EFFECT OF *CANNABIS SATIVA* BYPRODUCT SUPPLEMENTATION DURING TRANSITION PERIOD ON MATERNAL BEHAVIOR, FEED INTAKE, COLOSTRUM YIELD AND PIGLET SURVIVAL RATE IN HYPERPROLIFIC SOWS

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A Thesis Submitted in Partial Fulfillment of the Requirements
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ผลของการเสริมกากกัญชาในช่วงก่อนและหลังคลอดต่อ พฤติกรรมของแม่ ปริมาณอาหารที่กินได้ ปริมาณน้ำนมเหลือง และ อัตราการรอดชีวิตของลูก ในแม่สุกรสายพันธุ์ลูกดก

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Thesis Title	EFFECT OF *CANNABIS SATIVA* BYPRODUCT SUPPLEMENTATION DURING TRANSITION PERIOD ON MATERNAL BEHAVIOR, FEED INTAKE,COLOSTRUM YIELD AND PIGLET SURVIVAL RATE IN HYPERPROLIFIC SOWS
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ระฟ้า บุญประกอบ : ผลของการเสริมกากกัญชาในช่วงก่อนและหลังคลอดต่อ พฤติกรรมของแม่ ปริมาณอาหารที่กินได้ ปริมาณน้ำนมเหลือง และ อัตราการรอดชีวิตของลูก ในแม่สุกรสายพันธุ์ลูกดก. (EFFECT OF *CANNABIS SATIVA* BYPRODUCT SUPPLEMENTATION DURING TRANSITION PERIOD ON MATERNAL BEHAVIOR, FEED INTAKE,COLOSTRUM YIELD AND PIGLET SURVIVAL RATE IN HYPERPROLIFIC SOWS) อ.ที่ปรึกษาหลัก : ศ. น.สพ.ดร.เผด็จ ธรรมรักษ์, อ.ที่ปรึกษาร่วม : รศ. ภญ.ดร.สรกนก วิมลมั่งคั่ง

อุตสาหกรรมการเลี้ยงสุกรในปัจจุบันกระบวนการอักเสบและปวดในแม่สุกรหลังคลอดมีความสำคัญอย่างมากต่อสวัสดิภาพสัตว์กัญชามีชื่อทางวิทยาศาสตร์ *Cannabis sativa* เป็นพืชสมุนไพรที่มีฤทธิ์ในการลดปวดลดอักเสบและลดไข้และเป็นแหล่งที่อุดมไปด้วยเยื่อใยวัตถุประสงค์ในการศึกษาครั้งนี้เพื่อศึกษาผลที่ได้จากเสริมกากกัญชา(*Cannabis sativa* byproducts) ในแม่สุกรก่อนคลอดและหลังคลอด 7-10 วัน (transition period) ต่อพฤติกรรมการแสดงออกของแม่สุกรหลังคลอดปริมาณอาหารที่กินได้ภาวะท้องผูก ระยะเวลาการคลอดปริมาณน้ำนมเหลืองและประสิทธิภาพทางการผลิตในลูกสุกรการทดลองครั้งนี้ทำในแม่สุกรจำนวน 100 แม่สายพันธ์ผสมแลนด์เรซ x ยอร์คเชียร์แม่สุกรถูกจัดแบ่งตามลำดับท้องเป็น 2 กลุ่มได้แก่กลุ่มควบคุม 54 แม่และกลุ่มทดลอง 46 แม่กลุ่มควบคุมได้รับอาหาร 3.0-3.5 กิโลกรัม/ตัว/วัน ในช่วง 7 วันก่อนและหลังคลอดในขณะที่กลุ่มทดลองได้รับอาหารเช่นเดียวกับกลุ่มควบคุมแต่เสริมกากกัญชาจำนวน 150 กรัม/ตัว/วันโดยมีความเข้มข้นของสารออกฤทธิ์แคนนาบินอยด์ (CBD) หลังผ่านการวิเคราะห์อยู่ที่ 0.24 % (w/w) ดังนั้นแม่สุกรได้รับ CBD จำนวน 360 มิลลิกรัม/ตัว/วัน อาหารแม่เลี้ยงลูกเดิมของฟาร์มมีเยื่อใย 4.3% ในขณะที่อาหารทดลองเสริมกากกัญชา จะมีสัดส่วนเยื่อใย 16.9 % กล้องวงจรปิดถูกติดตั้งบนฝ้าเพดานของโรงเรือน เพื่อสังเกตและบันทึกพฤติกรรมการแสดงออกของสุกรภายใน 24 ชั่วโมงหลังคลอด ระยะเวลาในการแสดงออกของแต่ละพฤติกรรมของแม่สุกรได้ถูกบันทึกอย่างละเอียดได้แก่ การนอน การนั่ง การยืน การกินอาหาร และการเลี้ยงลูก นอกจากนี้ในแม่สุกรที่มีอุณหภูมิทางทวาร $\geq$39.5 องศาเซลเซียสจะถูกพิจารณาว่ามีไข้คะแนนมูลสุกรในแม่ที่ $\leq$2 จะถูกพิจารณาว่าเป็นแม่ท้องผูกในวันที่สามหลังคลอด แม่สุกรกลุ่มทดลองมีสัดส่วนของแม่สุกรที่เป็นไข้น้อยกว่ากลุ่มควบคุม (20% และ 38.9% ตามลำดับ P=0.051) ในขณะที่แม่สุกรกลุ่มที่ได้รับกากกัญชา จะมีระยะเวลาในการยืนและการเข้ากินอาหารที่มากกว่ากลุ่มควบคุม (P<0.05) เป็นที่น่าสนใจว่าแม่ที่ไม่พบท้องผูกจะใช้ระยะเวลาในการเข้ากินอาหารมากกว่ากลุ่มแม่ที่ท้องผูก (P = 0.006) ความชุกของสัดส่วนแม่ทีท้องผูกในกลุ่มทดลองน้อยกว่ากลุ่มควบคุมอย่างมีนัยยสำคัญ (17.4 และ 81.5% ตามลำดับ P < 0.001) นอกจากนี้แล้วแม่กลุ่มเสริมกากกัญชากินอาหารได้มากกว่ากลุ่มควบคุม (P < 0.05) ปริมาณน้ำนมเหลือง การกินนมน้ำเหลืองได้ในลูกสุกรและอัตราการตายก่อนหย่านม ไม่แตกต่างกันในระหว่างกลุ่มควบคุมและทดลอง (P >0.05) สรุปได้ว่าการเสริมกากกัญชาในช่วงเปลี่ยนผ่านก่อนและหลังคลอด 7-10 วัน ในภูมิอากาศร้อนชื้นส่งผลดีในเรื่องลดปัญหาแม่สุกรท้องผูกเพิ่มพฤติกรรมที่ดีในการผลผลิต เช่น ระยะเวลาในการยืน และกินอาหารของแม่ในช่วงเวลา 24 ชั่วโมงหลังคลอด

สาขาวิชา	วิทยาการสืบพันธุ์สัตว์	ลายมือชื่อนิสิต ....
ปีการศึกษา	2566	ลายมือชื่อ อ.ที่ปรึกษาหลัก ....
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Rafa Boonprakob : EFFECT OF *CANNABIS SATIVA* BYPRODUCT SUPPLEMENTATION DURING TRANSITION PERIOD ON MATERNAL BEHAVIOR, FEED INTAKE,COLOSTRUM YIELD AND PIGLET SURVIVAL RATE IN HYPERPROLIFIC SOWS. Advisor: Prof. PADET TUMMARUK, D.V.M., M.Sc., Ph.D. Co-advisor: Assoc. Prof. SORNKANOK VIMOLMANGKANG, R.Ph., M.Sc.,Ph.D.

In the modern swine industry, addressing inflammation and pain in sows after farrowing is a crucial animal welfare concern. *Cannabis sativa*, a medicinal plant, possesses properties that serve as an analgesic, anti-inflammatory, and antipyretic, while also being abundant in fiber. The objective of this study is to examine the impact of supplementing sows with *Cannabis sativa* byproducts during transition periods on various aspects including postpartum behavior, feed intake, constipation, farrowing duration, colostrum yield, and piglet performance. The experiment involved a total of 100 Landrace × Yorkshire sows. The sows were distributed according to parity numbers into 2 groups, i.e., control (n = 54) and treatment (n = 46). The control group was provided with a lactation diet 3.0-3.5 kg per day for a period of seven days before and after farrowing. The treatment groups received the same quantity of the diet but with an additional supplementation of 150 g/d of *Cannabis sativa* byproduct. The byproduct was analyzed and found to contain 0.24% (w/w) concentration of cannabidiol (CBD), resulting in a daily intake of 360 mg of CBD per sow. The conventional lactational diet had a dietary fiber content of 4.3%, whereas the diet supplemented with *Cannabis sativa* byproduct had a higher content of 16.9% dietary fiber. Video cameras were employed to observe and document the behavior of sows within the initial 24 h after farrowing. The duration in which sows engaged in activities such as sleeping, sitting, standing, feeding, and nursing their piglets was quantified. Additionally, the rectal temperature of the sows was measured, and a temperature equal to or exceeding 39.5 °C was considered indicative of fever. The fecal score of the sows was assessed and a fecal score of ≤2 was classified as constipation. On the third day postpartum, the proportion of sows with fever in the treatment group was lower than that in the control group (20.0% and 38.9% respectively, *P*=0.051). Sows receiving supplementation with *Cannabis sativa* byproducts exhibited increased durations of standing and feeding compared to the control group (*P*<0.05). Notably, sows without constipation issues spent more time consuming feed than those experiencing constipation (*P*=0.006). The prevalence of constipation was significantly lower in the treatment group compared to the control group (17.4% and 81.5%, respectively, *P*<0.001). Furthermore, the postpartum sows demonstrated increased feed intake following the supplementation of *Cannabis sativa* byproducts (*P*<0.05). Sow colostrum yield, piglet colostrum intake, piglets mortality and other piglets traits did not differ between control and treatment groups (*P*>0.05). In conclusion, supplementing *Cannabis sativa* byproducts during the transition periods in peri-parturient sows under tropical conditions resulted in a reduction in constipation issues and improved sow activities, such as increased time spent standing and consuming feed within the first 24 h postpartum.

Field of Study:	Theriogenology	Student's Signature ....
Academic Year:	2023	Advisor's Signature ....
		Co-advisor's Signature ....

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Rafa Boonprakob

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ABBREVIATIONS

°C	degree Celsius
µg	microgram
µl	microliter
cm	centimeter
CORR	correlation
CV	coefficient of variation
ELISA	enzyme-linked immunosorbent assay
g	gram
GLIMMIX	generalized linear mixed model
GLM	generalized linear model
h	hour
IU	international unit
kg	kilogram
LH	luteinizing hormone
LSD	least significant difference
M	molar
Mcal	megacalories
MF	number of mummified fetuses per litter
mg	milligram
min	minute

CHAPTER I

INTRODUCTION

Importance and rationale

Due to genetic improvement, the modern sows that had large litter size are now currently used in swine industry in major pig producing countries worldwide including Thailand. In tropical regions, there is a consistent upward trend in both the average litter size and the percentage of sows with litter sizes exceeding 16 piglets per litter (referred to as hyperprolific sows) among the new genetic sows (Taechamaeteekul *et al.*, 2022; Vongsariyavanich *et al.*, 2021). An earlier study has revealed that the duration of farrowing in the modern hyperprolific sows in a commercial swine herd in Thailand with a total number of piglets born per litter (TB) of 17.0 is as long as 5.6 h (Vongsariyavanich *et al.*, 2021). The extended duration of farrowing can increase the proportion of sows that had fever during the first few days postpartum and causing a high incidence stillborn piglets (Tummaruk & Pearodwong, 2015). According to Langendijk *et al.* (2018), an extended duration of the foetus remaining in the uterus during the second stage of parturition (expulsion stage) increases the risk of stillbirth or neonatal mortality due to compromised blood oxygen saturation. In Europe, the average farrowing duration in modern hyperprolific sows with extremely large litters can be longer than 7 h (Oliviero *et al.*, 2019) and the percentage of piglet with low birth weight is also increasing (Edwards *et al.*, 2019). The piglet birth weight is the most important factor associated with survival rate and performance of pre-weaning piglets (Muns *et al.*, 2016). In Thailand, the percentage of piglets that had birth weight below 1.0 kg in the litters with 17.5 TB accounts for 30.5% of the lived born piglets

(Juthamanee & Tummaruk, 2021). These challenges can result in diminished vitality among newborn piglets, increasing their vulnerability to factors such as starvation and hypothermia. Consequently, there is an elevated risk of a substantial proportion of piglets succumbing before reaching the weaning stage, particularly within the initial days following birth (Muns *et al*., 2016). The use of modern hyperprolific sows in the swine industry has given rise to numerous challenges concerning neonatal piglets (Baxter *et al*., 2008; Farmer & Edwards, 2022; Udomchanya *et al*., 2019). As a result, it is imperative to explore further management and feeding strategies to mitigate neonatal piglet losses.

The time period from 105 days of gestation to farrowing is generally known as the transition period (Theil *et al*., 2011). This period holds great complexity and significance as it involves hormonal changes, metabolic and nutritional adjustments, all of which greatly influence the performance of lactating sows (Feyera *et al*., 2017). In this period, maternal nutrition can be transferred to the fetus, subsequently impacting the energy status and colostrum production of the sows during the time around parturition (Feyera *et al*., 2017). During the last decade, a number of research has been conducted to evaluate optimal feeding strategies to reduce neonatal loss of piglets (Feyera *et al*., 2017; Khamtawee *et al*., 2021; Tucker *et al.*, 2022). For instance, 5providing a transition diet with high fiber feed can prolong energy uptake from hind gut fermentation and decrease the farrowing duration in sows (Feyera *et al*., 2017). Moreover, feeding a high fiber diet in prepartum sows can also decrease the incidence of constipation (Oliviero *et al*., 2009).

In the modern swine industry, addressing inflammation and pain in sows after farrowing is a crucial animal welfare concern (Martínez-Burnes *et al*., 2021). For swine veterinarians, it is crucial to employ suitable anti-inflammatory medications (Plush *et al*., 2021; Tummaruk & Sang-Gassanee, 2013) and implement effective pain management strategies for postpartum sows. Hence, there is a pressing need to thoroughly explore practical approaches that involve providing both high-fiber diets and anti-inflammatory agents to prepartum and postpartum sows. *Cannabis sativa*, a medicinal plant, possesses properties such as analgesic, anti-inflammatory and antipyretic effects (Cabrera *et al*., 2021; Fallahi *et al*., 2022). Additionally, *Cannabis sativa* is known to contain a significant amount of dietary fiber (Fallahi *et al*., 2022). During the pharmacological extraction process of *Cannabis sativa* for both human and animal medicine, more than 90% of the byproducts are generated. As a result, the pharmaceutical manufacturing of *Cannabis sativa* for medical and veterinary applications is projected to produce a significant volume of waste in the coming years. Consequently, it becomes imperative to investigate the potential utilization of these byproducts in order to achieve zero waste in the *Cannabis sativa* industry. In recent studies, it has been found that the inclusion of hemp seed in the diet of sows during late gestation and lactation can enhance the oxidative status in both the sows and their offspring (Palade *et al*., 2019). However, the potential advantages of dietary hemp supplementation on sow reproductive performance and piglet characteristics, including colostrum intake, have not yet been established. Additionally, to the best of our knowledge, there have been no investigations conducted on the utilization of *Cannabis sativa* byproducts in livestock animals.

Objectives of the study

To examine the impacts of supplementing *Cannabis sativa* byproducts during transition periods in peri-parturient sows on various aspects, including postpartum behavior, feed intake, constipation, farrowing duration, sow rectal temperature, colostrum IgG levels, and piglet mortality within the first week of post-natal life.

Expected output

1. Supplementing *Cannabis sativa* byproducts during the transition periods in peri-parturient sows under tropical conditions can reduce constipation problem and improved sow farrowing performances.

2. Supplementing *Cannabis sativa* byproducts during the transition periods in peri-parturient sows under tropical conditions can improve the average daily feed intake of postpartum sows.

3. Supplementing *Cannabis sativa* byproducts during the transition periods in peri-parturient sows under tropical conditions can improve sow colostrum yield, IgG concentration and reproductive outcomes.

4. Supplementing *Cannabis sativa* byproducts during the transition periods in peri-parturient sows under tropical conditions can lead to improvements in piglet colostrum intake and reduce piglet mortality rate during the first week of life.

CHAPTER II

LITERATURE REVIEW

The use hyperprolific genetics in modern swine industry

Due to genetic improvement, the modern sows that had large litter size are now currently used in swine industry in major pig producing countries worldwide including Thailand. In tropical countries, the average litter size as well as the proportion of sows that have litter size above 16 piglets per litter (i.e., hyperprolific sows) of the new genetic sows are increasing continuously (Taechamaeteekul *et al.*, 2022; Vongsariyavanich *et al.*, 2021). An earlier study has revealed that the duration of farrowing in the modern hyperprolific sows in a commercial swine herd in Thailand with a total number of piglets born per litter (TB) of 17.0 is as long as 5.6 h (Vongsariyavanich *et al.*, 2021). The extended duration of farrowing can increase the proportion of sows that had fever during few days postpartum and high stillbirth rate (Tummaruk & Pearodwong, 2015; Tummaruk & Sang-Gassanee, 2013). Langendiik *et al*. (2018) has been reported that the longer time the foetus remains in the uterus during the second stage of parturition (i.e., expulsion stage), the higher risk of either stillbirth or neonatal mortality due to poor blood oxygen saturation. In Europe, the average farrowing duration in modern hyperprolific sows with extremely large litters can be longer than 7 h (Oliviero *et al.*, 2019) and the percentage of piglet with low birth weight is also increasing (Edwards *et al.*, 2019). In Thailand, the percentage of piglets that had birth weight below 1.0 kg in the litters with 17.5 TB accounts for 30.5% of the lived born piglets (Juthamanee and Tummaruk ,2021). These problems can cause poor vitality in newborn piglets, predisposing factors for starvation and hypothermia and ultimately lead to high proportion of piglets died before weaning particularly during the first few days postpartum (Muns *et al*., 2016). Nevertheless, other factors associated piglet characteristics, such as body shape and intra-uterine growth restriction (IUGR), are also important (Farmer & Edwards, 2022; Vallet *et al*., 2013). This morphological trait is associated with IUGR piglets, so call dolphin-like head shape (Vallet *et al*., 2013). The IUGR characteristics is associated with piglet vitality and their ability to consume colostrum (Baxter *et al*., 2020; Edwards *et al*., 2019). Neonatal piglet characteristics associated with vitality include IUGR, birth weight, body shape and colostrum intake (van Rens *et al*., 2005). The placenta size and efficiency are important biological marker for fetal development (Foxcroft *et al*., 2009). The percentage of IUGR in the neonatal piglets is associated with the quality of sows' placenta (Baxter *et al*., 2008). In large litter, intra-uterine crowding decreases the surface area available per fetus. The use of modern hyperprolific sows in swine industry has led to many problems in neonatal piglets (Udomchanya *et al*., 2019; Ward *et al*., 2020). Therefore, additional management strategies should be investigated to minimize the neonatal loss of piglets.

Feeding management during transition period

The period of time during 105 days of gestation until the day of farrowing is generally known as transition period (Theil *et al*., 2011). This period of time is very complex and importance due to the several hormonal, metabolic nutritional changes and corresponds to the lactating sows after parturition (Feyera *et al.*, 2017). During this period, nutrition can be transferred from dams to the fetus and subsequently influence the energy status as well as colostrum production of the sows around parturition. During the last decade, a number of research has been done to evaluate optimal feeding strategies reduce neonatal loss of piglets. For instance, providing a transition diet with high fiber feed can prolong energy uptake from hind gut fermentation and decrease the farrowing duration in sows (Feyera *et al.*, 2017). Moreover, feeding a high fiber diet in prepartum sows can also decrease the incidence of constipation (Oliviero *et al.*, 2010). Currently, treatment of inflammation and pain management in postpartum sows is an important issue for animal welfare in modern swine industry (Martínez-Burnes *et al*., 2021). In practice, it is very important for swine veterinarian to utilize appropriate anti-inflammatory drug (Plush *et al*., 2021) and perform efficient pain management for postpartum sows. Therefore, a practical solution to provide prepartum and postpartum sows with both high fiber diet and anti-inflammatory agent should be concentratedly investigated.

Use of *Cannabis sativa* in animal diet

Recently, the use of *Cannabis sativa*, generally known as hemp, has been intensively reviewed (Fallahi *et al*., 2022). In recently publication, interest in cannabis plants use has grown owing to medical properties. Several compositions of this *Cannabis sativa* plant, for instance; seeds, leaves, flowers, and stems are used in human medicine and hemp industry. CBD abbreviation from Cannabidiol has several properties advantage; anti-inflammatory, antioxidative, analgesic or reduce pain and anti-depressant effects. CBD is a non-psychoactive that can stimulate both of central and peripheral nervous system in many different species. In veterinary medicine both of companion and livestock animals have several reports to adapt these beneficial properties to help improve health and productive performances. In companion animals:

dogs and cats, CBD has been used to alleviate cancer pain, osteoarthritis, neuropathic pain, and mood disorders (Hartsel *et al*., 2019; Kogan *et al*., 2019). In goat, supplementation of CBD can increase milk yield and concentration of conjugated fatty acid and PUFAs in the milk (Cozma *et al*., 2015). Moreover, in livestock animals, stress level will be drop dramatically after adding hemp to male Holstein diets (with a target dose of 5.5 mg/kg CBDA). Improve welfare issue by increasing the good behavior. Group of Holstein diet that receive the hemp shown lying behaviors more than control group and decrease in cortisol level and PGE2 level different significantly (Kleinhenz *et al*., 2022).

In swine industry, many researchers demonstrated that CBD have many beneficial advantages on neurological system for instance; relieve pain and brain damage or Hypoxic-ischemic (HI) from lack of oxygen saturation or oxygen insufficient in brain tissue (Garberg *et al.*, 2017). Moreover, interesting report in pregnant sows, supplementation of CBD for 10 days before farrowing and 21 days after farrowing (lactating periods) can improve oxidative status during lactation (Palade *et al*., 2019).

Cannabis sativa is a medical plant that have analgesic, anti-inflammatory and antipyretic properties (Cabrera *et al.*, 2021). Moreover, the *Cannabis sativa* also rich in fiber composition. During pharmacological preparation of *Cannabis sativa* for human/ animal medicine, over 90% of byproduct is archived from the extraction process. Thus, in the future, the pharmaceutical production of *Cannabis sativa* for medical and/or veterinary drug will obtain a lot of waste. Therefore, to obtain zero waste in the hemp industry, the use of the byproduct needs to be concerned. Recently, the supplement of dietary hemp seed in sows during late gestation and lactation can significantly improve oxidative status in both sows and offspring (Palade *et al.*, 2019). However, the benefit of dietary hemp supplementation on sow reproductive performance and piglet characteristics, such as colostrum intake, has never been demonstrated. Moreover, to our knowledge, the use of *Cannabis sativa* byproduct in livestock animals has never been studied.

CHAPTER III

MATERIALS AND METHODS

Animals

The present study adhered to the ethical principles and guidelines set forth by the National Research Council of Thailand (NRCT) for conducting scientific research involving animals. Furthermore, the study received approval from the Institutional Animal Care and Use Committee (IACUC) in compliance with the regulations and policies of the university and government concerning the care and use of experimental animals (protocol number 2331004). The study was conducted in a commercial swine herd in the Northern region of Thailand. A total of 100 Landrace × Yorkshire crossbred sows were included in the experiment. The sows had an average parity number of 1.9 ± 0.8, ranging from 1 to 3. Among the included sows, there were 36 sows with parity number 1, 40 sows with parity number 2, and 24 sows with parity number 3. Sows were distributed according to parity numbers into 2 groups, i.e., control (n = 54) and treatment (n = 46). Sows in the control group received a conventional lactation diet 3.0 - 3.5 kg daily during a 7-days period before and after farrowing, while sows in the treatment groups received the same volume of the diet and supplemented with *Cannabis sativa* byproduct 150 g per sow per day. The concentration of cannabidiol (CBD) in the examined byproduct was determined to be 0.24% (w/w). Consequently, every 100 g of the byproduct derived from *Cannabis sativa* contained 240 mg of CBD. This meant that each sow received a daily dose of 360 mg of CBD. On average, sows at 109 days of gestation had a body weight of 234.2 ± 29.8 kg. Consequently, the CBD dosage administered to each sow averaged 1.5 mg per kilogram of body weight per day. Sow parameters collected during the experiment included farrowing duration (the time interval from the first to the last piglet born), TB, number of piglets born alive per litter (BA), percentage of stillborn piglets per litter (SB) and percentage of mummified fetuses per litter (MF). Within the initial 24 h following parturition, sow behaviors were captured and saved using video cameras. The duration of various behaviors, such as sleeping, sitting, standing, consuming feed, and lactating, was recorded. The colostrum IgG of the sows was assessed using a brix refractometer (Hasan *et al.*, 2016). Rectal temperature was measured using a digital thermometer, and sows with a rectal temperature of 39.5 °C or higher were classified as having a fever. Furthermore, the fecal score of sows was assessed both 3 days prior to and after parturition. Sows with a fecal score of 2 or lower were categorized as experiencing constipation.

General management, backfat measurement and farrowing supervision

The sows and gilts were housed in a conventional evaporative cooling system. They were initially kept in a group-housing system from 3 days after insemination until 109 ± 2.0 days of gestation. The sows were kept in groups of 260 – 280 with six electronic sow feeders. The gestation group-housing has measurements of 23.1 meters in width, 31.5 meters in length, and a height of 0.8 meters. This results in a total space allowance per sow is 2.6 m^2. After that sows were transferred to the farrowing unit. The farrowing pen was designed as a free-farrowing system and featured an adjustable swing hinge and plastic slatted floor. Each farrowing pen had dimensions of 2.00 × 2.35 × 0.90 m, providing a total space of 4.7 m^2 per pen. During the day of farrowing and for the following 3 days, the metal swing hinge was closed, and the sows were confined to individual crates measuring 1.80 × 0.60 × 0.90 m, allowing for a space allowance of 1.08 m^2 per sow. The swing hinge was fully opened starting from 4 days postpartum until the weaning period. Sows and their piglets were housed in separate individual farrowing pens during the lactation period. The creep area was equipped with a heating lamp, a rubber mattress, and a feeding bowl. Throughout the experimental period, the average daily temperature inside the barn ranged from 26.7 ± 0.4 °C, with a minimum to maximum range of 24.7–29.2 °C. The average daily humidity levels inside the barn ranged from 67.0 ± 2.0%, with a minimum to maximum range of 62.0–73.7%. During the different stages of gestation, the sows were provided with varying amounts of feed per sow per day. In the first, middle, and last periods of gestation, the sows received 3.0-3.5 kg of feed per day. Three days before farrowing, the feed quantity was reduced to 2.5-3.0 kg per sow per day. The gestation diet consisted of 12.7% crude protein, 2,700 kcal/kg of metabolizable energy, 5.7% fiber, and 0.7% lysine. Following farrowing, the sows were allowed to consume feed *ad libitum*. For lactating sows, an automatic feeding machine was used to provide feed, enabling the sows to consume it freely. This resulted in an average daily feed intake of 5.0-6.0 kg per sow during lactation. The lactation diet contained 17.2% crude protein, 3,300 kcal/kg of metabolizable energy, 4.3% fiber, and 1.1% lysine. The conventional lactational feed had a dietary fiber percentage of 4.3%, while the feed supplemented with *Cannabis sativa* byproduct had a dietary fiber percentage of 16.9%. Water was made available to the sows *ad libitum* through drinking nipples. The backfat thickness of the sows was measured using A-mode ultrasonography (Renco Lean-Meater®, Minneapolis, MN, USA) at 109 ± 2.0 days of gestation and at weaning (20 days of lactation). The backfat measurements were taken at the level of the last rib, approximately 6-8 cm from the midline, on both sides. The average measurement from the left and right sides was calculated and backfat losses during lactation were computed.

The researcher diligently monitored the farrowing process round the clock for 24 h. Key details, including the onset and conclusion of farrowing, birth weight of live-born piglets, and the status of the piglets at birth (whether they were live-born, stillborn, or mummified fetuses), were recorded. Assistance during the farrowing process was provided exclusively in cases of dystocia. When dystocia was clearly identified, assistance was administered, which involved manual extraction of the piglets and the intramuscular administration of 20 IU of oxytocin (Phenix Pharmaceuticals N.V. co. ltd., Hoogstraten, Belgium) when the interval between expulsions exceeded 60 min. Furthermore, once the 10th piglet was born, all sows routinely received an intramuscular administration of 20 IU of oxytocin to initiate placental expulsion and milk letdown. Towards the end of the parturition process, all sows in the control group were treated with an antipyretic drug, ketoprofen (3.0 mg/kg intramuscularly using Ketaprofen®, KELA N.V., Hoogstraten, Belgium). In the treatment group, sows did not receive a standard ketoprofen treatment as a routine, but instead received it after the detection of fever. The health of the sows was regularly monitored by the herd veterinarian. Prior to farrowing, the gestating sows were vaccinated against foot and mouth disease (AFTOPOR®, Merial SAS, Lyon, France) and Aujeszky's disease virus (Porcilis® Ad Begonia, Merck Animal Health, Madison, USA). Following farrowing, the sows were vaccinated against classical swine fever (Ceva-Phylaxia Veterinary Biologicals co. ltd., Budapest, Hungary) and Porcine Parvovirus- Leptospira- Erysipelas (Eryseng®, Laboratorios Hipra, S.A., Amer (Girona), Spain). The piglets, on the other hand, received vaccination against *Mycoplasma hyopneumoniae* (Hyogen®, Ceva Santé Animale S.A, Libourne, France) between 18 to 22 days of age.

Data collections

The experiment collected various parameters related to the sows, including sow identities, gestation length, farrowing duration, parity number, backfat thickness, and measurements of TB, BA, SB, and MF. To observe the behaviors of the sows within the first 24 h after farrowing, a video camera (IMOU®, Ranger 2-D, Hangzhou, China) was positioned on the ceiling of the farrowing barn to capture the entire pen. The camera recorded the duration of time the sows spent on different activities such as sleeping, sitting, standing, consuming feed, and lactating. The researchers carefully measured the amount of feed consumed by sows in the 7 days leading up to and following farrowing. The feed intake of each sow was calculated for every meal by subtracting the remaining feed (after drying) collected 2-3 h after the meal from the initial feed allowance. Consequently, the total feed intake for each sow was recorded twice a day. The sows were fed four times daily at 6:30 AM, 10:00 AM, 1:00 PM, and 4:00 PM. The daily feed intake of the sows was determined by adding up the feed intake from all meals. The level of sow colostrum IgG was assessed using a brix refractometer (Hasan *et al.*, 2016). The severity of constipation was evaluated based on the previous study (Olivero *et al.*, 2010). Using a scoring system: 0 denoted very severe constipation, 1 indicated severe constipation, 2 represented moderate constipation, 3 indicated normal feces, 4 stood for fairly soft feces, and 5 denoted very soft feces. Moreover, sows were classified as constipated if their fecal score was equal to or less than 2. To measure rectal temperature, a digital thermometer (Omron MC-246®, Omron Healthcare co. ltd., Kunotsubo Terado-cho Muko, Japan) was used for three days after farrowing. Sows with a rectal temperature equal to or higher than 39.5 °C were considered to have a fever (yes or no).

The newborn piglets characteristics collected in the experiment consisted of the status at birth (i.e., live born, stillbirth or mummified foetuses), body weight of liveborn piglet at birth (g), birth interval (i.e., the time elapsed between each piglet born), and cumulative birth interval (i.e., the time elapsed from the first piglet born to the given piglet). The percentage of stillborn piglets and mummified fetuses per litter was used to express their occurrence. The body weight of the piglets that were born alive was measured immediately after farrowing using a digital balance (SDS® IDS701-CSERIES, SDS, Yangzhou, Digital Scale Co. Ltd., Yangzhou, China). Each piglet was individually identified at birth by writing a number on a neotape and placing it on their back. The body weight of each piglet was measured again between 17 to 24 h after birth to calculate their weight gain and colostrum intake. Colostrum intake (CI) for each piglet was determined using an equation developed by Theil *et al.* (2014) Colostrum intake (g) = $-106 + 2.26\ WG + 200\ BWB + 0.111D - 1414\ WG/D + 0.0182\ WG/BWB$, where WG represents piglet weight gain over 24 hours (in grams), BWB represents birth weight (in kg), and D represents the duration of colostrum sucking (i.e., the time interval from birth to weighing at 24 h, measured in min). The colostrum yield for sows was calculated as the sum of the colostrum intakes of each individual piglet (Tospitakkul *et al.*, 2019). Additionally, the piglets were divided into two groups based on their colostrum consumption: < 300 g and ≥ 300 g. Piglets with colostrum intake below 300 g were categorized as having inadequate colostrum intake (Juthamanee & Tummaruk, 2021). The occurrence of piglet deaths at 3 and 7 days of lactation was also recorded, and the pre-weaning mortality rate for piglets at 3 and 7 days of postnatal life was calculated.

Bodyweight measurement and colostrum intake

The piglet's weight will be measured immediately after farrowing by using a digital balance (SDS® IDS701-CSERIES, SDS (Yangzhou) Digital Scale Co. Ltd., Yangzhou, China). An ear tattoo will be performed at birth for identification. Colostrum intake (CI) of each piglet will be measured by this equation, from Theil (2014) study: Colostrum intake (g) = $-106 + 2.26WG + 200BWB + 0.111D - 1414WG/D + 0.0182WG/BWB$ where WG is piglet weight gain over 24 h (g), BWB is birth weight (kg) and D is the duration of colostrum sucking (i.e., the interval from birth to 24 h weighting in minutes). Yield of colostrum for sows will be assumed as the total of the colostrum intakes of the individual piglet (Tospitakkul *et al.*, 2019). Moreover, the piglets will be classified into two groups according to their colostrum consumption: < 300 g and ≥ 300 g.

Statistical analyses

The statistical analyses were carried out using SAS version 9.4 (SAS Institute Inc., Cary, NC, USA). Descriptive statistics for continuous variables were obtained using the MEAN procedure. Frequency analyses were conducted for categorical variables using the FREQ procedure. Considering sows as the experimental unit, general linear model procedures were employed to analyze the continuous variables. The continuous traits of sows that were analyzed included gestation length (days), backfat thickness (mm), TB, BA, SB, MM, farrowing duration (min), daily feed intake of sows (kg/sow/day), brix value (%), rectal temperature (°C), and colostrum yield (kg). The statistical models included the effect of *Cannabis sativa* by product supplementation (control and treatment), sow parity number (1, 2, and 3), and interaction between treatment group and sow parity number. Least-square means were obtained from each class of the factors and were compared by using the least significant difference test. The analysis of categorical traits, such as the proportion of sows with prolonged farrowing, fever, and constipation, was performed using logistic regression analyses with the generalized linear mixed model (GLIMMIX) procedure. Furthermore, the fecal scores of sows were compared between the control and treatment groups using the Wilcoxon rank sum test.

Using the piglets as the experimental unit, a comparison was made between the control and treatment groups for various continuous data variables, including piglet body weight at birth (g), body weight at 24 h after birth (g), body weight gain (g), colostrum intake (g), birth interval (min), and cumulative birth interval (min). The analysis was conducted using the general linear mixed model (MIXED) procedure. The statistical models incorporated the fixed effects of *Cannabis sativa* byproduct supplementation (control and treatment), sow parity number (1, 2, and 3), piglet birth weight classes ($<$1.0 kg, 1.0 - 1.29 kg, and $\geq$1.3 kg), and the interaction between the treatment group and piglet birth weight classes. To account for repeated measurements within the litter, sow identity was included in the model as a random factor. Least-square means were calculated for each class of the factors, and a least significant difference test was employed to compare these means.

The categorical data regarding piglet traits, including stillbirth (yes/no), mortality rate during the first 3 days of life (yes/no), mortality rate during the first 7 days of life (yes/no), and the proportion of piglets with colostrum intake below 300 g (yes/no), were analyzed using logistic regression analyses with the GLIMMIX procedure. The statistical models incorporated the fixed effects of *Cannabis sativa* byproduct supplementation (control and treatment), sow parity number (1, 2, and 3), piglet birth weight classes (<1.0 kg, 1.0-1.29 kg, and ≥1.3 kg), and the interaction between the treatment group and piglet birth weight classes. The data distribution was assigned as a binomial distribution. To account for repeated measurements within the litter, sow identity was included in the model as a random factor. Least-square means were calculated for each class of the factors, and a least significant difference test was used for pairwise comparisons. A *P* value of less than 0.05 was considered statistically significant.

CHAPTER IV

RESULTS

Descriptive data

Table 1 displays the descriptive statistics for the reproductive performance of all the sows included in the experiment. On average, the farrowing duration, TB, BA, and SB of the sows were 205 ± 169 min, 14.4 ± 3.3 piglets/litter, 12.5 ± 4.0 piglets/litter, and 5.7%, respectively. The proportion of sows that had TB values above 16 was found to be 26.0%. Furthermore, the average backfat thickness at 109 days of gestation and at weaning was 20.5 ± 3.6 mm and 15.5 ± 3.1 mm, respectively. On average, sows experienced a 24.3% reduction in backfat during lactation. The colostrum yield of sows, across all groups, had an average value of 5.4 ± 1.3 kg, with variation observed among sows ranging from 0.7 to 9.3 kg (Table 1).

In terms of piglets, the average body weight of liveborn piglets at birth and 24 h after birth was 1315 ± 327 g and 1441 ± 357 g, respectively. The average colostrum intake of piglets was 447.6 ± 157.3 g. The cumulative birth interval, across all groups, was 89.4 ± 99.0 min. The cumulative piglet mortality rates within the first 3 and 7 days of life were 10.1% and 12.4%, respectively (Table 1).

Table 1 Descriptive statistics on reproductive performance of Landrace × Yorkshire sows and the characteristics of their piglets included in the experiment

Variables	Mean ± SD	Range
Sow (n = 100)		
Parity number	1.9 ± 0.8	1 – 3
Gestation length (d)	114.8 ± 1.1	113 – 117
Total number of piglets born per litter	14.4 ± 3.3	5 – 21
Number of piglets born alive per litter	12.5 ± 4.0	0 – 19
Stillborn piglets per litter (%)	5.7	0 – 40
Mummified fetuses per litter (%)	4.6	0 – 50
Farrowing duration (min)	205 ± 169	24 – 963
Sows with prolonged (>300 min) farrowing (%)	16.2	-
Backfat thickness at 109 days of gestation (mm)	20.5 ± 3.6	11.0 – 28.0
Backfat thickness at weaning (mm)	15.5 ± 3.1	9.0 – 22.5
Backfat loss (%)	24.3	-
Colostrum yield (kg)	5.37 ± 1.35	0.67 – 9.37
Brix value (%)	25.8 ± 2.8	18.8 – 33.2
Average daily feed intake (kg/sow/day)	3.5 ± 0.4	1.6 – 4.5

Table 1 (continued)

Variables	Mean ± SD	Range
Piglets (n = 1449)		
Body weight at birth (g)	1315 ± 327	435 – 2325
Birth interval (min)	14.3 ± 37.1	0 – 778
Cumulative birth interval (min)	89.4 ± 99.1	0 – 963
Body weight at 24 h after birth (g)	1441 ± 357	500 – 2525
Body weight gain during 0–24 h (g)	115.2 ± 116.1	- 370 – 855
Colostrum intake (g)	447.6 ± 154.3	0 – 929
Piglets that had colostrum intake < 300 g (%)	17.5	-
Piglet mortality rate during the first 3 day of life (%)	10.1	-
Piglet mortality rate during the first 7 day of life (%)	12.4	-

Reproductive parameters, farrowing duration, and rectal temperature

Table 2 Reproductive data from sows in the control group, which received a conventional lactation diet, compared with the reproductive data from sows that received the conventional lactation diet supplemented with Cannabis sativa byproduct (treatment group) at a rate of 150 g/sow/day for a period of 7 days both before and after farrowing (least-square means ± SEM).

Variables	Control	Treatment	*P* value
Number of sows	54	46	
Parity number	1.8 ± 0.1	2.0 ± 0.1	0.240
Gestation length (days)	114.8 ± 0.15	114.9 ± 0.17	0.772
Backfat thickness at 109 days of gestation (mm)	20.0 ± 0.5	21.1 ± 0.6	0.182
Total number of piglets born per litter	13.9 ± 0.5	14.7 ± 0.5	0.239
Number of piglets born alive per litter	12.2 ± 0.5	12.8 ± 0.6	0.346
Stillbirth (%)	5.3	6.0	0.649
Mummified fetuses (%)	4.7	6.4	0.348
Farrowing duration (min)	199.9 ± 24.0	202.2 ± 26.5	0.994
Sows with prolonged farrowing (%)	16.7	15.6	0.881
Feed intake (kg/sow/day)	3.46 ± 0.06	3.61 ± 0.07	0.098
- Before farrowing	3.03 ± 0.03	3.06 ± 0.03	0.393
- After farrowing	4.15 ± 0.11	4.50 ± 0.12	0.045

Table 2 (continued)

Variables	Control	Treatment	*P* value
Fecal score (0 – 5)	2.03 ± 0.06	3.04 ± 0.07	<0.001
Sows with constipation (%)	81.5	17.4	<0.001
- Before farrowing	81.5	15.2	<0.001
- After farrowing	79.6	6.5	<0.001
Brix value (%)	25.5 ± 0.4	26.3 ± 0.4	0.141
Rectal temperature (°C)			
- Day 1	39.8 ± 0.06	39.8 ± 0.07	0.858
- Day 2	39.4 ± 0.06	39.3 ± 0.06	0.128
- Day 3	39.2 ± 0.07	39.1 ± 0.07	0.194
Sows that had fever (%)			
- Day 1	72.2	68.9	0.991
- Day 2	38.9	31.1	0.587
- Day 3	38.9	20.0	0.051
Colostrum yield (kg/day)	5.34 ± 0.21	5.42 ± 0.21	0.808

Table 2 presents the reproductive parameters, farrowing duration, and rectal temperature of sows in the control and treatment groups. The average gestation length, farrowing duration, litter traits, and backfat thickness of sows before farrowing did not show any significant differences between the control and treatment groups (Table 2).

The average rectal temperature and the proportion of sows with fever (defined as rectal temperature ≥39.5 °C) during the first 3 days postpartum were compared between the control and treatment groups, as shown in Table 2. No significant differences were observed in the proportion of sows with fever between the control and treatment groups on the first and second days postpartum (Table 2). However, on the third day postpartum, there was a tendency for a lower proportion of sows with fever in the treatment group compared to the control group (20.0% vs. 38.9%, respectively, P = 0.051, Table 2).

Behaviour of sows during the first 24 h postpartum

Behavioural data of 98 sows during the first 24 h postpartum were collected for analysis. Two sows were excluded from the analysis due to a high proportion of mummified fetuses and illness. The sow behavior during this period was compared between the control and treatment groups and is presented in Table 3. The average total duration of behavior observed by the video camera was 1439 ± 30.7 min. The proportions of time that sows spent sleeping, sitting, standing, consuming feed and lactating during the first 24 h postpartum were 61.3%, 4.4%, 6.1%, 10.5%, and 17.7%, respectively. Notably, the time allocated for lactating varied significantly among individual sows, ranging from 3.3% to 27.4% and the duration of lactating during this period varied from 48 min to 394 min.

When compared to the control group, sows that received *Cannabis sativa* supplementation spent more time standing and consuming feed (Table 3). Conversely, the time spent sleeping and sitting during the first 24 h postpartum was significantly lower in the *Cannabis sativa* supplementation group compared to the control group

(Table 3). However, no significant difference was found in the time allocated for lactating between the control and treatment groups (Table 3). Interestingly, sows without constipation issues before farrowing spent more time eating compared to sows with constipation problems (11.9 ± 0.7% vs. 9.2 ± 0.7%, $P = 0.006$).

Table 3 The behavior of sows during the first 24 h postpartum in the control group, which received a conventional lactation diet, compared with the behavior of sows that received the conventional lactation diet supplemented with Cannabis sativa byproduct (treatment group) at a rate of 150 g/sow/day for a period of 7 days both before and after farrowing (least-square means ± SEM).

Variables	Control	Treatment	*P* value
Number of animals	53	45	
Sleeping (%)	63.8 ± 0.9	58.9 ± 1.0	<0.001
Sitting (%)	4.6 ± 0.3	3.6 ± 0.4	0.049
Standing (%)	5.1 ± 0.5	7.4 ± 0.5	0.002
Consuming feed (%)	9.3 ± 0.7	12.0 ± 0.7	0.009
Lactating (%)	17.1 ± 0.7	18.2 ± 0.8	0.339

Figure 1 The classification of sow behavior during the first 24 h postpartum includes: (a) sleeping, (b) sitting, (c) standing, (d) consuming feed and (e) lactating.

Constipation and sow feed intake

There were significant differences in the fecal score and the prevalence of constipation before and after farrowing between the control and treatment groups (Table 2). The prevalence of constipation in the treatment group was notably lower compared to the control group (17.4% and 81.5%, respectively, $P < 0.001$). The average daily feed intake of sows in the control and treatment groups was 3.46 ± 0.06 kg and 3.61 ± 0.07 kg, respectively ($P = 0.098$). Although there was no significant difference in feed intake before farrowing between the control and treatment groups, the treatment group exhibited significantly higher feed intake compared to the control group after farrowing (Table 2). The frequency distribution of average daily feed intake in postpartum sows is shown in Figure 2, comparing control sows with those receiving *Cannabis sativa* byproduct supplementation. On average, the feed intake of postpartum sows increased from 4.15 ± 0.11 kg to 4.50 ± 0.12 kg per sow per day after *Cannabis sativa* byproduct supplementation (*P* = 0.045).

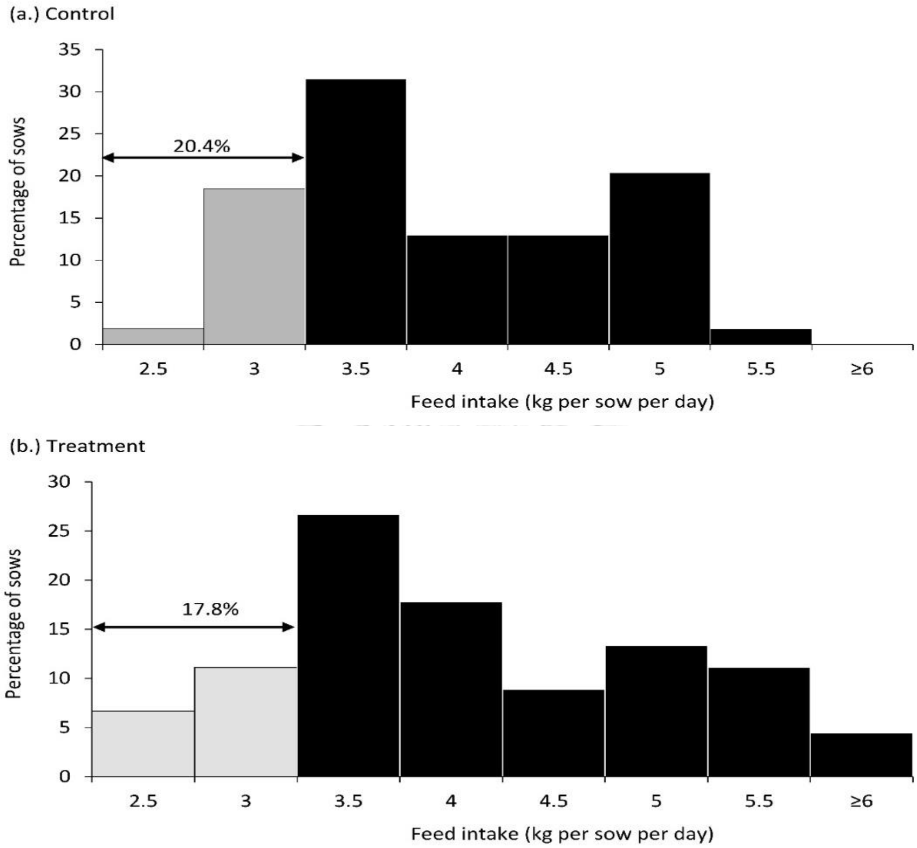

Figure 2 The frequency distribution presents the average daily feed intake of sows after parturition in both the control group (a) and the treatment group (b), where the sows received Cannabis sativa byproduct supplementation

Piglet colostrum intake and performances

Table 4 displays the colostrum intake and performances of piglets from sows that received *Cannabis sativa* byproduct supplementation during the transition period, compared to the control group. On average, the colostrum intake of piglets in the control and treatment groups was 456.6 ± 11.9 g and 445.6 ± 11.1 g, respectively (P = 0.496). The proportion of piglets with inadequate colostrum intake was 17.8% in the control group and 17.2% in the treatment group, showing no significant difference between the two groups (P > 0.05). Figure 3 illustrates the frequency distribution of piglets' colostrum intake and the proportion of piglets with inadequate colostrum intake in both the control and treatment groups. Piglet mortality rates at 3 and 7 days postpartum did not differ significantly between the control and treatment groups (Table 4). Similarly, no significant differences were observed in other piglet traits between the control and treatment groups (Table 4).

Furthermore, piglets with a birthweight of ≥1.3 kg exhibited higher colostrum intake compared to piglets with birthweights of 1.0 – 1.29 kg and < 1.0 kg (512.2 ± 7.8 g vs. 417.9 ± 9.0 g and 306.8 ± 11.1 g, respectively, P < 0.001). Additionally, the proportion of piglets with inadequate colostrum intake was lower among those with a birthweight of ≥ 1.3 kg compared to piglets with birthweights of 1.0 – 1.29 kg and < 1.0 kg (6.4% vs. 17.9% and 52.3%, respectively, P < 0.001). The piglet mortality rates during the first 3 days of life were 6.3%, 11.1% and 18.6% for those with birthweights of ≥ 1.3 kg, 1.0 – 1.29 kg, and < 1.0 kg, respectively (P < 0.001). Similarly, the piglet mortality rates during the first 7 days of life were 8.1%, 13.5% and 22.1% for those with birthweights of ≥ 1.3 kg, 1.0–1.29 kg and <1.0 kg, respectively (P < 0.001). No significant interaction was found between treatment and piglet birthweight regarding piglet colostrum intake and piglet mortality rates ($P > 0.10$).

Table 4 The colostrum intake and performance of piglets from sows that received *Cannabis sativa* byproduct supplementation during the transition period (treatment) compared with those from the control group (least-square means ± SEM).

Variables	Control	Treatment	*P* value
Number of piglets	764	685	-
Birth interval (min)	15.1 ± 1.7	13.0 ± 1.7	0.379
Cumulative birth interval (min)	90.5 ± 8.3	75.7 ± 7.2	0.170
Stillbirth (%)	6.1	6.9	0.657
Birth weight (g)	1318 ± 289	1324 ± 255	0.881
Body weight at 24 h (g)	1451 ± 321	1460 ± 312	0.845
Weight gain (g)	115.7 ± 7.7	115.6 ± 7.7	0.987
Colostrum intake (g)	456.6 ± 11.9	445.6 ± 11.1	0.496
Piglets that had inadequate colostrum intake (%)	17.8	17.2	0.913
Duration of colostrum suckling (min)	1348 ± 7.5	1351 ± 7.2	0.771
Piglets mortality at 3 days postpartum (%)	10.5	9.6	0.422
Piglets mortality at 7 days postpartum (%)	12.5	12.0	0.685

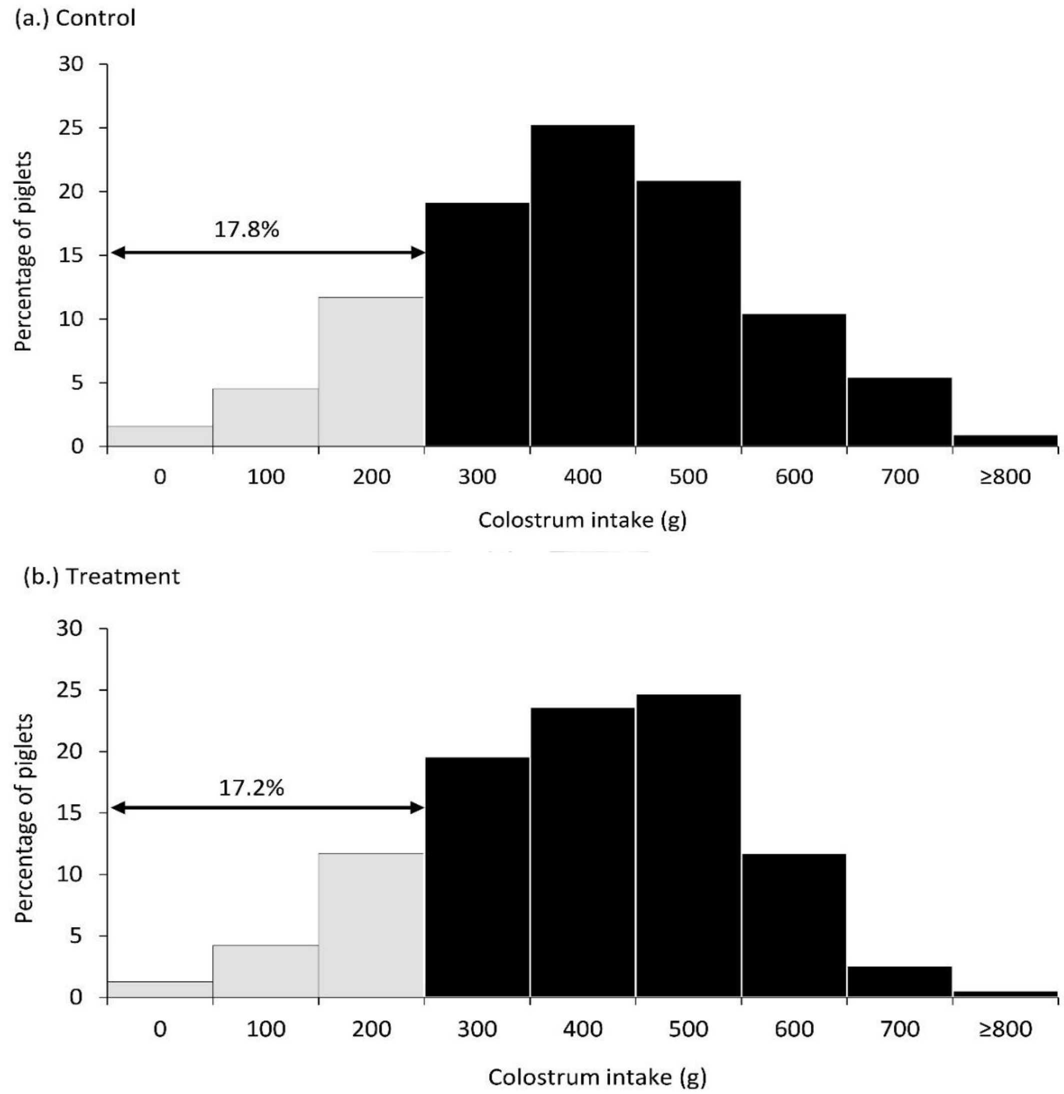

Figure 3 The frequency distribution shows the colostrum intake of newborn piglets in both the control group (a) and the treatment group (b), where the sows received Cannabis sativa byproduct supplementation during the transition period.

CHAPTER V

Discussion

The present study highlights the potential utilization of *Cannabis sativa* byproduct supplementation during the transition period for pre- and postpartum sows under field conditions. It provides insights into the effects of *Cannabis sativa* byproduct supplementation during the transition periods on various aspects including postpartum behavior, feed intake, constipation score, farrowing duration, rectal temperature, and colostrum yield in sows. Additionally, it examines the characteristics and performance parameters of newborn piglets, such as colostrum intake and piglet mortality rate during the first week of postnatal life. Overall, the supplementation of *Cannabis sativa* byproduct brings about changes in sow behavior within the first 24 h after giving birth, improves feed intake, and reduces constipation issues. Moreover, there is a tendency for a reduced incidence of sows experiencing fever on day 3 postpartum in the group receiving *Cannabis sativa* byproduct supplementation. However, there were no significant differences observed between the control and treatment groups in terms of other reproductive parameters and piglet characteristics.

Fever and farrowing duration

It is noteworthy that the percentage of sows experiencing fever was relatively elevated in both the control and treatment groups on the first day after giving birth, with rates of 72.2% and 68.9% respectively. This high incidence of sows with fever during the initial postpartum day is commonly observed in tropical regions and aligns with the findings of our previous studies (Tummaruk & Pearodwong, 2015; Tummaruk & Sang-

Gassanee, 2013). These observations suggest that the sows experienced significant inflammation and pain, likely attributed to either a lengthy farrowing process or moderate to severe heat stress. Consequently, the administration of anti-inflammatory and analgesic medication is strongly recommended for postpartum sows, particularly those encountering farrowing complications such as prolonged farrowing and dystocia. In the current study, ketoprofen at a dosage of 3.0 mg/kg intramuscularly was regularly employed in both groups to alleviate pain and reduce fever in postpartum sows. Jeeraphokhakul *et al*. (2023) illustrated that administering ketoprofen to postpartum sows for a period of two days effectively managed post-parturient disorders in sows, comparable to the use of tolfenamic acid. Interestingly, in the current study, there was a tendency for a lower proportion of sows experiencing fever on day 3 postpartum in the treatment group compared to the control group, which solely received ketoprofen (20.0% and 38.9%, respectively). These findings suggest that the use of a combination of ketoprofen and *Cannabis sativa* byproduct supplementation may contribute to reducing the occurrence of fever in sows during the initial days following parturition. Indeed, in the treatment group, ketoprofen was not administered routinely to all sows but was selectively used only for those sows exhibiting fever. Therefore, this protocol is rather practical and can be recommended to implement under field conditions. However, it is challenging to accurately identify the clinical signs indicative of pain in sows. Nonetheless, in the group supplemented with *Cannabis sativa* byproduct, the sows spent a greater proportion of time standing within the initial 24 h after giving birth compared to the control group. This extended duration of standing in sows during the early postpartum period could serve as an indirect indication of improved recovery among the sows after farrowing.

The average duration of farrowing for sows in this study was 205 min, with significant variation ranging from 24 to 963 min. Approximately 16.2% of the sows experienced a prolonged farrowing duration, exceeding 300 min. The extended farrowing duration observed in certain sows in this study may be attributed to the utilization of highly productive sow genetics in the swine industry over the past ten years (Adi et al., 2022; Kirkwood *et al*., 2021). Factors associated with the prolonged farrowing duration in sows included breed, age of sow, gestation length, number of piglet born, housing (i.e., pen versus crate), body condition of the sow and constipation score (Oliviero *et al*., 2010). On average, the farrowing duration of sows farrowed in the crate system was longer than that farrowed in the free-farrowing pen, i.e., 301 versus 212 min (Oliviero *et al*., 2010). In this study, all sows gave birth in a free-farrowing system, and the duration of farrowing was comparable to the findings reported in Finland (Oliviero *et al*., 2010). Pearodwong *et al*. (2016) revealed that the occurrence of fever in sows on the first day after farrowing was twice as high in sows experiencing constipation compared to those with normal bowel movements. Additionally, the severity of constipation in sows before farrowing showed a significant correlation with the duration of farrowing (Oliviero *et al*., 2010). Furthermore, sows with parity numbers 5-7 and 8-10 exhibited longer farrowing durations compared to sows with parity numbers 1 and 2-4 (Adi *et al*., 2022). In the present study, the inclusion of *Cannabis sativa* byproduct as a supplement for sows prior to farrowing demonstrated a significant decrease in constipation issues and potentially improved the farrowing duration, particularly in older and highly productive sows. However, there was no notable difference in the farrowing duration or the proportion of sows with prolonged farrowing duration between the control and treatment groups. This lack of significant findings may be attributed to the relatively small number of animals in each group and the limited occurrence of prolonged farrowing in both the control and treatment groups, providing insufficient evidence for conclusive results.

Behavior of sows during the first 24 h postpartum

In the initial 24 h after farrowing, the sows dedicated the majority of their time to sleeping (61.3%) and nursing their piglets (17.7%). However, when sows were provided with a *Cannabis sativa* byproduct during the transitional period, their sleeping time decreased (-4.9%), while their time spent standing increased (+2.3%) and feeding increased (+2.7%) compared to the control group of sows. As a result, the group supplemented with *Cannabis sativa* byproduct showed a significant rise in postpartum feed consumption. The therapeutic qualities of cannabidiol (CBD), which is derived from *Cannabis sativa* or hemp, are widely acknowledged for their ability to alleviate pain and inflammation, as well as treat conditions such as anorexia, nausea, and anxiety disorders (Fallahi *et al*., 2022). Therefore, it is possible that the observed enhancements in sow activity within the initial 24 h after farrowing, along with the increased feed consumption among the sows in the study, could be attributed to the mild analgesic properties of CBD found in the *Cannabis sativa* byproduct. Numerous studies, involving various animal species and humans, have extensively investigated the pain-relieving effects of hemp oil or CBD in a dose-dependent manner (Fallahi *et al*., 2022). In postpartum sows, pain and inflammation frequently coexist due to the prolonged duration of farrowing and intense uterine contractions (Mota-Rojas *et al*., 2022). Consequently, it is crucial to cautiously administer analgesic therapy that does not interfere with the natural process of labor. It is worth noting that cannabinoid receptors are present in the central and peripheral nervous system as well as the brain of dogs and cats (Chiocchetti *et al*., 2019; Gebremedhin et al., 1999). Additionally, the endocannabinoid system, which is found in various body tissues, has been shown to effectively alleviate pain and improve appetite in numerous animal species (Della Rocca & Di Salvo, 2020). Cannabidiol has been used in dogs and cats to alleviate pain associated with conditions like osteoarthritis, neuropathic pain, cancer, and mood disorders (Chiocchetti *et al*., 2019; Kogan *et al*., 2019). In pigs, CBD has been investigated for its neuroprotective effects in hypoxic-ischemic brain injury in newborn pigs, where it has been shown to modulate excitotoxicity, oxidative stress, and inflammation (Pazos *et al*., 2013). Treatment with 1 mg/kg of CBD in pigs was able to prevent physiological alterations caused by hypoxic-ischemic brain injury (Pazos *et al*., 2013). These findings suggest that daily consumption of a small amount of CBD from *Cannabis sativa* byproduct may possess anti-inflammatory properties and provide pain relief in peri-partum sows. In the present study, the average daily CBD dose in the treatment group was 1.5 mg/kg. Consequently, the behavior of sows during the first 24 h postpartum was altered, particularly in terms of indicators of postpartum recovery such as increased standing and feed consumption. Conversely, sows in the control group exhibited more time spent sitting and sleeping, indicating a slower postpartum recovery rate. However, there were no significant differences observed in the duration of lactation between the control and treatment groups. Therefore, no distinction in colostrum consumption by the piglets could be observed.

Constipation and feed intake

Interestingly, the treatment groups showed an improvement in constipation scores. Our previous study has indicated that constipation in sows before farrowing can have negative effects on farrowing performance and postpartum complications (Pearodwong *et al*., 2016). Pearodwong *et al*. (2016) found that sows experiencing moderate to very severe constipation had a farrowing duration that was 28 min longer than sows without constipation problem. Moreover, constipation in sows on the day of farrowing led to reduced appetite on the first day after farrowing (Pearodwong *et al*., 2016). The incidence of sows with fever on the first day after farrowing was found to be twice as high in sows with constipation compared to sows with normal bowel movements (36.2% and 16.7% respectively). Likewise, the occurrence of fever in sows on the third day after farrowing was lower in the treatment group compared to the control group. The improvement in constipation scores among sows treated with the *Cannabis sativa* byproduct may be attributed to the higher fiber content in the pre-farrowing diet, which increased from 4.3% in the control diet to 16.9% in the diet supplemented with the *Cannabis sativa* byproduct. Therefore, augmenting the fiber percentage in the sow's diet prior to farrowing through the addition of the *Cannabis sativa* byproduct supplementation may assist in reducing constipation issues and enhancing the postpartum feed intake of sows. Recent studies have provided evidence that incorporating fiber-rich supplements into the diets of sows during transition periods can improve the composition of colostrum, but not its yield (Feyera *et al*., 2021; Jiang *et al*., 2019; Loisel *et al*., 2013). For instance, Loisel *et al*. (2013) conducted a study where they increased the fiber content in the gestation diet of nulliparous sows from 13.3% to 23.4% using soybean hulls, wheat bran, sunflower meal, and sugar beet pulp.

Although this dietary change resulted in an increase in the lipid composition of sow colostrum, it did not impact colostrum yield or alter the peripartum concentrations of key hormones involved in lactogenesis, such as progesterone, prolactin, estradiol-17β, and cortisol (Loisel *et al*., 2013). Similarly, in the current study, the addition of *Cannabis sativa* byproduct supplementation did not lead to an improvement in the colostrum yield of sows. While the specific composition of colostrum was not assessed, the estimated concentration of IgG in sow colostrum, measured using a brix refractometer, did not show any significant differences between the control and treatment groups. Furthermore, Feyera *et al*. (2021) found that the choice of fiber-rich supplement had an impact on nutrient digestibility and colostrum composition, cautioning against the use of palm kernel expellers as a fiber source for late gestating sows. In the current study, nutrient digestibility was not specifically assessed. However, no adverse effects were observed on piglet colostrum intake or piglet mortality rate in the first few days after birth when *Cannabis sativa* byproduct was used as a fiber source during the transition periods. Additionally, the use of *Cannabis sativa* byproduct as a fiber source was found to reduce constipation and improve feed intake in postpartum sows. In Meishan sows, a study showed that increasing the crude fiber content in the diet from 2.5% to 7.5% throughout the entire farrowing interval had several positive effects. This dietary adjustment regulated the secretion of steroid hormones, such as progesterone and estradiol. Additionally, it influenced the gut by enhancing the presence of cellulose-degrading bacteria and probiotic bacteria like *Lactobacillus*, *Ruminococcus*, and *Fibrobacter*. Simultaneously, it reduced the abundance of opportunistic pathogens like *Clostridium*, *Streptococcus*, and *Escherichia-Shigella*. These changes are believed to contribute to the improvement of reproductive performance and welfare in sows. In terms of reproduction, gilts that were provided with a high-fiber diet, specifically consisting of 50% unmolassed sugar beet pulp, for a duration of 19 days before insemination demonstrated several positive outcomes. These included an increase in LH pulse frequency, improved oocyte maturity, and enhanced embryo survival (Ferguson *et al.*, 2007). Therefore, the reduction in constipation incidence and the improvement in feed intake observed in postpartum sows after the supplementation of *Cannabis sativa* could potentially be attributed to the increased crude fiber content in the diet during the transition period (from 4.3% to 16.9%). These findings highlight the efficacy of *Cannabis sativa* byproduct supplementation as a reliable source of fiber for pigs.

Piglet colostrum intake and performances

In the current study, the supplementation of *Cannabis sativa* byproduct in sows during the transition period for a duration of 7 to 10 days did not lead to improvements in piglet colostrum intake or a reduction in mortality rates during the first week after birth. Interestingly, the percentage of piglets that had inadequate colostrum intake (less than 300 g) was relatively low in both the control and treatment groups (ranging from 17.2% to 17.8%) compared to a previous study where the percentage was 26.0% (Juthamanee & Tummaruk, 2021). This difference could be attributed to the fact that all newborn piglets in both groups received close supervision by the research team for 24 h. Additionally, the number of live-born piglets in the present study (ranging from 12.2 to 12.8 piglets per litter) was lower than the number reported in the previous study (15.4 piglets per litter) (Juthamanee & Tummaruk, 2021). Consequently, all the piglets in the current study were able to receive sufficient attention and care from the caretakers. However, it is worth noting that the mortality rates of piglets at 3 and 7 days postpartum remained relatively high in both the control and treatment groups, standing at 10.1% and 12.4% respectively. This may be attributed to the recent implementation of a free-farrowing system in the herd, where sows are allowed to move freely during the postpartum period. The utilization of a free-farrowing system in sows experiencing moderate to severe heat stress can result in a higher occurrence of piglet crushing (Dumniem *et al*., 2023). Dumniem *et al*. (2023) conducted a study that demonstrated that sows kept in a free-farrowing system produced a greater amount of colostrum compared to sows kept in crates. However, the preweaning mortality rate of piglets and the proportion of piglet loss due to crushing were higher in the free-farrowing system than in the crated sows. Further understanding is necessary to mitigate the prevalence of piglet crushing incidents by sows in free-farrowing systems, particularly under tropical conditions.

Limitation of CBD treatment

Extensive research has been conducted on the hepatotoxicity of CBD in humans and several animal species, including dogs, cats, and poultry (Fallahi *et al*., 2022; Gamble *et al*., 2018). However, there is a scarcity of information regarding the potential impact of CBD on liver function in pigs. In dogs, the administration of CBD oil at a dosage of 2-8 mg/kg every 12 h for a duration of 4 weeks has been shown to cause a significant increase in serum alkaline phosphatase levels, without any observed clinical side effects (Gamble *et al*., 2018). In pigs, pregnant sows that were provided with a diet containing 2.0% hemp seed for 10 days prior to farrowing, followed by 5.0% hemp seed for 21 days during lactation, experienced notable improvements in certain oxidative enzymes. These improvements included enhanced activity of antioxidant enzymes such as catalase and superoxide dismutase, as well as increased production of glutathione and nitric oxide (Palade *et al*., 2019). However, the previous study Palade *et al*. (2019). did not specify the exact amount of CBD utilized. In the current study, we have analyzed the concentration of CBD present in the *Cannabis sativa* byproduct. The analysis revealed a CBD concentration of 0.24% (w/w) in the byproduct, resulting in an average daily CBD intake of 360 mg per sow. Therefore, the average dosage of CBD administered to the sows in this study was 1.5 mg/kg/day, and the treatment duration was less than 10 days. These doses and treatment duration are below the thresholds known to cause liver function side effects in dogs. However, it is important to note that alkaline phosphatase and other liver enzymes were not assessed in the current study. Based on clinical evaluation, the supplementation of *Cannabis sativa* byproduct in sows with a CBD dose of 1.5 mg/kg/day did not result in any harmful effects on the sows.

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