Variation in sow and piglet behaviour and welfare over time during a 5-week nursing period in individual loose housing pens

개방형 분만사 내 5 주 포유기간 동안 모돈과 자돈의 행동 및 복지수준 변화

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Abstract

This master thesis aimed to investigate variation in the sow and piglet behaviour and welfare over time during a 5-week nursing period in the loose housing pen. This study was performed through analysis of video-recorded behaviours in 17 Swedish and Dutch Yorkshire sows and their piglets (284 piglets, pure-bred Yorkshire × Hampshire, average litter size with standard error = 16.7 ± 0.56). All behaviours in the sows and their piglets were recorded by using a continuous sampling method in every second and 30-minute interval scan sampling. The behaviours were recorded from 09.00 to 20.00 for two consecutive days each week postpartum (pp) during the 5-week nursing period.

According to the results of behavioural observation in the sows and piglets, the sows showed a gradual decrease of nursing behaviour such as the number of nursing occurrence (from 18.5 in week 2 pp to 12.3 in week 5 pp), nursing duration (from 7 minutes in week 1 to 5.6 minutes in week 5 pp), and total nursing duration (from 111.9 minutes in week 1 pp to 68.1 minutes in week 5 pp). On the other hand, the piglets became more active and vigorous over time during the nursing period with showing the highest percentage of exploration (10.3 % in week 3 pp, 12.1 % in week 4 pp, and 12.5 % in week 5 pp vs 6.6 % in week 1 pp and 6.3 % in week 2 pp) and the percentage of contact to the littermates gradually increased week by week during the nursing period, from 0.2 % in week 1 pp to 2.5 % in week 5 pp.

This thesis used the sow location in the pen and piglet mortality as indicators to evaluate the sow and piglet welfare because the slatted floor can cause severe injuries to limbs and udder in sows and the piglet mortality has been well known as the piglet welfare indicator. The sow welfare might be impaired after week 1 pp because the percentage of lying and staying on slatted floor in the sows was significantly increased from 17.8 % in week 1 pp to 40.3 % in week 5 pp. The piglet welfare might be impaired during week 1 pp because the piglet mortality (the percentage of piglets crushed by the sow, euthanized and total mortality) were significantly higher in week 1 pp than the other weeks with reaching respectively 7.20 %, 7.89 %, and 18.15 % in the week 1 pp.

In conclusion, the piglets became more active and vigorous while the sows showed more avoiding behaviours related to nursings over time during the 5-week nursing period. Also, the sows showed an increased preference for lying and staying on the slatted floor from week 2 pp which could cause severe injuries to their legs and udder and irritated respiration caused by ammonia gas from the slatted floor. For the reasons above, the sow welfare might be impaired from week 2 pp. Regarding the high piglet mortality with piglets crushed by their sows in week 1 pp, the piglet welfare might be impaired during week 1 pp because crushed piglets by a sow are hardly seen in natural environments. However, there were no piglets crushed by their sows and the piglet mortality significantly decreased from week 2 pp. For the reasons above, the piglet welfare might become better from week 2 pp. However, missing data, imbalanced sample size in each week, and the absence of fixed effects of sow's parity and batch and litter size in the continuous and scan sampling data might affect the assessment of the sow and piglet behaviour and welfare in this master thesis. Hence, to improve the accuracy of welfare assessment and behaviour assessment for the sows and piglets, non-missing data, larger same sample size and improved balance between multiparous and primiparous sows considering their parities and batches and litter size are needed.

Keywords: Nursing behaviour, suckling behaviour, sow welfare, piglet welfare, maternal behaviour

Sow and piglet behaviour and welfare were changed over time during a 5-week nursing period

This master thesis aimed to investigate how sow and piglet behaviour was changed over time during a 5-week nursing period and how the changed behaviour in the sow and piglet affected their welfare. This thesis found that nursing behaviour in sows was gradually decreased during the nursing period while active behaviour in piglets gradually increased. Also, the sow's welfare might be impaired from 2 weeks after farrowing due to high preference of staying and lying on the slatted floor which might cause severe injuries to its legs and teats. Also, the piglet's welfare might be impaired in the first week after farrowing due to high piglet mortality with crushing death by their sows which is barely seen in wild conditions.

In this study, 17 Swedish and Dutch Yorkshire sows with their piglets were kept in individual loose housing pens. All their behaviours were video-recorded and analysed from 09:00 to 20:00 for two consecutive days each week by using the (every second) continuous and (30-minute intervals) scan sampling method.

In the results, nursing occurrence, total nursing duration, and nursing duration decreased gradually during the 5-week nursing period. Also, the sows increasingly rejected suckling by their piglets increasing lying on the belly during the nursing period. These behavioural changes might be caused by the weaning process. Also, The sows were very active in the first week after farrowing compared to other weeks for the nursing period. Eating behaviours increased gradually during the nursing period. From the second week after farrowing, the sows seemed to get heat stress due to their high preference of lying and staying on the slatted floor which might lead to severe injuries to their legs and teats.

The results also showed that the piglets became more active over time during the nursing period. However, high piglet mortality occurred in the first week after farrowing. Also, crushing death by their sows only occurred in the first week, which is barely seen in natural environments.

Overall, regarding variance in sow and piglet behaviour during the 5-week nursing period, nursing behaviours in sows gradually decreased for the nursing period due to the weaning process. The piglets became more active and vigorous over time during the nursing period. When it comes to variance in sow and piglet welfare during the nursing period, the sows might be exposed to high injury risks from the second week after farrowing due to their high preference of the slatted floor which could lead to severe injuries to their legs and teats. Hence, the sow welfare seemed to be impaired from the second week after farrowing. Additionally, due to the occurrence of high piglet mortality with crushing by their sows in the first week which is not seen in natural conditions, the piglet's welfare seemed to be impaired during the first week after farrowing.

Preface

This master thesis was conducted through the master's programme in Animal Science at the Swedish University of Agricultural Sciences (SLU). During the master's programme at SLU, I have learned a lot of things about Animal welfare more than I expected. Also, I could not only develop analysing skills but also broaden my perspective on pig welfare during working on this master thesis. Therefore, I have been very glad to study the behaviour and welfare of pigs through this master thesis.

I believe that all things that I have achieved at SLU have come from God. Also, I could finish my master's programme and master thesis thanks to the people who helped me during the master programme:

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Table of contents

List of tables **1**

List of figures **2**

Abbreviations **3**

1. Introduction **4**

2. Literature review **6**

2.1. Pig's behavioural patterns during the nursing period 6

2.2. Nursing behaviour of sows 6

2.3. Suckling behaviour of piglets 7

2.4. Social behaviour 8

2.5. Behavioural changes during the nursing period in sows and piglets 9

2.6. Sow and piglet welfare issues during the nursing period 10

2.6.1. Nursing period for piglets 10

2.6.2. Sow and piglet location in the pen 11

2.6.3. Piglet mortality 11

3. Material and Methods **13**

3.1. Animals, housing, feeding and management 13

3.1.1. Animals 13

3.1.2. Housing 14

3.1.3. Feeding and management 15

3.2. Registration 15

3.2.1. Behaviour observations 15

3.2.1.1. Continuous sampling method *18*

3.2.1.2. Scan sampling method *19*

3.2.2. Piglet mortality 19

3.3. Missing data 20

3.4. Statistical analysis 21

4. Results 22

4.1. Behaviour observation 22

4.1.1. Continuous sampling for nursing behaviour in sows and piglets 22

4.1.2. Scan sampling for behaviours in sows 22

4.1.3. Scan sampling for behaviours in piglets 22

4.2. Piglet mortality 23

5. Discussion 28

5.1. Variation in sow and piglet behaviour during the nursing period 29

5.1.1 Nursing behavioural pattern 29

5.1.2. Behavioural activity 30

5.1.2.1. Sows 30

5.1.2.2. Piglets 31

5.2. Variation in sow and piglet welfare during the nursing period 32

5.2.1. Location in the pens for sows 32

5.2.2. Piglet mortality 33

5.3. Social and ethical aspects and sustainable aspects 34

5.3.1. Social and ethical aspects for the master thesis 34

5.3.2. Sustainable aspects for the master thesis 35

6. Conclusion 36

References 37

Acknowledgements 48

Appendix 1 49

Appendix 2 50

List of tables

Table 1. Distribution of sows between parities and batches 14

Table 2. Ethogram of sow and piglet behaviours 15

Table 3. Status of the recorded video samples for the 17 sows and their piglets per week during the 5-week nursing period[1)] 20

Table 4. Number of time that nursing occurred, duration time (minutes) and percentage of time that nursing was initiated and terminated by the piglets and sows, respectively for each week. Results presented as least squares means with standard errors from the continuous sampling for nursing behaviour in sows and piglets (N= 167). 24

Table 5. Percentage of sows' behavioural patterns and locations in loose housing pens for each week. Results presented as least squares means with standard errors from the scan sampling data for sow behaviour (N=157). 25

Table 6. Percentage of piglets' behavioural patterns and locations in loose housing pens for each week. Results presented as least squares means with standard errors from the scan sampling data for piglet behaviour (N=157). 26

Table 7. Percentage of piglet mortality for each week during the 5-week nursing period 27

List of figures

Figure 1. Design of layout for two Swedish loose housing pens. The video camera was installed on the ceiling in the centre of each pen. 14

Figure 2. Behaviour registration in ’Ethogram’ in the BORIS program 19

Abbreviations

To make it easier for the reader, you can make a list with common abbreviations in alphabetical order. Here you have a table you can use to make your list.
See the example below:

GLM	General Linear Model
pp	Postpartum or post-partum or post partum

1. Introduction

The comprehension of animals' abilities to perform their natural behaviour in natural conditions is necessary to define the meaning of good animal welfare (Kiley-Worthington 1989). Hence, the awareness of the natural behaviour is helpful to identify animal welfare issues (D'Eath & Turner 2009) and it is obvious that lack of the natural behaviour in the animals indicates their impaired welfare (Kiley-Worthington 1989). Therefore, many studies of the natural behaviour in domestic pigs kept into free-ranging environments were conducted by recording their behavioural patterns and defining ethograms of their behaviours (Jensen 1986 and 1988; Stolba & Wood-Gush 1989; Petersen et al. 1990; Dellmeier & Friend 1991).

Since the 1990s or even earlier, Sweden, Norway, Switzerland, and the United Kingdom have prohibited the use of farrowing crates (Baxter et al. 2018) and adopted alternative farrowing systems in pig productions such as loose housing pens (Cronin et al. 2000; Weber 2000; Baxter et al. 2012). This is because the farrowing crates impair sow welfare by restricting natural behaviours in sows such as nest building before farrowing and social contact with their piglets (Jensen 1986 and 1988). On the other hand, the loose housing pens leads to improving the welfare of the sows by increasing their space allowance (Singh et al. 2017) as well as increase their possibilities to perform maternal behaviour (Cronin et al. 1996) and social behaviour in the piglets (Oostindjer et al. 2011).

Plenty of studies for understanding pigs' natural behaviours have been conducted to improve productive performance in sows and growth performance in piglets related to the quality and quantity of pig productions. Although many studies of different farrowing systems for sows and piglets during the nursing period have been performed to evaluate their welfare, those studies have not clearly shown how the sows and piglets' behavioural patterns interact with their welfare during the

nursing period in the loose housing pens. Also, little is known about how the sow and piglet welfare and their behaviour in the loose housing pens are changed over time during a 5-week nursing period.

Hence, this master's thesis aimed to investigate variation in sow and piglet behaviour and welfare over time during the 5-week nursing period in the individual loose housing pens.

The specific questions investigated in this master's thesis are:

- How sow and piglet behaviour varies over time during the 5-week nursing period.
- How variation in sow and piglet behaviour relates to their overall welfare.

2. Literature review

To provide better comprehension of this master's thesis, this literature review provides information about behavioural patterns and variation in sow and piglet behaviour during nursing and a nursing period. Also, the sow and piglet welfare issues will be discussed in the literature review.

2.1. Pig's behavioural patterns during the nursing period

Unlike other ungulates, pigs show complex behavioural patterns with specific features during the nursing period (Fraser 1980; Petersen et al. 1990). Studying behaviours of sows and piglets in unrestricted condition can lead to useful information about the variance and role of their behaviour (D'Eath & Turner 2009). Hence, a number of studies investigated behavioural patterns of pigs in free-ranging environments by recording their behavioural patterns and defining ethograms of their behaviours (Jensen 1986 and 1988; Stolba & Wood-Gush 1989; Petersen et al. 1990; Dellmeier & Friend 1991). The behavioural patterns during a nursing period are categorized as the following behaviour: lying, foraging (including rooting, grazing, and licking the rest of feed) or manipulating, locomotion, nursing, nasal contacts between sows and their piglets or among littermates (Jensen 1988; Stolba & Wood-Gush 1989; Petersen et al. 1990).

2.2. Nursing behaviour of sows

Fraser (1980) and Špinka et al. (2002) defined sow nursing behaviour as following the five certain phases: 1. Nursing start; 2. Teat massage before milk

ejection; 3. Milk ejection; 4. Teat massage by her piglets after milk ejection; 5. Nursing end. To be specific, when nursing starts, a sow lies on lateral recumbency exposing its udder upwards (Fraser 1976) and then the sow rhythmically grunts (Algers et al. 1990; Špinka & Illmann 2014). Thereafter, her piglets assemble at the udder and start massaging the udder for 1 to 3 minutes before milk ejection (Fraser 1984; Špinka et al. 2002; Špinka 2017). The milk ejection becomes available for about 25 seconds (Špinka et al. 2002). At the same time, the sow's grunting rate increases to about 2 to 4 grunts per second (Illmann et al. 1999) and the piglets suckle their teats for about 20 seconds (Fraser 1977; Fraser 1984; Špinka et al. 2002; Špinka & Illmann 2014). Thereafter, the grunting rate gradually decreases and eventually stops (Whittemore & Fraser 1974). After the short milk ejection, the piglets restart the udder massaging (Špinka & Illmann 2014). Hence, during nursing, the udder massaging and suckling teats occur repeatably and progressively. The nursing behaviour is terminated by the sow when she stands up after nursing or rolls on her belly rejecting her piglets to massage the udder (Špinka 2017) or by her piglets when they fall asleep or leave to rest (Špinka & Illmann 2014).

2.3. Suckling behaviour of piglets

When piglets are born in order, they strive to find the udder and teats for the colostrum, the early milk that is rich in energy and immunoglobulins (Fraser 1984; Dyck & Swierstra 1987; Špinka 2017). The piglets have active competition with their littermates within a few minutes postpartum (pp) to possess functional teats (De Passillé et al. 1988) as the sow‘s anterior teats are more functional and productive than her posterior teats (Fraser 1984). When one of the piglets begins suckling, the piglet attempts to suckle several teats pushing or biting littermates for tasting the other teats (De Passille & Rushen 1989). This behaviour is defined as 'teat sampling' which lasts for about 8 hours pp (De Passillé et al. 1988). At this time, all the piglets try to suckle about 7 different teats without any preference for the anterior or posterior teats (Špinka & Illmann 2014). Eventually, the heavier piglets, however, possess the anterior teats and show relatively higher weight gains than the other piglets (Fraser 1984). This teat competition decreases from day 4 pp

(Špinka & Illmann 2014) or day 7 pp (D'Eath & Turner 2009). Also, the suckling behaviour in a litter is synchronised on day 3 pp (Špinka & Illmann 2014).

Also, the piglet suckling behaviour is specifically defined through 5 distinct phases. In the first phase, the piglets gather at the udder by their sow's rhythmical grunting and set their positions at the udder (Fraser 1980). Thereafter, they start to massage the udder rhythmically for a few seconds or minutes (Fraser 1984; Špinka et al. 2002; Špinka 2017). In the third phase, the piglets stop the udder massaging and wrap their tongue around the teat they possess with slow vigorous movements (Fraser 1980). The fourth phase occurs for all the piglets uniformly. They begin to suckle their teats together pulling the teats back slightly with gentle movements of the head, flattened their ears, and rapid mouth movements (Signoret et al. 1975; Fraser 1980). This phase lasts for about 20 seconds (Fraser 1980; Fraser 1984; Špinka et al. 2002). The last phase begins after the end of the fourth phase. The piglets leave the udder voluntarily, or they suckle their teats with slow movement or resume the udder massage as the first phase (Signoret et al. 1975; Fraser 1980).

2.4. Social behaviour

Pigs communicate with other pigs by using their olfactory sense or vocalization (Špinka 2017). Also, they distinguish between familiar and unfamiliar pigs through the olfactory sense and remember at least 30 individual pigs (Špinka 2017). During and after farrowing, sows contact and attempt to sniff their piglets increasingly (Jensen, 1986) and social contact between the sows and their piglets increases after 10 hours pp (Pedersen et al. 2003). Also, the sows communicate with their piglets through vocalization. For example, when the sows are ready for nursing, they emit rhythmical gruntings several times not only to attract their piglets at the udder (Algers et al. 1990; Špinka & Illmann 2014) but also to get them to massage or suckle their teats (Signoret et al. 1975; Fraser 1980). The rhythmical gruntings are reflected to the piglets' behaviour (Castren et al. 1989) and the time of milk ejection (Fraser 1980).

Snout contact behaviour is also a method of communication between the sows and their piglets (Blackshaw & Hagelsø 1990). The attempts of snout contact

between the sows and the piglets decrease gradually during the nursing period (Blackshaw & Hagelsø 1990; Blackshaw et al. 1997).

Unlike the sows, the piglets show various patterns of social behaviour during the nursing period. The social behaviour is divided into agonistic behaviour and play behaviour.

When the piglets are born, they are promptly exposed to active competition for occupying their teats (De Passillé et al. 1988) and establishing a dominance hierarchy (Signoret et al. 1975). In this process, the agonistic behaviour is displayed such as head-knocking, biting and pushing littermates with sharp canine teeth during nursing (De Passille & Rushen 1989; Špinka 2017). However, the agonistic behaviour in the piglets occurs much less after the establishment of the teat order (D'Eath & Turner 2009; Špinka & Illmann 2014). and the dominance hierarchy (Signoret et al. 1975).

The play behaviour in the piglets begins on day 2 pp (Stanged & Jensen 1991). However, the playful behaviour gradually decreases from week 6 pp or post-weaning, due to increased motivation of foraging behaviour (Newberry et al. 1988). The play behaviour consists of three patterns: social play, solitary play and play with objects (Frädrich 1974). The social play is interpreted that the piglets nudge and push their sow or littermates (Blackshaw et al. 1997). Fighting behaviour is, also, defined as social play when the fighting occurs between littermates of the same size (Frädrich 1974). The solitary play means that a piglet performs jumping or swinging its head without any companion (Frädrich 1974). This behaviour is defined as the play with objects when a piglet shakes or carries some objects (Frädrich 1974; Newberry et al. 1988). The play behaviours may play a role in the establishment of a dominant hierarchy among the piglets in a litter (Dellmeier & Friend 1991).

2.5. Behavioural changes during the nursing period in sows and piglets

During a nursing period, sow and piglet behaviour such as nursing frequencies and nursing patterns gradually changes. In the early nursing period, the sow initiates most nursings allowing her piglets to massage and suckle teats at the udder for a longer time than in the late nursing period (Jensen 1988; Bøe 1991). Since week 2 pp, the nursings are mostly occurred by her piglets (Špinka 2017). However, according to the passing of the nursing period, the frequencies of terminated nursings by the sow increase as gradually as nursing duration decreases (Jensen 1988; Valros et al. 2002). The piglets are given more milk if the nursing intervals become shorter and the nursing frequencies increase (Špinka et al. 1997). However, the nursing frequency and nursing duration become lower gradually during the nursing period. This is because the sow shows a gradually increased rate of lying on her belly over time during the nursing period, preventing her piglets to massage the udder (Blackshaw et al. 1994; Harris & Gonyou 1998; Valros et al. 2002).

2.6. Sow and piglet welfare issues during the nursing period

2.6.1. Nursing period for piglets

Domestic sows kept in semi-natural environments wean their piglets around week 11 to 17 pp (Jensen & Recén 1989; Bøe 1991). On the other hand, domestic sows kept under commercial conditions are weaning from 3 to 6 weeks pp (Špinka & Illmann 2014). According to the Swedish regulations for pigs and the EU Council Directive, the weaning age of piglets should be at least 28 days of age but the weaning age can be shortened by 7 days earlier if a maximum of 10% of the piglets can be weaned before 26 days of their age or if the piglets have a normal weight for their age, cleaned and disinfected housing system, no behavioural disorders and so on (Council Directive 2008/120/EC; SJVFS 2019:20 Saknr L106, 3KAP: 2 §). However, due to the short nursing period for piglets kept in the commercial conditions and abrupt removal of the sow to initiate weaning, the piglets suffer from various stressors caused by changed diet from liquid (milk) to solid feed, abrupt separation from their mother, and social challenges with other piglets (Campbell et

al 2013). Hence, compared to the weaning process in piglets kept in semi-natural environments, the welfare of the commercial piglets might be compromised by the short nursing period for adapting to solid feed, separation from their mother, and compulsive mixing with strange piglets from the weaning period.

2.6.2. Sow and piglet location in the pen

A sow and her piglets have respectively different issues of their welfare because they have contrary requirements regarding suitable thermal environments. The sow has a thermoneutral temperature of 15 to 26 ℃, whereas her piglets weighing 3 to 15 kg have a thermoneutral temperature of 26 to 32 ℃ (ASAS 2020). Hartmann et al. (1997) suggested that a thermoneutral temperature of lower than 30℃ is inappropriate for the piglet's zone of thermal comfort and a temperature of higher than 24 ℃ is inappropriate for the sow's zone of thermal comfort. At ambient temperatures of above 20 to 25 ℃, the sow shows a high preference of lying behaviour on cool areas such as slatted floors for cooling their body temperature (EFSA 2005). However, slatted floors are associated with leg weakness (Jørgensen 2003), capped hock in the hind limb (Mouttotou et al. 1998; KilBride et al. 2008), and severe injuries on the udder in the sow (Verhovsek et al. 2007) and on the knees in the piglets (Lewis et al. 2005). Also, pigs kept on the slatted floors are exposed to higher ammonia concentrations (Philippe et al. 2011). The ammonia concentration is one of the aerial pollutants in pig houses (Wathes et al. 1998), irritating the respiration of the pigs (Banhazi et al. 2008). Hence, high frequencies and numbers of staying or lying on the slatted floor for the sow and piglets indicate impaired their welfare and needs for improvement of housing management.

2.6.3. Piglet mortality

Piglet mortality is associated with older parity in sows, large litter size (Marchant et al. 2000; Pedersen et al. 2006), low birth weights in piglets (Baxter et al. 2008) and housing system (Hales et al. 2014). More than 50 % of dead liveborn piglets

are mainly caused by crushing by their sow during the first four days pp (Marchant et al. 2000). The crushing deaths of piglets are barely seen in wild boars or feral domestic sows (D'Eath & Turner 2009). The loose housing system commonly used in Sweden for farrowing and lactating sows shows higher piglet mortality with crushing death by sows than the crating system that confines movements of sows during the nursing period (Blackshaw et al. 1994; Marchant et al. 2000; Moustsen et al. 2013; Hales et al. 2014). The sows kept in the loose housing pen exhibit more postural changes which led to an increased risk of crushing by sows (Baxter et al., 2015; Yun et al., 2019). On the other hand, according to studies by Weber et al. (2009) and Goumon *et al.* (2018), there are no significant effects on the piglet mortality between the crating system and loose housing system. However, it is fact that the loose housing system leads to improving the welfare of sows by increasing their space allowance (Singh et al. 2017) as well as allowing them to perform maternal behaviour (Cronin et al. 1996) and social behaviour with her piglets (Oostindjer et al. 2011).

3. Material and Methods

This master's study was performed as a pilot study at the Swedish Livestock Research Centre which is certificated as a Specific Pathogen Free (SPF) herd in Funbo-Lövsta, outside Uppsala. The study was conducted through analysis of recorded video samples of sow and piglet behaviours during a 5-week nursing period.

3.1. Animals, housing, feeding and management

3.1.1. Animals

17 pure-bred Swedish and Dutch Yorkshire sows and their litters (284 piglets, pure-bred Swedish or Dutch Yorkshire × Hampshire, average litter size with standard error = 16.7 ± 0.56) were used in this study. The information of the sows' parities and batches was presented in Table 1. Their behaviours were recorded 24 hours every day from farrowing to weaning. They were moved to loose housing pens individually about 1 week before the expected farrowing date. Before the sows were moved to the pens, they were weighed and backfat thickness was measured. After farrowing, all litters were weighed. Cross-fostering, which is moving a few piglets from large litter sows to smaller litter sows, was conducted within 48 hours after farrowing. The sows stayed with their piglets in the pens for about 5 weeks since they farrow.

Table 1. Distribution of sows between parities and batches

Sow's parity	Sow's batch					Total number
	1	**2**	**3**	**4**	**5**	
1	-	-	4	1	-	**5**
2	1	1	-	-	1	**3**
4	-	-	3	1	1	**5**
5	1	1		1		**3**
8	-	-	1	-	-	**1**
Total number	**2**	**2**	**8**	**3**	**2**	**17**

3.1.2. Housing

The pen measured 6.5 m^2 (3.25 m × 2.00 m) and consisted of a lying area in a concrete floor, a slatted floor, a feed trough, two drinking nipples, and a separate piglet corner or creep area with a heat lamp on the concrete floor in one corner of the pen. Three steel pipes to protect piglets from being crushed by the sow were installed along the pen walls. The layout of the pen design is illustrated in figure 1.

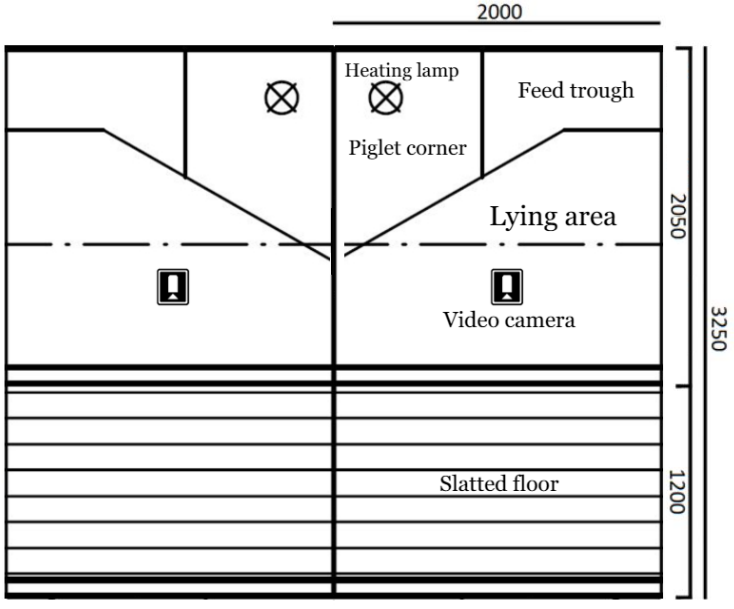

Figure 1. Design of layout for two Swedish loose housing pens. The video camera was installed on the ceiling in the centre of each pen.

3.1.3. Feeding and management

The sows were fed twice per day until 10 days pp through anautomatic feeding system. Thereafter, the sows were fed three times per day until weaning and given water ad libitum by the drinking nipples all the time. Their piglets were injected with an iron supplement on 5 days and 14 days pp. Piglets were given basic solid feed adapted for the piglets through a feed dispenser in the piglet corner when they reached an age of 3 weeks pp. The loose housing pens were manually cleaned by the staff in the morning and were thereafter provided straw as bedding material. The photoperiod in the farrowing rooms was from 09.00 to 20.00.

3.2. Registration

3.2.1. Behaviour observations

All behaviours in the 17 sows and their piglets were video-recorded in the loose housing pens. At the beginning of this master study, four sows' and their piglets' behaviours were recorded and analysed as a pilot study to establish an ethogram of sow and piglet behavioural patterns during a 5-week nursing period and to evaluate the feasibility of the methodology and statistical analysis. The pilot study was performed through the BORIS program (Friard & Gamba 2016) by using a continuous sampling method in every second and scan sampling method every 30 minutes from 09.00 to 20.00 as the photoperiod in the farrowing rooms for two set consecutive days every week: day 2 and 3 pp in week 1, day 9 and 10 pp in week 2, day 16 and 17 pp in week 3, day 23 and 24 pp in week 4, and day 30 and 31 pp in week 5. Based on the analysis of the recordings in the pilot study, an ethogram and variables for the continuous sampling data and the scan sampling data for the sows and piglets were established as presented in Table 1.

Table 2. Ethogram of sow and piglet behaviours

Sampling type	Response variable	Definition
Continuous sampling		

	Nursing occurrence	Number of nursings, counted when more than half of the litter suckled for over 60 seconds.
	Total nursing duration	Accumulated nursing time for all the nursing occurrences
	Nursing duration	Average nursing time between starting of nursings and ending of nursings in all the nursing occurrences
	Nursing initiated by the piglets	When the piglets suckle teats before or without grunting from the sow.
	Nursing initiated by the sow	When the sow makes short grunting to attract her piglets for suckling teats or when the sow performs lying on her side and contracting her belly instantaneously and repeatedly with tilting her head upward and four legs into the belly before any piglet massages her udder.
	Nursing terminated by the piglets	When less than half of the litter suckled or inactive at the udder.
	Nursing terminated by the sow	When the sow roll over on her belly, stand up or sit on the floor, making her teats unavailable for her piglets.
Scan sampling		
Sow		
Behavioural pattern		
	Lying on her side	When the sow lies on her side.
	Lying on her belly	When the sow lies on her belly or not perfectly in the lateral position.
	Standing	When her body is supported by her four legs.

	Sitting	When the sow's rump and rear legs on the floor, standing by front legs.
	Drinking	When sow drinks water from the water nipple.
	Eating	When the sow's head is in the feed trough for over 5 minutes.
	Exploration	When the sow's snout touches or manipulates the bedding materials on the floor and pen fittings.
Location in pen		
	Feed trough	When the sow's head in the feed trough.
	Concrete floor	When the majority of the sow's body is on the concrete floor.
	Slatted floor	When the majority of the sow's body is on the slatted floor.
Piglets		
Behavioural pattern		
	Lying	When the piglet lies on its side or its belly.
	Standing and sitting	When the piglet's body is supported by its four legs and the piglet's rump and rear legs are on the floor, standing by the front legs.
	Eating	When the piglet's head in the feeder in the piglet corner.
	Exploration	When the piglet walks and runs in the pen, touching and sniffing the floors, pen fittings and straw bedding material.
	Suckling	When the piglet suckles a teat at the udder.

Location in the pen	Drinking	When the piglet drinks water through the water nipple.
	Contact to the sow	When the piglet's snout touches its sow's snout.
	Contact to the littermates	When the piglet touches or chases or pushes or mounts the littermates.
	Feed trough	When the majority of the piglet's body is in the feed trough.
	Creep feeder	When the piglet's head is in the creep feeder in the piglet corner.
	Piglet corner	When the piglet is invisible in the pen.
	Concrete floor	When the majority of the piglet's body is on the concrete floor.
	Slatted floor	When the majority of the piglet's body is on the slatted floor.

3.2.1.1. Continuous sampling method

The continuous sampling was performed in the same way as in the pilot study regarding the ethogram in Table 1. Behavioural patterns were registered in every second in the BORIS program (Friard & Gamba 2016) from 09:00 to 20:00 for the two consecutive days in each week as shown in Figure 2. When each behaviour in the continuously sampling occurred, the behaviour was submitted into the BORIS program. Thereafter, the results of the continuous samples were formulated by the BORIS program.

All the results of the continuous samples were presented in seconds. By using Microsoft Office 365 Excel, the results were re-formulated in minutes.

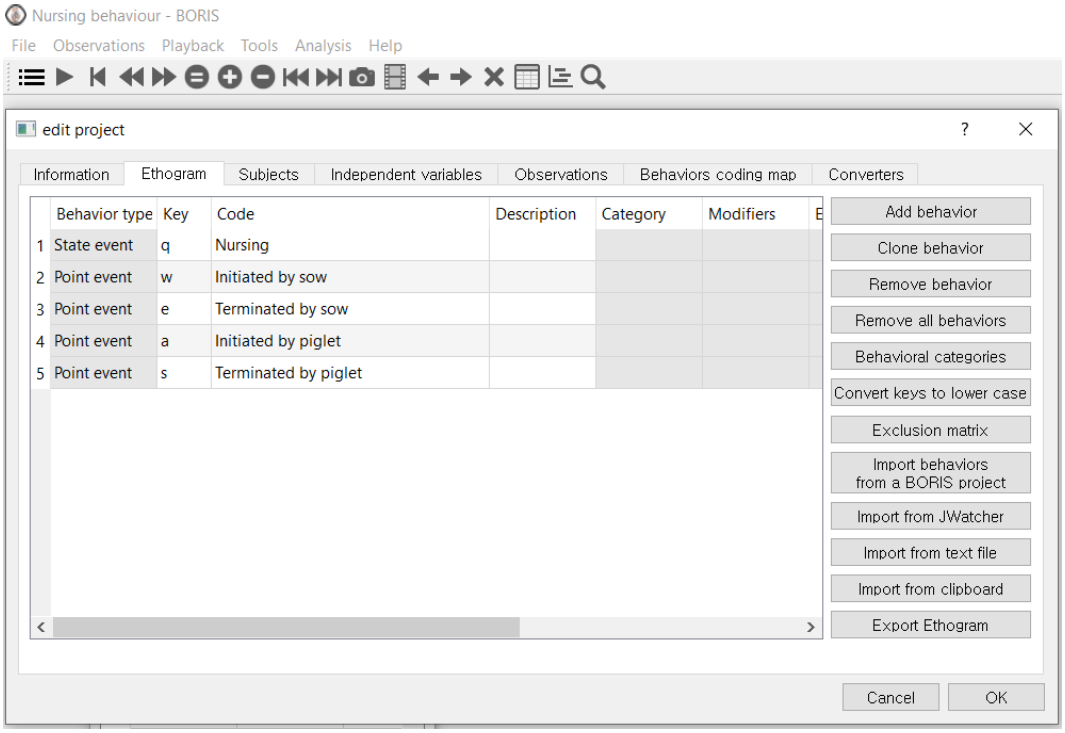

Figure 2. Behaviour registration in 'Ethogram' in the BORIS program

3.2.1.2. Scan sampling method

The scan sampling was also performed through the BORIS program (Friard & Gamba 2016) in the same way as in the pilot study. Unlike the continuous sampling, all behaviours in the sows and piglets were manually recorded every 30 minutes from 09:00 to 20:00 for two consecutive days in each week on two datasheets created considering the ethogram in Table 1 using the Microsoft Office 365 Excel. This was due to that the ethogram in BORIS was set up for the continuous sampling method. The datasheets for the scan sampling in the sows and piglets are presented in Appendix 1 and 2.

3.2.2. Piglet mortality

Piglet mortality was registered per week during the nursing period to investigate the weekly variation of the piglet mortality. Causes of mortality were defined by the animal caretakers at the Swedish Livestock Research Centre. The causes were

categorized into 4 categories: 1) Stillbirth, 2) Crushed by the sow, 3) Euthanasia due to weakness, illness, and poor growth, and 4) Unidentifiable reasons. The results of the piglet mortality were based on the number of liveborn piglets.

3.3. Missing data

The expected total number of the recorded video samples was 34 each week during the 5-week nursing period before starting this master study. However, due to the power failure for a few days and earlier weaning schedule at the Swedish Livestock Research Centre in Funbo-Lövsta, 13 samples (5 samples in week 2 pp, 4 samples in week 4 pp, and 4 samples in week 5 pp) were missing. Also, on account of technical problems with video cameras, 4 samples (1 sample in week 1 pp and 3 samples in week 2 pp) were recorded from 9:17. 4 samples (1 sample in week 4 pp and 3 samples in week 5 pp) were recorded from 14:47. The status of the recorded video samples is shown in Table 3.

Table 3. Status of the recorded video samples for the 17 sows and their piglets per week during the 5-week nursing period[1)]

Category	Week 1	Week 2	Week 3	Week 4	Week 5
Intact sample	33	26	34	29	27
Missing samples	-	5	-	4	4
Late start, 9:17	1	3	-	-	-
Late start, 14:47	-	-	-	1	3
Expected total sample	34	34	34	34	34

[1)] Number of recorded video samples was presented

3.4. Statistical analysis

After collecting all data of observation records from continuous sampling and scan sampling for sow and piglet behaviour, the continuous sampling data was formulated by BORIS program (Friard & Gamba 2016) while the scan sampling data was formulated by Microsoft Office 365 EXCEL. Thereafter, all variables in the observation records from continuous and scan sampling for sow and piglet behaviour and piglet mortality were statistically analysed to investigate the normal distribution of all the response variables by using a General Linear Model (GLM) procedure of Version 9.4 SAS program (SAS 2013).

All the response variables consisted of 7 variables in the continuous sampling, 11 variables in the scan sampling for the sow behaviour, 15 variables in the scan sampling for the piglet behaviour, as shown in Table 2, and 5 variables in the piglet mortality (stillbirth, piglets crushed by the sow, euthanasia, unidentifiable reasons, and total liveborn death). Except for the nursing occurrence, nursing duration, and total nursing duration in data of the continuous samplings, units of all the response variables from the continuous samplings, scan samplings, and piglet mortality were converted into percentage of each variable. The fixed factors were week in the 5-week nursing period (week 1, week 2, week 3, week 4, and week 5). All the response variables of the continuous sampling and scan sampling data and the piglet mortality were respectively tested by using procedure GLM for the fixed effects of week through the statistical model followed below.

The statistical model: Y= week + residual

After performing the GLM procedure, the Tukey-Kramer adjustment was used to find pairwise significant differences of the fixed factors in all the behaviours included in the continuous sampling data and the scan sampling data for the sow and piglet behaviour as well as for the variables for the piglet mortality. All results were presented as the least square means (LS means) and standard errors (SE). The results were concerned as statistically significant differences if the probability values (P-value) were less than 0.05.

4. Results

4.1. Behaviour observation

4.1.1. Continuous sampling for nursing behaviour in sows and piglets

Results of the continuous sampling for nursing behaviour in sows and piglets are presented in Table 4. The number of nursing occurrence decreased from 18.5 in week 2 pp to 12.3 in week 5 pp. Nursing duration decreased from 7 minutes in week 1 to 5.6 minutes in week 5 pp as well as total nursing duration reduced from 111.9 minutes in week 1 pp to 68.1 minutes in week 5 pp. The percentage of nursings terminated by the sow gradually increased from 40.6 % in week 1 pp to 62.1 % in week 5 pp. On the other hand, the percentage of nursings initiated by the sow gradually decreased from 44.3 % in week 1 pp to 14.6 % in week 5 pp.

4.1.2. Scan sampling for behaviours in sows

Results of the scan sampling for behaviours in sows are shown in Table 5. The percentage of lying on the belly increased from 16.6 % in week 1 pp to 33.4 % in week 5 pp. The percentage of exploration was significantly higher in week 1 pp than in week 3 pp with the comparison between 9.8 % and 5.0 %. The percentage of lying and staying on concrete floor significantly decreased from 77.7 % in week 1 pp and 49.1% in week 5 pp while the percentage of lying and staying on the slatted floor was significantly increased from 17.8 % in week 1 pp to 40.3 % in week 5 pp.

4.1.3. Scan sampling for behaviours in piglets

The result of the scan sampling for behaviour in piglets is shown in Table 6. The highest percentage of exploration was shown in week 3, 4, and 5 pp reaching 10.3 %,

12.1 %, and 12.5 % respectively compared to other weeks pp: 6.6 % in week 1 pp and 6.3 % in week 2 pp. The percentage of drinking gradually increased from 0.0 % in week 2 pp to 0.4 % in week 5 pp. The percentage of contact to the littermates gradually increased week by week during the nursing period, from 0.2 % in week 1 pp to 2.5 % in week 5 pp.

4.2. Piglet mortality

Results of the piglet mortality are presented in Table 7. The piglet mortality (percentage of piglets crushed by the sow, euthanized and total mortality) were significantly higher in week 1 pp than the other weeks with reaching respectively 7.20 %, 7.89 %, and 18.15 % in the week 1 pp.

Table 4. Number of time that nursing occurred, duration time (minutes) and percentage of time that nursing was initiated and terminated by the piglets and sows, respectively for each week. Results presented as least squares means with standard errors from the continuous sampling for nursing behaviour in sows and piglets (N= 167).

Response variable	**Week 1**	**Week 2**	**Week 3**	**Week 4**	**Week 5**	**F-value**	**P-value**
Nursing occurrence, n	15.8 ± 0.59^{a}	18.5 ± 0.64^{b}	16.4 ± 0.59^{ab}	14.3 ± 0.63^{bc}	12.3 ± 0.63^{c}	13.72	< 0.001
Total nursing duration, min	111.9 ± 4.65^{a}	120.1 ± 5.01^{a}	101.4 ± 4.65^{ab}	83.3 ± 4.93^{bc}	68.1 ± 4.93^{c}	18.62	< 0.001
Nursing duration, min	7.0 ± 0.27^{a}	6.5 ± 0.29^{ab}	6.3 ± 0.27^{ab}	6.0 ± 0.28^{ab}	5.6 ± 0.28^{b}	3.79	0.006
Nursings							
Initiated by the piglets, %	55.7 ± 3.34^{a}	67.7 ± 3.60^{ab}	75.1 ± 3.34^{bc}	80.7 ± 3.54^{bc}	85.4 ± 3.54^{c}	11.56	< 0.001
Initiated by the sow, %	44.3 ± 3.33^{a}	32.1 ± 3.59^{ab}	24.9 ± 3.33^{bc}	19.3 ± 3.54^{bc}	14.6 ± 3.54^{c}	11.58	< 0.001
Terminated by the piglets, %	59.4 ± 4.09^{a}	61.6 ± 4.41^{a}	47.2 ± 4.09^{ab}	41.5 ± 4.34^{b}	37.9 ± 4.34^{b}	6.07	< 0.001
Terminated by the sow, %	40.6 ± 4.09^{a}	38.5 ± 4.41^{a}	52.8 ± 4.09^{ab}	58.5 ± 4.34^{b}	62.1 ± 4.34^{b}	6.03	< 0.001

Different upper case letters in the same row indicate pairwise significant differences of $P < 0.05$.

Table 5. Percentage of sows' behavioural patterns and locations in loose housing pens for each week. Results presented as least squares means with standard errors from the scan sampling data for sow behaviour (N=157).

Response variable	Week 1	Week 2	Week 3	Week 4	Week 5	F-value	P-Value
Behavioural pattern, %							
Lying on the side	66.5 ± 3.10^{ab}	70.3 ± 3.35^{a}	55.6 ± 3.10^{bc}	50.4 ± 3.30^{c}	46.2 ± 3.30^{c}	9.93	< 0.001
Lying on the belly	16.6 ± 2.70^{a}	15.2 ± 2.92^{a}	25.3 ± 2.70^{ab}	31.0 ± 2.88^{b}	33.4 ± 2.88^{b}	8.35	< 0.001
Standing	0.4 ± 0.27	0.2 ± 0.29	1.0 ± 0.27	1.0 ± 2.29	0.4 ± 0.29	1.97	0.102
Sitting	0.6 ± 0.37	0.6 ± 0.40	1.2 ± 0.37	1.2 ± 0.39	1.2 ± 0.39	0.60	0.660
Exploration	9.8 ± 1.06^{a}	5.9 ± 1.15^{ab}	5.0 ± 1.06^{b}	6.0 ± 1.13^{ab}	5.8 ± 1.13^{ab}	3.26	0.014
Eating	3.3 ± 0.71^{a}	6.5 ± 0.77^{b}	9.0 ± 0.71^{ab}	7.0 ± 0.76^{b}	10.4 ± 0.76^{c}	13.59	< 0.001
Drinking	1.5 ± 0.51	1.5 ± 0.55	2.6 ± 0.51	3.0 ± 0.54	2.6 ± 0.54	1.69	0.155
Contact to the piglet	1.3 ± 0.54	1.7 ± 0.58	2.1 ± 0.54	0.9 ± 0.57	1.0 ± 0.57	0.91	0.460
Location in pens, %							
Concrete floor	77.7 ± 4.16^{a}	54.5 ± 4.51^{b}	50.4 ± 4.16^{b}	53.2 ± 4.43^{b}	49.1 ± 4.43^{b}	7.90	< 0.001
Slatted floor	17.8 ± 4.12^{a}	39.2 ± 4.46^{b}	40.4 ± 4.12^{b}	39.4 ± 4.39^{b}	40.3 ± 4.39^{b}	5.63	< 0.001
Sow feed trough	4.0 ± 0.71^{a}	6.6 ± 0.77^{ab}	8.8 ± 0.71^{bc}	6.8 ± 0.76^{ab}	10.4 ± 0.76^{c}	11.08	< 0.001

Different upper case letters in the same row indicate pairwise significant differences of $P < 0.05$.

Table 6. Percentage of piglets' behavioural patterns and locations in loose housing pens for each week. Results presented as least squares means with standard errors from the scan sampling data for piglet behaviour (N=157).

Response variable	Week 1	Week 2	Week 3	Week 4	Week 5	F-Value	P-Value
Behavioural pattern, %							
No vision	31.8 ± 2.60	25.4 ± 2.82	25.1 ± 2.60	29.8 ± 2.77	28.0 ± 2.77	1.16	0.331
Lying	39.4 ± 2.80	44.9 ± 3.03	40.8 ± 2.80	35.7 ± 2.98	38.1 ± 2.98	1.28	0.279
Standing and sitting	0.2 ± 0.08	0.3 ± 0.09	0.4 ± 0.08	0.4 ± 0.09	0.3 ± 0.09	2.26	0.065
Suckling	20.8 ± 1.22^{ab}	21.6 ± 1.32^{a}	20.5 ± 1.22^{ab}	18.2 ± 1.30^{ab}	16.4 ± 1.30^{b}	2.69	0.034
Exploration	6.6 ± 0.68^{a}	6.3 ± 0.74^{a}	10.3 ± 0.68^{b}	12.1 ± 0.73^{b}	12.5 ± 0.73^{b}	17.00	< 0.001
Drinking	0.0 ± 0.05^{a}	0.0 ± 0.05^{a}	0.1 ± 0.05^{ab}	0.2 ± 0.05^{bc}	0.4 ± 0.05^{c}	9.46	< 0.001
Eating[1)]	-	-	0.4 ± 0.18^{a}	0.8 ± 0.19^{ab}	1.3 ± 0.19^{b}	5.75	0.005
Contacting to the sow	1.1 ± 0.45	0.4 ± 0.49	0.6 ± 0.45	0.7 ± 0.48	0.4 ± 0.48	0.40	0.808
Contacting to the littermates	0.2 ± 0.20^{a}	1.1 ± 0.21^{b}	1.8 ± 0.20^{bc}	2.1 ± 0.21^{c}	2.5 ± 0.21^{c}	19.34	< 0.001
Location in pens, %							
Concrete floor	51.4 ± 2.06^{a}	45.2 ± 2.23^{ab}	41.7 ± 2.06^{b}	41.5 ± 2.19^{b}	44.3 ± 2.19^{ab}	3.68	0.007
Slatted floor	15.0 ± 2.16^{a}	28.1 ± 2.34^{ab}	29.5 ± 2.17^{c}	22.6 ± 2.30^{abc}	19.9 ± 2.03^{bc}	7.30	< 0.001
Piglet corner	33.7 ± 2.75	26.6 ± 2.98	28.5 ± 2.75	35.0 ± 2.93	33.5 ± 2.93	1.62	0.173
Creep feeder[1)]	-	-	0.4 ± 0.18^{a}	0.8 ± 0.19^{ab}	1.3 ± 0.19^{b}	5.99	0.004
Sow feed trough	0.0 ± 0.15^{a}	0.0 ± 0.16^{a}	0.6 ± 0.15^{b}	1.4 ± 0.16^{c}	2.3 ± 0.16^{d}	40.82	< 0.001

Different upper case letters in the same row indicate pairwise significant differences of $P < 0.05$.

[1)] Piglets are given the creep feed from week 3 pp and the number of observations used is 94.

Table 7. Percentage of piglet mortality for each week during the 5-week nursing period

Response variable	Week 1	Week 2	Week 3	Week 4	Week 5	SE	F-Value	P-Value
Mortality, %								
Stillbirth	9.21	-	-	-	-	-	-	-
Crushed by the sow	7.20[a]	0.00[b]	0.00[b]	0.00[b]	0.00[b]	1.29	6.23	< 0.001
Euthanasia[1)]	7.89[a]	0.69[b]	0.33[b]	0.00[b]	0.00[b]	0.98	12.12	< 0.001
Unidentifiable reasons	3.06	1.38	1.09	0.00	0.35	0.86	1.93	0.114
Total piglet mortality	18.15[a]	2.07[b]	1.42[b]	0.00[b]	0.35[b]	1.63	22.43	< 0.001

Different upper case letters in the same row indicate pairwise significant differences of $P < 0.05$.

[1)] Euthanasia occurred due to weakness, illness, and poor growth.

5. Discussion

This master study was performed through analysis of recorded video samples in 17 pure-bred Yorkshire sows and their 284 piglets. Prior to the practical analysis of the sows and piglet's behaviours in the recorded video samples, four Yorkshire sows and their piglets' behaviours were recorded and analysed in a pilot study to establish a methodology for video- and statistical analyses. However, during the main study period, two issues were found which might affect the obtained results in this master study.

Firstly, the sample size in each week for the continuous and scan sampling data varied. Due to the power failure for a few days, earlier weaning schedule, and technical problems with video cameras, 13 recorded video samples were missing. Hence, a total of 157 recorded video samples (149 intact recorded video samples with 8 late recorded video samples as shown in Table 3) were analysed in this study.

Secondly, behavioural patterns in sows during the nursing period are affected by parity in sows (Thodberg et al. 2002) and litter size (Pedersen et al. 2006). Also, different behavioural patterns in sows might be shown in each batch during the nursing period. In this master study, however, behavioural patterns in the sows and piglets from the continuous and scan sampling data were statistically analysed only considering the fixed effect of week without sow's parity and batch and litter size in each sow because of small and imbalanced sample size in the parity and batch that was presented in Table 1.

Hence, the two factors might affect the obtained results of the continuous and scan sampling data to assess the sow and piglet behaviour and welfare.

5.1. Variation in sow and piglet behaviour during the nursing period

5.1.1 Nursing behavioural pattern

In this study, nursing occurrence, total duration, duration mean, initiated nursing by the sow, and terminated nursing by the piglets decreased over time during the 5-week nursing period. Also initiated nursing by the piglets and terminated nursing by the sow increased over time for the period. Bøe (1993) and Jensen (1988) found similar result on the nursing occurrence and stated that nursing occurrences and frequencies in sows gradually decreased until weaning. Valros et al. (2002) supported the results of the total nursing duration, the terminated nursing by the sow in this study. This author suggested that the total nursing duration decreased significantly from day 13 pp to day 35 pp and the nursings were terminated by sows increasingly week by week during the 5-week nursing period. The duration means also decreased gradually for the period (Valros et al. 2002). The increase of the terminated nursing by the sow was also shown in a study by Jensen (1988). Those behavioural changes were caused by the weaning process during the nursing period (Bøe 1993; Valros et al. 2002). However, terminated nursings by the sows and initiated nursing by the piglets may be affected by illness in the sows such as mastitis and lesions at the udder. In this study, a few sows with mastitis symptom were found. The sows showed such lower nursings than other sows but their piglets showed quite active sucklings. Therefore, behaviours in sows and piglets during nursing were affected by the progress of the weaning phase and the illness or injuries at the udder in the sows.

5.1.2. Behavioural activity

5.1.2.1. Sows

In the early nursing period, nursing behaviour varies in a way that refers to an ongoing weaning process (Valros et al. 2002). Sows increasingly show belly lying postures defending their piglets to massage or suckle their teats. Hence, lying postures in the sows are closely related to the weaning process. Other previous studies suggested that the lying on the side gradually decreased while lying on the belly in the sows increased over time during the nursing period (Bøe 1991; Blackshaw et al. 1994; Harris & Gonyou 1998; Valros et al. 2002; Špinka 2017). In this thesis, sows increasingly showed belly lying postures as the previous studies suggested. Thus, due to the increased belly lying posture, the access to the udder became harder for piglets and then total nursing duration, nursing occurrence, and average nursing duration correspondingly decrease with lateral lying postures in the sows. Bøe (1993) and Valros et al. (2002) indicated that the decrease of total nursing duration, occurrence, and average nursing duration occurred by the weaning process in the sows. Hence, the decrease of the lying on the side and the increase of the lying on the belly were indicated a way as the ongoing weaning process.

Exploration behaviour was significantly higher in week 1 pp than in week 3 pp in this study. This result is in line with the result of Blackshaw et al. (1994) on active behaviour in sows. The author mentioned that the sows in crates and pens both are more active from day 1 to 5 pp than from day 6 to 10 pp. Also, Thodberg et al. (2002) found that the highest activity in sows kept in open farrowing pens was shown on the first day after farrowing. Therefore, the result in this master thesis with the previous studies indicated that sows are more active in week 1 pp than other periods during the nursing period.

Eating behaviour gradually increased week by week during the nursing period in the current study. During the early nursing period, voluntary feed intake was reduced due to a limited capacity of the gastrointestine, which requires time to adapt to the high volume of daily feed intake (Dourmad 1991). Koketsu et al. (1996)

stated that sows showed a low level of feed intake after farrowing and that the feed intake increased, as lactation proceeds, for supplying enough milk production to their piglets minimizing bodyfat losses and the sows reached the maximum level of feed intake in the second or third week pp. Also, the result of the eating might be affected by the feeding management at the Swedish Livestock Research Centre in Lövsta. The sows were fed twice per day until 10 days pp by the automatic feeding system. Thereafter, the sows were fed 3 times per day until weaning. Hence, the increased eating behaviour during the nursing period was obvious.

5.1.2.2. Piglets

Suckling behaviour in piglets is strongly related to nursing behaviour in sows. In the current study, suckling behaviour was significantly higher in week 2 pp than in week 5 pp as the nursing occurrence presented in the continuous sampling data for the sows in the current study. This is because sows stop initiating nursing from week 3 or 4 pp (Jensen 1988; Bøe 1991) and the sows increasingly reject their piglets to massage the udder with early terminating the nursings, which may result in the gradually decreased suckling (Špinka & Algers 1995). Bøe (1993) presented a similar result as presented in this study. The author stated that sucklings significantly decreased from week 2 pp until week 4 pp during a 10-week nursing period.

Exploration was significantly higher in week 3, 4, and 5 pp than in week 1 and 2 pp and contact to the littermates increased gradually during the 5-week nursing period in this study. Previous studies found similar results as presented in this study. Blackshaw et al. (1994) observed the gradual increase of active behaviour in piglets during a 30-day nursing period. Špinka (2017) suggested that piglets show active behaviour since day 1 pp and the frequency of play behaviour raises by week 3 pp and whereafter the play behaviour decreases. Also, Blackshaw et al. (1997) found that active behaviours such as spring, run, and social play were increased correlatively with their ages during the 30-day nursing period.

Drinking behaviour was barely seen in week 1 and 2 pp. However, the behaviour increased gradually when the piglets were given creep feed since week 3 pp. Hence,

the eating behaviour was increased from week 3 to week 5 pp as the drinking behaviour. Water intake in piglets given creep feed increased with lying behaviour due to exhaustion caused by active interactions with the littermates or the higher ambient temperatures (Kutzer et al. 2009) or the poor milk provision by their sows (Fraser et al. 1990). However, in this study, lying behaviour was not significantly different over time during the nursing period. Fraser et al. (1990) stated that the water intake was related to the intake of the creep feed because solid types such as the creep feed led to dehydration in the piglets. Also, due to decreased nursing duration and occurrences caused by the weaning process (Bøe 1993; Valros et al. 2002), the piglets ate the creep feed to fulfil their energy requirements with showing increased drinking behaviour (Fraser et al. 1990).

5.2. Variation in sow and piglet welfare during the nursing period

5.2.1. Location in the pens for sows

One of the welfare issues in sows is the discomfort caused by types of flooring and ambient temperatures in the farrowing unit (Bergeron et al. 2008). Solid concrete floors show a better foothold than metal slatted floors (Christison & De Gooijer 1986) and fewer injuries to sows' teats and legs than perforated floors (Edwards & Lightfoot 1986; Verhovsek et al. 2007). According to a previous study by Phillips et al. (1996), farrowing sows preferred concrete floors after farrowing and overall the nursing period, avoiding metal flooring type. However, the preference of the flooring type can be changed due to the thermal comfort environments for sows. The thermal comfort temperatures for the sows range from 12 to 20 ℃ (Black et al. 1993) or 15 to 26 ℃ (ASAS 2020). If the sows were kept in above 20 to 25 ℃ of the ambient temperatures, the sows stayed or lied on cool areas such as slatted floors for cooling their body temperature (EFSA 2005). According to the result of the location in pens for the sows in Table 5, the percentage of lying on the slatted floor increased while the percentage of lying on

the concrete floor was significantly decreased while since week 2 pp. Hence, the sows might be exposed to heat stress and more risk of injuries to their legs and teats since week 2 pp. According to a previous study, sows preferred a 35 ℃ floor more than a 22 or 29 ℃ floor during 3 days after farrowing in the room temperature of 24 ℃ and thereafter, they preferred the coolest floor of 22 ℃ from 7 to 14 days after farrowing (Phillips et al. 2000). Also, the author mentioned that perhaps, the sows select warm areas to maintain warm temperatures at the udder for newborn piglets, avoiding temperatures that may be so cool for the piglets (Phillips et al. 2000). Hence, the previous study interpreted why the sows preferred the concrete floor near the heat lamp in the piglet corner more than the slatted floor in week 1 pp and why they preferred the slatted floor after week 2 pp in the current study. Regarding the results of the location in the pens, the sows might be exposed to heat-stress environment and injury risks to the limbs and the udder from week 2 pp because of high preference of lying on the slatted floor from week 2 pp. Therefore, the sow welfare might be impaired from week 2 pp during the nursing period.

5.2.2. Piglet mortality

Piglet mortality has been concerned as a welfare issue in piglets. The piglet mortality, mainly caused by stillbirth, starvation and crushing by a sow, accounts for 16 to 20 % of the total newborn piglets (Fraser 1990; Puppe et al. 2008; Edwards & Baxter 2015; Baxter & Edwards 2018) and most mortality occurs during the first 3 days pp (Barnett et al. 2001). As in the previous studies, the majority of piglet mortality in this study occurred in week 1 pp (day 3 and 4 pp) and accounts for 18.15 % of the total liveborn piglets as shown in Table 7. The crushed by the sow and euthanasia was 7.20 % and 7.89 % of the total piglet mortality respectively. Also, the percentage of stillbirth was 9.21 % of the total born piglets.

Hypothermia, starvation and crushing by the sow are associated with hypoxia during farrowing and low vitality (Edwards & Baxter 2015). Stillbirth is closely related to decreased gestation length and average litter weight, an increased total number of liveborn piglets, and old sow's parity (Leenhouwers et al. 1999; Hales et al. 2014). The total number of piglet mortality is negatively affected by the large

litter size and the old parities of the sows (Marchant et al. 2000). Even crushed piglets by a sow are hardly seen in wild boars or feral domestic sows (D'Eath & Turner 2009). Hence, regarding the results of the piglet mortality with the previous studies, the piglet welfare might be impaired in week 1 pp due to the occurrence of dead piglets crushed by their sows.

5.3. Social and ethical aspects and sustainable aspects

5.3.1. Social and ethical aspects for the master thesis

Regarding social and ethical aspects, this master thesis was well performed without any harms to experimental animals used for this thesis. This master thesis was performed only through analysis of video-recorded behaviours in sows and piglets. The animals were kept in individual loose housing pens that meet the EU and Swedish legislation for animal protection, especially for pigs. During working on the master thesis, there were no human interventions to the experimental animals and their areas. This means that the animals had no fearfulness caused by human interventions during the experimental period. Also, the Swedish Livestock Research Centre where the sows and piglet are kept was certificated as a Specific Pathogen Free (SPF) herd. Additionally, animal caretakers at the Swedish Livestock Research Centre clean the loose housing pens and provide the sows and piglets straw bedding materials every day. Thus, the animals were living in optimum places with pathogen fee environments and well-established feeding and housing managements during the experimental period.

Overall, this master thesis was performed without any social and ethical issues during the experimental period. Also, the sows and piglets used for the master thesis were kept in optimum places to meet their primary needs such as suitable environments to perform their natural behaviour and fulfil energy requirements. They were safely kept under the management of the animal caretakers.

5.3.2. Sustainable aspects for the master thesis

This thesis investigated where sows prefered to stay and lie in the loose housing pens. There were three areas in the pen: solid concrete floor, slatted floor, and feed trough. The sows showed a high preference of slatted floor from week 2 pp in this thesis which can cause severe injuries to their limbs and udder. The severe injuries in the sows could be a reason that the sows should be culled. If culled sows increased, the sustainability decreased because of economic losses and decreased productivity from the sows. Even though the sows showed the high preference of lying and staying on the slatted floor, this thesis obtained no culled sows.

Piglet mortality was investigated in this master thesis. High piglet mortality negatively affects the sustainability in pig production because of the economic losses from liveborn piglet losses and the high number of stillbirth piglets. In this master thesis, the total piglet mortality reached to 18.15 % of total liveborn piglets. This master thesis showed similar levels of the piglet mortality compared to previous studies by Fraser (1990), Puppe et al. (2008), Edwards & Baxter (2015), and Baxter & Edwards (2018). However, during the experimental period, two sows that reached 5 and 8 parities respectively showed over two folded number of stillbirth piglets compared to other sows that reached parity 1 to 4.

Overall, in order to develop sustainability in this master thesis, severe injuries in sows caused by the slatted floor should be prevented. If the sows showed the high preference of lying and staying on the slatted floor, the animal caretaker should regularly check skin lesions and abrasions on the sows' limbs and udder to prevent severe injuries in the sows. Moreover, old parity sows need to be excluded as much as possible to reduce the number of stillbirth piglets.

6. Conclusion

Taking all the results of the continuous and scan samplings in the sows and piglets used for this master thesis, the piglets became more active and vigorous while the sows showed more avoiding behaviours related to nursings over time during the 5-week nursing period. Also, the sows showed an increased preference of lying and staying on the slatted floor from week 2 pp which could cause severe injuries to their legs and udder and irritated respiration caused by ammonia gas from the slatted floor. For the reasons above, the sow welfare might be impaired from week 2 pp. Regarding the high piglet mortality with piglets crushed by their sows in week 1 pp, the piglet welfare might be impaired during week 1 pp because piglets crushed by a sow are hardly seen in natural environments. However, there were no piglets crushed by their sows and the piglet mortality significantly decreased from week 2 pp. For the reasons above, the piglet welfare might become better from week 2 pp. However, missing data, imbalanced sample size in each week, and the absence of fixed effects of sow's parity and batch and litter size in the continuous and scan sampling data might affect the assessment of the sow and piglet behaviour and welfare in this master thesis. Hence, to improve the accuracy of welfare assessment and behaviour assessment for the sows and piglets, non-missing data, larger same sample size and improved balance between multiparous and primiparous sows considering their parities and batches and litter size are needed.

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If you want to give special thanks to someone that has helped you with your thesis, you can do it here.

Appendix 1

Datasheet for scan sampling of active behaviour in piglets

DATE: Sow number: Parity:

	Piglet number										Area				
Time	No vision	Lying	Standing	Sitting	Suckling	Exploring	Drinking	Eating	Contact to piglet	Contact to sow	Sow feed trough	Creep feeder	Piglet corner	Concrete floor	Slatted floor
9:00															
9:30															
10:00															
10:30															
11:00															
11:30															
12:00															
12:30															
13:00															
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17:00															
17:30															
18:00															
18:30															
19:00															
19:30															
20:00															

Appendix 2

Datasheet for scan sampling of active behaviour in a sow

DATE: **Sow number:** **Parity:**

Time	Sow									Area		
	Lying on her side	Lying on her belly	Exploring	Eating	Walking	Standing	Sitting	Drinking	Contacting to piglet	Feed trough	Concrete floor	Slatted floor
9:00												
9:30												
10:00												
10:30												
11:00												
11:30												
12:00												
12:30												
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