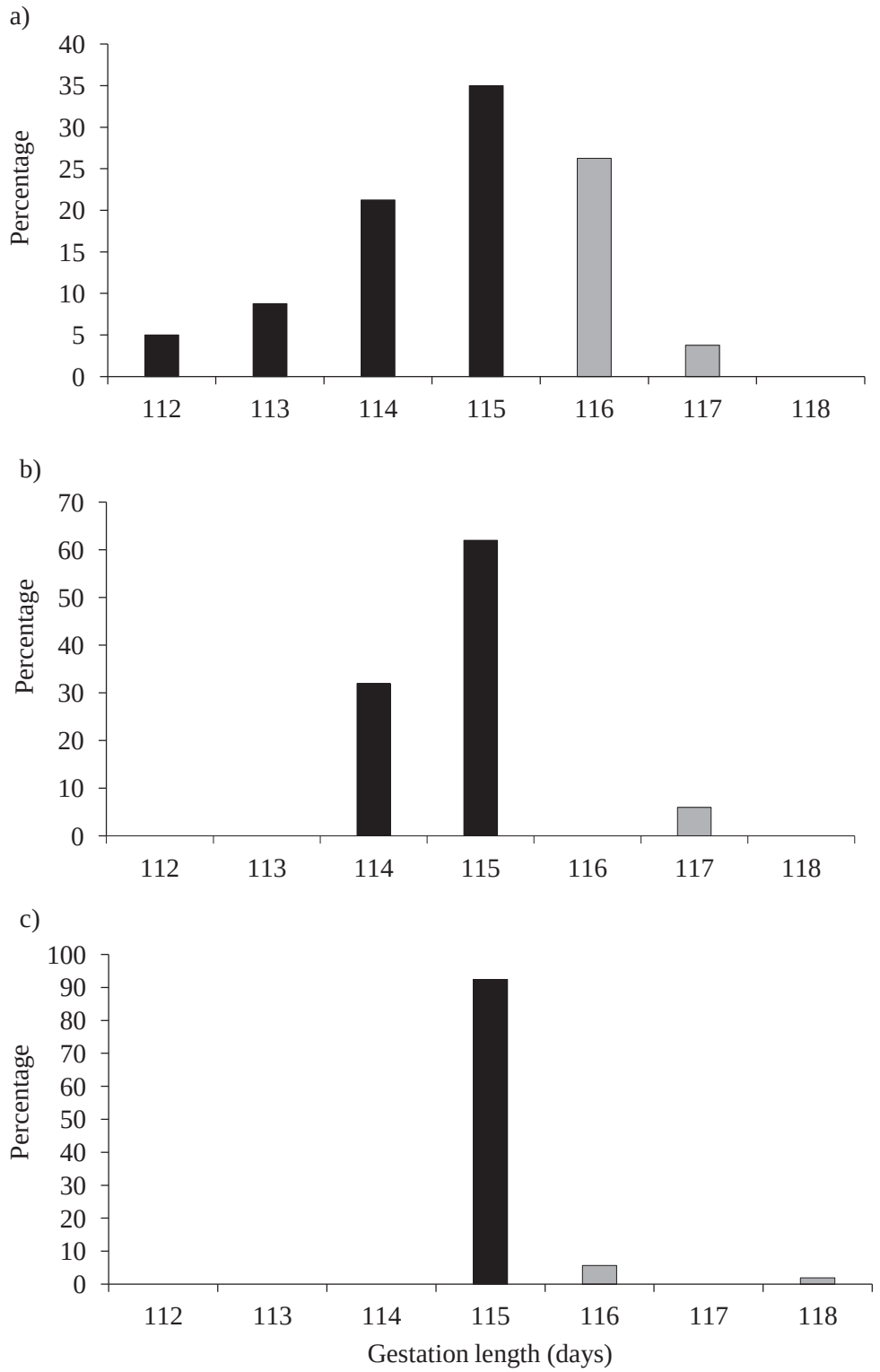

Fig. 1. Distribution of gestation length (days) in sows that farrowed naturally (a) compared to those that were induced by prostaglandin $F_{2\alpha}$ ($PGF_{2\alpha}$) (b) or $PGF_{2\alpha}$ in combination with carbetocin (c).

carbetocin group was lower than in the control ($P = 0.018$) and PGF ($P = 0.006$) groups. The colostrum yield of multiparous sows was higher than primiparous sows (5020 ± 115 and 4767 ± 196 g, respectively; $P = 0.002$).

3.1.5. Stillborn piglets and birth assistance

On average, the proportion of stillborn piglets was 6.1%, 4.0% and 4.7% in the control, PGF and carbetocin groups, respectively (Table 1). No significant difference in the proportion of stillborn piglets was observed among groups ($P > 0.05$). Of the 183 sows, 92 (50.3%) did not require any birth assistance. Among the sows that needed birth assistance, the number of piglets that needed assistance at birth varied among litters, ranging from 1 to 11. The proportion of birth assistance was 33.8%, 50.0% and 73.6% for the control, PGF and carbetocin

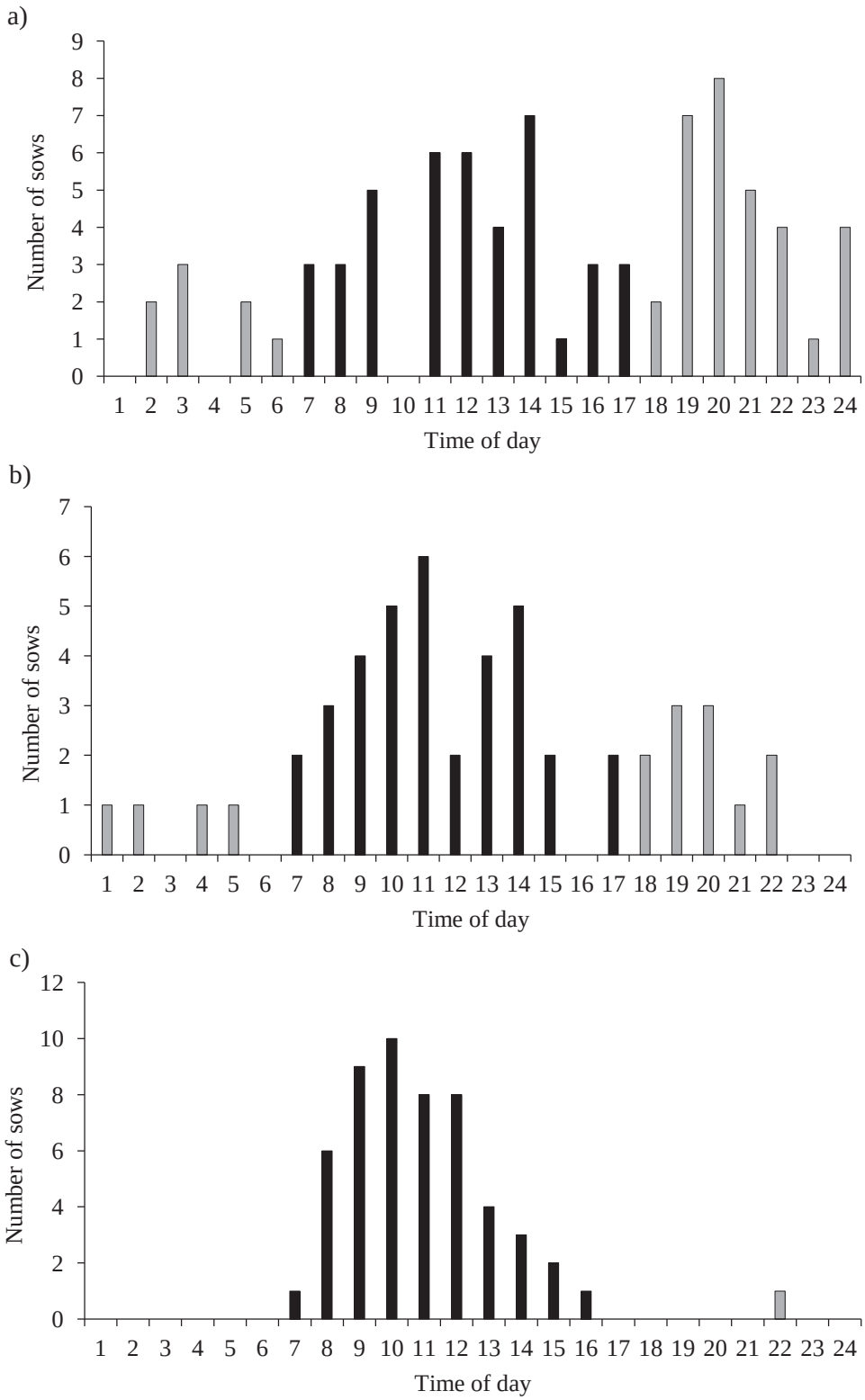

Fig. 2. Distribution of the onset of farrowing in sows that farrowed naturally (a) compared to those that were induced by prostaglandin $F_{2\alpha}$ ($PGF_{2\alpha}$) (b) or $PGF_{2\alpha}$ in combination with carbetocin (c).

groups, respectively (Table 1). The incidence of birth assistance was higher in the carbetocin group than the control ($P < 0.001$) and PGF ($P = 0.011$) groups, respectively.

3.2. Piglet characteristics

The effects of treatment on piglet characteristics are presented in Table 1. The piglets birth interval (20.7 ± 55.8 min) did not differ among treatments ($P > 0.05$). The body weight of the piglets at 24 h in the carbetocin group was lower than piglets in the control group

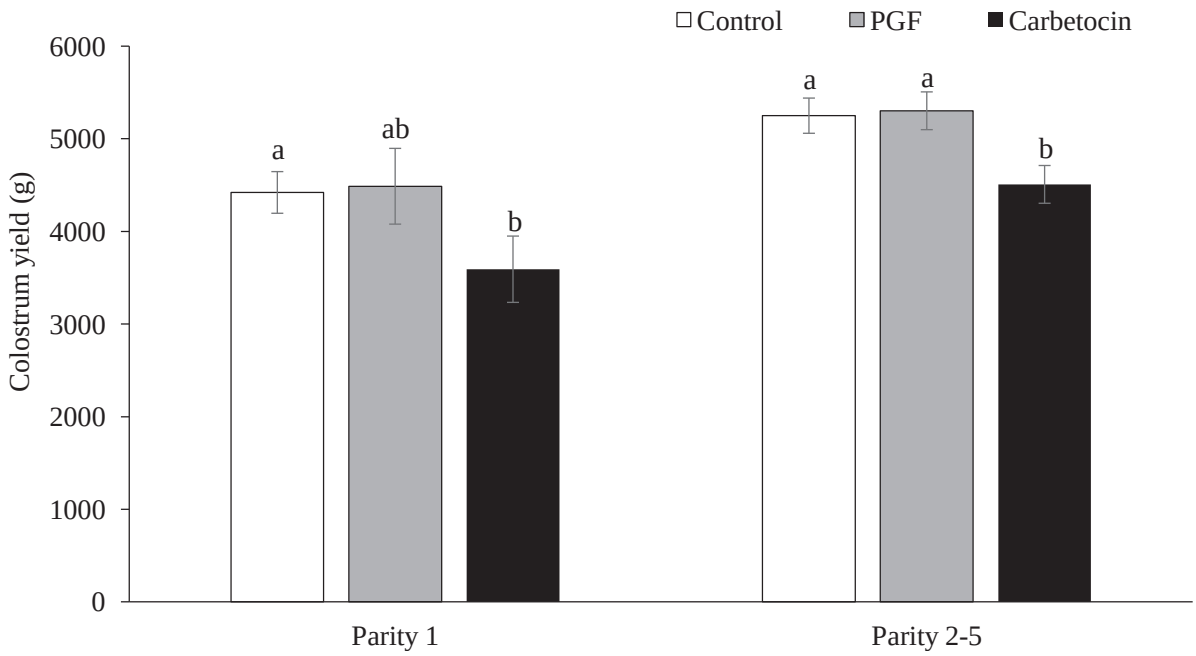

Fig. 3. Colostrum yield (least squares means ± SEM) in sows that farrowed naturally (control group) and those that were induced by prostaglandin $F_{2\alpha}$ ($PGF_{2\alpha}$; PGF group) or $PGF_{2\alpha}$ in combination with carbetocin (carbetocin group).

($P = 0.005$) and tended to be lower than the piglets in the PGF group ($P = 0.061$; Table 1). The rectal temperature at 24 h in the control group was higher than in the PGF ($P = 0.045$) and carbetocin ($P < 0.001$) groups, respectively (Table 1). The average colostrum intake was 411.6 ± 174.9 g (range 8.9–1581.0 g). The colostrum intake of piglets in the carbetocin group was lower than in the control ($P < 0.001$) and PGF ($P = 0.025$) groups (Table 1).

4. Discussion

4.1. Proportion of sows farrowing during working hours

The present study revealed that the induction of parturition using either $PGF_{2\alpha}$ alone or in combination with carbetocin can increase the proportion of sows that farrow during working hours by up to 66% and 98%, respectively. Furthermore, these treatments also reduce the proportion of sows that farrow after 115 days gestation. Earlier studies reported that only 50–60% of sows treated with $PGF_{2\alpha}$ alone farrowed during the working hours of the day (Kirkwood and Aherne, 1998; De Rensis et al., 2002; Cassar et al., 2005). Interestingly, the use of carbetocin after $PGF_{2\alpha}$ administration significantly improve the efficiency of farrowing induction by increasing the proportion of sows that farrow during the working hour. This enable farrowing supervision to be performed effectively. The reasons might be associated with a long-action oxytocin-like properties of carbetocin that stimulate uterine contraction and initiate the farrowing process of sow. In the present study, the onset of farrowing occurs at 3.3 h after carbetocin treatment. Furthermore, the variation of the timing of farrowing after $PGF_{2\alpha}$ treatment is significantly reduced after carbetocin administration. Therefore, the combination of $PGF_{2\alpha}$ and carbetocin could be an option for controlling the time of parturition in sows. Gunvaldsen et al. (2007) demonstrated that induction of farrowing can increase labour efficiency, minimise weekend farrowing and promote all-in/all-out management. Moreover, Nguyen et al. (2011) found that 75% of sows that received $PGF_{2\alpha}$ alone farrowed during working hours. As a result, the prevalence of stillbirths was lower for sows that had induced farrowing and assistance on the day of farrowing than those that were not induced and provided a minimal amount of assistance. In addition, Kirkden et al. (2013) found that the induction of farrowing using $PGF_{2\alpha}$ increased the synchrony of farrowing, making it more economical to provide continual supervision as well as making cross-fostering management easier and more effective. In agreement with our results, Gheller et al. (2011) observed that the application of carbetocin 24 h after the administration of $PGF_{2\alpha}$ resulted in a higher proportion of sows farrowing during working hours compared to the application of $PGF_{2\alpha}$ alone (88.7% and 62.0%, respectively). Likewise, Leike and Hühn (1992) found that the combination of cloprostenol and carbetocin increased the number of sows that farrowed during the day time. In the present study, induction of farrowing by a combination of $PGF_{2\alpha}$ and carbetocin increased both the synchrony of farrowings and the proportion of sows farrowing during working hours.

4.2. Farrowing duration

The present study revealed that the duration of farrowing in sows (274 ± 209 min) is relatively long and varies considerably among animals (from 30 to 1763 min). This is in agreement with earlier studies that found that the average duration of farrowing for sows housed in pens or crates ranged from 78 to 1410 min (van Dijk et al., 2005; Björkman et al., 2017). Furthermore, the duration of farrowing has increasing over the past decade due to increased litter sizes in the modern swine industry. In Denmark, where the total number of piglets born per litter is 19.0 piglets, the mean farrowing duration is as long as 580 min (Muns et al., 2016a). In Thailand, Tummaruk and Sang-Gassanee (2013) demonstrated that the farrowing duration among individual sows varied considerably from 76 to 500 min, with an average of 178 min. It has been demonstrated that a longer farrowing duration negatively influences the sow's health and may increase the risk of neonatal death of the piglets (Tummaruk and Sang-Gassanee, 2013). A recent study indicated that a prolonged parturition also impairs placenta expulsion and can lead to retained placenta in sows (Björkman et al., 2017). Thus, the control of parturition is important. In a previous study, the total duration of parturition could be reduced from 240 to 150 min by administering oxytocin (Mota-Rojas et al., 2005). Interesting, the average farrowing duration in the present study was slightly longer than that observed in a previous study by our research group (178.0 ± 73.5 min) (Tummaruk and Sang-Gassanee, 2013). One possible explanation may be the increased litter

size in the present study compared to the previous study (13.4 versus 11.1 piglets per litter, respectively). The duration of farrowing is influenced by many factors including breed, age of the sow, gestation length, number of piglets born, housing system, body condition of the sow and incidence of constipation (Oliviero et al., 2010). On average, sows with constipation had a 28-min longer farrowing duration than sows with normal to soft faeces (213 versus 185 min, respectively) (Pearodwong et al., 2016). Furthermore, among sows with a long farrowing duration (> 300 min), 80% had moderate to very severe constipation on the day of farrowing (Pearodwong et al., 2016). Moreover, it was found that the proportion of stillborns and the duration of farrowing were strongly correlated (van Dijk et al., 2005). An earlier study suggested that sows that were allowed to move freely before farrowing had a reduced incidence of constipation and did not show excessive fattening during late pregnancy, which lead to a reduction in farrowing time (Oliviero et al., 2010). In Thailand, most gestating sows are kept in stalls, therefore, the movement of gestating sows is limited. As a result, the risk of a long farrowing duration is high. In the present study, the proportion of sows with a long farrowing duration (> 240 min) was considerably high in all groups (36.3–54.0%). However, we found no significant effect of farrowing induction on the farrowing duration in the present study. Although the incidence of birth assistance in the carbetocin group was higher than the control group, most of the sows (98%) in the carbetocin group farrowed during working hours, making farrowing assistance possible.

4.3. Colostrum yield and colostrum intake

Devillers et al. (2007) observed that colostrum yield was reduced by up to 15% when farrowing was induced on day 113 of gestation. On the other hand, Foisnet et al. (2010) found no impact of farrowing induction on day 113 of gestation on colostrum yield. In the present study, farrowing was induced on day 114 of gestation, and the use of $PGF_{2\alpha}$ alone did not influence either the colostrum intake of piglets or the colostrum yield of the sows. However, significant reductions in both colostrum intake by piglets and colostrum yield of sows were observed when farrowing was induced by a combination of $PGF_{2\alpha}$ and carbetocin. This indicates that carbetocin might have a negative effect on colostrum production and/or the ability of the newborn piglets to suckle during the first 24 h postpartum. Nevertheless, the mechanism behind the negative effect of carbetocin on colostrum production and or intake remains unknown. Declerck et al. (2017) also demonstrated a negative effect of oxytocin administration during farrowing on the colostrum intake of piglets. It was hypothesised by these authors that hormonal imbalance resulting in prolonged farrowing requiring the use of oxytocin may be the mechanism underlying the lower colostrum production. The lower colostrum intake could also be related to the consequences of oxytocin use, including intrapartum asphyxia, which impairs the vitality of piglets and compromises their colostrum intake. Likewise, the same mechanisms might be responsible for the results observed with carbetocin, although further studies are needed. In the current study, multiparous sows had a higher colostrum yield than primiparous sows. Similarly, second- and third-parity sows showed a tendency toward greater colostrum production compared to primiparous or older sows in a study by Devillers et al. (2007).

Low vitality of piglets at birth, especially due to hypoxia suffered during delivery, might impair their ability to successfully extract colostrum from the teats (Trujillo-Ortega et al., 2007; Kammersgaard et al., 2011). The amount of colostrum ingested increases with birth weight and decreases if any complications occur, such as a ruptured umbilical cord, breathing difficulties or splay leg (Delivers et al., 2007). Mota-Rojas et al. (2006) found that the piglets that were born from oxytocin-treated sows had more than a 5-min delay in standing on their feet at birth, indicating severe anoxia and extreme weakness. In the present study, the colostrum intake of piglets from sows that had undergone farrowing induction using $PGF_{2\alpha}$ in combination with carbetocin was lower than the other groups. This could be because carbetocin is a long-acting oxytocin analogue which stimulates prolonged uterine contraction. Therefore, like oxytocin, carbetocin can also cause adverse effects on the piglets. However, studies investigating the use of carbetocin observed no adverse effect on the frequency of farrowing assistance (Gheller et al., 2011) or on piglet blood pH (an indicator of intra-partum asphyxia) (Wehrend et al., 2005). According to our study, there was no significant difference in the proportion of stillborn piglets among the groups. Nevertheless, the present study is the first to demonstrate the negative effect of carbetocin treatment on piglet colostrum intake. Based on our results, piglets born after carbetocin treatment should be supervised carefully. If possible, colostrum consumption should be enhanced by providing extra colostrum or energy booster supplementation (Muns et al., 2017).

Farrowing supervision and care of neonatal piglets are important management strategies to increase the colostrum intake of the piglets. Enhanced assistance of weak piglets can improve their vitality and ability to suckle (Boulot et al., 2008). However, preparing the sows before parturition (e.g., reduced fatness and constipation) is essential to reduce the farrowing duration and minimize birth assistance, thereby reducing the number of weak and hypoxic piglets at birth (Oliviero et al., 2010).

In conclusion, induction of parturition by $PGF_{2\alpha}$ in combination with carbetocin administered 24 h later increased the proportion of sows that farrowed during working hours. However, piglets born after induction of parturition using $PGF_{2\alpha}$ in combination with carbetocin had a lower colostrum intake compared to piglets from natural farrowings or induction by $PGF_{2\alpha}$ alone. Thus, the care of newborn piglets should be increased when the combined protocol ($PGF_{2\alpha}$ + carbetocin) is implemented.

Conflicts of interest

We declare that we have no conflicts of interest.

Acknowledgments

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Porcine circovirus type 3 (PCV3) shedding in sow colostrum

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ABSTRACT

The major objective of this work was to investigate the shedding of porcine circovirus type 3 (PCV3) in sow colostrum. PCV3 titers in the serum and colostrum samples of 38 sows were determined using qPCR. Interestingly, this is the first report regarding the identification of PCV3 from the colostrum samples. In the studied farm, the prevalence of PCV3 in the colostrum samples was 44.74% (17/38). When sows were grouped based on the PCV3 titers in the serum into the "High-viremic", "Low-viremic" and "Non-viremic" sows, it was shown that the High-viremic sows showed significantly higher PCV3 colostrum prevalence (100%; 9/9) with the PCV3 titers ranging from 4.01 to 7.33 genomic copies/mL. The results indicated that PCV3 in the colostrum might be partly influenced by the viremic stage of the infection. However, the results also showed that approximately 41% of sows shedding PCV3 with low titers in the colostrum (7/17) were non-viremic sows. In conclusion, this study identified the presence of PCV3 in sow colostrum. Clinical impacts and mechanisms of colostrum shedding of PCV3 should be further investigated.

1. Introduction

Porcine circovirus type 3 (PCV3) is a newly emerging virus in pigs, which has been reported worldwide. Although the pathogenesis of PCV3 is still unknown, the virus has been detected in pigs with several clinical outcomes including reproductive failure in sows (Palinski et al., 2017; Tochetto et al., 2017; Wang et al., 2017), aborted/mummified/stillborn fetuses (Faccini et al., 2017; Ku et al., 2017; Palinski et al., 2017), myocarditis (Phan et al., 2016), porcine dermatitis and nephropathy syndrome (PDNS) (Palinski et al., 2017; Wang et al., 2017), diarrhea (Zhai et al., 2017), respiratory disease (Kedkovid et al., 2018; Phan et al., 2016; Shen et al., 2017), and neurologic disease (Chen et al., 2017; Phan et al., 2016). The virus can also be found in clinically healthy pigs (Kedkovid et al., 2018; Zheng et al., 2017).

PCV3 has been detected in pigs of different ages (Kedkovid et al., 2018; Kwon et al., 2017; Palinski et al., 2017; Stadejek et al., 2017). However, PCV3 transmission in the infected herds has not been well-characterized. In general, vertical transmission of the virus could be extremely crucial to maintenance and spread within a herd. Previously, it has been shown that PCV2 transmission via colostrum has played a major role for the infection of suckling piglets and the virus could consequently be found in weanling pigs later via horizontal transmission (Dvorak et al., 2013; Ha et al., 2010).

It should be noted that PCV3 shedding via the colostrum has not previously been reported. In this study, we describe the first known identification of PCV3 from colostrum samples of sows in a PCV3-infected herd in Thailand. The relationship of PCV3 titers in serum and colostrum samples was investigated and discussed.

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2. Materials and methods

2.1. Samples and data collection

Matched serum and colostrum samples for this study were used with permission from a previous study by Juthamanee et al. (2017). The samples were collected cross-sectionally from 38 sows of parity 1–6, from a farm in Ratchaburi province, Thailand, in 2017. Both serum and colostrum samples were collected within 6 h after parturition. The sample collection protocol has been reviewed and approved by Chulalongkorn University Animal Care and Use Committee (Animal use protocol number: 1731064). In this farm, porcine reproductive and respiratory syndrome virus (PRRSV) and PCV2 are endemic and sow vaccinations against these viruses are routinely performed. PCV3 was previously identified in this farm by PCR during farm monitoring. Reproduction parameters of the studied sows including total born (TB), born alive (BA), stillborn (SB), and mummified fetuses (MF), were retrieved from the farm records.

2.2. Virus detection and quantification

Virus nucleic acid was extracted from the serum and colostrum samples using NucleoSpin RNA Virus Kit (Macherey-Nagel, Germany). Prior to the extraction, the fat layer was removed from the colostrum samples by centrifugation at 900*g* for 10 min, as previously described (Ha et al., 2010). The serum was used directly for the extraction. For each extraction reaction, 150 µL of the samples were used. For PCV3 detection and quantification, a previously published TaqMan-based qPCR assay (Wang et al., 2017) targeting nt 1351 to 1428 of PCV3 genome (ORF2) was used with minor modification. Briefly, the PCR reaction was performed using QuantiFast Probe PCR Kit (Qiagen, Germany) and MyGo Pro (IT-IS Life Science, Ireland) instrument. DNA fragment covering nt 601 to 1626 of PCV3 genome was generated using previously published PCR assay (Palinski et al., 2017) and used in the standard curve generation. This DNA fragment was also used as a positive control for the qPCR assay. The standard curve was generated using 10-fold serial dilutions ranging from 10^8 to 10^1 copies/µL of the positive control DNA fragment. Copy number calculation of the target DNA was done using the internal software of the instrument. The detection limit of the assay was 4 log genomic copies/mL. PCV2 detection was done using a previously published conventional PCR assay targeting PCV2 ORF1 (Paphavasit et al., 2009) with minor modification. The PCR reaction was performed using DreamTaq Green PCR MasterMix (Thermo Fisher Scientific, USA). The PCR product of 356 bp was determined using 1.5% agarose-gel electrophoresis.

To confirm the presence of PCV3 in the colostrum sample, DNA sequencing was performed. A colostrum sample showing high PCV3 titer was randomly selected. PCR targeting partial ORF2 region (nt 1 – 363 of the full 645 nt ORF2) of PCV3 was done using a previously reported assay (Palinski et al., 2017). The PCR product was submitted to First BASE Laboratories Sdn Bhd (Malaysia) for sequencing. The sequence was analyzed using BioEdit 7.0.9.0. The sequence of this Thai PCV3 was named PCV3/Thailand/RB01/17 and deposited in GenBank (www.ncbi.nlm.nih.gov/genbank/) with the accession number MH158731. Nucleotide identity calculation and cladogram generation were done using MEGA 5.2. Previously reported ORF2 DNA sequences of PCV3 (n = 177), PCV2 (GenBank accession number AF027217), and PCV1 (GU799575) were retrieved from GenBank for nucleotide identity calculation. For cladogram, PCV3 ORF2 sequences used (n = 51) were from 1) PCV3 previously characterized into four subgroups: a1, a2, b1, and b2 (n = 40) (Fux et al., 2018); 2) PCV3 strains showing high nucleotide identity (over 99.00%) with PCV3/Thailand/RB01/17 (n = 4); 3) a previously reported Thai PCV3 (n = 1); and 4) recently reported PCV3 strains from Italy and Denmark (n = 5).

2.3. Statistical analysis

Statistical analysis was performed using GraphPad Prism 5. The overall prevalence and virus titers of PCV3 between the serum and colostrum samples were compared using McNemar test (for prevalence comparison) and Wilcoxon signed rank test (for titers comparison). The relationship between the PCV3 titers in the serum and colostrum samples was determined using Spearman's rank correlation test. The strength of the correlation was interpreted from the Spearman's rho values as follows: 0.00–0.19, very weak; 0.20–0.39, weak; 0.40–0.59, moderate; 0.60–0.79, strong; 0.80–1.00, very strong. Pigs were divided into three groups based on the PCV3 titers in the serum including "Non-viremic" (PCV3 was not detected), "Low-viremic" (PCV3 titers below the median of the positive serum titers), and "High-viremic" (PCV3 titers above the median of the positive serum titers). Prevalence and titers of PCV3 in the colostrum were compared among these three groups using Fisher's exact test (for prevalence comparison) and Kruskal-Wallis H test (for virus titers comparison). Comparisons of reproduction parameters between PCV3 positive and negative animals were done using Mann Whitney U test. Statistical significance was set at $p < 0.05$. Mean values were reported as mean ± standard deviation.

3. Results

3.1. PCV3 prevalence in serum and colostrum samples were not different

The prevalence of PCV3 in the serum and colostrum samples was determined to provide an initial data on PCV3 viremia and colostrum shedding status. The numbers of PCV3-positive serum and colostrum samples using qPCR from all sows are shown in Table 1. The prevalence of the PCV3-positive serum and colostrum samples were not statistically different (Fig. 1A). The virus titers between these sample types were not statistically different either. The average PCV3 titers in the serum and colostrum of the positive animals were 5.06 ± 0.44 (n = 18) and 5.02 ± 1.08 (n = 17) log genomic copies/mL, respectively. When taking both types of samples into account, the prevalence of PCV3-positive animals (in at least one type of the samples) increased to 65.79% (25/38). However, it was not significantly different from the single sample prevalence. PCV3 prevalence in the sows of each parity is shown in Fig. 1B.

The presence of PCV3 in the colostrum samples was confirmed by DNA sequencing. Partial ORF2 DNA sequences of PCV3/Thailand/RB01/17 showed 95.04–99.17% nucleotide identity with the other PCV3 strains. However, the virus showed 54.41 and 52.92% nucleotide identity with PCV2 and PCV1, respectively. PCV3/Thailand/RB01/17 showed 97.80% nucleotide identity with the previously reported Thai PCV3. The cladogram showed that PCV3/Thailand/RB01/17 clustered in PCV3a subgroup (Fig. 2).

3.2. PCV3 titers in the serum and colostrum samples were positively correlated

To gain more information regarding the relationship between PCV3 in the serum and colostrum samples, correlation between the PCV3 DNA from both sample types was determined. From the data of all sows, a significant positive correlation of PCV3 titers between the serum and

Table 1
PCV3 DNA detection results from the serum and colostrum samples.

		Serum		
		Positive	Negative	Total
Colostrum	Positive	10	7	17
	Negative	8	13	21
	Total	18	20	38

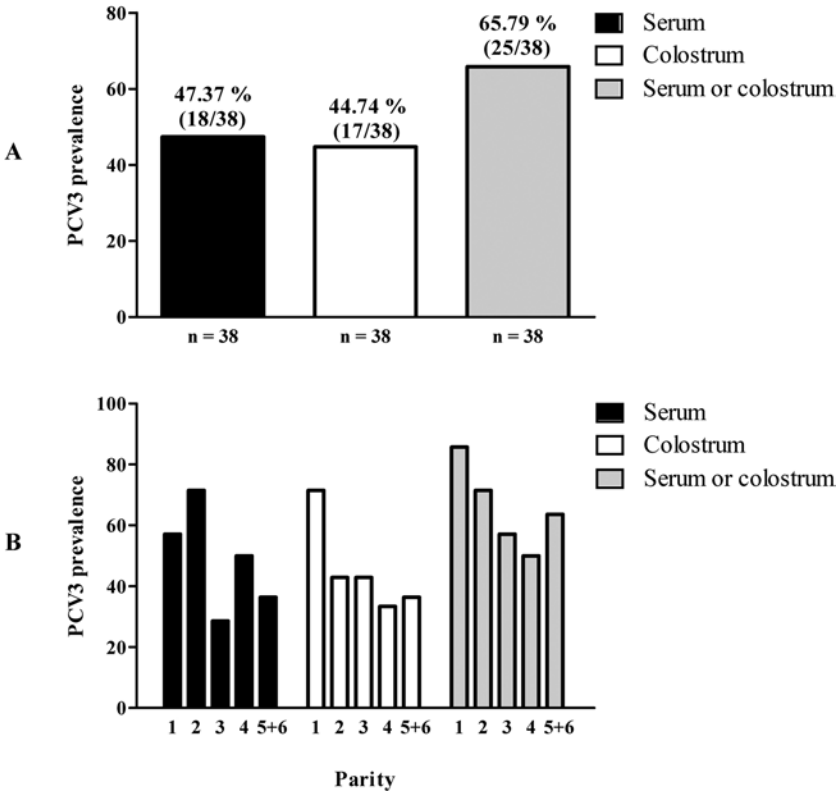

Fig. 1. Prevalence of PCV3 in the serum and colostrum samples of sows. Overall prevalence of PCV3 in each sample type (A) and PCV3 prevalence in different parities of sows (B) were measured using qPCR. Percentages of PCV3 positive samples are shown above the graph. Number of positive animals and total animals are shown in the parenthesis.

colostrum samples was found, with the correlation coefficient of 0.49. The colostrum shedding was then characterized in more detail regarding to the PCV3 viremia level.

Sows were further divided into three groups based on the viremia status, including High-viremic, Low-viremic and Non-viremic sows. The serum virus titers of the serum-positive animals ranged from 4.36 to 6.15 log genomic copies/mL with the median of 5.04 log genomic copies/mL. The prevalence and titers of PCV3 in the colostrum samples of the Non-viremic, Low-viremic, and High-viremic sows are shown in Fig. 3. The PCV3 titers in the colostrum of the non-viremic and viremic pigs ranged from 4.06 to 4.42 and 4.01–7.33 log genomic copies/mL, respectively. The prevalence and titers of PCV3 in the colostrum samples of the High-viremic sows were significantly higher than the other groups (Fig. 3A and B, respectively). It should be noted that PCV2 was not detected in any of the colostrum samples tested.

3.3. Performance of sows with different PCV3-viremic and PCV3-shedding statuses were not different

To describe the clinical impact of PCV3 viremia/shedding status in this farm, sows' reproduction parameters were determined. The numbers of TB and BA were not significantly different between the PCV3-viremic sows (12.94 ± 2.78 and 12.61 ± 2.75, respectively) and non-viremic sows (12.30 ± 4.26 and 10.85 ± 3.36, respectively). The numbers of TB and BA in the sows with PCV3-colostrum shedding (12.53 ± 3.41 and 11.59 ± 2.62, respectively) were not significantly different from the non-shedding sows (12.67 ± 3.83 and 11.76 ± 3.62, respectively).

4. Discussion

This study was conducted to investigate the colostrum shedding of PCV3 in sows from a PCV3-infected herd in Thailand. An association between colostrum shedding and viremia status, and the colostrum shedding patterns of sows of each parity were also described.

At present, vertical transmission of PCV3 is not well characterized. From previous studies, two routes including trans-placenta and direct-contact transmission could be implied. It has been shown that PCV3 could be detected from sows showing reproductive failure and also from the mummified and stillborn fetuses (Faccini et al., 2017; Ku et al., 2017; Palinski et al., 2017; Tochetto et al., 2017), suggesting trans-placental transmission. Direct-contact transmission might occur from the virus shedding via oral fluids. A work from Kwon and colleagues showed that PCV3 can be found in the oral fluid samples of naturally infected pigs (Kwon et al., 2017). Additionally, PCV3 DNA can also be detected in the salivary gland (Kedkovid et al., 2018). In this study, we showed the first evidence of shedding of PCV3 via colostrum.

Interestingly, there was a relationship between the colostrum shedding and the viremia status. In the studied farm, the PCV3 prevalence in the colostrum was not different from the serum (approximately 45–47%). The results further showed that the virus titers in the serum and colostrum were positively correlated. These results indicated that, as could be expected, PCV3 shedding in the colostrum might in part be influenced (directly or indirectly) by the virus in the blood circulation. However, the degree of correlation between the colostrum and serum titers was found to be only 'moderate'. This could be partly explained by the pattern of PCV3 shedding in the colostrum observed in this study. Apparently, when the serum titers were above the median value (5.04 log genomic copies/mL), all sows shed PCV3 in the colostrum. When the serum titers were below the median value, the colostrum virus titers, if present, dropped rapidly to the baseline level, rather than gradually decreasing. It was also shown in this study that approximately 41% of pigs (7/17) showing PCV3 in the colostrum were non-viremic pigs. All of these pigs shed low amount of PCV3 in the colostrum. Similarly, shedding by non-viremic pigs could also be observed in PCV2-infected pigs (Schmoll et al., 2008), and could occur in the late or recovery stage of sows, before farrowing. However, the mechanism for this has not yet been clarified. For PCV3, further studies should also be conducted to investigate the mechanisms of colostrum shedding, especially in the non-viremic pigs.

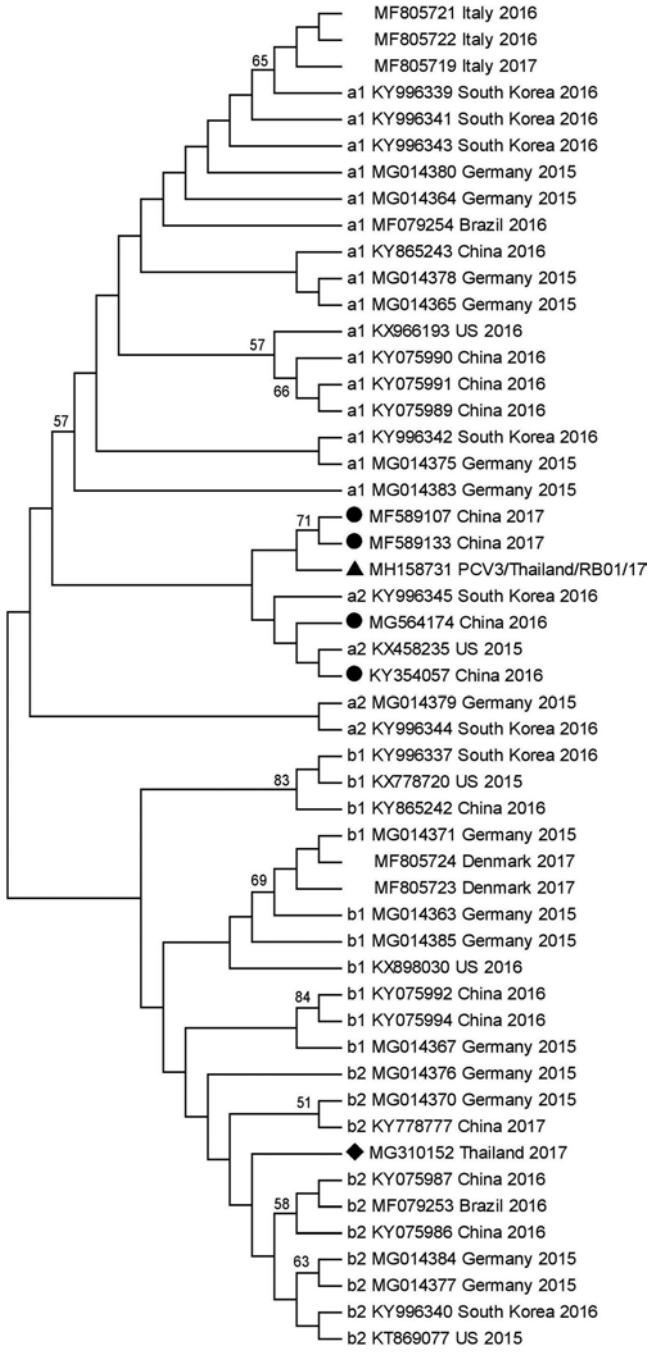

Fig. 2. Maximum likelihood cladogram of PCV3/Thailand/RB01/17 and other PCV3 strains based on partial ORF2 nucleotide sequences. The tree was constructed based on the general time reversible model with G + I. Bootstrap values (1000 replicates) for each node are displayed next to the branch if > 50%. PCV3 strains are shown with the GenBank accession numbers, the country of origin, and the collection year. PCV3/Thailand/RB01/17 is labeled with a black triangle. The previous Thai PCV3 is labeled with a black diamond. PCV3 strains with high nucleotide identity (> 99.00%) with PCV3/Thailand/RB01/17 are labeled with black circles. PCV3 strains previously classified into subgroups; a1, a2, b1, and b2 (Fux et al., 2018); are shown with prefixes indicating the subgroup.

The colostrum titers of PCV3 observed in this study is comparable to a previous study of PCV2. Dvorak and colleagues have shown that in five studied farms, average PCV2 titers in the colostrum ranged from approximately 4 to 7 genomic copies/mL (Dvorak et al., 2013). In the present study, PCV3 titers in the colostrum also ranged from 4.01 to 7.33 genomic copies/mL. In this study, the prevalence of PCV3 shedding in the colostrum of the primiparous sows was approximately 71% while the multiparous sows showed approximately 33–43%. Not only that, lower parity sows tend to have more positive animals than higher parity sows based on the presence of PCV3 in the serum and colostrum. This is in line with our previous study (Kedkovid et al., 2018). In PCV2, the clinical impacts of primiparous sows were also reported (Fraile et al., 2009). It was shown that piglets from primiparous sows had higher risk of PCV2-PRRSV coinfection compared with the multiparous sows. The impacts of PCV3 shedding in primiparous sows should be further investigated so effective management and control can be identified in the future.

Clinical impact of PCV3 shedding in the colostrum was not observed in this study. The sow performance parameters were not different among sows with different PCV3 statuses. It is possible that the number of sows used in this study is not sufficient to detect a small or infrequent effect. More importantly, it should be noted that data regarding PCV3 (and other pathogens) identification and clinical signs in the suckling piglets of these sows were not available in this study. Pathological study of PCV3 infected pigs during suckling period is still limited. In one study, PCV3 has been identified in a 19 days old pig (Phan et al., 2016). Clinical signs of the pigs included severe dyspnea and neurologic disease. Microscopic examination showed interstitial lymphocytic myocarditis, histiocytic interstitial pneumonia and acute bronchitis. Together with PCV3, porcine astrovirus 4 and equine hepacivirus were also identified from that pig using metagenomic approach. It is not clear whether PCV3 was the major pathogen (or a pathogen) in the diseased pig or not.

It is also possible that protective antibody against PCV3 is present in the colostrum. It is well-known that PCV2 maternal immunity protects the piglets against porcine circovirus associated disease (PCVAD), but not the PCV2 infection. PCVAD can become apparent after the decline of the maternally derived immunity (Calsamiglia et al., 2007; Dvorak et al., 2013; Madson and Opriessnig, 2011; McKeown et al., 2005). Early PCV3 infection (from PCV3 in the colostrum) might affect pigs at later stages of production. Recently, it has been shown that PCV3 could be involved in porcine respiratory disease complex (PRDC) in grower pigs (Kedkovid et al., 2018). In the previous study, PCV3 infection occurred as early as 5 weeks of age (the earliest age of the study). Subclinical infection of PCV3 was also identified in that study. Therefore, PCV3 infection during suckling period might result in a more severe outcome in the nursery and grower periods.

Colostral shedding of PCV2 was not observed in this study while the shedding of PCV3 was found in approximately 45% of the tested sows. Interestingly, it has been previously shown that coinfection between PCV3 and other viruses especially PCV2 could be observed (Ku et al., 2017; Zhang et al., 2017; Zheng et al., 2017). The absence of PCV2 in the colostrum in this study may be partly due to the routine sow vaccination against PCV2 (Madson et al., 2009). It has been shown that PCV2 dynamics could be affected by co-infection with other pathogens (Sinha et al., 2011). It is unknown whether PCV3 shedding pattern would be altered or not if animals were co-infected with other pathogens. Further studies are needed to clarify the effects of co-infection on PCV3 shedding.

Previously, it has been suggested that PCV3 can be classified into two major groups PCV3a and PCV3b (Fux et al., 2018). PCV3 identified in this study belongs to PCV3a as the virus clustered with the previously proposed PCV3a (Fux et al., 2018). It would be interesting to determine whether PCV3 genetic variation could affect colostrum shedding or not. Further studies are needed to clarify this issue.

5. Conclusion

In this study, the results showed that PCV3 can be shed in the sow colostrum. In the studied farm, 44.74% of the studied sows shed PCV3 in the colostrum. PCV3 titers in the serum and colostrum samples were

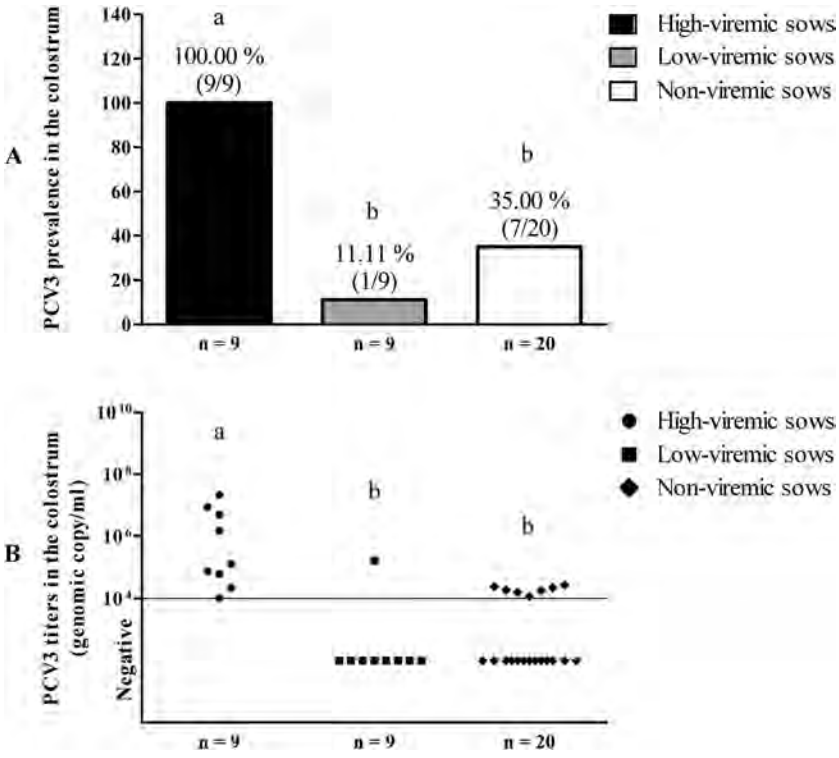

Fig. 3. PCV3 detection from the colostrum of sows with different PCV3 viremia statuses. PCV3 was measured in the colostrum samples of the High-viremic, Low-viremic, and Non-viremic sows. Prevalence (A) and virus titers (B) of PCV3 were determined using qPCR. Percentages of PCV3 positive samples are shown above the graph. Number of positive animals and total animals are shown in the parenthesis. A horizontal line (B) indicates the detection limit of the qPCR at 10^4 genomic copies/ml samples. Lower case letters above the graphs indicate statistically significant difference using Fisher's exact test (A) and Kruskal-Wallis H test (B) with $p < 0.05$.

positively correlated. However, it should be noted that non-viremic sows also shed low levels of PCV3 in the colostrum. The clinical impact of PCV3 shedding in the colostrum should be further investigated.

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Conflict of interest statement

None.

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Administration of carbetocin after the first piglet was born reduced farrowing duration but compromised colostrum intake in newborn piglets

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ABSTRACT

Carbetocin is an oxytocin-like compound with long acting properties that has recently been introduced to both human and domestic animal obstetrics. The aims of the present study were to evaluate the effects of carbetocin administration after the first piglet was born on farrowing duration, birth interval, colostrum consumption and vitality index in newborn piglets. In total, 186 sows and their offspring (n = 2611 piglets) were distributed into three groups: 1) CONTROL: sows were allowed to farrow naturally (n = 66); 2) OXY: sows were administered oxytocin 20 IU intramuscularly after the first piglet was born (n = 62); and 3) CARBE: sows were administered carbetocin 0.6 μg/kg intramuscularly after the first piglet was born (n = 58). The reproductive data of sows including farrowing duration, total number of piglets born per litter (TB), number of piglets born alive per litter (BA), proportion of stillborn piglets per litter (SB) and proportion of mummified fetuses per litter (MF) were recorded. Piglet vitality index including skin colour, integrity of the umbilical cord, heart rate, blood oxygen saturation, screaming score, udder stimulation score, movement capacity and number of completed circles around enclosure were determined. Birth weights of the piglets were measured immediately at birth and again at 24 h thereafter to determine the individual colostrum intake of the piglets. On average, the farrowing duration, birth interval and BA were 188.0 ± 95.7 min, 12.5 ± 18.3 min, and 12.3 ± 2.9 piglets per litter, respectively. The farrowing duration of the sows was reduced in CARBE group (151.2 ± 11.9 min) compared to OXY (180.2 ± 11.5 min, $P = 0.003$) and CONTROL (227.7 ± 11.2 min, $P < 0.001$) groups. Birth interval of piglets in all categories of birth weight in the CARBE group was shorter than those in the CONTROL group ($P < 0.05$). However, the colostrum yield of sows in CARBE group (2398 ± 133 g) was lower than CONTROL and OXY groups (3371 ± 125 g and 3549 ± 128 g, respectively; $P < 0.001$). Similarly, colostrum intake of piglets in the CONTROL and OXY groups was higher than in the CARBE group (276.4 ± 11.0 g, 286.4 ± 13.6 g and 225.3 ± 14.0 g, respectively; $P < 0.05$). The percentage of stillborn piglets in CARBE was higher than OXY (8.7 ± 1.1% vs 5.3 ± 1.1%, $P < 0.05$) but did not differ significantly compared to CONTROL (7.5 ± 1.1%, $P > 0.05$). The piglet movement capacity in CONTROL was lower than CARBE group (1.36 vs 1.48, $P < 0.05$) but was not different compared to OXY group (1.40, $P > 0.05$). In conclusion, administration of carbetocin after the birth of the first piglet reduced the farrowing duration of sows, but increased the number of stillborn piglets and reduced the colostrum yield of sows.

1. Introduction

The aims of farrowing supervision in sows are to reduce newborn piglet mortality and preserve sows' health postpartum.

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Successful parturition can be generally defined as a farrowing without evidence of dystocia, with no stillborn and with vigorous newborn piglets. Understanding of the farrowing process is crucial to reduce the risks of postparturient disorders in sows and mortality of newborn piglets [1,2]. The use of exogenous hormones to promote uterine contraction is one of the most practical procedures used under field conditions to control the farrowing process. Oxytocin is usually administered to assist in prolonged farrowings and/or when dystocia occurs. However, oxytocin has been observed to increase the number of stillborn piglets in some circumstances [3] but not in others [4]. Administration of oxytocin 30–40 IU at the onset of fetal expulsion significantly increases the number of intrapartum stillbirths, increases the degree of meconium staining on skin and increases the evidence of ruptured umbilical cords [5]. However, no significant effect of oxytocin administration on umbilical cord morphology, degree of meconium staining and the number of stillborn piglets per litter was observed when 10 IU of oxytocin was used [4]. Additionally, the use of oxytocin can reduce the piglet vitality and increase uterine inertia in some sows [6].

Carbetocin is an oxytocin-like compound with long acting properties that has recently been introduced to both human and domestic animal obstetrics [7,8]. Carbetocin treatment is claimed to be safer and more effective than oxytocin [9]. While there are few studies on the use of carbetocin to induce parturition [8,10], no comprehensive studies on the clinical use of carbetocin to assist the farrowing process and the colostrum production in pig have been done to date. Therefore, the aims of the present study were to evaluate the effects of carbetocin administration, compared to oxytocin, on farrowing duration, birth interval, colostrum production, and piglet survival and vitality.

2. Materials and methods

2.1. Experimental design

The present study was carried out in a 3000-sow commercial swine herd at the western part of Thailand. The study included 186 Landrace x Yorkshire crossbred sows and their offspring (n = 2611 piglets). The sows were randomly distributed into three groups: 1) CONTROL (n = 66): sows were allowed to farrow naturally; 2) OXY (n = 62): sows were administered oxytocin 20 IU intramuscularly (1 ml of oxytocin sterile injection, VetOne®, Idaho, USA) after the birth of the first piglet, and 3) CARBE (n = 58): sows were administered carbetocin 0.6 μg/kg intramuscularly after the birth of the first piglet (0.05 mg/ml, Decomoton®, Laboratorios Calier, Barcelona, Spain) (1.5, 2.0 and 2.5 ml for sows with a body weight of 200, 250, 300 kg, respectively).

2.2. Animals, housing and management

The present study followed the guidelines documented in The Ethical Principles and Guidelines for the Use of Animals for Scientific Purposes edited by the National Research Council of Thailand, and was approved by the Institutional Animal Care and Use Committee (IACUC) in accordance with Chulalongkorn University regulations and policies governing the care and use of experimental animals (animal use protocol no. 1731063).

The average ambient temperature during the experimental period ranged from 25.8 °C to 30.0 °C. The daily minimum and maximum temperatures ranged from 21.1 °C to 26.3 °C and from 28.1 °C to 37.6 °C, respectively. The average relative humidity varied from 72.0% to 96.0%. Sows were kept in individual stalls (1.2 m^2) during gestation in a conventional open-housing system and were provided with fans and individual water sprinklers to reduce the impact of high ambient temperature. During gestation, sows were fed a commercial gestation diet twice a day following a standardized feeding pattern, resulting in an average of 2.5 kg per sow per day to meet or exceed their nutritional requirements [11]. At day 109 of gestation, sows were moved to a farrowing room and allocated to individual farrowing crates (1.5 m^2) placed at the center of pens with a space allowance of 4.2 m^2. The pens were fully slatted with concrete at the center for sows, and had steel slats at both sides of the farrowing crate for piglets. Each pen was provided with a creep area covered by a sack or a plastic plate for piglets placed on the floor on one side of the pen (0.60 m^2). A heating lamp was provided at the creep area during the first week after farrowing. The heating lamp was usually turned on during the night or when the environment temperature fell below 30 °C. In general, the temperature in the creep area was between 30 and 36 °C. During farrowing sows were not offered feed. The farrowing process was carefully supervised by a research team for 24 h. Birth intervention was performed only when dystocia was clearly identified. Dystocia was considered when an interval of 30–60 min elapsed from the birth of the last 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 30–60 min without any piglet being born. The birth assistance included the stimulation of uterine contraction by palpating dorsal wall of vagina (Ferguson reflex) and manual extraction of the piglets.

During lactation, sows were fed twice a day with a commercial lactation diet to meet or exceed their nutritional requirements [11]. After farrowing, the amount of feed offered to sows increased daily according to litter size and body condition, until *ad libitum* was reached after one week of lactation [12]. 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, tooth clipping and 1 ml (200 mg) iron supplement administered intramuscularly (Gleptosil®, Alstoe Ltd. Animal Health, Leicestershire, England) on the first day of life. Piglets were orally administered a coccidiocide (Baycox®, Bayer Pharma AG, Berlin, Germany) on the third day of life. Weaning took place at 23.0 ± 2.0 days after farrowing.

2.3. Data collection

The sows average parity number was 4.5 ± 2.4 (ranged 1–9). The following reproductive variables of the sows were collected during and 24 h after farrowing: farrowing duration (i.e., time between first and last piglet birth), total number of piglets born per litter (TB), number of piglets born alive per litter (BA), proportion of stillborn piglets per litter (SB) and proportion of mummified fetuses per litter (MF). Backfat thickness of the sows was measured on the day before parturition at the last rib at 6–8 cm from the midline using A-mode ultrasonography (Renco-Lean meter®, Minneapolis, MN, USA).

For each piglet born alive, birth order, birth interval (the time elapsed between each piglet born), and sex were recorded. Also, whether piglets required birth assistance was recorded (yes/no). Skin colour of the piglets was recorded at birth and was classified into two groups (normal and meconium staining). Integrity of the umbilical cord of each piglet was examined and classified into two groups (intact and broken umbilical cords). The piglets were monitored for heart rate and blood oxygen saturation within 5 min after birth using a veterinary pulse oximetry (EDAN VE-H100B Pulse Oximeter, Edan Instrument Inc®, San Diego, CA, USA). Rectal temperature was measured at 24 h after birth (T24h) with a digital thermometer (Veridian 08–357 9-s digital thermometer, Veridian®, Illinois, USA, with a display resolution of 0.01 °C). All piglets were individually identified by ear tattoo. Birth weights of the

piglets (Bwt) were measured immediately at birth and again at 18–24 h after birth using a digital bench scale (SDS IDS701-C SERIES Bench Scale, SDS® (YANGZHOU) DIGITAL SCALE CO., LTD, Yangzhou, China). The piglet vitality was evaluated at 30 min and 24 h after farrowing using the piglet vitality score measurements scale of Muns et al. [13]. The definition of the vitality scoring system is presented in Table 1. Individual colostrum intake of the piglets was estimated with the equation developed by Foisnet et al. [14]: Colostrum intake (g) = −217.4 + (0.217 * t) + (1,861,019 * BW2/t) + BW * (54.8−1,861,019/t) * ((0.9985−3.7 * 10−4 tFS) + (6.1 * 10−7 * tFS2)); where BW is body weight at birth (kg), BW2 is body weight at the second weighing (kg), t is time elapsed between the first and the second weighing (min) and tFS is the interval between birth and first suckling (min). According to Devillers et al. [15], the tFS can be estimated between 15 and 30 min without major error. Therefore, in the present experiment the tFS was estimated to be 15 min. The colostrum yield of sows was calculated by summing colostrum intake of each individual piglet within the litter.

2.4. Statistical analyses

The data were analyzed using SAS (SAS version 9.0, Cary, NC. USA). Descriptive statistics, i.e., means, standard deviation (SD), range, and frequency tables were conducted for all reproductive parameters. Continuous data were presented as mean ± SD and range. The data were classified into two groups, i.e., sow data (n = 186) and piglet data (n = 2611). The sow data included gestation length, parity number, backfat thickness, farrowing duration, TB, BA, SB, and MF. The piglet data included birth interval, birth weight, body temperature at 24 h, body weight at 24 h, and colostrum intake. The sow data were compared among groups using one-way analysis of variance (ANOVA). Least square means were obtained from each class and were compared by the least significant difference (LSD) test.

Continuous data of piglets naturally farrowing (control) were compared with those controlled farrowing using oxytocin or carbetocin by multiple ANOVA using the general linear models procedure (PROC GLM) of SAS. The dependent variables in the statistical models included treatment groups (CONTROL, OXY, CARBE), sow parity category (1, 2–5, 6–9), piglets' birth weight category (≤1.35, 1.36–1.60, >1.60 kg), and the two-way interactions. Least-square means were obtained from each class of the factors and were compared using the LSD test. In addition, the data were also classified according to bodyweight at birth of the piglets and the general linear models procedure was performed to compare the birth interval among groups.

Categorical data including vitality index, (i.e., screaming, udder stimulation, stillborn (yes/no), birth interval >30 min (yes/no), farrowing assistance (yes/no), umbilical cord rupture (yes/no), meconium staining (yes/no), and proportion of piglets with blood oxygen saturation < 95%) were analyzed using the generalized linear mixed models procedure (GLIMMIX) of SAS. The statistical models included treatment groups (CONTROL, OXY, CARBE), sow parity category (1, 2–5, 6–9), piglets' birth weight category (≤1.35, 1.36–1.60, >1.60 kg), and the two-way interactions. Sow was considered the experimental unit and introduced as a random effect nested within treatment group. Least-square means were obtained from each class of the factors and were compared using the LSD test. Vitality score data (i.e., movement capacity (0–3) and number of completed circles around enclosure (0–2) were analyzed using Kruskal-Wallis tests. Pairwise comparisons were made using Wilcoxon's rank sum test. For all statistical tests, $P < 0.05$ was considered to be statistically significant.

3. Results

3.1. Sow performances

The reproductive data of sows for the different treatment groups is presented in Table 2. The gestation length did not differ among groups ($P > 0.05$). Frequency distribution of the farrowing duration of sows in CON, OXY and CARBE groups is presented in Fig. 1. The farrowing duration of the sows was reduced in the CARBE group (151.2 ± 11.9 min) compared to OXY (180.2 ± 11.5 min, $P = 0.003$) and CONTROL (227.7 ± 11.2 min, $P < 0.001$) groups. Similarly, the duration of farrowing after dividing by the total number of piglets born was higher in the CONTROL than in OXY and CARBE groups ($P < 0.05$, respectively). However, the colostrum yield of sows in the CARBE group (2398 ± 133 g) was lower than CONTROL and OXY groups (3371 ± 125 g and 3549 ± 128 g, respectively; $P < 0.001$). On average, the colostrum yield of sow parity numbers 1, 2–5 and 6–9 were 2915 ± 209 g, 3077 ± 110 g and 3195 ± 115 g, respectively ($P > 0.05$).

3.2. Piglet characteristics

Factors affecting the percentage of stillborn piglets included treatment group ($P = 0.102$), parity number ($P < 0.001$) and birth weight of the piglet class ($P < 0.001$). The percentage of stillborn piglets in CARBE was higher than OXY (8.7 ± 1.1% vs 5.3 ± 1.1%, $P < 0.05$) but did not differ significantly from the CONTROL (7.5 ± 1.1%, $P > 0.05$). The percentages of stillborn piglet per litter were 3.8%, 6.4% and 10.5% in sow parity numbers 1, 2–5 and 6–9, respectively ($P < 0.001$). Factors affecting birth interval included treatment group ($P = 0.02$) and birth weight of the piglet class ($P < 0.001$). Birth interval in the CONTROL sows was higher than that in OXY and CARBE groups ($P < 0.05$) (Table 2). The proportion of piglets with a birth interval >30 min was higher in the CONTROL group than in the CARBE group ($P < 0.05$) (Table 2). Furthermore, the percentage of farrowing assistance in the CARBE group was

Table 1
Definitions of the behavioral parameters evaluated to establish the vitality scores of the piglets (adapted from Muns et al. [10]).

Variable	Score	Description
Screaming	0	Piglet did not scream within 30 s after testing
	1	Piglet screamed within 30 s after testing
Udder stimulation	0	No head movement or searching for udder within 30 s after testing
	1	Head movement or searching for udder within 30 s after testing
Movement capacity	0	The piglet cannot stand within 30 s after testing
	1	The piglet can stand but cannot move within 30 s after testing
	2	The piglet can stand and move slowly
	3	The piglet can stand and move quickly within 15 s after testing
Number of completed circles around enclosure	0	The piglet cannot move for one circle within 30 s after testing
	1	The piglet can move for one circle within 30 s after testing
	2	The piglet can move for two circles within 30 s after testing

Table 2
Reproductive data of sows and piglets (least squares mean ± SEM) for the different treatment groups: sows that farrowed naturally (CONTROL), and sows treated with oxytocin (20 IU/sow, OXY) or carbetocin (0.6 μg/kg, CARBE) during the farrowing process.

Variable	CONTROL	OXY	CARBE	*P* value
Number of sows	**66**	**62**	**58**	
Gestation length (days)	115.0 ± 0.2	114.9 ± 0.2	114.9 ± 0.2	0.928
Parity number	4.2 ± 0.3	4.7 ± 0.3	4.8 ± 0.3	0.349
Backfat thickness (mm)	15.0 ± 0.4	14.9 ± 0.4	14.9 ± 0.4	0.997
Total number of piglets born/litter	14.6 ± 0.3	13.8 ± 0.4	13.7 ± 0.4	0.149
Number of piglets born alive/litter	12.7 ± 0.4[a]	12.7 ± 0.4[a]	11.6 ± 0.4[b]	0.071
Stillborn piglet/litter (%)	7.5 ± 1.1[ab]	5.3 ± 1.1[a]	8.7 ± 1.1[b]	0.095
Mummified fetuses/litter (%)	3.5 ± 0.6[a]	2.4 ± 0.6[a]	3.3 ± 0.6[a]	0.476
Farrowing duration (min)	227.7 ± 11.2[a]	180.2 ± 11.5[b]	151.2 ± 11.9[b]	<0.001
Duration farrowing/piglets born (min)	15.9 ± 1.0[a]	13.8 ± 1.0[ab]	11.7 ± 1.0[b]	0.011
Colostrum yield (kg)	3370 ± 124[a]	3549 ± 128[a]	2398 ± 133[b]	<0.001
Number of piglets	**967**	**850**	**794**	
Birth interval (BI) (min)	14.1 ± 0.8[a]	12.5 ± 0.9[ab]	11.2 ± 1.0[b]	0.063
BI in piglets born with ≤1.35 kg (min)	12.0 ± 0.8[a]	9.4 ± 0.9[b]	8.4 ± 0.9[b]	0.006
BI in piglets born with 1.36–1.60 kg (min)	15.1 ± 1.2[a]	13.9 ± 1.2[ab]	10.6 ± 1.3[b]	0.034
BI in piglets born with >1.60 kg (min)	16.4 ± 1.2[a]	15.4 ± 1.2[ab]	12.5 ± 1.2[b]	0.067
Piglets with birth interval > 30 min (%)	14.1[a]	11.3[ab]	8.8[b]	0.002
Farrowing assistance (%)	16.5[a]	14.1[ab]	11.0[b]	0.004

[a,b] different superscripts within row differ significantly ($P < 0.05$).

lower than in the CONTROL group ($P < 0.05$), but did not differ significantly compared to OXY group (Table 2).

In addition, birth weight of the piglets also influenced birth interval ($P < 0.001$). Across treatments, piglets born with ≤1.35 kg had shorter ($P < 0.001$) birth interval than 1.36–1.60 kg and >1.60 kg piglets (9.9 ± 0.6 vs 13.1 ± 0.8 and 14.7 ± 0.7 min, respectively). Birth interval of piglets in all categories of birth weight in the CARBE group was shorter than those in the CONTROL group ($P < 0.05$), but in the OXY group, only the piglets with ≤1.35 kg of birth weight had a shorter birth interval than the CONTROL group ($P < 0.05$) (Table 2). A lower proportion of piglets in the CARBE group needed farrowing assistance than in the CONTROL group ($P < 0.001$) (Table 2). The percentage of stillborn piglets by birth interval is presented in Fig. 2. The risk of being stillborn was below 10% when birth interval was less than 15 min in all groups. However, when birth interval was more than 40 min, risk of being stillborn in the CARBE group was increased up to 22–50%.

Vitality measures of piglets from the three treatment groups are presented in Table 3. The proportion of live born piglets with umbilical rupture in the CARBE and OXY groups was higher than in the CONTROL group ($P < 0.001$). The incidence of umbilical rupture of piglets with >1.60 kg of birth weight in both CARBE (76.3%) and OXY groups (83.9%) was higher than the CONTROL group (67.1%, $P < 0.05$). The incidence of umbilical rupture of piglets with ≤1.35 kg and 1.36–1.60 kg of birth weight in the CARBE group was higher than the CONTROL group but did not differ significantly compared to OXY group (Table 3). Body temperature of piglets at 24 h was lower in the CARBE group than in the CONTROL group ($P < 0.05$). Similarly, colostrum intake of piglets in the CONTROL and OXY groups was higher than in the CARBE group (276.4 ± 11.0 g, 286.4 ± 13.6 g and 225.3 ± 14.0 g, respectively; $P < 0.05$).

The influences of carbetocin and oxytocin treatment on the piglet vitality scores measured at 30 min and 24 h after birth (day 0 and 1) are presented in Table 4. On day 0, the screaming score in the CONTROL group was higher than the OXY group ($P < 0.05$), but did not differ significantly from the CARBE group ($P > 0.05$). On day 1 postpartum, piglet movement capacity in the CONTROL group was lower than the CARBE group (1.36 vs 1.48, $P < 0.05$) but was not different from the OXY group (1.40, $P > 0.05$). Similarly, completed circles capacity in CARBE was higher than in the OXY ($P < 0.05$) group but not the CONTROL group ($P > 0.05$). However, the screaming score in the CARBE group was lower than both the OXY and CONTROL groups ($P < 0.05$).

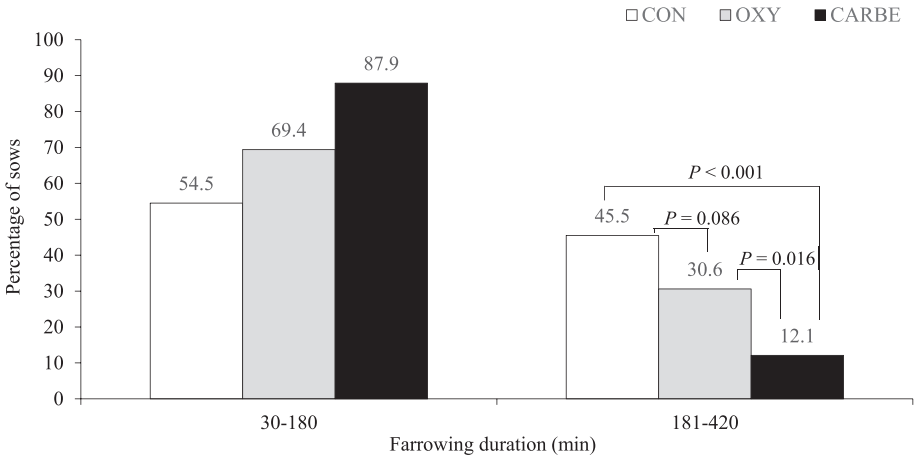

Fig. 1. of sows with short (30–180 min) and long (181–420 min) farrowing durations in control (CON, n = 66), oxytocin (OXY, n = 62) and carbetocin (CARBE, n = 58) groups.

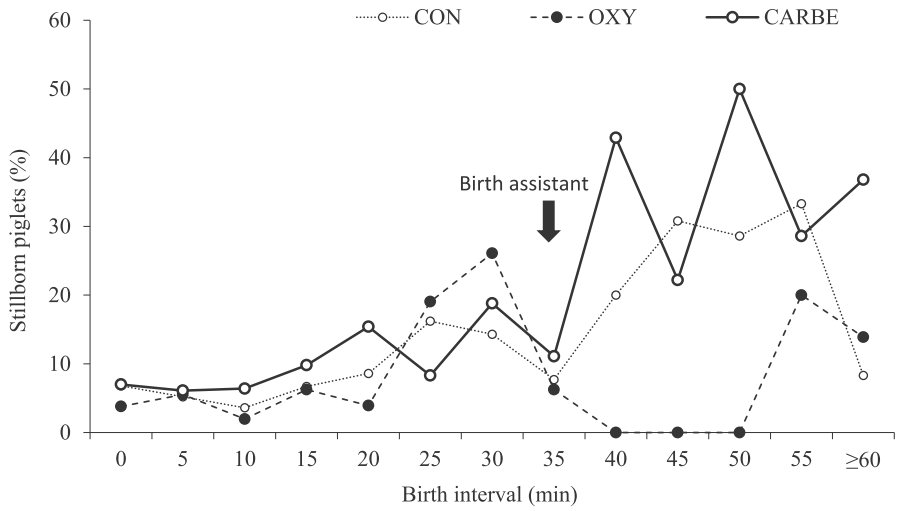

Fig. 2. of stillborn piglets by birth interval in control (CONT), oxytocin (OXY), and carbetocin (CARBE) groups. Black arrow indicates the onset of farrowing assistant performed during farrowing process.

4. Discussion

4.1. Effect of carbetocin on the sows

A previous study demonstrated that the administration of oxytocin during parturition increases the number, intensity, and duration of myometrial contractions [16]. Björkman et al. [16] also demonstrated that a prolonged parturition was associated with increased incidence of retained placenta in sows and negatively associated with the number of live born piglets. Therefore, a clinical approach to reduce the duration of parturition is important. The present study successfully demonstrated that the use of carbetocin treatment after the birth of the first piglet significantly reduced the duration of parturition by 77 and 29 min compared to control and oxytocin sows, respectively. Likewise, birth interval between each piglet was reduced from 14.1 to 11.2 min with the use of carbetocin.

Carbetocin is a synthetic octapeptide analogue of oxytocin and can bind to the oxytocin receptor in the myometrium. A previous study has shown that oxytocin-treated sows had a decreased farrowing duration and birth interval [17]. A recent literature review suggested that carbetocin could be used as an alternative to oxytocin since it is long-acting, safe, and effective [18]. In the present study, the rapid onset of action and prolonged duration of carbetocin reduced the farrowing duration in sows. Thus, the uterine response is sustained with contractions of high amplitude and frequency [19]. Accordingly, the present study achieved a 33.4% reduction (from 228 to 151 min) in farrowing duration. Administration of carbetocin in sows accelerates the parturition process by reducing the birth interval between the piglets [10]. Gheller et al. [20] and Zaremba et al. [21] also found a shorter farrowing duration in the carbetocin treated sows. Another explanation for the prolonged activity of carbetocin might be associated with lipophilic properties that cause a longer half-life at the receptor compartment [22]. The present study also found that the percentage of farrowing assistance in the carbetocin group was lower than in the control group. This might be related to carbetocin reducing the birth interval of piglets, especially in piglets born with high body weight, therefore decreasing the risk of manual extraction.

4.2. Effect of carbetocin on the piglets

In the present study, the percentage of stillborn piglets increased when the birth interval increased. This evidence was most pronounced in the sows treated with carbetocin. The reason could be due to that carbetocin increase the amplitude and frequency of the uterine contraction for a long period of time. The piglets that remain in the uterus for a longer period might have got more pressure due to uterine contraction. In humans, carbetocin caused contraction of the uterus at a higher amplitude and frequency than oxytocin [19]. In pigs, administration of oxytocin at early phases of parturition increased the duration and intensity of uterine contractions but decreased placenta perfusion and

Table 3
Vitality measures of (live born) piglets from the three treatment groups: sows that farrowed naturally (CONTROL), and sows treated with oxytocin (20 IU/sow, OXY) or carbetocin (0.6 μg/kg, CARBE) during the farrowing process.

Live born piglets	CONTROL	OXY	CARBE	*P* value
Umbilical cord rupture (UR) (%)	66.0^{a}	74.8^{b}	75.1^{b}	<0.001
UR in piglets born with ≤1.35 kg (%)	64.3^{a}	65.9^{a}	73.5^{b}	0.033
UR in piglets born with 1.36–1.60 kg (%)	67.2^{a}	74.9^{ab}	75.8^{b}	0.062
UR in piglets born with >1.60 kg (%)	67.1^{a}	83.9^{b}	76.3^{c}	<0.001
Meconium staining (%)	62.4^{a}	67.1^{b}	68.0^{b}	0.028
Blood oxygen saturation (%)	88.3 ± 0.6	88.4 ± 0.7	88.7 ± 0.8	0.888
Piglets with blood oxygen saturation < 95% (%)	71.4	71.4	69.3	0.748
Heart rate (bpm)	80.8 ± 3.1	88.9 ± 3.8	79.8 ± 4.1	0.169
Body temperature at 24 h (°C)	38.4 ± 0.1^{a}	38.3 ± 0.1^{ab}	38.1 ± 0.1^{b}	0.029
Body weight at 24 h (kg)	1.54 ± 0.01^{ab}	1.55 ± 0.02^{a}	1.50 ± 0.02^{b}	0.105
Colostrum intake (g)	276.4 ± 11.0^{a}	286.4 ± 13.6^{a}	225.3 ± 14.0^{b}	0.004

^{a,b,c} Different superscripts within row differ significantly ($P < 0.05$).

Table 4
Results of the vitality scores of piglets from the different treatment groups: sows that farrowed naturally (CONTROL), and sows treated with oxytocin (20 IU/sow, OXY) or carbetocin (0.6 μg/kg, CARBE) during the farrowing process.

Vitality score	CONTROL	OXY	CARBE	*P* value
Day 0 (30 min after birth)				
Screaming (%)	34.5[a]	29.3[b]	31.6[ab]	0.076
Udder stimulation (%)	97.4	96.0	97.0	0.252
Movement capacity (mean ± SD)	1.43 ± 0.56	1.40 ± 0.55	1.45 ± 0.56	0.166
Completed circles (mean ± SD)	0.59 ± 0.69	0.56 ± 0.70	0.59 ± 0.71	0.483
Day 1 (24 h after birth)				
Screaming (%)	36.7[a]	40.1[a]	31.5[b]	0.003
Udder stimulation (%)	94.7	93.8	94.6	0.736
Movement capacity (mean ± SD)	1.36 ± 0.59[a]	1.40 ± 0.54[a]	1.48 ± 0.55[b]	<0.001
Completed circles (mean ± SD)	0.60 ± 0.69[ab]	0.57 ± 0.67[a]	0.66 ± 0.71[b]	0.098

[a,b] Different superscript within row differ significantly ($P < 0.05$).

produced adverse fetal outcomes [23]. Zaremba et al. [21] demonstrated that the use of 35 μg or 70 μg of carbetocin was equally effective for induction of parturition in sows. Thus, the lower dose was recommended. In the present study, the doses of carbetocin were 75 μg (1.5 ml), 100 μg (2.0 ml) and 125 μg (2.5 ml) in sows with a body weight of 200, 250 and 300 kg, respectively. Therefore, to reduce the deleterious effect of carbetocin on the number of stillborn piglets, a lower dose of carbetocin should be considered. Stillbirth in pigs can be classified into two types based on the time of death. Type 1 stillbirths are when a piglet dies just before the end of gestation and the cause of death is often due to infection. Type 2 stillbirths are when the piglet dies during parturition (intra-partum) and the cause of death is mostly a non-infectious etiology. Most of the type 2 stillbirths are due to a lack of oxygen, which can happen when the umbilical cord is twisted or ruptured [24]. Studies have demonstrated that myometrium activity has an impact on the circulatory physiology and survival of piglets. For instance, fetal hypoxia can be the result of intense uterine contractions which cause a significant decrease in blood flow and gas exchange in the placenta [25]. Under field conditions, the use of oxytocin during parturition resulted in a higher number of stillborn piglets per litter and a higher number of piglets with ruptured umbilical cords [4,17]. However, the influence of oxytocin administration on the number of stillborn piglets per litter was significant when the dose of oxytocin was higher than 30 IU [5,17], while it was not significant when the dose of oxytocin was 10 IU [4]. In the present study, the proportion of piglets born with meconium staining was significantly increased when oxytocin or carbetocin was used at the beginning of the parturition process. During asphyxia there is blood redistribution from the intestine to vital organs which causes an increase of intestinal peristalsis and a relaxation of the anal sphincter. These two responses to hypoxia are followed by the discharge of meconium into the amniotic fluid. The passing of meconium into the amniotic fluid can be an indicator of fetal distress [26]. Piglets suffering from asphyxia are often born covered in meconium [26]. The use of 30–40 IU oxytocin in sows after the expulsion of the first piglet increases myometrial activity and can cause rupture of the umbilical cord and increase the extent of meconium staining and intra-partum stillbirths [3]. For carbetocin, studies demonstrated that the use of carbetocin in combination with $PGF_{2\alpha}$ for induction of parturition in sows reduced the proportion of stillborn piglets per litter [8,21]. In contrast, Gheller et al. [20] observed a higher stillborn piglet per litter when carbetocin or oxytocin was used for induction of parturition in combination with $PGF_{2\alpha}$. The difference among these studies could be due to the difference of farrowing supervision among herds. Therefore, intensive farrowing supervision as well as proper neonatal care is strongly recommended when using carbetocin or oxytocin before or during parturition in sows.

In the present study, the piglet vitality score was evaluated. These behavioral traits are useful to identify weak piglets or piglets at high risk of neonatal death [13]. The movement capacity and completed circles scores in the carbetocin group were higher than control and oxytocin groups at day 1 post-partum. At birth, piglets have to overcome the sudden drop in temperature and the extreme change of environment at the same time that they begin breathing and moving. Newborn piglets take an average of 13.7 min to first reach the udder [27], and in the vitality test adapted from Muns et al. [13] piglets were only evaluated for 30 s. The lack of differences at day 0 is probably due to the short duration of the vitality test and the close proximity to birth. However, at day 1 postpartum, a treatment effect was observed. Interestingly, carbetocin piglets not only had the highest vitality scores but also the lowest colostrum intake. This finding suggest that the vitality score adapted from Muns et al. [13] might be related to the level of intra-partum hypoxia suffered by the piglet rather than to the amount of colostrum ingested during the first 24h of life. However, the blood oxygen saturation, the proportion of piglets with blood oxygen saturation <95.0% and the heart rate of the newborn piglets did not differ significantly among groups. Likewise, Nuntapaitoon et al. [28] did not observe any association between blood oxygen saturation and heart rate of the newborn piglets and the piglet survival rate during the first 7 days after birth.

4.3. Effect carbetocin on colostrum intake

At least 50% of piglet pre-weaning deaths occur within 3 days of birth [29]. Those piglets are characterized by a low birth weight and a low weight gain, which is related to a low colostrum intake [30]. Low colostrum intake is one of the major causes of neonatal death [29,31]. Neonatal piglets require a colostrum intake of at least 160–170 g per kg of body weight [15]. Colostrum intake by piglets depends on their ability to extract colostrum from teats and the ability of sows to produce enough colostrum for the whole litter. In the present study, colostrum intake in the oxytocin group was higher than in the carbetocin group. Our results are in agreement with Boonraundgrod et al. [8] who observed a reduction in colostrum intake in piglets born after inducing farrowing using carbetocin in combination with $PGF_{2\alpha}$ (compared to control and $PGF_{2\alpha}$ groups). According to Maged et al. [8], in human medicine, the uterotonic treatment with carbetocin in caesarean sectioned women resulted in a reduction of blood pressure due to a decrease of systemic vascular resistance, while heart rate remained stable [9]. This may decrease blood venous return for a certain period. Thus, the colostrum production might be interfered. Another mechanism might be associated with a competition between carbetocin and oxytocin to bind with oxytocin receptors in the mammary gland of sows. Since oxytocin is associated with milk

letdown, if carbetocin was able to bind with oxytocin receptor, the milk letdown process might be altered. In general, colostrum production is under hormonal control and factors that affect colostrum yield are less known than those affecting milk yield [32]. Milk letdown is the process by which milk is removed from the mammary gland during lactation by the nursing offspring. In general, prolactin release from anterior pituitary gland is important for milk synthesis and secretion, while oxytocin from posterior pituitary gland is required for milk letdown. Milk letdown in sows occur before parturition and before an increase in the concentration of circulating oxytocin, suggesting that the mammary tissue has increased sensitivity to basal oxytocin concentrations [33]. The binding oxytocin with its receptor is time-dependent with equilibrium attained by 2 h at 24 °C [33]. Furthermore, the binding is also a concentration-dependent and saturable [33]. The concentration of oxytocin binding site for the mammary tissue increased during milk let down period (114 days of gestation) and remained elevated until 3 h postpartum [33]. For the uterus, it has been hypothesized that a high concentration of oxytocin can cause myometrial tetany and result in uterine dystocia [33]. Likewise, this mechanism can also occur with the mammary tissue. These data indicate that if carbetocin was able to bind with oxytocin receptor, some physiological responses of the mammary tissue might have been altered due to saturation of oxytocin receptor. Thus, the colostrum production might be compromised through the interruption of milk let down process. Therefore, a low dose of carbetocin should be considered when using during milk let down period (114 days of gestation) until 3 h postpartum. Moreover, the negative effect of carbetocin on the colostrum production might be more severe, when the number of piglets born per litter was increased. In the present study, the average colostrum consumption of the piglets was 224 g/piglet when the number of piglets born alive per litter averaged 11.6. Therefore, it is recommended that intensive postpartum care of piglets should be enhanced when carbetocin is administered. For instance, Muns et al. [34] demonstrated that administering two doses of an oral supplementation product within 8 h postpartum could enhance the level of IgG at day 5 postpartum of the piglets. Furthermore, Moreira et al. [35] demonstrated that feeding up to 200 ml (50 ml every 6 h) of colostrum through an orogastric tube provided sufficient IgG concentrations at 24 h of life in low-birth-weight piglets (body weight at birth between 800 and 1200 g). These management practices could be applied when carbetocin is used.

5. Conclusions

In conclusion, administration of carbetocin after the birth of the first piglet significantly reduced the farrowing duration and birth interval of the piglets. Furthermore, some of the piglet vitality indexes increased and required farrowing assistance was lowest with carbetocin administration. However, piglets born after carbetocin administration had a lower colostrum intake than control animals. Therefore, postpartum management to enhance the colostrum consumption of the newborn piglets should be implemented when carbetocin is administered to reduce farrowing duration. However, further studies are needed to confirm the findings and to establish best practices.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.theriogenology.2019.01.021.

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REGULAR ARTICLES

Impact of parity and housing conditions on concentration of immunoglobulin G in sow colostrum

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Abstract

Colostrum is crucial for the survival and growth of suckling piglets. However, both the quantity and quality of colostrum are highly variable among sows. The aim of the present study was to determine the impact of sow parity number and housing conditions on concentration of immunoglobulin G in sow colostrum. A total of 358 colostrum samples were collected from two commercial swine herds in Thailand. The colostrum samples were collected from all teats at 1 and 6 h after the onset of farrowing and kept at − 20 °C until analysis. The concentration of IgG was determined using ELISA. The concentration of IgG in colostrum at 1 h after the onset of farrowing was greater than the concentration of IgG at 6 h after the onset of farrowing ($P < 0.001$). Moreover, herd A had a greater colostral IgG concentration than herd B ($P < 0.001$). The concentration of IgG in primiparous sows (64.0 mg/ml) was lower than that in sow parity numbers 3 (75.1 mg/ml, $P = 0.05$) and 6 (79.2 mg/ml, $P = 0.04$). In conclusion, the variation in colostral immunoglobulin concentration in the sow colostrum was influenced by their parity number and housing conditions. The concentration of IgG declined significantly within 6 h after the onset of farrowing ($P < 0.001$).

Keywords Colostrum · Farrowing · Immunoglobulin · Piglet · Sow

Introduction

Colostrum is crucially important for the survival of suckling piglet by providing energy for growth and thermoregulation as well as immunoglobulin for disease resistance (Le Dividich and Noblet 1984; Herpin et al. 1994; Sangild 2003). However, both the quantity and quality of colostrum are highly variable among sows. The colostrum yield is reported to range from 3.5 to 6.6 kg (Devillers et al. 2007; Decaluwé et al. 2013; Ferrari et al. 2014; Krogh et al. 2015). Similarly, colostrum immunoglobulin G (IgG) is highly variable, ranging from 20.0 to 176.0 mg/ml (Foisnet et al. 2010; Bovey et al. 2014); the heritability of colostrum IgG concentration averaged 31.0 to 35.0% (Balzani et al. 2016; Declerck et al. 2017).

Immunoglobulin G in sow colostrum declines rapidly within 24 h after the onset of parturition (Markowska-Daniel and Pomorska-Mol 2010; Quesnel 2011; Amdi et al. 2013; Decaluwé et al. 2014). Markowska-Daniel and Pomorska-Mol (2010) demonstrated that IgG declined from 98.2 to 71.4 mg/ml from 1 to 6 h after the onset of farrowing. Furthermore, the concentration of IgG in sow colostrum after the onset of farrowing and before the first suckling was strongly associated with the concentration of IgG in piglet plasma (Kielland et al. 2015).

Factors influencing colostrum IgG included the physiology of the mammary gland, parity, vaccination, management, and nutritional status (Quesnel 2011; Kirkden et al. 2013; Theil et al. 2014). Moreover, the negative influence of tropical climate on piglet pre-weaning mortality was more evident in primiparous sows (Nuntapaitoon and Tummaruk 2018). We hypothesised that sows that were reared in an evaporative cooling system would have a greater IgG level in the

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colostrum than those in a conventional open-housing system, because heat stress negatively influences animal physiology. The average daily temperature in an evaporative cooling-housing system is usually 1.0 to 3.0 °C below the ambient temperature, and the temperature as well as the humidity inside the house is usually more stable than that in the open-housing system (Stinn and Xin 2014). Lontoc et al. (2016) compared sow reproductive performance in an evaporative cooling system and open-housing system and found that the sows kept in the evaporative cooling system had a higher piglet birth weight and shorter weaning to oestrous interval than sows kept in the open-housing system. To our knowledge, no comprehensive study of the impact of sow parity number and housing conditions on the concentration of IgG in the colostrum has been reported, but such knowledge may be used to improve management strategies for enhancing piglet survival. The aim of the present study was to determine the impact of sow parity number and housing conditions on the concentration of IgG in sow colostrum.

Materials and methods

The experiment followed the guidelines documented in the Ethical Principles and Guidelines for the Use of Animals for Scientific Purposes edited by the National Research Council of Thailand and was approved by the Institutional Animal Care and Use Committee in accordance with the university regulations and policies governing the care and use of experimental animals (approval number 1731064).

Housing and general management

The present study was carried out in two commercial swine herds in the western part of Thailand. The breed of the sows was Landrace x Yorkshire F1 crossbred. Herd A sows were kept in individual crates (1.2 m^2) during gestation and lactation in a conventional open-housing system equipped with fans and water sprinklers to reduce the impact of high ambient temperature. Outdoor temperature and humidity data were obtained from an official meteorological station within 100 km from the herds. Daily 24-h average temperatures during this period were 29.8 °C. The average minimum-maximum daily temperatures were 26.7 to 34.0 °C. The 24-h average humidity was 75.8%. Herd B sows were kept in individual crates (1.2 m^2) during gestation and lactation in an evaporative cooling-housing system. The automatic temperature and relative humidity regulation in the housing during the experimental period were set at 27.0 °C and 75.0%, respectively. During gestation, sows in herds A and B were fed a commercial gestation diet to meet or exceed the nutritional requirements (NRC 2012). Feed was provided twice a day following a standardised feeding pattern, resulting in an average of 2.5 kg of feed per sow per day. The animals received water ad libitum in a continuous feed and water channel. During lactation, sows were fed twice a day with a commercial lactation diet to meet or exceed their nutritional requirements (NRC, 2012), increasing the daily amount of feed offered according to litter size and body condition of the sow, until ad libitum was reached after 1 week of lactation.

The routine vaccinations were applied in replacement gilts and sows, i.e. classical swine fever, foot and mouth disease, porcine circovirus type 2, *Mycoplasma hyopneumoniae*, porcine parvovirus, Aujeszky's disease, and porcine reproductive and respiratory syndrome (Table 1). The sows received routine vaccinations after mating and farrowing and received mass vaccination every 3 months for some specific diseases according to the herd veterinarian recommendation (Table 1).

Sample collection

A total of 358 colostrum samples were randomly collected from two commercial swine herds in the western region of Thailand ($n = 221$ and 137 in herds A and B, respectively). The colostrum samples were manually collected from all functional glands at 1 ($n = 149$ and 81 in herds A and B, respectively) and 6 h after the onset of farrowing ($n = 58$ and 79 in herds A and B, respectively). Oxytocin (0.3 ml, 10 IU/ml, Bimeda-MTC Animal Health Inc./Santé Animale Inc., Ontario, Canada) was administered intravenously for colostrum sampling at 6 h after the onset of farrowing, according to Krogh et al. (2016). The colostrum samples from all functional glands were pooled and filtered through gauze. Colostrum samples were kept in a clean bottle (30 ml) and were stored on ice in a Styrofoam box (4 °C) during the collection process. The samples were kept at − 20 °C until analyses.

Determination of IgG concentrations in the sow colostrum

The colostrum samples were centrifuged at 15,000×*g* for 20 min at 4 °C (Centrifuge 5810 R, Eppendorf AG, Hamburg, Germany). Thereafter, the fat was discarded, and the remaining liquid was 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 ELISA. The ELISA plate was coated with polyclonal antibody of Pig-IgG (Bethyl Laboratories Inc., TX, USA). Briefly, 100 μl of anti-IgG antibody was added to 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). After that, 200 μl of blocking solution (50 mM Tris buffer, 0.14 M NaCl, and 1%BSA) was added into each well and incubated at room temperature (25 °C) for 30 min and washed five times with

Table 1 Routine vaccination programme in replacement gilts and sows in swine commercial herds A and B

Time period	Herd A	Herd B
Week of age		
10	Foot and mouth disease	Foot and mouth disease
11	PRRS	Aujeszky's disease
12		APP
13		Foot and mouth disease
14		Porcine circovirus type 2
15		Foot and mouth disease
16		Aujeszky's disease
18		PRRS
19		Classical swine fever
20		Foot and mouth disease
21		PRRS
22		APP
23	Foot and mouth disease	Atrophic rhinitis
24	PRRS	Aujeszky's disease
25	Classical swine fever, Porcine parvovirus	Porcine parvovirus
26	Aujeszky's disease	Porcine circovirus type 2
27	PRRS	PRRS
28	Porcine circovirus type 2, *Mycoplasma hyopneumoniae*	
29	Classical swine fever, Porcine parvovirus	Porcine parvovirus
30	Aujeszky's disease	
31	Foot and mouth disease	
32	Porcine circovirus type 2, *Mycoplasma hyopneumoniae*	
2 weeks after mating	Foot and mouth disease	
12 weeks after mating	Foot and mouth disease	Foot and mouth disease
2 weeks after farrowing	Classical swine fever	Porcine parvovirus
At weaning date	Porcine parvovirus	
Mass vaccination every 3 month	Aujeszky's disease	PRRS
	PRRS	Classical swine fever
		Foot and mouth disease

APP, *Actinobacillus pleuropneumonia*; *PRRS*, porcine reproductive and respiratory syndrome

the washing buffer. Thereafter, 100 μl of a standard solution or colostrum sample was added to each well and incubated at room temperature (25 °C) for 60 min and washed five times with washing buffer. The concentrations of IgG in the standard solutions were 500.0, 250.0, 125.0, 62.5, 31.25, 15.6, and 7.8 mg/ml. All samples were analysed in duplicate. After that, 100 μl of horseradish peroxidase and antibody was added. The plates were incubated for 60 min at room temperature and were washed five times with the washing buffer. One hundred microliters of TMB (3,3′,5,5′-tetramethylbenzidine) substrate solution was added to 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 sulphuric acid. The absorbance was recorded at 450 nm using an ELISA plate reader (Tecan Sunrise™, Männedorf, Switzerland). The IgG concentration in the colostrum samples was 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 6.9% and 2.3%, respectively.

Statistical analyses

The statistical analyses were performed using SAS (SAS Inst. Inc., Cary, NC, USA). Descriptive statistics (i.e. number of non-missing values, means, standard deviation, and range) of the data were analysed using the MEANS procedure. The frequency distribution of the concentration of IgG in colostrum was obtained using the FREQ procedure. Regardless of

the herd, box plots were used to explore and describe the colostrum IgG concentration at 1 and 6 h after the onset of farrowing from herds A and B. The effect of parity and housing conditions on concentration of immunoglobulin G in sow colostrum was analysed using the general linear model (GLM) procedure. The final model included sow parity number (1, 2, 3, 4, 5, 6, and 7 to 10), herd (A and B), time from the onset of farrowing to sample collection (1 and 6 h), and interaction between herd and parity number and herd and time from the onset of farrowing to sample collection. The concentration of IgG was classified into three classes (less than 50 mg/ml, 50–80 mg/ml, and greater than 80 mg/ml). The classification of the IgG was made according to frequency distribution with some minor adjustment based on biological reliability. The effect of parity and housing conditions on concentration of immunoglobulin G classes in sow colostrum was analysed using the GLM procedure. Least square means were obtained from each class of the variable and were compared among groups using the least-significant difference test. $P < 0.05$ was regarded to be statistically significant.

Results

Concentration of immunoglobulin G in colostrum

Descriptive statistics on sow reproductive performance and total IgG concentration in the colostrum of sows are presented in Table 2. The mean colostrum IgG in all samples was 71.1 mg/ml. The frequency distribution of the concentration of IgG in all samples is illustrated in Fig. 1. Of all the colostrum samples, 46.4% had an IgG concentration less than 60.0 mg/ml and 14.1% had an IgG concentration above 100 mg/ml. On average, the concentration of IgG in colostrum at 1 and 6 h after the farrowing was 77.6 ± 35.4 and 60.1 ± 28.5 mg/ml ($P < 0.001$), respectively. The ranges of IgG concentration were 21.8 to 242.9 and 21.8 to 180.4 mg/ml at 1 and 6 h after the onset of farrowing, respectively (Fig. 2). Regardless of the time of colostrum collection, the concentration of IgG in the colostrum in herd A (79.1 ± 39.8 mg/ml) was greater than in herd B (60.8 ± 28.5 mg/ml, $P = 0.002$).

Table 2 Descriptive statistics of sow reproductive performance ($n = 358$) and total immunoglobulin G concentration in the colostrum of sows

Variables	Mean ± SD[1]	Range
Parity	3.3 ± 2.2	1–10
Total number of piglets born/litter	13.6 ± 3.5	3–23
Number of piglets born alive/litter	12.3 ± 3.0	3–20
Backfat thickness (mm)	14.6 ± 2.7	9.0–24.5
Immunoglobulin G concentration (mg/ml)	71.1 ± 33.9	21.8–242.9

[1] *SD*, standard deviation

Factor influencing immunoglobulin G in colostrum

The concentration of IgG in colostrum at 1 and 6 h after the onset of farrowing by herd is illustrated in Fig. 3. The figure shows that herd A had a greater concentration of IgG in the colostrum than herd B at 1 h (82.5 vs 71.8 mg/ml, $P = 0.03$) and 6 h (72.3 vs 53.4 mg/ml, $P = 0.001$) after the onset of farrowing. The concentration of IgG in primiparous sows (64.0 mg/ml) was lower than that in parity numbers 2 (66.2 mg/ml, $P = 0.70$), 3 (75.1 mg/ml, $P = 0.05$), 4 (65.7 mg/ml, $P = 0.76$), 5 (66.9 mg/ml, $P = 0.64$), 6 (79.2 mg/ml, $P = 0.04$), and 7 to 10 (73.1 mg/ml, $P = 0.19$). Figure 4 shows the concentration of IgG in sow colostrum in herds A and B by parity classes. The concentration of IgG in herd A was greater than in herd B in parity numbers 1 (76.2 vs 51.7 mg/ml; $P < 0.001$), 2 (78.1 vs 54.2 mg/ml; $P = 0.01$), and 5 (76.9 vs 56.7 mg/ml; $P = 0.04$) but did not differ significantly compared with parity numbers 3 (78.6 vs 71.6 mg/ml), 4 (69.4 vs 62.0 mg/ml), 6 (81.6 vs 76.7 mg/ml), and 7 to 10 (81.0 vs 65.2 mg/ml) ($P > 0.05$). Table 3 illustrates the impact of herd on the concentration of IgG classes in sow colostrum. For the concentration of IgG greater than 50 mg/ml class, herd A had a greater concentration of IgG in colostrum than herd B both at 1 and 6 h after the onset of farrowing, respectively.

Discussion

The present study revealed that the concentration of IgG in the colostrum of sows varied considerably among individual sows. The concentration of IgG postpartum in the sow colostrum is reported to range from 20.0 to 316.2 mg/ml at 1 h after the onset of farrowing (Foisnet et al. 2010; Markowska-Daniel and Pomorska-Mol 2010; Kielland et al. 2015; Moreira et al. 2017; Souphannavong and Sringarm 2017) and from 39.8 to 196.8 mg/ml at 6 h after the onset of farrowing (Markowska-Daniel and Pomorska-Mol 2010; Decaluwé et al. 2013; Souphannavong and Sringarm 2017). The range of IgG concentrations both at 1 (21.8 to 242.9 mg/ml) and 6 (21.8 to 180.4 mg/ml) h after the onset of farrowing in the present study was within the normal range and comparable with that in previous studies (Foisnet et al. 2010; Markowska-Daniel and Pomorska-Mol 2010; Decaluwé et al. 2013; Kielland et al. 2015; Moreira et al. 2017; Souphannavong and Sringarm 2017).

Colostrum IgG concentration declines rapidly within the first 24 h after the onset of farrowing (Markowska-Daniel and Pomorska-Mol 2010; Hurley 2015). The present study indicated a reduction of 25% in colostral IgG concentration in the first 6 h after the onset of farrowing, which is within the range of values reported in previous studies (Markowska-Daniel and Pomorska-Mol 2010; Foisnet et al. 2010). Previous studies demonstrated that colostrum IgG decreased

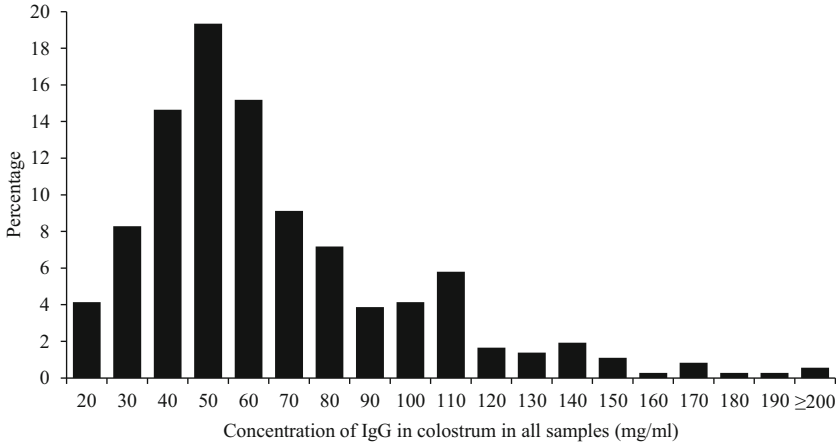

Fig. 1 Frequency distribution of immunoglobulin G concentration in colostrum ($n = 358$)

by 23 to 28% from 1 to 6 h after the onset of farrowing. The amount of IgG in piglet plasma is strongly correlated with the level of IgG in sow colostrum. Kielland et al. (2015) found that every 1 mg/ml of IgG in colostrum increased the piglet plasma IgG by 0.1 mg/ml. Being born late following intrapartum hypoxia suffered during the birth process affects piglet vitality after birth (Herpin et al. 1996). Piglets with low viability spend a long time from birth to first attempts to stand, resulting in low colostrum consumption (Nuntapaitoon et al. 2018). The present study revealed that late-born piglets had ingested colostrum with lower levels of immunity. Therefore, those piglets had a high risk of mortality in suckling period due to received low immunity. Management strategies for highly prolific sows should attempt to reduce farrowing time and help piglets receive adequate colostral immunoglobulin as soon as possible.

The effect of parity on the concentration of IgG in sow colostrum was investigated in the present study. Regardless of the time of colostrum collection, primiparous sows had lower IgG than multiparous sows. This may be because older sows had received more vaccinations than primiparous sows, which would have affected the level of immunoglobulins in the sows' bloodstream and colostrum (Bourne et al. 1975). The effect of parity on colostrum IgG concentration is controversial. Although multiparous sows had a greater IgG than primiparous sows in previous studies, the differences were not statistically significant (Devillers et al. 2007; Quesnel 2011; Decaluwé et al. 2013; Kielland et al. 2015). Furthermore, the present study found that herd A had significantly greater and more stable colostrum IgG than herd B. Therefore, strategies to enhance colostrum immunoglobulin with stable health performance in the herd should be investigated.

Herd management is a crucial factor influencing sow colostrum IgG concentration. The present study found that the range of IgG concentrations in sow colostrum differs between farms. In another study, Kielland et al. (2015) found that the colostrum IgG in four herds varied due to different management characteristics. Management solutions in gestating sows that improved colostrum IgG concentration include vaccination programmes and farrowing environment (Kirkden et al. 2013; Yun et al. 2014). The effectiveness of the immune system was reduced by suppression of immune cells, and this decreased the IgG level in sow colostrum (Couret et al. 2009). Yun et al. (2014) found that provision of nest-building materials to pre-partum sows contributes to better

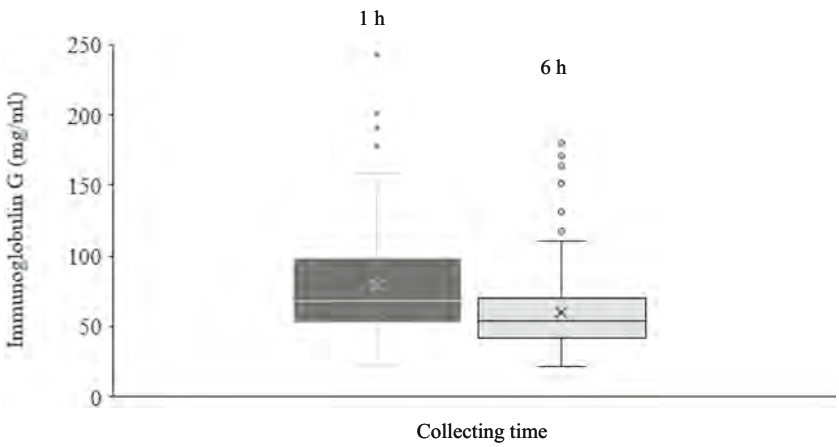

Fig. 2 Box plot of colostrum immunoglobulin G (mg/ml) concentration based on 358 colostrum samples collected at 1 and 6 h after the onset of farrowing, regardless of the herds

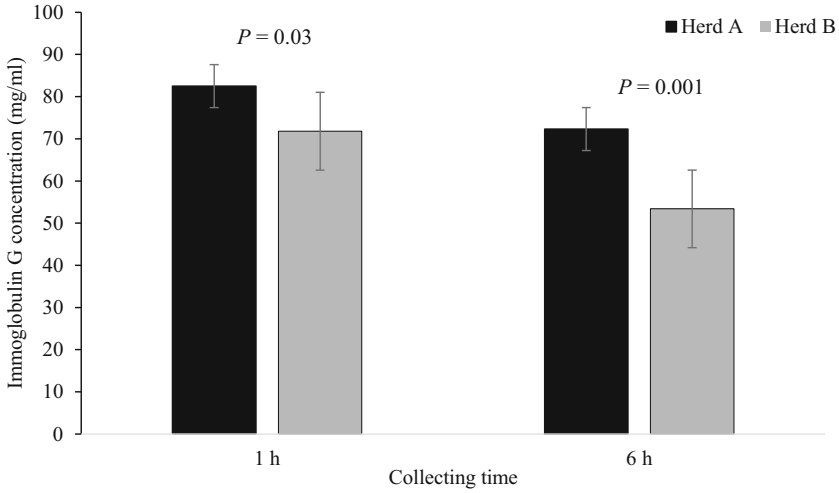

Fig. 3 Immunoglobulin G concentrations in colostrum at 1 and 6 h after the onset of farrowing in herd A (a conventional open-housing system, $n = 198$) and B (an evaporative cooling-housing system, $n = 160$); [a,b] different superscripts between herds show significant difference ($P < 0.05$)

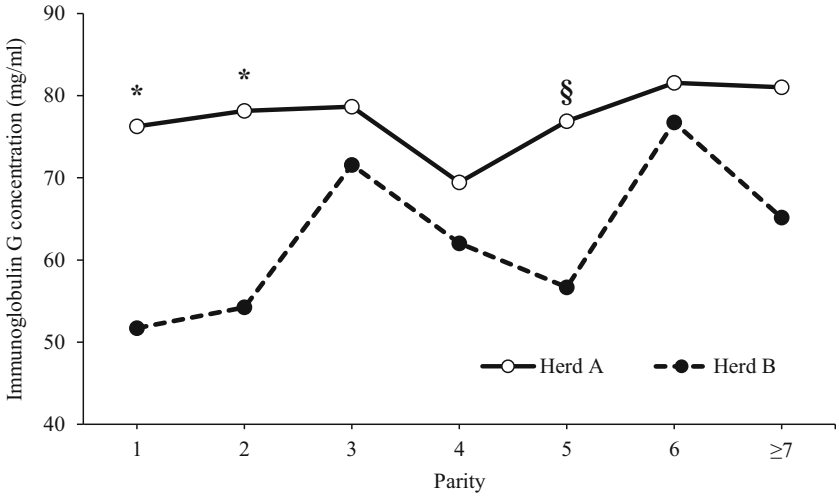

Fig. 4 The concentration of IgG in herd A and B by parity. *Different superscripts between herds show significant difference ($P < 0.05$). [§]Different superscripts between herds show significant difference ($P < 0.001$)

environments in lactation pen and enhanced IgG concentration in newborn piglets. The present study was carried out in different types of housing in a tropical climate (i.e. open-housing system (herd A) and evaporative-cooling system (herd B)). Surprisingly, the concentration of IgG in the colostrum in herd A was greater than in herd B in this study. In contrast to our finding, previous study reported no effect of housing conditions on IgG concentration in colostrum (Zhao et al. 2013). It can be concluded that different management (i.e. housing system, vaccination programme, and farrowing environment) approaches may influence colostrum IgG concentration and should be investigated in the future.

In conclusion, the immunoglobulin concentration in the colostrum of sows averaged 71.1 mg/ml. Among all the colostrum samples, 46.4% had an IgG concentration less than 50 mg/ml and 14.1% had an IgG concentration above 100 mg/ml. During the first 6 h after the onset of farrowing, 4.1% of the colostrum samples had an IgG concentration less

Table 3 Effect of herd and collecting times on concentration of immunoglobulin G in sow colostrum in each immunoglobulin G concentration class (mean ± SEM)

Concentration of IgG in sow colostrum	1 h		6 h	
	Herd A	Herd B	Herd A	Herd B
Less than 50 mg/ml	41.8 ± 1.9	45.4 ± 1.6	41.0 ± 1.6	37.0 ± 1.2
50–80 mg/ml	65.1 ± 1.1[a]	60.7 ± 1.3[b]	63.7 ± 1.5[a]	59.2 ± 1.3[b]
Greater than 80 mg/ml	118.0 ± 4.4[a]	116.4 ± 6.8[b]	112.4 ± 7.7[a]	110.5 ± 14.3[b]

[a,b] Different superscript letters indicate significance between herd differences ($P < 0.05$)

SEM, standard error of mean

than 20 mg/ml. On average, the concentration of IgG in the colostrum at 1 and 6 h after the onset of farrowing was 77.8 ± 35.2 and 60.1 ± 28.5 mg/ml, respectively. The IgG concentrations ranged from 21.8 to 242.9 and from 21.8 to 180.4 mg/ml at 1 and 6 h after the onset of farrowing, respectively. The variation in the immunoglobulin concentration in the colostrum of sows was influenced by sow parity number and herd. Management strategies for enhancing the immunoglobulin concentration in the colostrum of sows under a tropical climate should be emphasised in primiparous sows.

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Compliance with ethical standards

The experiment followed the guidelines documented in the Ethical Principles and Guidelines for the Use of Animals for Scientific Purposes edited by the National Research Council of Thailand and was approved by the Institutional Animal Care and Use Committee in accordance with the university regulations and policies governing the care and use of experimental animals (approval number 1731064).

Conflict of interest The authors declare that they have no conflict of interest.

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Factors influencing colostrum consumption by piglets and their relationship with survival and growth in tropical climates

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ABSTRACT

Inadequate colostrum consumption increases preweaning mortality and reduces body weight gain. The aim of the present study was to determine which factors influence piglet colostrum consumption and to study their relationship with the piglet survival and growth in tropical climates. At birth, 1018 piglets from 1 to 7 parity sows were monitored for heart rate, blood oxygen saturation, blood glucose concentration, birth order, birth interval, sex, standing time, integrity of the umbilical cord and rectal temperature 24 h after birth (RT24h). Piglets were weighed at birth and postnatal days 1 and 21. The mortality rate of piglets was determined on day 21 of lactation. On average, individual colostrum consumption was 426 g. Litters with less than 12 piglets born alive, a low birth weight (BWB), birth order greater than 9 or standing time greater than 5 min had significantly lower colostrum consumption ($P < 0.001$) compared to those with a greater number of piglets born alive, higher BWB and shorter standing time. Sows with a low litter birth weight had low colostrum yield ($P < 0.001$). High mortality at postnatal day 21 was found for piglets with colostrum consumption less than 400 g and RT24h less than 38.5 °C ($P < 0.05$). Moreover, piglets with colostrum consumption less than 400 g and low BWB had reduced average daily weight gain ($P < 0.001$). In conclusion, the number of piglets born alive, BWB, RT24h, birth order and standing time influenced piglet colostrum consumption, with litter birth weight representing the most influential factor for colostrum yield in a tropical climate.

1. Introduction

Colostrum represents a rich source of nutrients, immunoglobulins, enzymes and hormones (Rooke and Bland, 2002), and plays a key role in thermoregulation and passive immunity acquisition of piglets (Devillers et al., 2011). Colostrum also contains a high number of cells including polymorphonuclear cells, lymphocytes, macrophages and epithelial cells, which are also very important in the protection of the neonatal piglet (Evan et al., 1982). In sow, immunoglobulins cannot cross the placenta during pregnancy, thus neonatal piglets are agammaglobulinemic at birth (Salmon et al., 2009). Therefore, the survival of the neonatal piglet is largely dependent on the acquisition of maternal immunity via colostrum and milk. Moreover, colostrum IgG is reported to stimulate brain protein synthesis and brain development during early postnatal life (Pierzynowski et al., 2014). The survival and growth of piglets has been positively associated with colostrum consumption (Decaluwé et al., 2014). Quesnel et al. (2012) observed that colostrum consumption is highly variable among littermates, ranging from 0 to 700 g/kg.

The huge variation in colostrum consumption and limited capacity for colostrum production by sows highlight the importance of a more comprehensive understanding of the factors that affect colostrum consumption. Piglets with low vitality at birth have a longer interval from birth until their first suckle, with an impaired ability to suckle properly (Amdi et al., 2013). Moreover, the degree of intrapartum asphyxia and the umbilical characteristics of piglets have also been used to reflect their vitality after birth (Trujillo-Ortega et al., 2007). Damage to the umbilical cord can lead to intrapartum hypoxia, reducing piglet vitality and colostrum consumption (Devillers et al., 2007; Panzardi et al., 2013).

The sow's parity number, backfat thickness and litter size can also affect the consumption by piglets (Quesnel, 2011; Decaluwé et al.,

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2013). Previous studies have reported that sows in parities 2–3 tend to produce more colostrum than primiparous and older sows (Devillers et al., 2007; Decaluwé et al., 2013). In addition, colostrum yield of the sow seems to be limited and poorly influenced by sow body condition before farrowing and the process of farrowing (Quesnel, 2011). The technical parameters associated with colostrum yield included parity of sows and back fat change from day 109 of gestation to day 1 post-partum (Decaluwé et al., 2013). Furthermore, one third of sows do not produce sufficient amount of colostrum (Decaluwé et al., 2013). Earlier studies demonstrated that sow body weight prior to farrowing, litter birth weight and the number of live-born piglets are positively correlated with colostrum and milk production (Declerck et al., 2015; Vadmand et al., 2015). However, Deviller et al. (2007) found that colostrum yield was not affected by litter size but tended to be influence by parity and was lower when farrowing was induced. The mammary glands are thought to be modified tubular sweat glands (Frandson et al., 2009). Thus, high ambient temperatures could be expected to increase the amount of blood directed toward the subcutaneous tissue surrounding the mammary glands, rather than increasing the nutrient supply to the mammary epithelium, particularly in sows reared in a tropical climate, which may consequently impair the production of colostrum and milk. Additionally, the impaired feed intake due to heat stress also negatively influence the colostrum and milk production of sows in the tropics (Ribeiro et al., 2018).

In larger litters (i.e., 13–15 piglets per litter), an increased number of fights between littermates during suckling was found to reduce colostrum consumption, enhance the risk of starvation, and increase piglet mortality before weaning (Milligan et al., 2002; Nuntapaitoon and Tummaruk, 2015). Additionally, while the rectal temperature of neonatal piglets is dependent on the environmental temperature (Kammersgaard et al., 2011), colostrum also plays an essential role in enabling thermoregulation (Devillers et al., 2007). Piglets with a high rectal temperature (>38.1 °C) in their first day of postnatal life were reported to have lower mortality (Panzardi et al., 2013). Knowledge of factors that influence colostrum consumption and colostrum yield are important to reduce preweaning mortality and increase growth of piglets; however, this remains to be clarified under hot climatic conditions. The objective of the present study was to evaluate which traits of newborn piglets in a tropical climate are important for piglet colostrum consumption and sow colostrum yield, which in turn affect preweaning mortality and piglet growth.

2. Materials and methods

2.1. Animals and general management

The experiment followed the guidelines documented in the Ethical Principles and Guidelines for the Use of Animals for Scientific Purposes of the National Research Council of Thailand, and was approved by the Institutional Animal Care and Use Committee (IACUC), in accordance with the regulations and policies of the university governing the care and use of experimental animals (approval number 1,431,063).

The present study was performed on a commercial swine herd in the western part of Thailand between June and August 2013. The number of productive sows in the herd was 3500. The average ambient temperature during the experimental period ranged from 25.8 to 30.0 °C. The minimum daily temperature ranged from 21.1 to 26.3 °C, and maximum daily temperatures from 28.1 to 37.6 °C. The average relative humidity varied between 72.0% and 96.0%.

Sows were kept in individual crates (1.2 m^2) in a conventional open-housing system during gestation, and provided with fans and individual water sprinklers to reduce the impact of high ambient temperature. Pregnant sows were moved to the farrowing house approximately 1 week before their expected farrowing date. In the farrowing house, sows were individually kept in farrowing crates (1.2 m^2, 0.6 × 2.0 m) that were placed at the centre of a 4.2 m^2 pens. The pens were fully slatted with concrete in the centre for the sows, and contained steel slats on both sides of the farrowing crate for the piglets. Each pen was provided with a creep area for piglets (0.60 m^2), which was placed on the floor on one side of the farrowing crate and covered with a plastic plate without any heating source. A heating lamp was provided to piglets in the creep area during the first week after farrowing. During gestation, sows were fed a commercial gestation diet to meet or exceed their nutritional requirements (NRC, 2012). Feed was provided twice a day following a standardised feeding regimen, resulting in an average feed of 2.5 kg per sow per day. During lactation, sows were fed twice a day with a commercial lactation diet to meet or exceed their nutritional requirements (NRC, 2012). The daily amount of feed offered increased depending on the litter size and body condition of the sow, until ad libitum feeding was reached after 1 week of lactation. The animals received ad libitum water in a continuous feed and water channel.

The parturition process was carefully supervised. Interference with sows was kept to a minimum during parturition. Birth intervention was performed only when dystocia was clearly identified. Dystocia was considered when an interval of 30 min elapsed from birth of the last piglet, accompanied by the sow showing intermittent straining with padding of the legs, or with the sow expelling small quantities of fetal fluid, together with marked tail switching without the birth of any piglets. Routine procedures performed on piglets included weighing, tail docking, tooth clipping and intramuscular administration of a 1 ml iron supplement (Gleptosil®, Alstoe Ltd. Animal Health, Leicestershire, England) on the day of birth. Piglets were also orally administered coccidiocide (Baycox®, Bayer Pharma AG, Berlin, Germany) and intramuscularly administered an antibiotic on postnatal day 3. The mean lactation length was 23 ± 2 days.

2.2. Data collection

A total of 1160 piglets born from 85 Norwegian Landrace × Finnish Yorkshire crossbred sows (the numbers of sow parities 1–7 were 28, 13, 13, 10, 11, 3 and 7 sows, respectively) were included in this study. The following reproductive variables of sows were recorded: farrowing duration (time between first- and last-born piglets, total number of piglets born per litter (TB), number of piglets born alive per litter (BA), mummified fetuses, stillborn piglets, and the number of piglets at weaning per litter. Within 5 min of birth, the piglets were monitored for heart rate and blood oxygen saturation by veterinary pulse oximetry of the left ear using a neonatal probe (EDAN VE-H100B Pulse Oximeter; Edan Instrument Inc®, CA, USA). Blood samples for glucose evaluation were collected from the umbilical cord of piglets before their first suckling, and contained a mixture of venous and arterial blood. Blood glucose concentration was evaluated using a portable human glucometer (Accu-Chek® Performa; Roche, Basel, Switzerland). The umbilical cord was tied and cut 5 cm from the abdominal wall.

For each piglet, the birth order, birth interval (time elapsed between the birth of each piglet), sex and standing time (time elapsed from birth until their first attempt to stand) were recorded. We also recorded whether piglets required birth assistance. The skin colour of piglets was recorded at birth and classified into two groups (normal or pale). The integrity of the umbilical cord of each piglet was examined and classified into two groups (intact or broken). Rectal temperature was measured 24 h after birth (RT24h) with a digital thermometer (Microlife®; Microlife AG Swiss Corporation, Widnau, Switzerland; display resolution of 0.01 °C with ± 0.1 °C accuracy). All the measurements including the skin colour, integrity of the umbilical cord and rectal temperature of the piglets were carried out by the same person (i.e., M. Nuntapaitoon) to standardize the measurement. All piglets were individually identified by an ear tattoo. The birth weight (BW_B) of piglets was measured immediately after birth and again 24 h after birth of the first born piglet (range: 18–24 h after birth). The sum of BW_B for all the live-born piglets in the litter was defined as the litter birth weight. Cross-fostering was performed 24–48 h after birth, and the

number of piglets within each litter was adjusted to 12–14 piglets per litter. The litter size (LS) was defined as the number of piglets per litter after cross-fostering. Piglets were weighed again at day (d) 21 of lactation, at which stage any piglet mortality was recorded. The backfat thickness of the sows was measured at the last rib, 65 mm from the dorsal midline, using A-mode ultrasonography (Renco Lean-Meater®; Minneapolis, MN, USA). The backfat measurement was performed in each sow at farrowing and at weaning.

The individual colostrum consumption of each piglet was estimated by a previously reported equation (Theil et al., 2014): Colostrum consumption (g) = $-106 + 2.26WG + 200BW_B + 0.111D - 1414WG/D + 0.0182WG/BW_B$, where WG is piglet weight gain over 24 h (g), BW_B is birth weight (kg), and D is the duration of colostrum suckling (min). The colostrum yield of the sows was defined as the sum of individual colostrum consumption by all piglets in the litter.

2.3. Statistical analysis

All statistical analyses were performed using SAS 9.0 (SAS Inst. Inc., Cary, NC, USA). Descriptive statistics and frequency tables were generated for continuous and categorical data, respectively. To identify the potential indicators for colostrum consumption, each recorded factor was subjected to univariate analysis using a generalised linear model (PROG GLM). Categorical variables (i.e., sex, skin colour, standing time, integrity of the umbilical cord and birth intervention) were individually tested by including one factor at a time. Continuous variables (i.e., TB, number of piglet born alive, BW_B, birth interval, RT24h, piglet heart rate, piglet blood glucose concentration and birth order) were measured for collinearity using Pearson's correlation.

The categories for number of live-born piglet and BW_B were based on our previous study (Nuntapaitoon and Tummaruk, 2015). The three classes created for number of live-born piglet were: less than 12 piglets/litter, 12–14 piglets/litter, and more than 14 piglets/litter. For BW_B, the categories were: low (less than 1.30 kg), medium (1.30–1.79 kg), and high (more than 1.79 kg). The categories for standing time (less than 1 min, 1–5 min, and more than 5 min) and birth order (less than or equal to ninth, and greater than ninth) were based on Panzardi et al. (2013). The categories for RT24h and litter birth weight were created by frequency analysis. The three classes of RT24h were: less than 38.5 °C, 38.5 to 38.8 °C, and more than 38.8 °C. The litter birth weight of sows were classified into three groups: low (less than 16.0 kg), medium (16.0–20.0 kg), and high (more than 20.0 kg). Parity of sows were classified into four groups, i.e., 1, 2, 3 and 4–7. Colostrum consumption and colostrum yield were compared among parity groups.

Colostrum consumption and colostrum yield were analysed using the generalised linear mixed model procedure (PROC MIXED) of SAS. The mixed models included both fixed and random effects, and used restricted maximum likelihood (REML) as the estimation method. Non-significant factors with $P > 0.10$ were removed from the models in a stepwise fashion. The fixed effects in the final models included effects of number of live-born piglet, BW_B, birth order and standing time on colostrum consumption, and effects of number of live-born piglet and litter birth weight on colostrum yield. Sow identification number was added into the statistical model as a random effect when analysing piglet colostrum consumption.

The analyses of pre-weaning mortality and average daily weight gain until postnatal d 21 (ADG21) were conducted using generalised linear mixed model procedures (GLIMMIX macro) and general linear mixed model (PROC MIXED), respectively. The independent variables included colostrum consumption class (≤400 and >400 g), skin colour (normal and pale), RT24h (38.5, 38.5–38.8 and >38.8 °C), birth intervention (no, yes), BW_B class (<1.30, 1.30–1.79 and >1.79 kg) and two-way interactions. In addition, multiple ANOVA was used to evaluate the effect of BW_B, litter birth weight or RT24h (regression) on colostrum consumption, colostrum yield, preweaning mortality and ADG21 after birth. Least-squared means were obtained from statistical models. Values with $P < 0.05$ were regarded as being statistically significant.

Table 1
Descriptive statistics of 85 sows and 1018 piglets evaluated at birth and during the lactation period in a commercial swine herd in Thailand.

Variables	*N*	Mean ± SD	Range
Sow data			
Parity	85	3.0 ± 1.9	1–7
Backfat thickness at farrowing (mm)	85	15.0 ± 3.1	8–22
Backfat thickness at weaning (mm)	85	12.1 ± 2.4	7–19
Relative loss of backfat (%)	85	18.9 ± 8.9	0–41.2
Number of total born piglets	85	13.8 ± 3.5	7–21
Number of piglets born alive	85	12.0 ± 3.1	4–19
Litter size	85	12.9 ± 1.5	9–16
Number of piglets at weaning	85	11.6 ± 1.6	7–15
Farrowing birth interval (min)	85	15.7 ± 22.2	0–38
Farrowing time (min)	85	213.2 ± 80.0	71–558
Gestation length (day)	85	115.2 ± 1.0	113–118
Piglet data			
Birth weight (g)	1018	1.5 ± 0.36	0.5–2.7
Heart rate (bpm)	1009	64.8 ± 31.75	23–250
Blood glucose (mg/dl)	1018	51.7 ± 25.56	10–485
Oxygen saturation (%)	1009	91.6 ± 8.26	10–100
Weight at day 1 (g)	987	1.6 ± 0.39	0.4–2.9
Weight at day 7 (g)	932	2.6 ± 0.66	0.7–4.6
Weight at day 21 (g)	891	5.9 ± 1.43	1.9–10.1
ADG[a] day 0 to 1 (g/day)	987	69.3 ± 102.17	−440.0 – 545.0
ADG day 1 to 7 (g/day)	932	156.2 ± 63.90	−16.4–340.7
ADG day 1 to 21 (g/day)	891	207.6 ± 60.43	24.0–376.9

[a] ADG, Average daily weight again (g/day); *Reference values of heart rate, blood glucose and oxygen saturation in newborn piglets are 158 bpm, 40.6 mg/dl and 76.3%, respectively (Panzardi et al., 2013).

3. Results

Descriptive statistics for sow reproductive performance and piglet performance are presented in Table 1. From the 1160 piglets included in the experiment, 96 were stillborn (8.4%), 46 were mummified (4.0%), and 1018 were BA (87.7%). On average, the colostrum yield was 4957 ± 1228 g (range 1694–7319 g). Piglet preweaning mortality amounted to 127 piglets (12.5%), and the number of dead piglets on d 1 and 21 of lactation was 31 (3.1%) and 96 (9.4%) piglets, respectively. The mean colostrum consumption for each piglet was 426 ± 5 g, with 6.6% of piglets having ingested less than 200 g, 38.6% ingested between 200 and 400 g, and 54.8% ingested more than 400 g of colostrum (Fig. 1). The piglets delivered after birth assistant had a higher colostrum consumption than piglets delivered without birth assistant (462 ± 14 and 422 ± 5 g, respectively, $P = 0.006$).

3.1. Factors associated with colostrum consumption

3.1.1. Univariate analysis

Colostrum consumption was influenced by number of live-born piglet, BW_B, birth interval, birth order, piglet heart rate, piglet blood glucose concentration, birth intervention and standing time ($P < 0.05$). The correlation analysis showed colostrum consumption to be positively correlated with BW_B, birth interval, RT24h, piglet heart rate, and piglet blood glucose concentration (Table 2). On the other hand, colostrum consumption was negatively correlated with TB, number of live-born piglet and birth order. Sow parity, farrowing time, sow backfat thickness at farrowing, piglet blood oxygen saturation, piglet skin colour, piglet sex and integrity of umbilical cord were not found to be correlated with colostrum consumption ($P > 0.10$). The regression analysis showed a relationship between colostrum consumption and number of live-born piglet, BW_B, birth order and blood glucose concentration (Fig. 2).

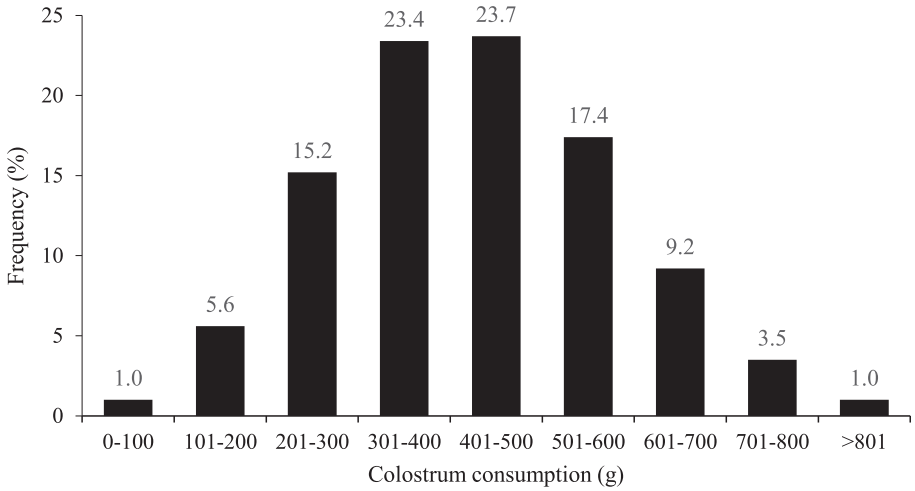

Fig. 1. Frequency distribution of individual colostrum consumption (g) in 987 neonatal piglets (excluding 31 piglets that died before 24 h) born from 85 Landrace × Yorkshire crossbred sows in a commercial swine herd in Thailand.

3.1.2. Final multivariate model

The final multi-covariate model for colostrum consumption included number of piglet born alive ($P < 0.001$), BW_B ($P < 0.001$), birth order ($P < 0.001$), standing time ($P = 0.002$) and parity classes ($P < 0.001$). Colostrum consumption decreased when number of piglet born alive, birth order or standing time increased. On the other hand, colostrum consumption increased as BW_B increased (Table 3). Colostrum consumption of piglets born from primiparous sows was lower than those from sows parity 2, 3 and 4–7 (362 ± 11, 413 ± 13, 425 ± 13 and 422 ± 9 g, respectively, $P < 0.001$).

3.2. Factors associated with colostrum yield

3.2.1. Univariate analysis

Colostrum yield was influenced by number of piglet born alive and litter birth weight ($P < 0.001$). However, sow parity, sow backfat thickness at farrowing and farrowing time were not correlated with colostrum yield ($P > 0.10$). Colostrum yield of primiparous sows was lower than sows parity 2 and 3 (4532 ± 225, 5372 ± 331 and 5505 ± 331 g, respectively, $P < 0.05$), but did not differ significantly compared to sows parities 4 – 7 (4936 ± 214, $P = 0.198$).

3.2.2. Final multivariate model

Litter birth weight was found to influence colostrum yield ($P = 0.012$). The colostrum yield of sows with a low litter birth weight (4975 ± 1321 g) was lower than that for sows with a medium litter birth weight (6009 ± 1343 g; $P = 0.001$) or a high litter birth weight (6548 ± 1321 g; $P < 0.001$).

3.3. Association between colostrum consumption and mortality at day 21 postnatal

Piglets with colostrum consumption greater than 400 g had a lower mortality rate. The mortality rates were 88.8%, 73.3%, 15.1%, 6.3% and 0.5–1.5% for piglets with colostrum consumption of 0–100, 101–200, 201–300, 301–400 and > 400 g, respectively ($P < 0.05$). Piglets that died before d 21 had a lower colostrum consumption than piglets that survived until weaning (263 ± 15 and 445 ± 5 g, respectively, $P < 0.001$). The factors found to significantly influence preweaning mortality in the final model included BW_B ($P < 0.001$), colostrum consumption ($P < 0.001$), RT24h ($P = 0.030$), birth intervention ($P = 0.017$), skin colour ($P = 0.045$) and the interaction between colostrum consumption and RT24h ($P = 0.045$; Table 4). Moreover, the amount of colostrum consumption influenced RT24h (Fig. 3), with RT24h increasing with higher colostrum consumption. Piglets with colostrum consumption less than 400 g and RT24h less than 38.5 °C (17.5%) had a higher rate of preweaning mortality compared to the other piglets (Fig. 4).

3.4. Association between colostrum consumption and average daily weight gain until day 21 postnatal

The factors found to influence ADG21 in the final model included BA ($P < 0.001$), BW_B ($P < 0.001$), colostrum consumption ($P <$

Table 2
Pearson's correlation coefficients (*r*) among factors associated with colostrum consumption by neonatal piglets.

	TB	BA	BW_B	BI	BO	RT24	HR	Glu
BA	0.823***							
BW_B	−0.282***	−0.331***						
BI	−0.139***	−0.126***	0.164***					
BO	0.328***	0.311***	−0.102**					
RT24			0.126***					
HR	−0.092**	−0.082**						
Glu	−0.124***	−0.121***	0.137***	0.159***	0.106***			
CC	−0.345***	−0.424***	0.615***	0.074*	−0.234***	0.258***	0.074*	0.086**

Abbreviations: TB, total piglets born; BA, piglets born alive; BW_B, birth weight; BI, birth interval; BO, birth order; RT24, rectal temperature 24 h after birth; HR, piglet heart rate; Glu, piglet blood glucose concentration; CC, colostrum consumption.
Significance levels:.
*** $P < 0.001$.
** $P < 0.01$.
* $P < 0.05$.

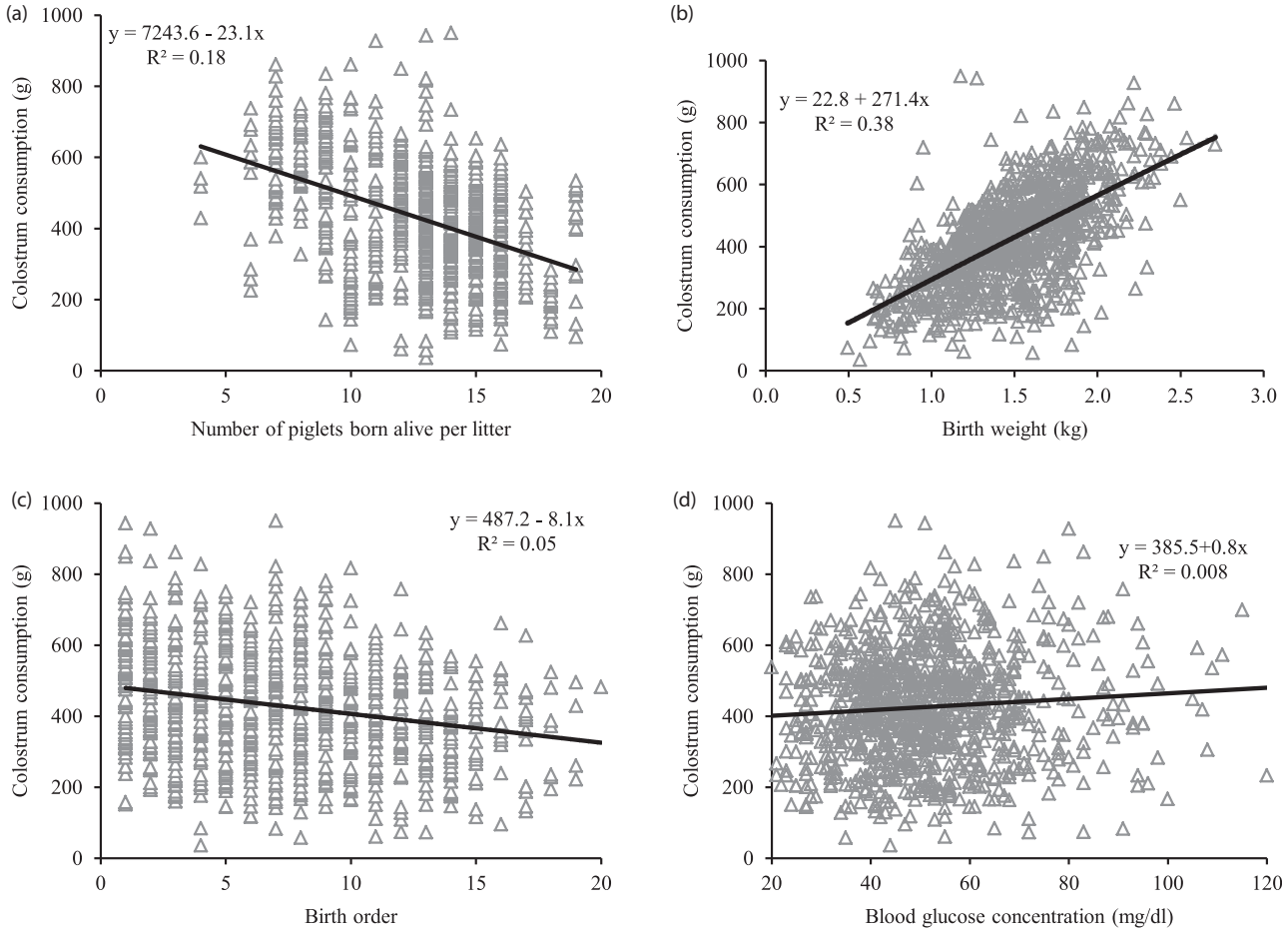

Fig. 2. Relationship between colostrum consumption and (a) number of piglets born alive, (b) birth weight, (c) birth order and (d) piglet blood glucose concentration in 987 neonatal piglets (excluding 31 piglets that died before 24 h).

Table 3
Results of multiple analyses of variance (ANOVA) using the general linear mixed model procedure (PROC MIXED) for factors influencing piglet colostrum consumption.

Variables	*N*	Colostrum consumption (g)
Number of piglets born alive per litter		
<12	272	460[a]
12–14	421	402[b]
≥15	293	369[b]
Piglet birth weight (kg)		
<1.30	290	305[c]
1.30–1.79	498	425[b]
>1.79	198	501[a]
Birth order		
<9	675	423[a]
≥10	311	397[b]
Standing time (min)		
<1	858	437[a]
1–5	89	412[b]
>5	39	382[b]

Different superscript letters within the column indicate significant differences ($P < 0.05$).

Table 4
Results of multiple analyses of variance (ANOVA) using the generalised linear mixed model procedure (PROC GLIMMIXED) for factors influencing piglet preweaning mortality.

Variables	*N*	Preweaning mortality (%)	95% CI
Piglet's birth weight (kg)			
<1.30	290	9.9[a]	5.0–18.9
1.30–1.79	499	3.0[b]	1.4–6.1
>1.79	198	2.7[b]	1.1–6.5
Colostrum consumption (g)			
≤400	446	10.3[a]	5.3–19.1
>400	541	1.8[b]	0.8–3.9
Rectal temperature 24 h after birth (°C)			
<38.5	338	6.8[a]	3.2–13.6
38.5–38.8	333	2.6[b]	1.1–5.9
>38.8	316	4.7[ab]	2.2–9.6
Birth intervention			
Yes	127	2.4[b]	0.9–6.8
No	860	7.6[a]	4.5–12.6
Skin colour			
Normal	948	2.8[b]	1.6–5.0
Pale	39	6.7[a]	2.6–16.4

Different superscript letters within the column indicate significant differences ($P < 0.05$).

0.001), and the interaction between BW_B and colostrum consumption ($P = 0.018$; Table 5). An influence of colostrum consumption on ADG21 by BW_B classes is evident in Fig. 5, which shows that piglets with colostrum consumption equal to or less than 400 g had a lower ADG21 than piglets with colostrum consumption more than 400 g in all BW_B classes ($P < 0.05$). Moreover, piglets with colostrum consumption more than 400 g and a high BW_B (246 g/day) had higher ADG21 than

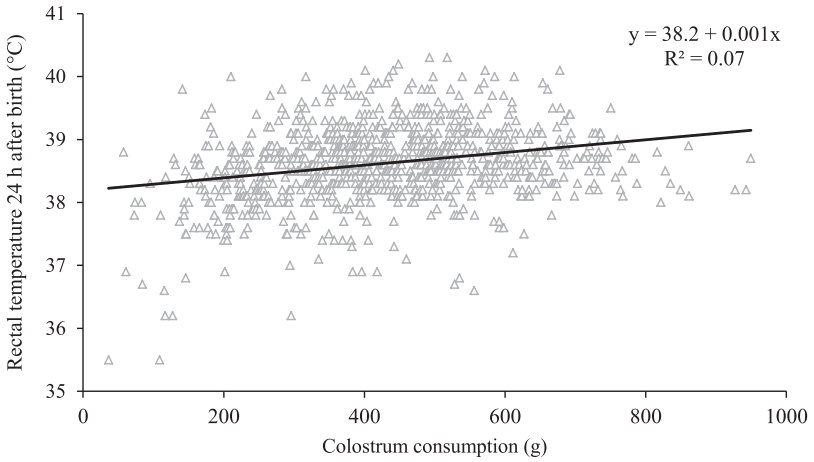

Fig. 3. Influence of colostrum consumption on rectal temperature 24 h after birth.

piglets with colostrum consumption greater than 400 g and a low or medium piglet BW_B (200 and 227 g/day, respectively; $P < 0.001$).

3.5. Regression analysis

All of the regression models related to colostrum consumption, colostrum yield, preweaning mortality and ADG21 included BW_B (Table 6). Results indicated that 38% of the variation in colostrum consumption was explained by BW_B, showing a positive regression coefficient of 0.271. There was a positive regression coefficient between litter birth weight of live-born piglets and colostrum yield. In contrast, the regression coefficients for piglet birth weight, RT24h and colostrum consumption were negatively correlated with mortality. Overall, BW_B, RT24h and colostrum consumption explained 14% of the variability in preweaning mortality, and BW_B and colostrum consumption explained 27% of the variability in ADG21.

4. Discussion

4.1. Colostrum consumption, ability to thermoregulate and neonatal piglet mortality

Colostrum consumption is crucial for the survival and growth of piglets in commercial herds. In the present study, piglet mortality decreased with increasing intake of colostrum until 400 g, above which piglet mortality was consistently below 2%. From these findings, we can conclude that 400 g of colostrum consumption per piglet during the first 24 h after birth is recommended to minimise the risk of death and to enhance growth performance until weaning. The recommended colostrum consumption from this study is considerably greater than that previously reported by Quesnel et al. (2012), who found that 200 g of colostrum was required to reduce piglet mortality. The reason for this discrepancy is mainly due to differences in the prediction equations used by the two studies. The prediction model used in the current study estimates colostrum consumption higher than the equation developed by Devillers et al. (2004) (437 ± 153 g vs 305 ± 140 g/day; Theil et al., 2014). The reason is mainly due to different techniques used (i.e., mechanistic model using D_2O dilution technique versus empirical predictive model developed for bottle-fed piglets) for developing the estimation model to quantify colostrum consumption of the piglets (Theil et al., 2014). It was suggested that the previous empirical predictive model underestimates colostrum consumption of sow-reared piglets by 30% (Theil et al., 2014). In the current study, the colostrum consumption of the piglets was estimated from the new mechanistic predictive model. Thus, the cut-off value for optimal colostrum consumption of the piglets should be considered. Based on the present results, piglet preweaning mortality was significantly reduced when the colostrum consumption estimated from the new mechanistic predictive

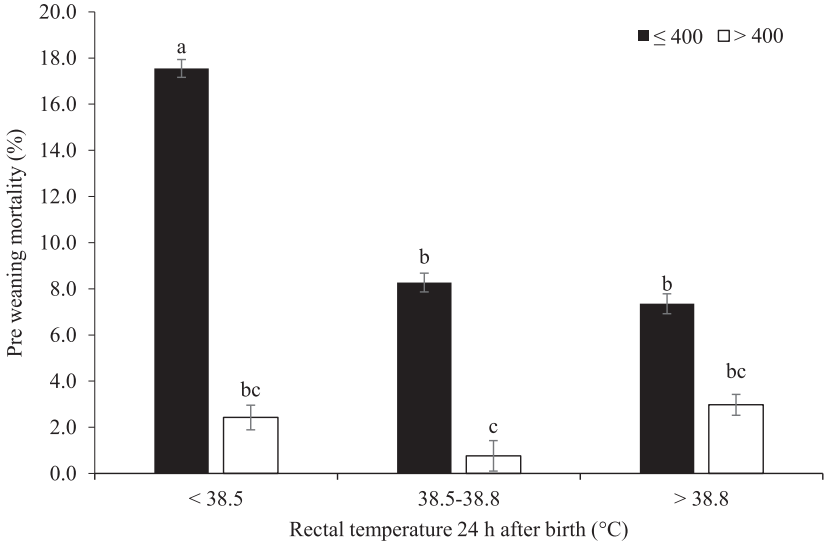

Fig. 4. Influence of colostrum consumption (≤400 or >400 g) on preweaning mortality for different classes of rectal temperature determined 24 h after birth (<38.5, 38.5–38.8, and >38.8 °C). Different superscript letters indicate significant differences ($P < 0.05$).

Table 5
Results of analyses of variance (ANOVA) using the general linear mixed model procedure (PROC MIXED) for factors influencing average daily weight gain at postnatal day 21.

Variables	*N*	Average daily weight gain at day 21 (g/day)
Number of piglets born alive per litter		
<12	257	218[a]
12–14	385	187[b]
≥15	247	202[ab]
Birth weight (kg)		
<1.30	226	183[b]
1.30–1.79	472	211[a]
>1.79	191	213[a]
Colostrum consumption (g)		
≤400	362	181[b]
>400	527	224[a]

Different superscript letters within the column indicate significant differences ($P < 0.05$).

model was greater than 400 g. Therefore, the optimal level of colostrum consumption should be as high as 400 g when the new mechanistic predictive model was used.

Rectal temperature in piglets after the colostral period is associated with the amount of colostrum consumed (Tuchscherer et al., 2000). Colostrum plays an important role in the thermoregulation of piglets during the neonatal period (Rooke and Bland, 2002). This is in agreement with current findings, whereby piglets ingesting more colostrum had higher rectal temperature 24 h after birth. Moreover, the piglets with low colostrum consumption and a rectal temperature less than 38.5 ºC 24 h after birth had greater mortality (up to 17.5%). From these findings it can be concluded that 400 g of colostrum consumption per piglet during the first 24 h after birth and rectal temperatures of more than 38.5 °C 24 h after birth are recommended. Therefore, management strategies for increasing colostrum consumption or keeping them warm during the colostrum period should be prioritised.

Table 6
Regression models determined through stepwise regression with a backward elimination approach for colostrum consumption (CC), colostrum yield (CY), preweaning mortality (PWM) and average daily weight gain during the 21 days (ADG21) after birth.

Regression model	R^2
CC (g) = 22.8 + 271 × piglet birth weight (kg)	0.38
CY (g/day) = 1596 + 194 × total litter weight at birth (kg)	0.46
PWM (%) = 2.3 − 0.1 × piglet birth weight (kg) − 0.05 × RT24h[a] (°C) − 0.0004 × CC (g)	0.14
ADG21 (g/day) = 93.3 + 20.9 × piglet birth weight (kg) + 0.18 × CC (g)	0.27

[a] RT24h, rectal temperature of the piglet at 24 h postnatal.

4.2. Colostrum consumption and growth performance of piglets during lactation

Colostrum is important for piglet growth performance and health during the lactation period (Rooke and Bland, 2002; Le Dividich et al., 2005). Current findings indicate that piglets consuming more than 400 g of colostrum had a higher growth rate during lactation than piglets consuming less than 400 g of colostrum, and this higher growth rate was especially evident in high-birth-weight piglets. High-birth-weight piglets therefore seem to have a greater ability to consume, digest or utilise colostrum for growth than low-birth-weight piglets (Quesnel et al., 2012; Amdi et al., 2013; Ferrari et al., 2014). Piglets with high colostrum consumption were previously reported to show greater growth performance both before and after weaning (Declerck et al., 2016; Krogh et al., 2016; Muns et al., 2016). The present results confirm that piglet birth weight and colostrum consumption influence piglet growth performance during the lactation period.

4.3. Factors affecting colostrum consumption and colostrum yield

4.3.1. Number of live-born piglets

A larger litter size increases the number of fights between piglets at suckling, increasing the risk of starvation and crushing of small piglets. Consequently, litter size is an important factor for neonatal piglet

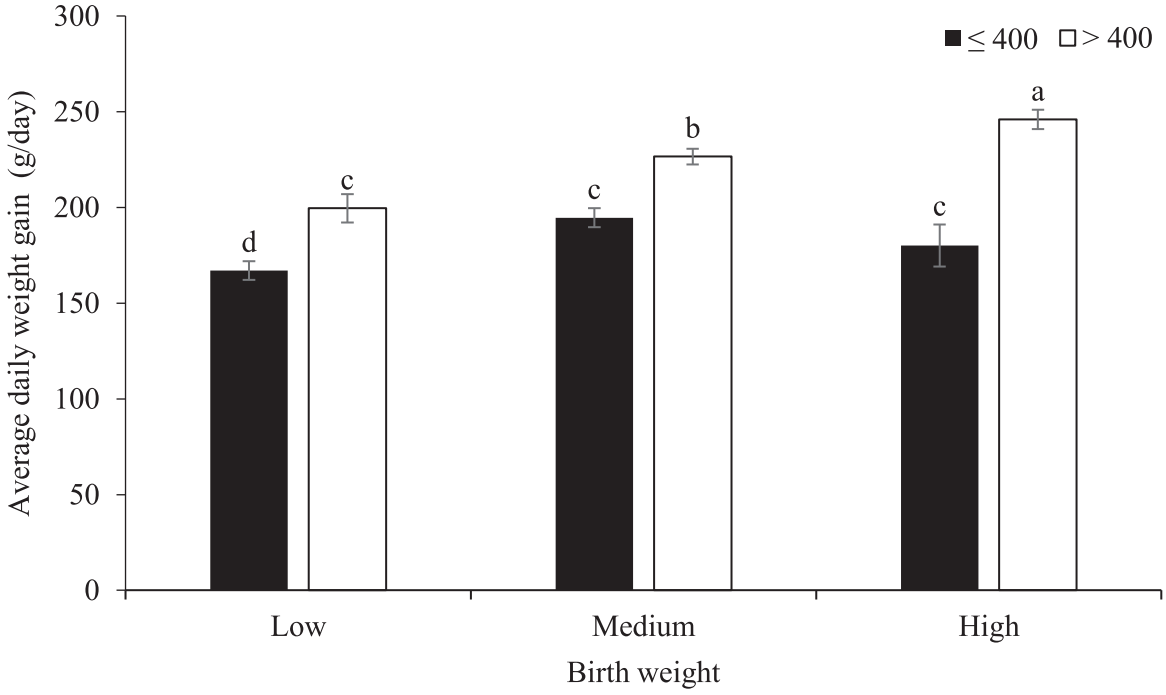

Fig. 5. Influence of colostrum consumption (≤400 or >400 g) on average daily weight gain until day 21 after birth for piglets classified into low (<1.30 kg), medium (1.30–1.79 kg) and high (>1.79 kg) birth weight classes. Different superscript letters indicate significant differences ($P < 0.05$).

survival (Milligan et al., 2002). In the present study, piglets in smaller litters had greater colostrum consumption. Likewise, an earlier study reported that litter size is negatively correlated with colostrum consumption (Anderson et al., 2011). Muns et al. (2016) reported that individual colostrum consumption was reduced in larger litters, especially in low-birth-weight piglets. Moreover, in high competition litters, piglets squealed more intensely before and after udder stimulation and during suckling. It was previously found that the squealing of piglets terminates suckling, and this especially during the first 24 h postpartum (Illmann et al., 2008). As a result, piglets likely do not consume an adequate amount of colostrum. Additionally, colostrum production is highly variable among sows (Quesnel, 2011). In the present study, litter weight at birth influence sow colostrum yield. Moreover, the number of live-born piglets tended to be related with increased colostrum yield. Previous studies showed that colostrum yield is related to litter size and birth weight (Devillers et al., 2007; Quesnel, 2011; Declerck et al., 2015), and is also associated with within-litter birth weight variation (Farmer et al., 2006; Devillers et al., 2007; Quesnel, 2011). Moreover, Vadmand et al. (2015) reported a positive relationship between litter weight at birth and total sow colostrum yield. From those and current findings, it is apparent that management of highly prolific sows is important for increasing colostrum consumption by piglets and colostrum production in sows. In a recent study, Muns et al. (2017) reported that energy boosters can increase the immunity and reduce mortality of piglets. Moreover, oral supplementation with colostrum, split suckling and cross-fostering are management strategies that may enhance colostrum consumption and improve the survival and growth performance of piglets (Donovan and Dritz, 2000; Cecchinato et al., 2008; Muns et al., 2014).

4.3.2. Piglet birth weight

Piglet birth weight was positively related to the amount of colostrum ingested by newborn piglets. In the present study, birth weight and litter weight at birth were the most influential factors for colostrum consumption by piglets and colostrum production in lactating sows. Wang et al. (2005) demonstrated that the weight of the stomach, small intestine and small intestinal mucosal were significantly lower in low birth weight piglets than normal birth weight piglets. Results of the present study showed that piglets with high birth weights (more than 1.80 kg) consumed 1.6 times more colostrum (501 vs 303 g) than piglets weighing less than 1.30 kg at birth. Moreover, the regression analysis indicated that every 100 g increase in piglet birth weight was associated with a 50 g increase in ingested colostrum. Many studies reported the use of different approaches to enhance either piglet birth weight or colostrum consumption, for instance, arginine supplementation in sow gestation diet (Che et al., 2013). Feeding a high-fibre diet to late pregnant sows may favour the consumption of colostrum in small piglets (Loisel et al., 2013); however, this is not likely to be a good solution for tropical climates as a greater fibre intake increases sow heat production and reduces sow appetite (Danielsen and Vestergaard, 2001).

4.3.3. Birth order, standing time and birth assistant

Piglet birth order and standing time were negatively associated with colostrum consumption in the present study. In contrast, others reported no relationship between birth order and colostrum consumption (Devillers et al., 2007; Declerck et al., 2016). Late-born piglets may suffer from intrapartum hypoxia as a result of uterine contractions, especially during prolonged farrowing, which may cause low viability (Herpin et al., 1996). A longer interval between birth and first suckling (i.e., standing time) was observed in late-born piglets (Tuchscherer et al., 2000; Baxter et al., 2008; Mota-Rojas et al., 2012). Accordingly, in the present study, birth order was positively associated with standing time, and both traits were negatively associated with colostrum consumption. Indeed, it is known that individual colostrum consumption depends on the piglet's ability to reach the teat and suckle. A reduced standing time may result in a shorter interval between birth and first suckling. In the present study, piglets with a standing time of less than 1 min ingested 55 g more colostrum (equivalent to a 14% increase) when compared to piglets with a standing time of more than 5 min. Piglets born later with a shorter standing time also had a shorter interval between birth and the first suckling. However, piglets born later acquired a lower level of immunity from colostrum due to decreased colostrum quality (Klobasa et al., 2004).

Piglets are often hypoglycaemic during the postpartum period due to a lack of hepatic enzymes (Odle et al., 2005). However, the blood glucose concentration of piglets may increase during the peripartum period because catecholamine hormones induce gluconeogenesis when piglets lack oxygen during uterine contractions (Herpin et al., 1996). Interestingly, the present study demonstrated that the piglets born after birth assistant had a higher colostrum consumption than those born without birth assistant. The reason could be due to the fact the piglets born with birth assistant received special care immediately after birth, e.g., put at the udder of the sows. Therefore, they might have had a short standing time and are able to obtain colostrum earlier than general piglets.

4.4. Limiting factors affecting colostrum yield

Colostrum production in sows is highly variable due to differences in breed, nutrition, sows, litter and farrowing characteristics, hormonal status and environmental factors (Quesnel, 2011; Theil et al., 2014; Declerck et al., 2015; Vadmand et al., 2015). The effect of temperature is of particular concern regarding colostrum production in tropical climate because heat stress may affect the endocrine status of the sow. Heat stress may increase the level of cortical hormones and influence the oxytocin released during parturition (Malmkvist et al., 2009), and subsequently increase farrowing duration and reduce colostrum production. Furthermore, the high temperatures characteristic of tropical climates may result in decreased blood supply to the mammary epithelium. In pigs, mammary glands are modified sweat glands (Frandson et al., 2009), and blood may be directed toward the subcutaneous tissue rather than the mammary epithelium when the sow body temperature becomes too high. Knowledge on the impact of temperature on mammary blood flow and colostrum production is currently lacking. The positive association between litter size and colostrum consumption suggests that colostrum removal is likely a limiting factor for sow colostrum yield. To our knowledge, no comprehensive studies on the limiting factors of colostrum yield have been performed in a tropical climate.

5. Conclusion

Increasing colostrum consumption is crucial to reduce piglet preweaning mortality. In tropical conditions, high litter size and low birth weight compromised colostrum consumption by piglets, thereby reducing their ability to thermoregulate, reducing piglet growth and increasing piglet mortality during lactation. Management actions performed the first day after birth aimed at increasing colostrum consumption by individual piglets (i.e., cross-fostering, feeding low-birth-weight piglets with colostrum collected from other sows, split suckling or helping piglets with warmed and dry areas) could substantially increase piglet colostrum consumption and reduce mortality.

Conflict of interest statement

The authors have no conflicts of interest.

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Factors associated with colostrum consumption of neonatal piglets

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Keywords: Sow, High prolificacy, Litter size, Reproduction, Tropical climate

Introduction

Colostrum is first milk secreted by the mammary gland that piglets can absorb to gut only within the first 24 h of age. Insufficient colostrum consumption is one of the major problem causing an increased neonatal piglet mortality. Colostrum provides neonatal piglets with both energy and immunoglobulins, thereby playing an essential role on piglet survival. Adequate colostrum consumption of neonatal piglets is therefore ensuring optimal passive immunity for piglets [1]. In addition, colostrum also provides the newborn piglets with high metabolisable energy, i.e., fat and lactose. These energies are efficiently used by the newborn piglets to cope with cold stress and maintaining its homeothermic balance during the first day of life. Quesnel et al. [2] estimated that 250 grams of colostrum consumption per piglet should ensure an optimal growth and passive immunity to the animals. A previous study found that colostrum consumption stimulates the development of the hippocampus structure by the stimulation of brain protein synthesis and brain development during the early postnatal period [3]. The aim of the present study was to investigate management factors associated with colostrum consumption of the neonatal piglets.

Materials and Methods

The study included 1,140 neonatal piglets from 80 Landrace x Yorkshire crossbred sows. The experiment was conducted in a commercial swine herd in the eastern part of Thailand in June 2017. Factors associated with piglet colostrum consumption determined included body weight at birth of the piglet, birth order, birth interval, heart rate, blood oxygen saturation, rectal temperature at 24 h, gestation length, total number of piglets born per litter (TB), number of piglets born alive per litter (BA), sow body conditions score and sow parity number.

The sows were moved to the farrowing house before their expected farrowing date about one week. The feed was provided twice a day (2-5 kg per day) during gestation. During lactation, the sows were fed 3 times a day (about 3-6 kg of feed per day). The sows were vaccinated against CSFV, ADV, PPV, PRRS and PCV2. All gilts and sows was performed FMD vaccine every 4 months. The herd was a PRRS seropositive herd.

Rectal temperature 24 h after birth measured using a digital thermometer (Verridian Healthcare Co. Ltd., IL, USA). Piglets were weighed immediately after birth and again at 24 h using a digital scale (SDS® Digital Scale Co. Ltd., Yangzhou, China). All piglets were individually identified by an ear tattoo performed at birth. Individual colostrum intake of the piglets was estimated by an equation published by Theil et al. [4]: Colostrum consumption (g) = -106 + 2.26WG + 200BWB + 0.111D - 1414WG/D + 0.0182WG/BWB, where WG is piglet weight gain (g), BWB is birth weight (kg) and D is the duration of colostrum suckling (min). The colostrum yield of the sows was defined as the sum of individual colostrum consumption of all piglets in the litter.

Statistical analyses were carried by using SAS. Descriptive statistics and frequency analysis were conducted. The associations among these factors and colostrum consumption of the piglets were analyzed by using Pearson's correlation. The effect of sow parity number on the colostrum consumption by piglets was analyzed by using general linear model procedure (PROC GLM) of SAS. Values with $P < 0.05$ were regarded as statistically significant.

Results and Discussion

The results revealed that the colostrum consumption averaged 405 ± 183 grams. Frequency distribution of colostrum consumption by piglets are presented in Figure 1. As can be seen, 20.1% of the piglets received colostrum below optimal level [2]. Thus, these piglets might have had a high risk of being death or had a poor growth rate.

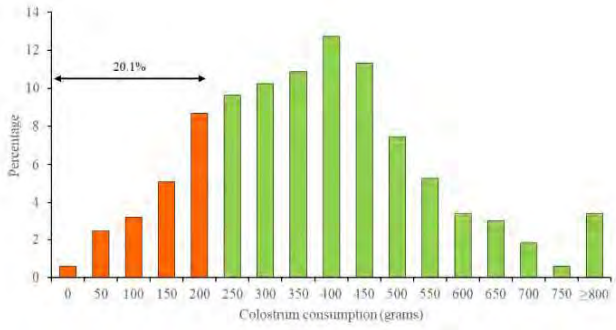

Figure 1 Frequency distribution on colostrum consumption of piglets in a commercial swine herd in Thailand (n = 1,140)

Body weight at birth of the piglet, birth order, TB, BA, body conditions score, heart rate and rectal temperature were significantly correlated with colostrum consumption of the neonatal piglets (Table 1). On the other hand, gestation length, birth interval, blood oxygen saturation and sow parity number were not correlated with colostrum consumption.

In the present study, the piglet rectal temperature is associated with colostrum consumption. Likewise, Tuchscherer et al. [5] found that rectal temperature in piglets is associated with colostrum consumption. These findings indicate that piglets with low rectal temperature at 24 h might have low thermoregulation abilities. Thermoregulation is a crucial physiological event for all newborn piglets. The piglets that die during the first day of life are not able to maintain optimal rectal temperature during the first 24 h of life. Nuntapaitoon et al. [6] found that rectal temperature at 24 h of life was associated with piglet pre-weaning mortality rate. Therefore, increasing colostrum intake of neonatal piglet during first day after birth is very important in swine herd.

Table 1 Correlation between colostrum consumption (mean ± SD = 405 ± 183 grams) and litters and piglet characteristics

Variables	Colostrum consumption		
	n	r	*P* value
Gestation length (days)	1,140	0.01	*NS*
Total born	1,140	-0.21	***
Born alive	1,140	-0.19	***
Body conditions score	1,140	0.06	*
Birth weight (grams)	1,140	0.29	***
Birth order	1,140	-0.07	**
Birth interval (min)	1,140	-0.02	*NS*
Heart rate (beat/min)	872	0.11	**
Blood oxygen saturation (%)	872	0.05	*NS*
Rectal temperature(°C)	862	0.30	***

*$P<0.05$, ** $0.05<P<0.01$, *** $P<0.001$, *NS* = $P > 0.05$

Figure 2 demonstrates colostrum consumption of piglets by parity number of sow. It was found that colostrum consumption of piglets was highest in sow parity number 3. The piglets reared by primiparous sow had a lower colostrum consumption than the piglets reared by sow parity number 3 ($P<0.05$). Likewise, piglets reared by sow parity number 5 also had a lower colostrum consumption than piglets reared by sow parity number 3.

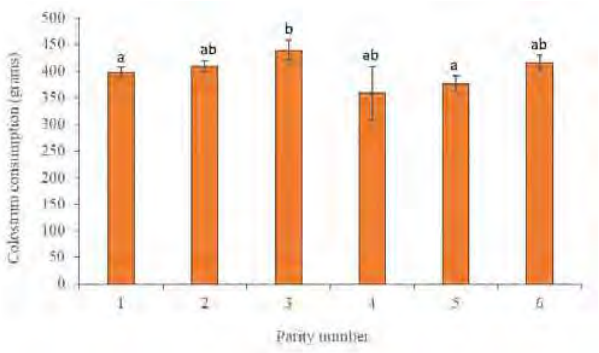

Figure 2 Colostrum consumption of piglets by sow parity numbers.

In conclusion, the body weight at birth of the piglet, birth order, total born, born alive, body conditions score, heart rate and rectal temperature at 24 h of life were significantly associated with piglet colostrum consumption in the swine herd.

Acknowledgements

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Concentrations of total immunoglobulin G in colostrum of sows

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Keywords: Colostrum, Concentration, IgG, Parity, Time

Introduction

Colostrum is a rich source of immunoglobulin and nutrient for newborn piglets. The concentration of total immunoglobulin G (IgG) in sow colostrum is associated with many factors (i.e., breed, parity and environment) [1]. Moreover, the concentration of IgG in colostrum is dramatically decreased after farrowing [2]. Therefore, the quantity of sow colostrum and time elapse from farrowing to first suckling are important for piglet survival and growth [3]. Knowledge concerning factors influencing the concentration of IgG in sow colostrum is important to reduce the proportion of piglet pre-weaning mortality and improve growth performance under field conditions. The present study was performed to investigate the concentration of IgG in colostrum and to determine the association between the time interval from farrowing to sample collection, sow parity number and IgG concentration in colostrum.

Materials and Methods

The present study was performed in a commercial swine herd in the western part of Thailand in February 2017. A total of 161 colostrum samples from 81 sows were investigated. The sows were classified into two groups, i.e., primiparous (n = 16) and multiparous sows (parity number 2-6, n = 65). The sows were kept in an evaporating cooling-housing system. The sows were moved to the farrowing pens about one week before the expected farrowing date. The colostrum samples were collected manually at 1 and 6 h after the onset of parturition. Colostrum samples were collected by hand from all functional mammary glands and were pooled. The samples kept in a clean bottle (30 ml) and were stored at 4 ºC on ice in a foam box during collection process. The samples were cryopreserved at –20 °C within 24 h after collection until analyzes. Colostrum were thawed at room temperature for 2 h and were centrifuged at 15,000 ×g for 20 min at 4 °C (Centrifuge 5810 R, Eppendorf AG, Hamburg, Germany). Supernatant was collected and was used for IgG assay. The fat was discarded and the remaining liquid was collected. Thereafter, the liquid part was diluted 1: 500,000 with sample conjugate diluent (50 mM Tris buffer, 0.14 M NaCl, 1%BSA and 0.05% Tween 20). Immunoglobulin G was determined by using ELISA. The ELISA plate was coated with polyclonal antibody of Pig-IgG (Bethyl Laboratories Inc., Texas, USA). The absorbance was recorded at 450 nm using ELISA plate reader (Tecan Sunrise™, Männedorf, Switzerland). The IgG concentration in the colostrum samples were quantified by interpolating their absorbance from the standard curve generated in parallel with the colostrum samples. The concentration of IgG in colostrum at 1 and 6 h after farrowing were analyzed by using the general linear models (GLM) procedure of SAS. The statistical model included the effect of sow parity number, time interval from the onset of farrowing to sample collection and interaction. Least square means were obtained from each class of the factor and were compared by using Student's *t* test. $P < 0.05$ was regarded to be statistically significant.

Results and Discussion

On average, the concentration of total IgG was 61.1 ± 28.8 mg/ml (range 20.8–201.7 mg/ml). Frequency distribution of the concentration of total IgG in the sow colostrum is demonstrated in Figure 1.

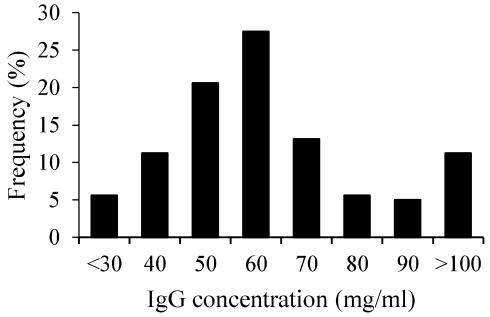

Figure 1 Frequency distribution of the concentration of total IgG in sow colostrum

Both sow parity number and collection time influenced the concentration of IgG ($P < 0.05$) but no effect of interaction between sow parity number and collecting time was found ($P > 0.05$). The concentration of IgG at 1 and 6 h after the onset of parturition were 66.1 ± 3.8 and 48.8 ± 3.8 mg/ml, respectively ($P < 0.001$). The concentration of IgG in sow colostrum in primiparous and multiparous sows are presented in Figure 2. The figure illustrated that multiparous sows (63.2 ± 2.4 mg/ml) had a higher concentration of IgG in colostrum than primiparous sows (51.8 ± 4.8 mg/ml, $P = 0.03$).

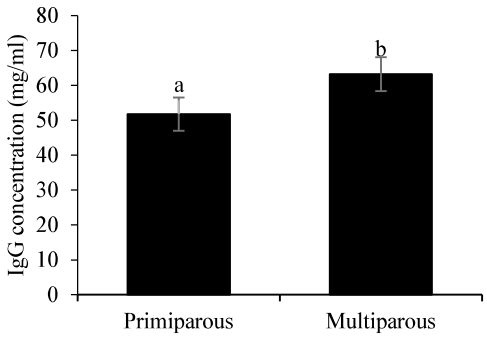

Figure 2 The concentration of total IgG in colostrum in primiparous and multiparous sows
[a, b] significant difference ($P < 0.05$)

In conclusion, the concentration of IgG in colostrum was decreased 26% from 1 to 6 h after onset of parturition. Multiparous sows had a higher concentration of IgG in colostrum than primiparous sows under field conditions in Thailand. Therefore, piglet should receive colostrum as soon as possible after birth especially in late-born piglets. In addition, the supplementation of colostrum in piglets born from primiparous sows is recommended.

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Effect of backfat loss during late gestation and lactation on milk yield in sows

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Keywords: Backfat, Milk yield, Sow, Piglet

Introduction

Nowadays, the size of swine commercial herd in Thailand has dramatically increased and become more industrialize due to a high competition. One of the most important componentsfor increasingthe sow productivity is the number of piglets at weaning per litter [1]. Utilizing superior reproductive performancesow is an important strategy to enhancethe number of piglet at weaning.

Reproductive performances of sows are determined by age, body weight, body condition score, estrus expression and backfat thickness [2,3]. Backfatconsists of water, collagen and lipid. Triacylglycerol is the main composition of lipidthat reserves in sow body [3]. Duringfarrowing, some sow lose part of their backfat for body maintenance,body growth (especially in gilt),the development of fetus and, the most important for piglet survival, the synthesis of colostrum and milk. Therefore, milk yield is one of the important factor that might be associated with backfat thickness in sow. Milk yield depends on genotype, feeding, stage of lactation, health statusand age of the sow. There is a lacking of study that determinethe influence of backfat thickness before farrowing and backfat loss after farrowing on milk yield in sows.The aim of the present study was to determine the influence of backfat thickness before farrowing and backfat loss after farrowingon milk yield in lactating sows.

Materials and Methods

The experiment was performed in June 2017 in a commercial swine herd in Thailand. Sows are reared ina continuous weekly system. In total, 80 Landrace x Yorkshire sows (parities number 1 to 6) were included in the study.Sows were kept in individual crates during gestation in an evaporative housing system equipped with individual water sprinklers. During gestation, sows were fed a commercial gestation diettwice a day and during lactation the sows received a lactation diet 4 times a day.

After farrowing, a daily amount of feed was offered to the sows until ad libitumfeed was reached after one week of lactation. The induction of parturition was not applied, and farrowing interventionwas kept to a minimum. Manual extraction was not performed. Cross-fostering was not performed in the present study. The pens were fully slatted with concrete at the center for sows and with steel slats at both sides of the farrowing crate for piglets. Each pen was provided with a creep area for piglets (0.60 m^2) placed on the floor on one side, covered by a plastic plate and heating lamp during the first week after farrowing. The heating lamp was turn on during the night time.

Backfatthickness of the sows was determined at P2 position (approximately 6-8 cm away from dorsal midline at the last rib curve) by using Renco® lean-meter [2]. An average value from both sides was used.

Milk yield of the sows was determined by weighing the body weight of the piglets at Days 0, 1, 3, 10 and 17 of lactation. The milk yield was predicted following a previous study in Denmark [4]. Milk sample(20 ml) was collected from each sow on day 3, 10, 17 of lactation to evaluate the milk compositions. Samples were collected by administrating 10 IU oxytocin and manually milking. The milk samples were immediately frozen at -20°C and analyzed by using an infrared milk analyser(Milko Scan 133B, Analyser; Foss Electric, Hillerød, Denmark).

Statistical analyses were performed using SAS 9.0 (SAS Inst. Inc., Cary, NC, USA). Descriptive statistics (mean, SD, median and range) were calculated. Pearson's correlation was usedto determine correlation between milk yield and backfat thickness. The effect of backfat loss and backfat thickness before farrowing on milk yield of sows were analyzed by regression analyses.

Results and Discussion

On average, backfat thickness of sows before farrowing was 14. 0 ± 2. 6 mm. After farrowing, the backfat thickness of sows at days 1, 3, 10, 17 and 21 were 13.7 ± 2.5, 13.7 ± 2.8, 14.3 ± 3.1, 13.8 ± 2.5 and 13.4 ± 2.4 mm, respectively. The backfat loss and the relative backfat loss from day 0 to 17 of lactation were -0. 34 mm and 1.4%, respectively. Of all the sows, 12.8% loss backfatfrom 0-17 days of lactation more than 20%.

The estimated milk yield of sows fromdays 3 to 10 of lactation was 10.4 ± 2.2 kg (3.9 to 15.1) and from days 10 to 17 of lactation was 12.8 ± 2.1 kg (6.2 to 17.2) per sow.

Table 1 Pearson's correlation between milk yield of sows and backfat thickness (BF) before farrowing and at 17 days of lactation, and backfat loss during lactation

	Milk yield (kg)	
	Day 3-10	Day 10-17
BF before farrowing	r = 0.316**	r = 0.183^{NS}
BF at day 17	r = 0.007^{NS}	r = 0.054^{NS}
BF loss	r = -0.381**	r = -0.186^{NS}

The correlation between milk yield of sows and backfat thickness variables are presented in Table 1.

Regression analyses on the effect of backfat loss during 0-17 days of lactation and BF before farrowing on milk yield of sows 3-10 days of lactation. Backfat loss was negative associated with milk yield but backfat before farrowing was positive associated with milk yield. The sow with an increased1 mm of backfat before farrowing was associated with an increase milk yield of sows between 3 and 10 days of lactation ($P = 0.008$) . In addition, for every 1 mm of backfat loss from farrowing to day 17 of lactation, the milk yield from days 3 to 10 was decreased 403 grams (P=0.002).

Table 2 Regression analyses on the effect of backfat(BF) loss during 0-17 days of lactation andBF before farrowing on milk yield of sows 3-10 days of lactation

Predictor	Intercept	Slope	*P* value
BF loss	10,273	-403.7	0.002
BF before farrowing	6,640	271.2	0.008

Backfat loss in sows is occurred due tobody maintenance, fetal development and milk synthesis. A negative association between milk yield and changes in backfatduring days 85-109of gestation could be seen because of a high energy demand of sows for mammary glands development and mammogenesis [5]. Besides, weight loss due to fat and protein mobilization is common in lactating sows. Sows are unable to consume sufficient energy and protein to meet their requirements for maintenance and milk production, resulting in a severe negative energy and nitrogen balance. In conclusions, decreasing of backfatfrom 0 to 17 days after farrowing affect milk yield of sows. Thus, appropriate management,e.g., nutrition, environment and stress, play an important role onbackfatthickness of postpartum sow.

Acknowledgements

Financial support was provided by the National Research Council of Thailand 2017. P. Tummaruk is granted by the International Research Integration: Chula Research Scholar, Ratchadaphiseksomphot Endowment Fund.

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Factors influencing litter size in a modern Landrace x Yorkshire hyper-prolific sows in a swine commercial herd in Thailand

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Keywords: Sow, High prolificacy, Litter size, Reproduction, Tropical climate

Introduction

The modern hyper-prolific sow is a new population of sows in swine breeding herd, in which their genotype has been selected for an extremely large litter size at farrowing. As a result, the number of piglets born alive per litter (BA) has increased up to 16-18 piglets per litter. Under field condition, litter size at farrowing comprises a variety of measurements, i.e., the total number of piglets born per litter (TB), BA, stillborn piglets (SB) and mummified fetuses (MM) per litter. Of these variables, BA is the parameter most correlated with the number of piglets weaned per litter. Litter size at farrowing in pig is affected by ovulation rate, fertilization rate, and embryonic/ fetal survival. The fetal survival of the piglets is highly correlated with size of the sow uterus (r = 0.9) [1]. Litter size depends on both genetic and environmental factors. The genetic impact on most reproductive traits is relatively small [2], while environmental factors, e.g., management, parity, climate, lactation length and nutrition, are known to have a relatively high impact on litter size [3]. The present study aims to determine the variation of litter size and to analyses potential factors influencing litter size in a modern Landrace x Yorkshire hyper-prolific sows under field conditions.

Materials and Methods

Data were collected from a 12,000-sow commercial swine herd in Thailand. The data included sow identities, farrowing date, parity number, BA, SB, MM, litter birth weight and number of piglets at weaning per litter. The total number of piglets born per litter (TB) was defined as the sum of BA, SB and MM. The data were collected from sows that farrowed from January to December 2017. The raw data were carefully scrutinized for accuracy. The analyses data included 23,517 litters from 11,961 Landrace x Yorkshire sows. The replacement gilts were produced within the herds using their own grandparent stock, imported from Denmark.

The gilts and sows were kept in individual crates during gestation. Pregnant sows were moved to the farrowing pens about 1 week before farrowing. In general, the gilts were mated at 8 months of age with a body weight of ≥ 135 kg at the second or later observed estrus. Artificial insemination was used for all gilts and sows. Feed was provided twice a day (1.5–3.5 kg per day) during gestation. The gestating feed contained 16% CP, 2,800 kcal/kg ME, and 0.9% lysine. The sows were fed 2-4 times a day during lactation (5–6 kg per day) with a corn-soybean-chicken ration. The lactation feed contained 18% CP, 3,250 kcal/kg ME, and 1.1% lysine. Water was provided ad libitum by water nipples. The health management was carried out by veterinarians. Both gilts and sows were vaccinated against CSF, AD, PPV, FMD and PRRS.

Statistical analyses were carried by using SAS. Descriptive statistics and frequency analysis were conducted. General linear models (GLM) were used to analyze factors associated with TB and BA. The models included parity number (1, 2, 3, 4, 5, 6, 7 and ≥8), farrowing month and unit (1 and 2) as independent variables. Least square means were obtained from each class of the factor and were compared by using least significant difference test. Values with $P < 0.05$ were regarded as statistically significant.

Results and Discussion

Descriptive statistics on the reproductive performances data of sows are presented in Table 1. Frequency distribution of TB are presented in Figure 1. As can be seen, 24.1% of the litter had TB ≥16 piglets/ litter (Figure 1). Likewise, the proportion of the litter with BA ≥14 and ≥ 16 piglets/litter was 34.7% and 9.9%, respectively.

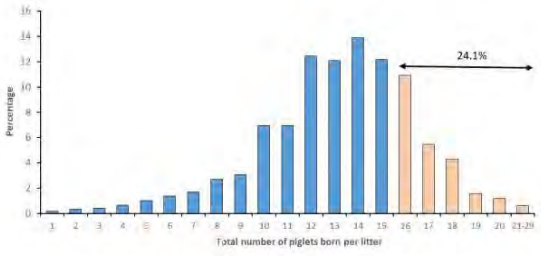

Figure 1 Frequency distribution on the total number of piglets born per litter in sows in a commercial swine herd in Thailand (24.1% of the sows produced ≥16 piglets/ litter) (n = 23,517 litters)

Factors influencing both TB and BA of sows included parity number (P<0.001) and farrowing month (P<0.001). The unit of farrowing (i.e., housing and management) significantly influenced TB (P<0.001) but not BA (P=0.813). Low TB was observed in September (12.9 TB) and October (12.9 TB), while high TB was observed in March (13.4 TB, P<0.001). Likewise, the same tendency was also observed for BA (12.3 *vs* 11.8 BA, P < 0.001). This indicated that a 0.5 piglet/ litter reduction of BA was observed during the farrowing that occur in late rainy season. These sows had been inseminated since late hot season (i.e., May). The reason might be due to that heat stress are able to directly induce autophagy in the porcine ovaries during follicular development [4]. An increased in ambient temperature during hot season are potentially compromise oocyte integrity and reduce developmental competence of embryo. Hence, the litter size at farrowing was reduced. A recent study demonstrated that a steadily increasing of room temperature from 20.0 °C to 31 °C for 5 days during follicular phase are able to alter some ovarian proteins (e.g., Beclin 1, microtube associated protein, ATG5 complex and BCL2L1) that play a role on autophagy and apoptosis of oocyte and granulosa cells [4]. Furthermore, an increase of room temperature during hot season may reduce feed intake of sows during lactation and subsequently compromise oocyte quality. Therefore, sow body weight loss or backfat loss during lactation should be carefully monitored during hot season.

Table 1 Descriptive statistics (n=23,517 litters)

Variables	Mean ± SD	Range
Parity number	3.82 ± 2.20	1 – 14
Total born/ litter	13.2 ± 3.3	1 – 29
Born alive/ litter	12.1 ± 3.1	0 – 25
Stillborn (%)	6.0	0 – 100
Mummy (%)	2.2	0 – 100
Weaned piglet/ litter	11.7 ± 1.6	0 – 18

Both TB and BA reached a plateau in sow parity numbers 3 and 4 and significantly declined after parity number 5 (Figure 2). Interestingly, primiparous sow had a larger TB than sow parity numbers 7 and ≥8 and had a larger BA than sow parity numbers 6, 7 and ≥8 (Figure 2).

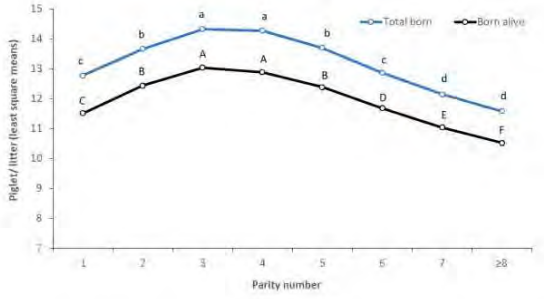

Figure 2 Litter size at farrowing in Landrace x Yorkshire sows by parity numbers

In conclusions, the modern hyper-prolific sows in Thailand produced up to 29 TB and 25 BA. Both TB and BA reach a plateau in sow parity numbers 3 – 4 and significantly declined after parity number 5. Interestingly, primiparous sow had a larger TB than sow parity numbers above 7 and had a larger BA than sow parity numbers above 6. Season significantly compromise litter size at farrowing in the hyper-prolific sows in Thailand.

Acknowledgements

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Association between meconium staining of the skin and incidence of stillborn piglets

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Keywords: Meconium, Piglet, Skin, Stillborn, Sow

Introduction

Stillborn pigs remain a major problem in intensive managed pig farms and account for 5% to 10% mortality in most commercial herds worldwide[1,2]. Factors associated with stillborn piglets includes umbilical status, sow parity number and skin color (meconium staining). Meconium staining of the skin and aspiration of meconium are clinical indicators of prolonged or severe intrauterine hypoxia in aborted fetuses and stillborn [3]. It has been demonstrated that all intrapartum stillbirths (100%) were stained with meconium, and 60% had meconium visible grossly in the oropharynx and 40% in trachea and bronchi [4].The objective of the present study was to determine the associationbetween skin color (meconium staining) and the incidence of stillborn piglets.

Materials and Methods

The experiment was carried out in a 2400-sow commercial swine herd in Thailand in June 2017.The sows were housed in an evaporative cooling system. Gestating sows were moved from breeding to farrowing unit within 1 week before parturition. Skin color (meconium stained) was collected from 992 newborn piglets from 80 Landrace x Yorkshire crossbred sows. Meconium stained was divided into 3 scores: 1, 2 and 3 (Figure 1). Score 1 was defined as the skin without meconium staining. Score 2 was defined as the skin having a small amount of meconium staining (light yellow). Score 3 was defined as the skin having a lot of meconium staining (dark yellow). Meconium staining was determined immediately after the piglets was born.

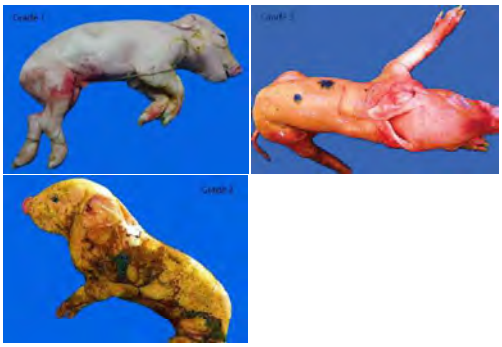

Figure 1 Grades of meconium stained on piglet's skin

SAS (SAS version 9.0 Cary, NC, USA) was used to analyze descriptive statistics (mean, standard deviation and range). Chi-square was used in the comparison between stillbirth (binomial trait) and meconium stainingscore.$P< 0.05$ was regarded to be statistically significant

Results and Discussion

Descriptive statistics on reproductive performances of sows included in the study are presented in Table 1. On average, the incidence of stillborn piglets was 6.6%. Descriptive data on piglets with meconium staining is presented in Table 2.The associationbetween skin color (meconium staining) and the incidence of stillborn piglets was significant ($P = 0.004$). It was found that the piglets born with the score 3 of meconium staining had a higher risk of being stillborn (Figure 2).

Table 1 Descriptive statistics on reproductive performances of sows (n=80)

Variables	Means ± SD	Range
Parity number	2.8 ± 1.88	1 – 6
Gestation length (days)	115.6 ± 1.52	113 – 121
Total born	17.5 ± 3.78	3 – 26
Born alive	15.3 ± 3.71	1 – 21
Stillborn piglets	1.3 ± 1.72	0 – 10
Mummified fetuses	1.0 ± 1.97	0 – 15
Stillborn (%)	6.6	-
Mummified fetuses (%)	5.4	-
Farrowing duration (min)	331 ± 314	58 – 1,818
Body condition score	3.0 ± 0.12	2.7 – 3.4
Backfat thickness (mm)	14.1 ± 2.62	8.0 – 24.0

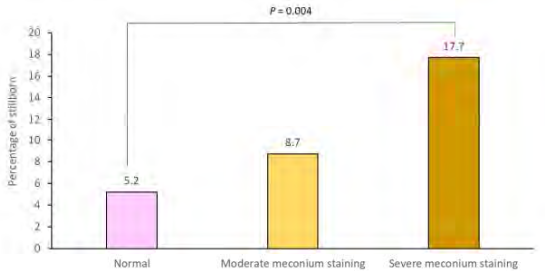

Figure 2 Incidence of stillborn in relation with the skin conditions of the neonatal piglets (n=992)

Table 2 Descriptive data on piglets with different score of meconium staining (n=992)

	Score 1	Score 2	Score 3
Born alive			
Number of piglets	766	137	28
Percent	94.8	91.3	82.4
Stillborn			
Number of piglets	42	13	6
Percent	5.2	8.7	17.6

In conclusion, increasing of score of meconium stainingon the skin of the newborn piglets wassignificantly associated with theincidence of stillbornpiglets.

Acknowledgements

Financial support was provided by the National Research Council of Thailand 2017. P. Tummaruk is granted by the International Research Integration: Chula Research Scholar, Ratchadaphiseksomphot Endowment Fund.

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VII-019

Milk yield and milk compositions in Danish Landrace x Yorkshire crossbred sows in Thailand

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Introduction
Sow milk is the main source of nutrients for the suckling piglet. Sow nutrition around farrowing and during lactation is associated with their milk production. The objective of the present study was to determine milk yield (MY) and milk composition in Danish Landrace x Yorkshire crossbred sows in commercial swine herd in Thailand in relation with backfat (BF) thickness before farrowing and sow parity.

Materials and Methods
A total of 113 milk samples from 101 sows were included. The mean temperature and humidity in this area were 29.7°C and 76%, respectively. The piglets were weight at day 3, 10 and 17 of lactation by electronic digital balance for estimating MY of the sows using the formula published by Hansen et al. (2012). Milk were collected at day 3, 10 and 17 of lactation for evaluating milk composition using MilkoScan® FT2. The BF were measured before farrowing and were classified into two groups: low (<12 mm) and normal (12 mm). Sows were classified according to parity number into 2 groups: primiparous (n = 23) and multiparous (parity 2-6, n = 51).

Results
On average, the MY of sows from day 3 to 10 (D3-10) and day 10 to 17 (D10-17) were 10.22.5 and 12.62.5 kg/day, respectively. The sow milk contained 7.2% protein, 6.2% fat, 4.5% lactose and 19.5% dry matter. The MY D3-10 was higher in normal BF than in low BF sows (10.6 vs 8.9 kg/day, P=0.006), but did not differ D10-17 (P>0.05). The MY D3-10 was numerically higher in multiparous sows than in primiparous sows (10.3 vs 9.3 kg/day, P=0.112). In primiparous sows, the MY D3-10 was numerically higher in normal BF compared with low BF sows (10.4 vs 8.2 kg/day, P=0.153). Milk protein was higher in normal BF than in low BF sows (8.5% vs 6.4 %, P=0.016). Milk lactose was lower in normal BF than in low BF sows (4.2% vs 4.6 %, P=0.039).

Conclusion
In conclusion, low BF before farrowing decreased milk production from day 3 to 10 and changed milk composition in Danish Landrace x Yorkshire crossbred sows in tropical climates.

Keywords: backfat, milk composition, Danish sows, milk yield

Association between backfat thickness of sows before farrowing and immunoglobulin G concentration in colostrum

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Keywords: colostrum, IgG, parity number, pig, reproduction

Introduction

Concentration of immunoglobulin G (IgG) in the sow colostrum is important for protecting newborn piglet from various pathogens in the farrowing house. Metabolic status of sow at farrowing is associated with their colostrum production (1). Backfat thickness is used for indicating the sow nutritional status at different stage of reproductive cycle (2). Knowledge concerning the association between backfat thickness and the concentration of IgG in the sow colostrum is therefore important. The present study was performed to investigate the association between the concentration of IgG in colostrum and backfat thickness of sows before farrowing.

Materials and Methods

The present study was conducted in a commercial swine herd in the western region of Thailand. In total, 145 colostrum samples obtained from postpartum sows were investigated. The sows were classified as primiparous (n=51) or multiparous sows (parity numbers 2-6, n=94). Backfat thickness of the sows was measured at the level of the last rib at about 6 to 8 cm from the midline using A-mode ultrasonography (Renco Lean-Meater®, Minneapolis, MN., USA.) (3). The backfat measurement was performed in each sow at farrowing. The sows were classified according to their backfat thickness into 3 classes: low (9.0 to 13.0 mm), moderate (13.5 to 16.0 mm) and high (16.5 to 24.5 mm).

Sows were kept in individual crates during gestation in a conventional open-housing system. The sows were moved to the farrowing pens about one week before the expected farrowing date.

The colostrum samples were collected manually at 1 h after the onset of parturition. Colostrum samples were collected by hand from all functional mammary glands and were pooled. The samples kept in a clean bottle (30 ml) and were stored at 4°C on ice in a foam box during collection process. The samples were cryopreserved at -20°C within 24 hours after collection until analyzes. Colostrum was thawed at room temperature for 2 h and was centrifuged at 15,000 x g for 20 min at 4°C (Centrifuge 5810 R, Eppendorf AG, Hamburg, Germany).

Supernatant was collected and was used for IgG assay. The fat was discarded and the remaining liquid was collected. Thereafter, the liquid part was diluted 1: 500,000 with sample conjugate diluent (50 mM Tris buffer, 0.14 M NaCl, 1%BSA and 0.05% Tween 20). Immunoglobulin G was determined by using ELISA. The ELISA plate was coated with polyclonal antibody of Pig-IgG (Bethyl Laboratories Inc., Texas, USA). The absorbance was recorded at 450 nm using ELISA plate reader (Tecan Sunrise™, Männedorf, Switzerland). The IgG concentration in the colostrum samples were quantified by interpolating their absorbance from the standard curve generated in parallel with the colostrum samples. The concentration of IgG in colostrum at 1 h after farrowing was analyzed by using the general linear models (GLM) procedure of SAS.

The statistical model included the effect of sow parity number, backfat thickness at farrowing classes and interaction. Least square means were obtained from each class of the factor and were compared by using Student's *t*-test. $P<0.05$ was regarded to be statistically significant.

Result and Discussion

Descriptive statistic on reproductive data is presented in Table 1. On average, the concentration of IgG was 82.3±36.6 mg/ml (range 21.8-242.9 mg/ml, Table 1).

Table 1 Descriptive statistic of the sow (n=145)

Parameter	Mean ± SD
Parity number	3.2 ± 2.2
Total number of piglet born/ litter	13.8 ± 3.5
Number of piglet born alive/ litter	12.3 ± 3.0
Backfat thickness (mm)	14.6 ± 2.7

The concentrations of IgG in primi-parous and multiparous sow were 79.7±5.9 and 81.9±4.1 mg/ml, respectively ($P>0.05$). A previous study has demonstrated that sow parity numbers >4 have a higher IgG concentration than other parities (10).

The concentrations of IgG in the sow colostrum associated with backfat thickness are presented in Fig. 1. The concentration of IgG in the colostrum of sow with low (87.5±5.6 mg/ml) moderate (80.4±4.8 mg/ml) and high backfat thickness (74.5±7.8 mg/ml) did not differ significantly ($P>0.05$).

The concentrations of IgG in primi-parous and multiparous sows by backfat thickness at farrowing are presented in Figure 2. It was found that the concentration of IgG in colostrum did not differ significantly among groups (Fig. 2).

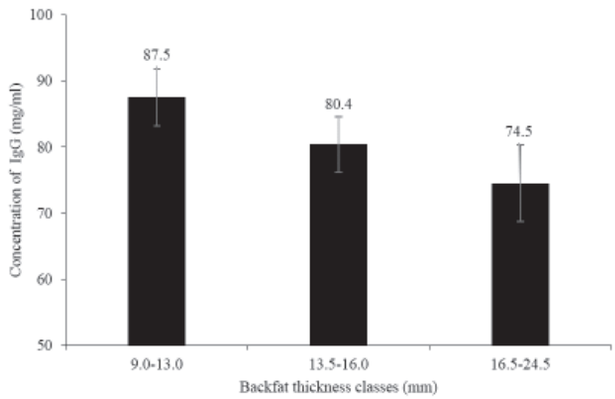

Figure 1 Concentration of immunoglobulin G (mg/ml) in colostrum of sows with different backfat thickness at farrowing.

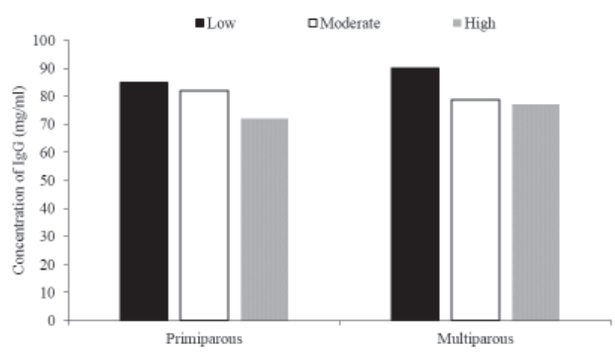

Figure 2 Concentration of immunoglobulin G (mg/ml) in primiparous and multiparous sows by backfat thickness at farrowing.

No effect of backfat thickness on IgG in sow colostrum was found in the present study. On the other hand, a previous study has demonstrated that changes in backfat thickness during late gestation influence both the colostrum production and the concentration of IgG in colostrum (1). Catabolic sows in late gestation seemed unable to produce optimal colostrum production and low IgG concentration in colostrum. However, excess back fat thickness before farrowing associated with low reproductive performance (4).

In conclusion, sow parity number and backfat thickness at farrowing did not influence the concentration of IgG in colostrum.

Acknowledgements

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Associations between colostrum production and milk progesterone in sows

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Keywords: colostrum yield, progesterone, parity number, sow

Introduction

Lactogenesis is associated with the levels of progesterone, prolactin and estrogen. High serum progesterone concentration in postpartum sows inhibits lactogenesis and compromise piglet performance (1). A previous study found that high serum progesterone was associated with a reduced colostrum production in sows (2). The detection of progesterone in several sample types, e.g., serum, feces and milk, has been reported (2, 3). However, the association between colostrum production and progesterone concentration in the sow milk has not been demonstrated. The present study was performed to investigate the association between the concentration of progesterone in milk and colostrum production in primiparous and multiparous sows.

Materials and Methods

The present study was conducted in a commercial swine herd in the western part of Thailand. In total, 49 milk samples collected at day 3 postpartum were included. The sows were classified as primiparous (n= 17) and multiparous sows (parity numbers 2-6, n=32). The sows were kept in individual crates during gestation in a conventional open-housing system. Individual birth weight of the piglets was measured immediately after birth and again at 24 h by using an electronic balance. The colostrum yield of the sows was defined as the sum of individual colostrum consumption of all piglets in the litter. Individual colostrum consumption of the piglets was estimated: colostrum consumption (g) = -106 + 2.26WG + 200BWB + 0.111D -1414WG/D + 0.0182WG/BWB, where WG is piglet weight gain (g), BWB is birth weight (kg), and D is the duration of colostrum suckling (min) (4). Milk samples were collected by administrating 10 IU oxytocin and manually milking at day 3 postpartum from all functional mammary glands and were pooled. The milk samples kept in a clean bottle (30 ml) and were stored at 4^{o}C on ice in a foam box during collection process. The samples were cryopreserved at -20^{o}C within 24 h after collection until analyzes. Milk was thawed at room temperature for 2 h and was centrifuged at 15,000 x g for 20 min at 4^{o}C (Centrifuge 5810 R, Eppendorf AG, Hamburg, Germany). Supernatant was collected and was used for progesterone assay. Progesterone concentrations in the milk were determined by using ELISA (5). The concentrations of milk progesterone were classified into 2 groups, i.e., low (≤2.5 ng/ml) and high (>2.5 ng/ml). The statistical analysis was performed by using general linear models (GLM) procedure of SAS. The statistical model included the effect of parity number (1 vs 2-6), milk progesterone concentration (low and high) and interactions. $P<0.05$ was regarded to be statistically significant.

Result and Discussion

On average, the colostrum production was 6.1±1.5 kg. The milk progesterone concentration averaged 3.0±1.4 ng/ml (range 0.7-5.4). The colostrum production in primiparous and multiparous sow were 4.8±0.7 and 5.4±0.5 kg, respectively (P>0.05). The colostrum production was associated with the concentration of milk progesterone (P<0.05). The colostrum yield in the sow with low milk progesterone concentration was higher than the sow with high milk progesterone concentration (6.1 vs 4.2 kg, respectively, P=0.04). The colostrum yield in primiparous and multiparous sows associated with milk progesterone is presented in Fig. 1.

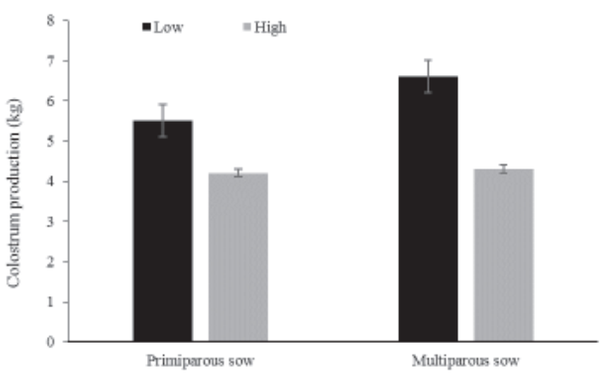

Figure 1 Colostrum production in low and high concentration of milk progesterone in primiparous and multiparous sows, $^{*}P$<0.05.

The colostrum yield in multiparous sows with low progesterone concentration was higher than those with high milk progesterone concentration (6.6 vs 4.3 kg, P = 0.03) but did not differ significantly in primiparous sows (P = 0.38). However, the previous study found that high serum progesterone in primiparous sow was associated with a reduced colostrum production (2).

In conclusions, the level of progesterone in the sow milk and sow parity number influenced colostrum production. High concentration of progesterone in milk is associated with a reduced colostrum production in multiparous sows.

Acknowledgements

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Effect of birth order on the incidence of stillborn piglet in primiparous and multiparous sows: A clinical observation

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Keywords: Stillbirth, farrowing, sow, parity

Introduction

In general, stillborn account for 3-8% of all piglets had born (1). The major cause for the death of piglets during delivery is hypoxia during prolonged expulsive stage (2). During the past 20 years, swine production in Thailand has become more industrialized, and the number of total piglets born per litter has increased rapidly. The key factors for successful intensive farrowing management include proper farrowing supervision, intervention for sows that need birth assistance and care of newborn piglets (2). The present study aims to determine the influence of birth order on the incidence of stillborn piglets in primiparous and multiparous sows under field conditions.

Materials and Methods

The present experiment followed the guidelines of The Ethical Principles and Guidelines for the Use of Animals for Scientific Purposes by the National Research Council of Thailand, and was approved by the Institutional Animal Care and Use Committee (IACUC). The experiment was performed in a commercial swine herd in the western part of Thailand. In total, 183 sows (parities 1-5) and 2,395 piglets were included in the experiment. The sows were housed in a conventional open housing system both during gestation and lactation periods. The farrowing process was carefully monitored individually. Data from each piglet were collected. The data included the onset of parturition, birth interval, body weight at birth, birth order, total born and born alive per litter (4). The incidence of stillborn piglets (0, 1) was analyzed by using logistic regression under GLIMMIX macro of SAS. The statistical model included parity (1 vs 2-5), birth order (1, 2, 3,.....,14 and 15-20) and two-ways interaction. $P<0.05$ were regarded to be statistically significant.

Results and Discussion

Of all the piglets born, 2,250 (91.7%), 145 (5.9%) and 59 (2.4%) were born alive, stillborn and mummified fetuses, respectively. Reproductive data of primiparous and multiparous sows are presented in Table 1. The effect of birth order on the incidence of stillborn piglets is presented in Figure 1. The present study demonstrated that the risk of being stillborn was increased as the birth order increased in both primiparous and multiparous sows ($P<0.001$). As can be seen from the Figure, intensive care of the neonatal piglets as well as the birth interval should be raised after the 8th piglet was born in primiparous sows and after the 10th piglet was born in multiparous sows (Fig. 1).

Table 1 Reproductive data (mean±SD) of primiparous and multiparous (parities 2-5) sows

Parameters	Primiparous	Multiparous
Number of sows	57	126
Number of piglets	752	1702
Backfat (mm)	14.8 ± 2.8	15.2 ± 3.0
Farrowing duration (min)	304 ± 293	260 ± 156
Birth interval (min)	18.7 ± 31.4	18.2 ± 30.9
Total born	13.7 ± 2.5	14.4 ± 3.0
Born alive	12.7 ± 2.4	13.1 ± 2.7
Birth weight (g)	1386 ± 326	1449 ± 350

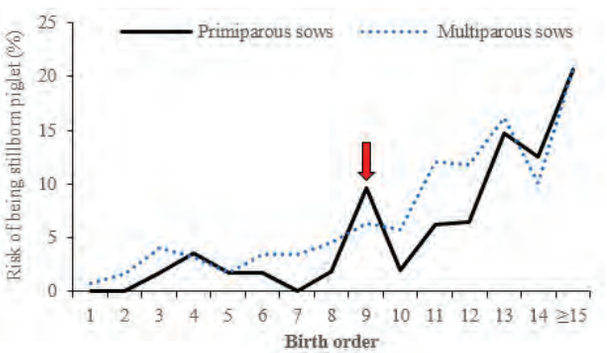

Figure 1 The incidence of stillborn piglets by each categories of birth order

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Factors associated with puberty attainment in gilts: An observational study

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Keywords: Gilt, estrus, puberty, reproduction, tropics

Introduction

The reproductive management of the replacement gilts is important factors driving reproductive performance and longevity of sows in the swine commercial herds (1, 2). Age at first estrus, mating and conception in gilts are associated with their subsequent reproductive performance, longevity and the reasons for culling (3). The proportion of gilts culled due to reproductive failure increased from 18.0% to 24.5% when the age at first conception increased from 200 to 300 days (4). Under tropical climates, 44% of the culled gilts are removed from herds due to failure to exhibit standing estrus (5). The present study was performed to determine some significant factors associated with the variation on age at first estrus (i.e., puberty) in gilts under field conditions.

Materials and Methods

The study was carried out in a commercial swine herds in western region of Thailand. The number of sows in production was 12,400 sows. The replacement gilts were produced within the herd. The data included 1,106 LY crossbred Landrace x Yorkshire gilts that entered into the herds from February to June 2018. A fence line boar contact was applied to the gilts for estrus induction twice a day between 140 to 210 days of age. The detection of estrus and boar exposure was performed on a daily basis until the gilt exited the gilt pool at 203 days of age. Estrus detection was carried out by the observation of vulvar symptoms and the back pressure test with the presence of a mature boar. Gilts expressing a standing response in front of the boar with clear vulvar symptoms were defined as estrus (1). The estrus was monitored by experienced stock persons; and the days of standing estrus were daily recorded into the herd book. The gilts were weighed once when exiting the gilt pool. Growth rate (g/d) from birth to exiting the gilt pool was calculated (1). Data were analyzed by using SAS. Descriptive statistics and Pearsonís correlation analyses were conducted. $P<0.05$ was regarded to be statistically significant.

Results and Discussion

Of all the gilts (n=1106), 960 gilts (86.6%) exhibited first estrus naturally without any hormonal treatment (Table 1). The age at first observed estrus was 196.2?16.7 days (range 140-289 d). Frequency distribution on age at first estrus is presented in Fig. 1. Age at first estrus in gilts was positively correlated with body weight (r=0.161, $P<0.001$) and negatively correlated with growth rate (r=-0.339, $P<0.001$). This indicated that gilts with superior growth rate attain puberty earlier than those with inferior growth rate. Thus, one selection criteria for gilts recruitment should include growth rate. Based on individual gilts, the age at first estrus of LY crossbred gilts in Thailand varies between 138 and 317

days (1, 3). Thus, the data observed in the present study are within the normal range.

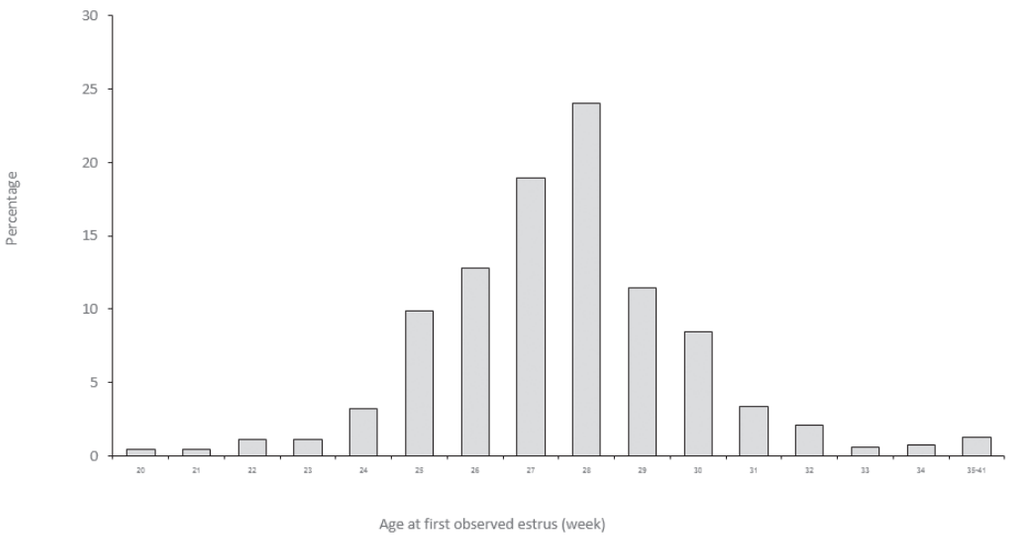

Figure 1 Age at first observed estrus in Landrace x Yorkshire crossbred gilts in a commercial swine herd in Thailand (n=960).

Table 1 Descriptive statistics

Variable	n	Mean ± SD	Range
Gilts exhibit natural estrus (%)	1106	86.6	-
Age at first estrus (days)	960	196.2±16.7	140-289
Body weight (kg)	392	124.5±11.2	93-166
Average daily gain (gram/day)	986	641.5±58.3	403-875
Number of teat	422	14.4±0.6	14-16
Gilts induced estrus by gonadotropin (%)	117	117/1106 (10.6)	-

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Immuno-expression of PRRS virus in the reproductive organs of gilts with and without PRRS vaccination

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Keywords: Gilt, immunohistochemistry, ovary, PRRS, uterus

Introduction

Porcine reproductive and respiratory syndrome (PRRS) virus primarily infects macrophages during acute infection (1). The macrophages from many tissues are the primary cell type that sustains the in vivo replication of the virus (2, 3). Using immunohistochemistry evaluation, about 66-100% of the lung tissue of pig infected with PRRS virus was observed (4). The objective of the present study was to determine the immune-expression of PRRS virus in the uterine and ovarian tissues associated with PRRS vaccination in gilts.

Materials and Methods

A total of 51 gilts (Landrace x Yorkshire x Duroc) ages 22 - 26 weeks were included in the experiment. The gilts received normal saline (control, n=26) or PRRS-MLV (Fostera® PRRS, Zoetis, USA, n=25), 2 mL intramuscularly at 22 week of age. Uterine and ovarian tissue samples were collected at 22, 24 and 26 weeks of age at slaughter house. Immunohistochemistry was carried out according to the previous studies in the uterine (3) and ovarian tissues (5). The tissue sections were defined as ëpositiveí if they contained at least one positive cell (brown intracytoplasmic staining, Fig. 1). Additionally, the tissues were also classified into 4 score: 0, no positive cells; 1, 1-2 positive cells on the whole tissue; 2, moderate number of positive cells; 3, large amount of positive cells. Score of immuno-histochemical staining of PRRS virus in the ovary and uterine tissues of gilts were compared by using Kruskal-Wallis test.

Results and Discussion

Immuno-expression of PRRS virus in the uterine and ovarian tissues of the gilts age 22-26 weeks was demonstrated (Figure 1). PRRS virus was detected in 71.2% of the uterus and 90.2% of the ovary in gilts. The percentage of the uterine and ovarian tissues containing PRRS virus did not differ between non-vaccinated and vaccinated gilts (72.0 vs 70.3% and 88.5 vs 92.0, respectively, $P>0.05$). However, the severity tended to be lower in the vaccinated than the non-vaccinated animals (Fig. 2). At 24 week of age, the score of PRRS virus detection in non-vaccinated gilts tended to be higher than vaccinated gilts (2.3 vs 1.4, respectively, $P=0.067$).

Apparently, the present finding indicates that the replacement gilts remained a risk of introducing PRRS virus into the breeding herd even though vaccination has been done. Moreover, under field condition, some of gilts might be mated when the virus remained in their uterine tissue. Therefore, their reproductive performances might be compromised.

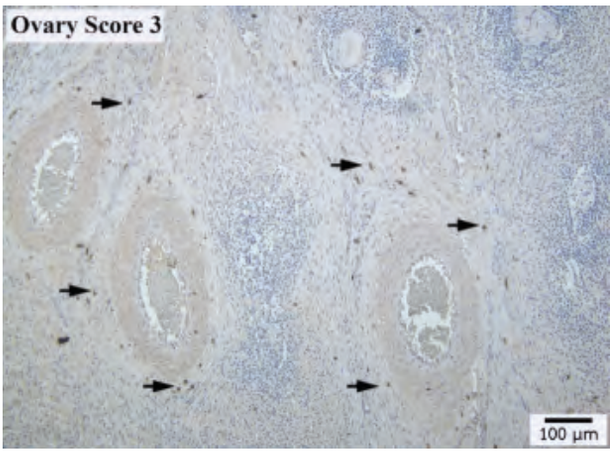

Figure 1 Immuno-expression of PRRS virus in an ovarian tissue of gilt.

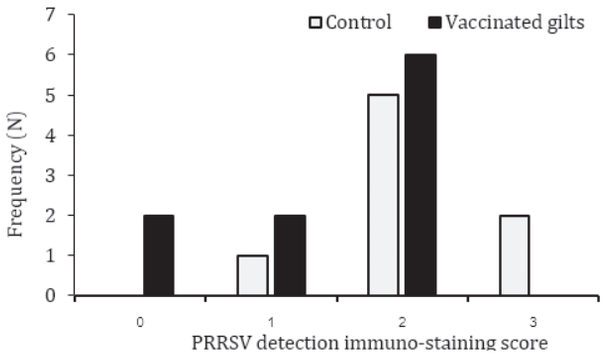

Figure 2 Immuno-expression score of PRRS virus in the uterine tissue of gilts without and without PRRS vaccination.

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Association between umbilical cord integrity and the incidence of stillborn piglets

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Keywords: hypoxia, piglet, sow, stillborn, umbilical cord

Introduction

Stillborn piglet is one of a major problem in a modern swine industry. In general, the incidence of stillborn piglets varies from 5.0% to 10.0% in most swine commercial herds worldwide (1, 2). Stillborn is caused by hypoxia during the piglet delivery (3). The predisposing cause of hypoxia during the piglet delivery is associated with uterine contraction, placental efficiency, umbilical cord integrity and vitality of the fetus (4). The objective of the present study was to evaluate the association between umbilical cord integrity and the incidence of stillborn piglets under field condition.

Materials and Methods

The study was carried out in a 2400-sow commercial swine herd in the eastern region of Thailand in June 2017. The sows were housed in a closed housing system equipped with an evaporative cooling system to reduce heat stress. Gestating sows were moved to the farrowing barn at one week before parturition. At farrowing, the umbilical cord integrity of the newborn piglets was determined in 989 newborn piglets from 80 litters. The integrity of the piglet umbilical cord was classified into 2 groups: intact and broken (Fig. 1). The umbilical cord integrity was evaluated within 5-10 min after the piglets were born. The piglets were classified into 2 groups: lived born and stillborn. The association between the umbilical cord integrity and the incidence of stillborn piglets was analyzed.

Figure 1 Umbilical cord integrity in newborn piglets (a) broken umbilical cord (b) intact umbilical cord

The statistical analyses were carried by using SAS version 9.0 (SAS Inst., Cary, NC, USA). Descriptive statistics (mean, standard deviation and range) were calculated. The umbilical cord integrity was compared between lived born and stillborn piglets by using Chi-square test. $P<0.05$ was regarded to be statistically significant.

Result and Discussion

Descriptive statistics on reproductive performances of sows were shown in Table 1.

Table 1 Descriptive statistics on reproductive performances of sows (n=80)

Variable	Means ± SD
Parity number	2.8±1.8
Gestation length (days)	115.6±1.5
Total born	17.5±3.78
Born alive	15.3±3.71
Stillborn piglets	1.3±1.7
Mummified fetuses	1.0±1.9
Stillborn (%)	6.6
Mummified fetuses (%)	5.4
Farrowing duration (min)	331±314
Body condition score	3.0±0.12
Backfat thickness (mm)	14.1±2.62

Broken umbilicus was found in 46.8% of stillborn piglets and 24.1% of lived born piglets (P<0.001) (Fig. 2). The reason might be due to that the high frequency and intensity of the uterine contraction during farrowing process may cause compression of the umbilical cord. Thus, the umbilical cord may be trapped between the fetal body and maternal pelvis. Piglet mortality and postnatal viability may be related to the time when the umbilical rupture occurs (5). Anoxia in neonatal piglets can be caused by umbilical cord rupture and therefore sudden death occurs during parturition or by the temporary obstruction of the umbilical cord producing subacute anoxia (6). Temporary hypoxia during birth may cause permanent brain damage and reduce lived born piglets. Pig fetuses are very susceptible to intrauterine asphyxia. In the present study, the total number of piglets born per litter and parity number of sows were 17.5±3.8 piglets and 2.8±1.8, respectively. The highest percentages of stillbirths occurred at birth order ≥9. Stillbirth rates usually occur in large litters and in the piglets born in the last third of the litter.

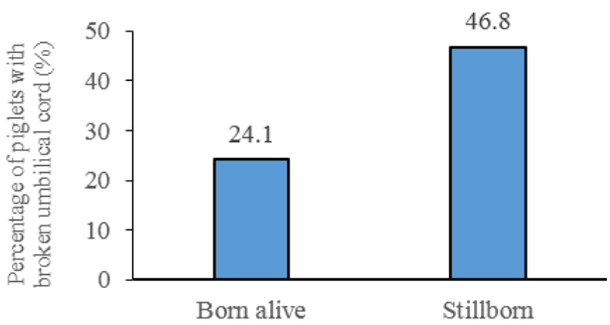

Figure 2 Percentage of broken umbilical at birth in lived born and stillborn piglets

Table 2 Descriptive data on piglets with intact and broken umbilical cord (n=989)

	Umbilical cord integrity	
	Intact	Broken
Lived born		
Number of piglets	704	223
Percent	75.9	24.1
Stillborn		
Number of piglets	33	29
Percent	53.2	46.8

In conclusion, of the percentage of piglets born with broken umbilical cord is higher in stillborn piglets than lived born piglets.

Acknowledgements

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