The effect of forage on piglets' behavior in connection with weaning

Vallfoders inverkan på smågrisars beteende i samband med avvänjning

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Abstract

Pigs' (*Sus scrofa*) behaviors are affected by the environment they are housed in, where an enriched environment offers pigs to perform more diverse behaviors. Pigs reared in barren environments perform more oral manipulation toward their pen mates, compared to pigs reared in enriched environments. In conventional pig production, straw is the most common bedding material in enriched system. Roughage have a beneficial use in animal production. For example, providing pigs with silage, in addition to straw, increases their opportunities to perform foraging and exploratory behaviors, and may also contribute to nutrient supply and promote gastric health. Weaning in conventional pig production usually means an abrupt feed-change. Problems associated with weaning are e.g., diarrhea and behavioral problems, like belly nosing, mounting and fighting due to regrouping after weaning. Pre-weaning enrichment may improve the welfare of the piglets by expanding the piglets' behavioral repertoire, stimulating foraging and feed-intake around weaning, and decreasing aggression and stress response post-weaning. Pigs have a strong motivation to perform foraging and exploratory behaviors, where environmental enrichment is used to provide pigs an environment suitable to perform these species-specific behaviors and to prevent damaging and undesirable behaviors. Silage have a positive impact on the pigs' welfare when given as an additional rooting substrate. Silage increases the time pigs spend on manipulating and exploring the substrate, e.g., in combination with straw, as well as it could serve as an additional nutritive feed source. The aim of this study was to investigate piglets' behavior, pre- and post-weaning, when having access to silage, in addition to straw, compared to no access to silage. In this study, 105 piglets (YxH), divided in two batches, were. Four different treatments were tested: no silage (C, n = 22), silage only pre-weaning (S_{pre}, n = 28), silage only post-weaning (S_{post}, n = 26), and silage both pre- and post-weaning (S_{pp}, n = 29). Piglets were weighed at three occasions and behavioral data was collected performing direct observation, using instantaneous (scan) sampling and continuous (focal) sampling. Minitab 18 was used to perform statistical analyses, and behavioral differences was tested using general linear model (ANOVA). Effects of silage were found on piglets' body weight (BW) ($P < 0.001$), where S_{post} and S_{pp} had the highest growth rates. Pre-weaning, suckling was the highest in S_{pre} and S_{pp} ($P < 0.001$). Further, nosing objects was most common in S_{post} ($P < 0.01$). S_{pp} performed the most ear and tail biting ($P < 0.05$). This study found no differences in behavior between piglets that were provided with silage pre-weaning, compared with those that only received silage post-weaning. In general, foraging and exploring behaviors increased if the piglets received silage in addition to straw. No effect of silage on social interactions and unwanted behaviors among the piglets was confirmed. However, silage may be a good enrichment and have potential to promote pigs' gastric health, due to its scent and nutrient composition.

Keywords: behaviour, enrichment, forage, pig, silage, weaning

Sammanfattning

Grisars (*Sus scrofa*) beteende påverkas av den miljö de hålls i, där en stimulerande och berikande miljö erbjuder grisarna att utföra fler varierande beteende. Grisar som hålls i en karg och ostimulerande miljö utför fler beteenden som riktas mot andra grisar, jämfört med grisar som hålls i en stimulerad och berikad miljö. Halm är det vanligaste strömaterialet som används till grisar i konventionell produktion. Det finns fördelar med att använda grovfoder i djurproduktion. Till exempel, genom att ge ensilage till grisar, i kombination med halm, ökar grisars möjligheter till att utföra födosökande och undersökande beteende, samtidigt som ensilage kan bidra till tillförsel av näring och främja mag- och tarmhälsan. I konventionell grisproduktion innebär avvänjning vanligtvis en plötslig foderförändring för smågrisen. Problem som ofta är förknippade med avvänjning är bland annat diarré och beteendeproblem. Beteendeproblemen kan till exempel vara att smågrisen trycker trynet mot en annan smågris och masserar dennes mage (eng. belly nosing) eller ridning och slagsmål till följd av omgruppering efter avvänjning. Miljöberikning före avvänjning kan förbättra smågrisarnas välfärd genom att utvidga deras beteenderepertoar, stimulera födosöksbeteende och foderintag kring avvänjning, samt minska aggression och stressrespons efter avvänjning. Grisar är starkt motiverade till att födosöka och utforska sin omgivning. Miljöberikning till grisar används därför för att ge dem en miljö som gör det möjligt att utföra dessa artspecifika beteende, samtidigt som det kan förhindra att grisarna utför skadliga och oönskade beteende. Ensilage har en positiv inverkan på grisarnas välfärd när det ges i samband med annat strömaterial. Ensilage, kombinerat med exempelvis halm, ökar tiden som grisarna spenderar på att tugga och utforska strömaterialet, samtidigt som det kan fungera som en ytterligare näringskälla. Syftet med denna studie var att undersöka smågrisarnas beteende, före och efter avvänjning, när de hade tillgång till ensilage, kombinerat med halm, jämfört med inte tillgång till ensilage. Studien inkluderade 105 smågrisar (YxH), uppdelade på två omgångar. Fyra behandlingar testades: ingen tillgång på ensilage (C, n = 22), tillgång till ensilage endast före avvänjning (S_{pre}, n = 28), tillgång till ensilage endast efter avvänjning (S_{post}, n = 26), och tillgång till ensilage både före och efter avvänjning (S_{pp}, n = 29). Smågrisarna vägdes vid tre tillfällen och beteendedata samlades in genom direktobservationer. Statistiska analyser utfördes i Minitab 18, där skillnader i smågrisarnas beteende analyserades med generella linjära modeller (ANOVA). Ensilaget hade en påverkan på smågrisarnas kroppsvikt ($P < 0,001$), där grisar i S_{post} och S_{pp} hade högt tillväxt av grupperna. Dibeteende före avvänjning var högst hos grisarna i S_{pre} och S_{pp} ($P < 0,001$). Nosa på, och undersöka, boxens inredning var vanligast i S_{post} ($P < 0,01$). S_{pp} hade högst förekomst av öron- och svansbitning ($P < 0,05$). Denna studie fann inga skillnader i beteende mellan smågrisar som hade tillgång till ensilage före avvänjning, jämfört med de som endast hade tillgång till ensilage efter avvänjning. Generellt ökade födosöks- och undersökningsbeteende hos smågrisarna som hade tillgång till ensilage. Någon effekt på sociala interaktioner eller oönskade beteenden kunde inte ses. Ensilage kan däremot vara en bra miljöberikning och har potential att främja grisars mag- och tarmhälsa, med tanke på dess doft och näringssammansättning.

Nyckelord: avvänjning, berikning, beteende, ensilage, gris, vallfoder

Preface

During my years at the university, my interest in pigs has increased and will probably continue to improve. By writing this master thesis I have proven to myself that everything is possible through hard work, stubbornness and support.

I would like to thank my supervisors **Magdalena Åkerfeldt** and **Linda Marie Hannius** for all your help, support and feedback throughout this project. Your supervision has been valuable!

Thank you, **Anna Wallenbeck**, for your help regarding the arrangement with the piglet litters, and the support with the statistical analyses.

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The stable personnel at Lövsta; you have helped me at the pig stable and answered my questions. Thank you!

Last but not least, I would like to thank my family and friends for believing in me and cheering when needed.

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Abbreviations

BW	Body weight
C	Control group, piglets who did not have access to silage
CP	Crude protein
DM	Dry matter
EE	Environmental enrichment
LAB	Lactic acid bacteria
ME	Metabolized energy
NDF	Neutral detergent fiber
S_{post}	Group of piglets who only had access to silage post-weaning
S_{pp}	Group of piglets who had access to silage both pre- and post-weaning
S_{pre}	Group of piglets who only had access to silage pre-weaning
SD	Standard deviation

1. Introduction

1.1. Background

Pigs' (*Sus scrofa*) behaviors are affected by the environment they are housed in, where an enriched environment offers pigs to perform more diverse behaviors (Wemelsfelder *et al*., 2000; Day *et al*., 2008). Pigs reared in barren environments perform more oral manipulation toward their pen mates, compared to pigs reared in enriched environments (McKinnon *et al*., 1989; Breuer *et al.,* 2003; Bolhuis *et al.*, 2005; Bolhuis *et al.*, 2006; Oostindjer *et al*., 2011). Animals that have been housed in a barren environment, and later are supplied with enrichment such as straw, change their behaviors; for example, they show increased activity, with play and exploratory behaviors directed to the substrate, and decreased oral manipulation toward other animals (Bolhuis *et al.,* 2006). Pigs who have been housed in an enriched environment, and later moved to a barren environment, redirect their exploratory behaviors toward pen fittings and could develop tail-biting (Munsterhjelm *et al.,* 2009).

According to the Swedish Board of Agriculture's regulations and general advice on pig farming in agriculture, etc. (SJVFS 2019:20, Saknr L 106, 4 Chap. 4 §), pigs need to have access to sufficient amount of bedding material to meet the animals' comfort and needs to root and explore. Straw is the most common bedding material in enriched conventional pig housing (Holinger *et al.*, 2018). In organic production, pigs should have access to roughage if they are not kept on pasture (Council Regulation No 834/2007), and silage is one resource for this.

Roughage have a beneficial use in animal production. For example, roughage can be used as an environmental enrichment for growing pigs and may have a positive impact on piglets' stress experience connected to weaning (Phillips, 2016). Silage, in addition to straw, increases the pigs' opportunities to perform exploratory and foraging behaviors (Presto *et al.,* 2013; Holinger *et al.,* 2018) and may contribute to nutrient supply (Wallenbeck *et al.,* 2015). Though, depending on what type of roughage is provided may influence the animals' behavior (Presto *et al*., 2013). In

a study by Jensen & Pedersen (2007), it was suggested that (maize) silage, mixed with (barley) straw, is more ingestible and might stimulate a prolonged exploratory behavior towards the substrate, compared to only straw. In another study, it was discussed if silage (of timothy) was a less effective rooting and explorative substrate because it might be eaten more by the pigs compared to the other materials (Ocepek *et al.,* 2020a).

Different grasses, legumes and cereals can be used for silage. By conserving the fresh grass or legumes, the crop can be stored and later used as a feed all-year round. Using silage is convenient in Sweden because of the dark and cold climate most time of the year. The crop can be harvested at different growth stages and the fermentation during storage may differ depending on the activities of the enzymes and microorganisms, whereas the silage properties and nutritive values depends on multiple factors (Frame & Laidlaw, 2011; McDonald *et al.,* 2011).

1.2. Natural behavior of the pig

Pigs are naturally social and group-living animals. The ancestor of the domestic pig, the wild boar, lives in maternal herds with their piglets, while the boars usually live solitary (D'Eath & Turner, 2009; Špinka, 2009; Ewing, 2011). The group sizes are depended on e.g., feed resources and shelter (Ewing, 2011). In nature, the diet of the wild boar is varied (D'Eath & Turner, 2009; Špinka, 2009). After farrowing, the piglets stay at the nest the first few days, e.g., in order to not have to compete for milk with piglets from other litters and to establish recognition between the piglets and the sow (D'Eath & Turner, 2009). At approximately 2 weeks of age, the piglets follow the sow to forage and socialize with other litters (D'Eath & Turner, 2009).

Pigs have a strong motivation to perform exploratory behaviors, like rooting and foraging (Jensen *et al.,* 1993; Breuer *et al.,* 2003; Špinka, 2009; Munsterhjelm *et al.*, 2009; Zwicker *et al.,* 2012; Yang *et al.,* 2018). This is a way for the animals to forage, explore and to gather information about their surroundings (Mkwanazi *et al.*, 2019). In captivity, this species-specific rooting behavior is limited (Zwicker *et al.*, 2012; Oostindjer *et al*., 2014; Mkwanazi *et al.,* 2019), compared to natural habitats. Though, the feed composition may influence the pigs' behavior toward the bedding material. Jensen *et al.* (1993) compared different groups of pigs given a feed of low, medium, or high crude protein (CP) content, where the pigs who received feed with low CP content performed more direct behavior toward the straw provided. Further, if a piglet early in life has the ability to perform its exploratory

behavior towards the environment, exploratory behavior directed towards other pen mates may be avoided (Munsterhjelm *et al*., 2009).

1.3. The process of weaning

In wild and semi-natural settings, the piglets are weaned at approximately 4 months of age, whereas in conventional pig production the piglets are weaned at 3-5 weeks of age (Špinka, 2009). It has also been shown that weaning, in the wild and semi-natural settings, is a gradual process without any drastic changes for the piglets (Jensen & Stangel, 1992), compared to an abrupt change in diet and removal of the sow in pig production (Jensen & Stangel, 1992; Yang *et al*., 2018). After studying domestic pigs in a semi-natural setting, the weaning was dependent on the season, and it was found that litters born in February suckled longer compared to litters born in August (Newberry & Wood-Gush, 1985).

Weaning is a process that involves a nutritional change and adjustment in the piglets feed intake, from mainly milk to only solid feed (Puppe *et al.,* 1997; Weary *et al*., 2008; Middelkoop *et al.,* 2019). Although piglets are provided with solid feed in the creep area pre-weaning, their intake is relatively low (Weary *et al.*, 2008; Middelkoop *et al*., 2019). At weaning, the physical and social environments are usually changed by moving the animals to a new environment and regrouping the piglets (Puppe *et al.,* 1997; Weary *et al.,* 2008; Middelkoop *et al*., 2019).

Problems associated with weaning are e.g., diarrhea (Madec *et al.,* 2000; Špinka, 2009; Ewing, 2011; Oostindjer *et al.,* 2014; Ruiz *et al.,* 2016), and behavioral problems, like belly nosing (Špinka, 2009; Oostindjer *et al.,* 2011) and mounting (Oostindjer *et al.,* 2014). Post-weaning diarrhea is known as multifactorial, caused by e.g., feed change and low feed-intake (Oostindjer *et al.,* 2014), Escherichia coli (Madec *et al.,* 2000) or *Campylobacter spp*. (Ruiz *et al.,* 2016). Belly nosing may develop in early weaned piglets, at 3 weeks of age or earlier (Špinka, 2009) but can also be developed when piglets are kept in barren environment post-weaning (Oostindjer *et al.,* 2011). Further, fighting and aggression may also occur due to regrouping after weaning (Weary *et al.,* 2008; Špinka, 2009). Belly nosing, fighting and mounting could all be categorized as damaging behaviors which compromise the animals' welfare (Oostindjer *et al*., 2014), and thus these behaviors are undesirable.

1.4. Environmental enrichment

The term environmental enrichment (EE) is usually associated with anything that is added to animals' environment in captivity (Docking *et al.,* 2008; van de Weerd & Ison, 2019). In pigs, EE is used to provide the animals an environment suitable to perform species-specific behaviors and to prevent damaging and undesirable behaviors, like tail biting (van de Weerd & Ison, 2019). Since pigs in general are kept in groups, the enrichment should be provided and accessible to all individuals (Docking *et al.,* 2008). How suitable an EE is for pigs is determined by the properties of the EE (Lewis *et al.,* 2006). An effective EE has long-lasting effects that provides a meaningful reinforcement (van de Weerd & Ison, 2019). If the EE is destructible and edible, the object is changing and thus may keep the pigs stimulated and curious about the EE and stimulates foraging behavior (Studnitz *et al.,* 2007). Pigs' explorative behavior toward objects, such as chains and tires, that are not exchanged regularly may decrease as the animals get habituated to the EE and the novelty of the EE is lost (Mkwanazi *et al.,* 2019). If objects are used as EE, these should be replaced regularly to maintain the novelty of the EE and thus maintain the pigs' curiosity and exploring toward the EE (Mkwanazi *et al.,* 2019). An optimal EE to pigs should be a material that is edible, chewable, investigable and manipulative (EC, 2016). Further, EE to pigs should motivate the animals to perform exploratory behavior (Jensen & Pedersen, 2007). When comparing different objects and substrates as EE to pigs, it was found that the most used enrichments by the pigs were compost and straw (Docking *et al*., 2008).

Another thing to consider when deciding EE, apart from the animals' species-specific behavior, is how it affects the production system. To make an EE sustainable in the long run, the requirements of the animals, the animal keeper and production system need to be taken into consideration (Scott *et al.,* 2007). For example, the welfare of the animals, the workload for the animal keeper, and the conditions/prerequisites of the production. According to van de Weerd & Ison (2019), an EE should improve the economics as well as function in the animal production. There are different reasons why EE is used in animal production. It can be used to improve production performance or to enhance animal welfare (van de Weerd & Ison, 2019). There could also be a combination of these two.

1.4.1. Pre-weaning enrichment

There are multiple studies showing that piglets are affected by earlier environmental experiences. For example, EE given pre-weaning expands the behavioral repertoire in the piglets and reduces fear in novel situations (Lewis *et al.,* 2006), reduces agonistic behaviors later in life (Munsterhjelm *et al.,* 2009),

stimulates foraging and feed-intake around weaning (Oostindjer *et al.,* 2014; Middelkoop *et al.,* 2019), and decreases aggression and stress response post-weaning (Ko *et al.,* 2020). EE pre- and post-weaning positively affects the piglets' behavior development, social and foraging related behaviors, and thus promotes the weaning process (Oostindjer *et al*., 2011). However, other studies state the piglets are mainly affected by the current environment they are housed in and not by their previous rearing (Bolhuis *et al.,* 2006; Martin *et al*., 2015).

Pre-weaning enrichment may improve the welfare of the piglets as it reduces the stress response during weaning by promoting positive behavior, such as play behavior (Yang *et al*., 2018). By providing EE pre-weaning, it may enhance the piglets to cope with the weaning process (O'Connell *et al*., 2005; Weary *et al*., 2008; Ko *et al.,* 2020; Luo *et al.,* 2020) as well as develop foraging-related behaviors and thus, have a beneficial effect on feed intake during this period (Oostindjer *et al.,* 2011). In a study comparing outdoor and indoor system, piglets reared in the outdoor system performed more rooting behavior both pre- and post-weaning as well as higher solid feed-intake post-weaning (Cox & Cooper, 2001). This could be explained by the piglets being reared outdoors having a larger variety of environmental stimulus and thereby could learn foraging-related behaviors from the sow (Cox & Cooper, 2001). In a study by Bench & Gonyou (2006), piglets pre-weaning spent more time interacting with the type of EE that they could bite and root in, compared to types of EE they only could nose and suckle on. Piglets having access to EE that they can root and eat, such as straw, sawdust and peat, had a higher weight gain as well as feed intake pre- and postweaning (Luo *et al.,* 2020). Providing wood-shavings and hanging toys also improved weight gain in piglets around weaning, as well as decreased aggressive behavior and increased exploratory behavior (Oliveira *et al.,* 2016). Although, it has been shown that piglets at 3 weeks of age show less interest in EE than older pigs, 5 and 13 weeks, respectively. This was probably due to a higher lactation frequency and that the piglets need to synchronize their suckling behavior to access food at younger age (Docking *et al.,* 2008).

1.4.2. Silage as an environmental enrichment

In 2016, the European Commission classified different enrichment materials into three categories: optimal, suboptimal and of marginal interest (EC, 2016). According to the EC (2016), the optimal materials are explained as materials that "can be used alone because they possess all the necessary characteristics to meet the pigs' needs", including e.g., straw, hay, grass, alfalfa and silage. From an animal welfare point of view, EE that promotes explorative and oral activities could

probably be the most effective way to redirect oral behaviors toward pen fittings and pen mates (Bench & Gonyou, 2006).

Silage have a positive impact on the pigs' welfare when given as an additional rooting substrate combined with straw (Olsen *et al.,* 2002; Presto *et al.,* 2013). Silage increases the time pigs spend on manipulating and exploring the substrate, e.g., in combination with straw (Jensen & Pedersen, 2007; Presto *et al.,* 2013) but also as a single substrate (Jensen *et al*., 2010). Silage and other types of roughage could also increase play behavior, reduce aggression and decrease redirected behavior toward pen mates and pen fittings (Olsen *et al.,* 2002). Also, there seems to be a decrease in aggression when providing silage in combination with other materials (Jensen & Pedersen, 2007; Ocepek *et al*., 2020a). Providing the pigs with a mixture of different rooting substrates, which includes silage, increased the pigs' play behavior and decreased the manipulation of ears and tails of other pigs (Ocepek *et al.,* 2020a).

Roughage could also affect the pigs' feeding behavior (Holinger *et al.,* 2018) and serve as an additional nutritive feed source, having the potential to contribute with both energy and protein (Wallenbeck *et al.,* 2015). The capacity to digest silage depends on the chemical composition, and where younger pigs, like growing pigs, have a lower capacity to digest dietary fiber compared to sows (Wallenbeck *et al*., 2015). Providing pigs with silage, in addition to straw, could increase the animals' time they spend on foraging and eating (Presto *et al*., 2013; Holinger *et al*., 2018). When chewing silage, this could also have a buffering effect on the pH in the pig's stomach (Holinger *et al*., 2018). Further, lactic acid bacteria (LAB), which can be found in silage, can to some extent be used as a probiotic in piglets to improve e.g., body weight (BW) and feed conversion (Abe *et al*., 1995; Guerra *et al*., 2007).

Different types of roughage may affect the animals differently. For instance, dry matter (DM), texture and complexity, smell and taste are characteristics that need to be considered when evaluating the effects of roughage (Olsen *et al.,* 2000). In the study by Presto *et al.* (2013), intact silage had a greater potential to reduce negative and damaging social behavior causing wounds, compared to silage that was chopped or pelleted. Further, Jensen & Pedersen (2007) could see that aggression was less performed when pigs were fed silage, in combination with straw, whereas Ocepek *et al.* (2020a) did not find any reduction in aggression when providing only silage, compared to other rooting materials, like straw or peat. When comparing maize silage and chopped straw as single substrates, the manipulation and exploratory behavior toward the maize silage was higher than to the straw (Jensen *et al.,* 2010). Additionally, the type of crop may also affect the animals' behavior, as the pigs could have silage preferences.

1.5. Aim, questions and hypothesis of this study

By providing silage, in addition to straw, the pigs may get further opportunities to perform their natural exploratory behaviors, i.e., foraging and rooting. This will increase their time being occupied with the bedding material, which can reduce the incidences of undesirable behaviors and may have the potential to increase the animal welfare. The aim of this study was therefore to investigate the impact of silage, in addition to straw, on piglets' behavior, pre- and post-weaning.

The questions asked in this study were:

- Will the piglets change their behaviors if they have access to silage? For example, will they become more active by showing foraging and exploratory behaviors?
- Will the piglets who had access to silage before weaning behave differently after weaning, compared to the piglets who did not have access to silage before weaning?
- Do the social interactions between the pigs change if the pigs have access to silage?
- Do the undesirable behaviors change if the pigs have access to silage?

The hypothesis is that a significant difference will be found in foraging and exploratory behaviors between pigs that have access to silage compared to pigs that only have access to straw, where piglets receiving silage will have an increased performance of foraging and exploratory behaviors. Further, the theory is that piglets who have access to silage both before and after weaning will manipulate the silage to a higher extent after weaning, compared to piglets that do not receive silage before weaning.

2. Materials and Methods

This research was conducted at the Pig Research Centre of the Swedish University of Agricultural Sciences at Funbo Lövsta, outside of Uppsala, Sweden. The practical parts of this study were performed between 8th April and 6th May 2021.

The silage used in this study was from the 2nd cut and consisted of grass and clover. It was stored in a silo at Lövsta Research Centre. Prior to the start of the study, silage was weighed into daily rations of approximately 1 kg to each pen and stored in a freezer at -20° C. Feed analyses of the silage used in this study can be seen in Table 1.

Table 1. Feed analyses of the silage.

Grass/clover silage from 2nd cut	
Dry matter (DM), g/kg	335
Crude protein (CP), g/kg DM	154
Crude fat, g/kg DM	33
Ash, g/kg DM	87
Neutral detergent fiber (NDF), g/kg DM	412
Lactic Acid, g/kg DM	59
pH	4.03

2.1. Animals and housing

The study was carried out in two different batches, under conditions according to Swedish conventional production (SJVFS 2019:20), where pigs e.g., need to have sufficient amount of bedding material (4 Chap. 4 §). The supervision of the animals and cleaning of the pens were managed by the staff at the Research Centre. In total, 105 piglets (Yorkshire x Hampshire) from two batches were included in the study: 54 animals in the first batch, and 51 animals in the second batch. Each pen housed 10-15 piglets from the same litter. Before weaning, the piglets and the sow were housed in a loose-housed farrowing pen (Figure 1). After weaning, which appeared

when the piglets reached an age of 5 weeks (± 4 days), the piglets stayed in the same pen as before weaning.

2.2. Study design

2.2.1. Treatments

The study included eight pens (pig groups) in total, four groups in each batch, allocated to four treatments, thus, two replicates per treatment (Figure 2). The four different treatments were:

- Control group (C, n = 22), no access to silage neither pre- nor post-weaning,
- Silage group (S_{pre}, n = 28), access to silage pre-weaning,
- Silage group ($S_{post,}$ n = 26), access to silage post-weaning, and
- Silage group (S_{pp}, n = 29), access to silage both pre- and post-weaning.

The silage was placed on the floor in the creep area (Figure 1) and was provided once a day in the morning by the stable personnel. On the days of observation, silage was provided twice a day: in the morning and in the afternoon right before each observation by the observer herself. Since this study wanted to compare piglets' behavior when having access to silage or not, in addition to straw, all animal groups received the same amount of straw daily, regardless if they had access to silage, according to SJVFS 2019:20 (4 Chap. 4 §).

The experimental period lasted 15 days in total for each batch, Additionally, all piglets in all groups were weighed at three occasions: in the beginning of the study (day 1), the day of weaning (day 8) and at the end of the study (day 15).

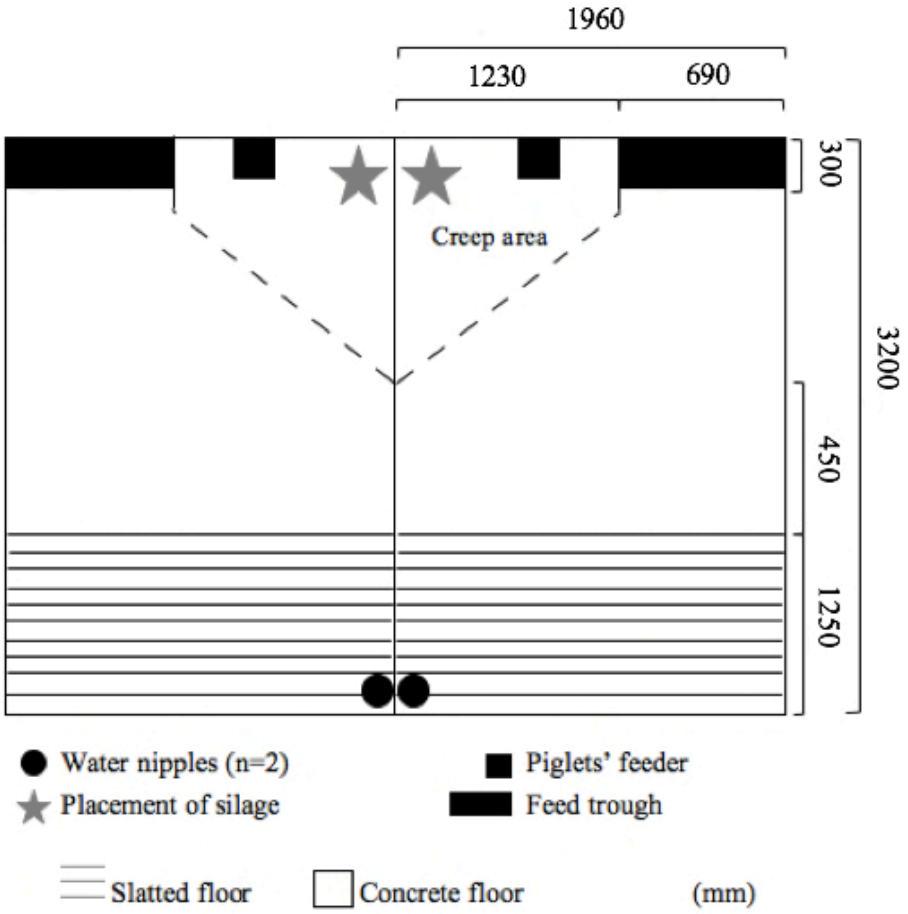

Figure 1. Layout of two pens in the stable. The wall into the creep area, that separates this area to the rest of the pen, was only used pre-weaning when the sow was present in the pen.

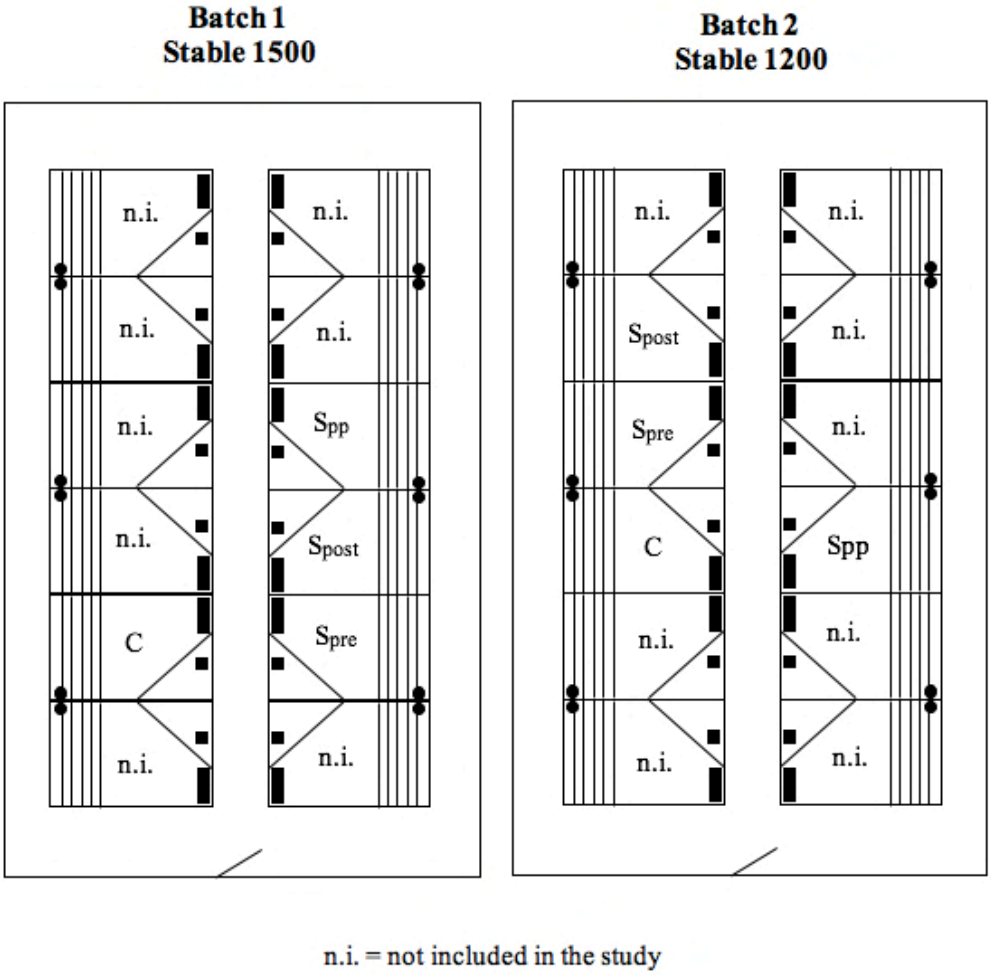

Figure 2. Layout of the stables for each batch and the distribution of the different treatments.

2.2.2. Behavioral protocol

To register the piglets' behaviors during the behavioral observations, a protocol was made in Microsoft Word (Version 16.43) (Appendix 1).

2.2.3. Behavioral observations

Direct observations were performed to record the behaviors of the piglets, including both instantaneous (scan) sampling and continuous (focal) sampling. The recordings of the piglets' behaviors were performed according to an ethogram (Table 2). During the scan sampling, the behaviors of all piglets in that specific moment were registered. When performing the continuous sampling, the focal animal's behaviors that occurred during a specific time frame were registered. In total, there were four focal animals per pen. The focal animals were randomly picked, as well as the observation order of them, before each observation took place.

No physical contact was made with the animals during the observations as the observer was standing outside the pen. The focal animals were individually marked by the observer with an animal marking crayon the same day as the observation to easier distinguish these individuals from the other piglets. An acclimatization period of approximately 10-15 minutes took place right before each observation in order to acclimatize the animals to the observer. This was done by walking back and forth in the middle aisle of the stable (Figure 2), and by standing outside each pen until the piglets did not give any attention to the observer. The silage was placed in the pens approximately 2 minutes before the acclimatization period ended, and the observation started.

Table 2. Ethogram.

Category	Behavior	Variable	Description	References
Scan sampling				
	Standing, sitting		Either stand or sit down without doing any other behaviors.	Ocepek *et al.* (2020b)
	Lying down		Stomach or the side of the body is touching the ground. The piglet is awake or sleeping. No exploration with snout.	Brajon *et al.* (2017)
	Exploring bedding material	In pen or creep area	Investigate or manipulate material on the floor by sniffing, rooting, pawing, chewing or lifting it in the mouth.	Ocepek *et al.* (2020a); Ocepek *et al.* (2020b)
	Nosing object		Snout pressing against or sniffing pen objects and/or pen walls.	Ocepek *et al.* (2020b)
	Social interaction		Snout or front legs are used to touch pen mate's body surface.	Ocepek *et al.* (2020b)
	Eating		The head of the piglet is in the piglets' feeder or sow's feed trough.	Brajon *et al.* (2017)
	Suckling (pre-weaning)		Piglet has one of the sow's teats in the mouth, massaging the udder or tries to participate in the lactation (body is in contact with other piglets or with the sow's udder).	Eriksson (2011)
	Other behavior		Displaying any other behavior.	Munsterhjelm *et al.* (2009)

Continuous sampling	Exploring bedding material	In pen or creep area	The same description as above.	
	Nosing object		The same description as above.	
	Social interaction	Nosing pig	Sniffing or touching body of another piglet with the snout.	O'Connell *et al*. (2005); Breuer *et al.* (2003)
		Belly nosing	Manipulate or rub the belly of another piglet.	O'Connell *et al*. (2005); Breuer *et al.* (2003)
		Mounting	Mounting another piglet with front legs off the ground.	Brajon *et al.* (2017)
		Biting	Mutual single or repeated snaps or teeth bites directed toward head or body of another piglet.	Ocepek *et al.* (2020b)
		Head knock	Making sharp, forceful movements of the head sideways towards the head of another pig.	Ocepek *et al.* (2020a)
		Ear or tail biting	Manipulate, suck or chew the ear or tail of another piglet.	O'Connell *et al*. (2005); Breuer *et al.* (2003); Ocepek *et al.* (2020a)
	Suckling (pre-weaning)		The same description as above.	
	Eating		The same description as above.	
	Other behavior		The same description as above.	

The behavioral observations were performed twice a day: in the morning, approximately between 8:30-10:00 am, after the pen was cleaned and new substrate was given, and in the afternoon, approximately between 2:30-4:00 pm. The observations were performed during daytime as this is the time when pigs are most active, thus observations during the night were excluded. Two days of observations were executed pre- and postweaning respectively (Figure 3).

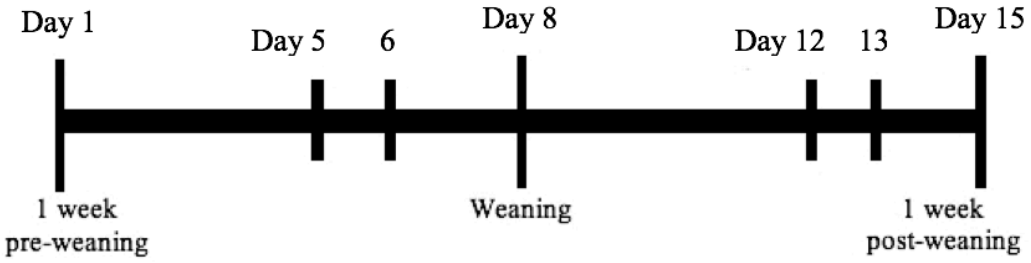

Figure 3. Timeline showing at which days the behavioral observations were performed in relation to weaning. Observations took place during day 5 and 6 (pre-weaning), and day 12 and 13 (post-weaning).

At each observation day, during both the morning and the afternoon, the observation started with an instantaneously sampling of all animals in each pen, observing and registering pen 1, 2, 3 and 4 separately. This was then followed by a continuous sampling for three minutes on the first focal animal in pen 1. After the continuous sampling, the scan sampling was repeated as mentioned above, registering all piglets' behavior in each pen (1, 2, 3 and 4), followed by a continuous sampling for three minutes on the first focal animal in pen 2. This procedure was repeated until the continuous sampling on the first focal animal in pen 4 ended (Figure 4). This was called a 'session' and took approximately 20 minutes. At each observation occasion, the session was repeated four times, giving in total 80 minutes of observations per occasion (20 minutes x 4 rounds = 80 minutes). The focal animal that was observed in each pen was changed in every round, having one specific focal animal per pen in each round. Thus, each observation included in total 64 scans (16 per treatment). For the continuous sampling, the corresponding figures were in total 48 minutes of continuous sampling (12 minutes per treatment).

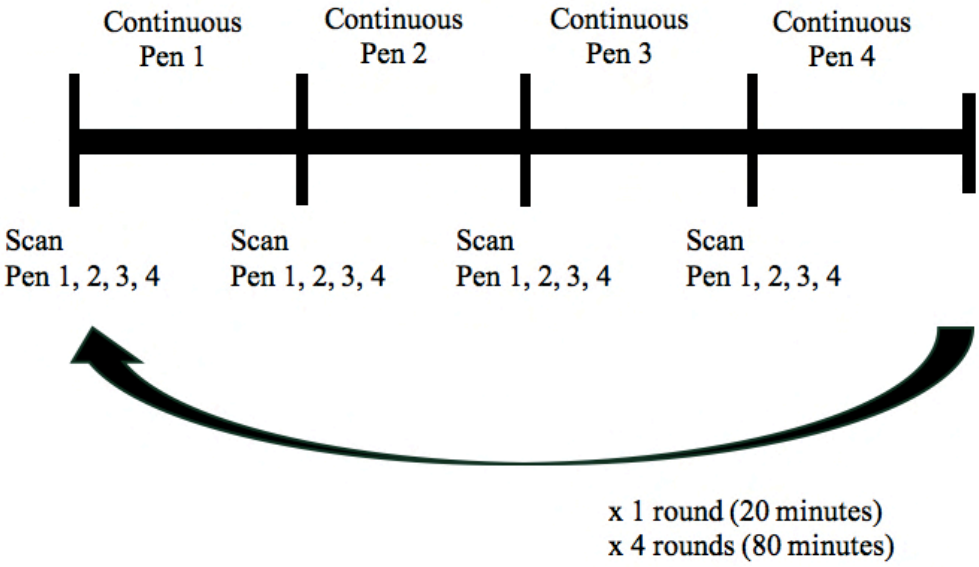

Figure 4. How the observations were performed, combining scan sampling with continuous sampling. Every observation started with a scan sampling of all four pens (all animals included), followed by a 3-minute continuous focal sampling of a focal animal in the first pen. Scan sampling was then repeated on all four pens, followed by a 3-minute continuous focal sampling of a focal animal in the second pen. This procedure was repeated until the 3-minute continuous focal sampling of the fourth pen ended and was defined as one round (20 minutes). One observation included four rounds (80 minutes).

2.3. Statistical analyses

After the behavioral observations, registrations were registered in Microsoft Excel (version 16.43). For the statistical analyses, Minitab 18 was used. After the observations were performed, the data collected was not normally distributed. To be able to analyze the collected data as approximately normally distributed, as well as study the data in the smallest unit possible (at pen level), data from the behavioral observations was reorganized (Table 3). Further, data of the piglets' BW were approximately normally distributed. Descriptive statistics on piglets' BW (day 1, 8 and 15) and behavioral data, including means and standard deviations (SD), was then calculated. Each recorded behavior from the scan samplings were displayed as percentage (%) of piglets that performed each specific behavior. The summarized data was then used in a general linear model (ANOVA) with the fixed factors of 'treatment', 'batch', 'observation period', 'time' and 'pen': 'y = treatment (class: C, S_{pre}, S_{post} or S_{pp}) + batch (class: 1 or 2) + observation period (class: pre- or post-weaning) + time (class: am or pm) + pen (batch) + observation period*treatment + time*treatment + e', where the response (y) represents each behavior from the ethogram.

For the continuous samplings, the same steps as for the scan samplings were repeated. The summarized data showed how many times a behavior was performed by all focal animals in the same pen during the same time period (minute 1-3). The ANOVA model used for the continuous sampling included the fixed factors 'treatment', 'batch', 'observation period', 'time', 'pen'. Thus, the model was: 'y = batch (class: 1 or 2) + observation period (class: pre- or post-weaning) + time (class: am or pm) + treatment (class: C, S_{pre}, S_{post} or S_{pp}) + pen (batch) + minute (class: 1, 2 or 3) + observation period*treatment + time*treatment + e', where the response (y) represents each behavior.

Table 3. How behavioral data for each pen was reorganized before displayed in Minitab.

Category	
Scan sampling	batch + treatment + pre-weaning + am
	batch + treatment + pre-weaning + pm
	batch + treatment + post-weaning + am
	batch + treatment + post-weaning + pm
Continuous sampling	batch + treatment + pre-weaning + am + 1st minute
	batch + treatment + pre-weaning + am + 2nd minute
	batch + treatment + pre-weaning + am + 3rd minute
	batch + treatment + pre-weaning + pm + 1st minute
	batch + treatment + pre-weaning + pm + 2nd minute
	batch + treatment + pre-weaning + pm + 3rd minute
	batch + treatment + post-weaning + am + 1st minute
	batch + treatment + post-weaning + am + 2nd minute
	batch + treatment + post-weaning + am + 3rd minute
	batch + treatment + post-weaning + pm + 1st minute
	batch + treatment + post-weaning + pm + 2nd minute
	batch + treatment + post-weaning + pm + 3rd minute

Each behavior was tested separately, followed by a pairwise comparison on the same behavior and the different factors included in the statistical model. Differences were regarded statistically significant if the probability value (P-value) was less than 0.05. To be able to compare different behavioral categories, e.g., foraging and explorative behaviors, between the treatments, behaviors from the ethogram was reorganized (Table 4). The same tests as described above were performed again, i.e., ANOVA and pairwise comparison, using the same models for scan samplings and continuous samplings, respectively.

Table 4. How behaviors were reorganized before the second round of analyses were performed.

Category	Category of behavior	Behavior variable(s) included
Scan sampling		
	Inactive behaviors	'standing, sitting' and 'lying down'
	Exploring and foraging	'exploring bedding material', 'nosing object', 'eating' and 'suckling (pre-weaning)'
	Social interactions	'social interaction'
	Other behaviors	'other behavior'
Continuous sampling		
	Foraging and exploring	'exploring bedding material', 'nosing object', 'eating' and 'suckling (pre-weaning)'
	Investigation social interactions	'nosing pig'
	Undesirable social interactions	'belly nosing', 'mounting', 'biting', 'head knock', 'ear or tail biting'
	Other behaviors	'other behavior'

To examine if there was a significant difference between treatment and BW, or between the two batches, a general linear model (ANOVA) was used, as well as a pairwise comparison between treatments and batches. The smallest statistical unit was piglet. To be able to estimate the effect of treatment on BW, each piglets' growth rate in kilograms (kg) between day 1-8 (pre-weaning), day 8-15 (post-weaning), and between day 1-15 (whole study) were included using the tool 'Calculator' in Minitab. The model included fixed factors of 'treatment', 'batch', 'pen', and 'start weight' was included as a continuous covariate. The model used was: 'y = treatment (class: C, S_{pre}, S_{post} or S_{pp}) + batch + pen (batch) + start weight + e', where the response (y) was the piglets' growth rate (day 1-8, 8-15 or 1-15), and 'start weight' was the start weight (day 1 or 8) of the specific period being analyzed.

3. Results

The whole study period included a total of 1 024 scans (256 per treatment), and 768 minutes of continuous sampling (192 minutes per treatment). Missing values from 5 scans and a 3-minute continuous observation in treatment group S_{pp} resulted in 1 019 scan and 765 minutes of continuous recordings. During the period of this research, no animal died.

3.1. Silage intake and body weight

All silage was consumed, and no silage leftovers was observed. Descriptive statistics of the piglets' average BW in the different treatment groups, and batches are presented in Table 5. In both batches, piglets in the control group (C) weighed more compared to the other groups, and piglets in the group receiving silage both pre- and post-weaning (S_{pp}) weighed the least from day 1.

Table 5. Descriptive statistics. Mean values of the piglets' body weight, in kilograms (kg) ± standard deviation (SD).

	Treatment				Batch	
	C	S_{pre}	S_{post}	S_{pp}	Batch 1	Batch 2
Day 1	10.6 ± 1.79	9.28 ± 1.38	8.22 ± 1.52	7.62 ± 1.65	9.04 ± 1.57	8.61 ± 2.20
Day 8	13.5 ± 2.34	12.1 ± 1.71	10.9 ± 2.14	10.3 ± 2.13	11.5 ± 1.88	11.7 ± 2.81
Day 15	15.9 ± 3.37	14.5 ± 1.90	14.0 ± 2.67	13.1 ± 2.28	13.6 ± 1.90	15.0 ± 3.22

There was a significant ($P < 0.001$) effect of batch on the piglets' average growth rate (Table 6). A significant effect of treatment was also found for the piglets' growth rate during day 8-15, where pigs in C and S_{pre} had lower growth rate than pigs in S_{post} and S_{pp} (2.20 and 2.30 kg vs. 3.16 and 2.95 kg for C, S_{pre}, S_{post} and S_{pp} respectively; P = 0001). Further, there was a significant effect of piglets' weight at the start of the growth period for all three growth variables, i.e., day 1-8, day 8-15 and day 1-15, indicating a higher growth rate for piglets that were heavier at the

start of each period (day 1-8; $P < 0.001$, $b = 0.23$), (day 8-15; $P = 0.013$, $b = 0.11$), (day 1-15; $P < 0.001$, $b = 0.39$).

Table 6. Corrected mean values and effect of treatment and batch on the piglets' growth rate (kg) and P-value for the different periods.

	Treatment					Batch		
	C	S_{pre}	S_{post}	S_{pp}	P-value	Batch 1	Batch 2	P-value
Day 1-8	2.56	2.74	2.86	2.97	0.475	2.40^{A}	3.16^{B}	< 0.001
Day 8-15	2.20^{A}	2.30^{A}	3.16^{B}	2.95^{B}	0.001	2.13^{A}	3.18^{B}	< 0.001
Day 1-15	4.68^{A}	5.02^{A}	6.05^{B}	5.98^{B}	< 0.001	4.48^{A}	6.39^{B}	< 0.001

Different letters$^{A\ B}$ in the same effect and row indicate pairwise differences of $P < 0.05$.

3.2. Scan sampling

3.2.1. Descriptive statistics

Time spent lying down was highest during the pre-weaning period, on average 40.5 % of the time compared to the post-weaning period where the piglets lied down on average 33.0 % of the time. Exploring the bedding material increased during the post-weaning period, both when exploring it in pen and exploring it in creep area. Exploring of the material in the pen occurred for 22.9 ± 14.3 % among the piglets in C, 15.7 ± 7.00 % in S_{pre}, 17.6 ± 6.49 % in S_{post} and 17.4 ± 9.06 % in S_{pp} during the pre-weaning period. Corresponding values for the post-weaning period were C: 22.7 ± 13.8 %, S_{pre}: 26.5 ± 9.91 %, S_{post}: 25.8 ± 7.33 % and S_{pp}: 26.5 ± 16.6 %)

The time spent on exploring the material in the creep area was during the pre-weaning period 7.59 ± 5.31 % in C, 13.2 ± 5.27 % in S_{pre}, 9.38 ± 4.83 % in S_{post} and 14.3 ± 7.08 % in S_{pp}. Corresponding values for the post-weaning period were C: 9.66 ± 6.49 %, S_{pre}: 14.8 ± 2.46 %, S_{post}: 21.9 ± 2.42 %, and S_{pp}: 21.3 ± 11.1 %.

Suckling behavior was performed more among piglets having access to silage during the pre-weaning period, S_{pre} and S_{pp} with 19.3 ± 1.91 and 17.6 ± 7.50 % for S_{pre} and S_{pp} compared with 13.7 ± 5.21 and 11.8 ± 2.04 % for C and S_{post}, respectively. Eating occurred more in the post-weaning period, on average 11.0 % compared with in the pre-weaning period when it occurred for 3.7 % of the time. In general, standing and sitting, nosing object and performing other behaviors increased during the post-weaning period in all groups.

C spent the most time inactive, including standing, sitting and lying down with 47.4 % compared with 41.0, 41.2 and 38.9 % for C, S_{pre}, S_{post} and S_{pp}, respectively (Figure 5). This was reflected in a lower proportion of time spent on foraging and explorative behavior in the piglets in C with 48.6 % compared with 52.7, 53.6 and 56.2 % in S_{pre}, S_{post} and S_{pp}, respectively. Also, Figure 5 presents the proportion of time spent on social interactions and other behaviors, which were in general performed less.

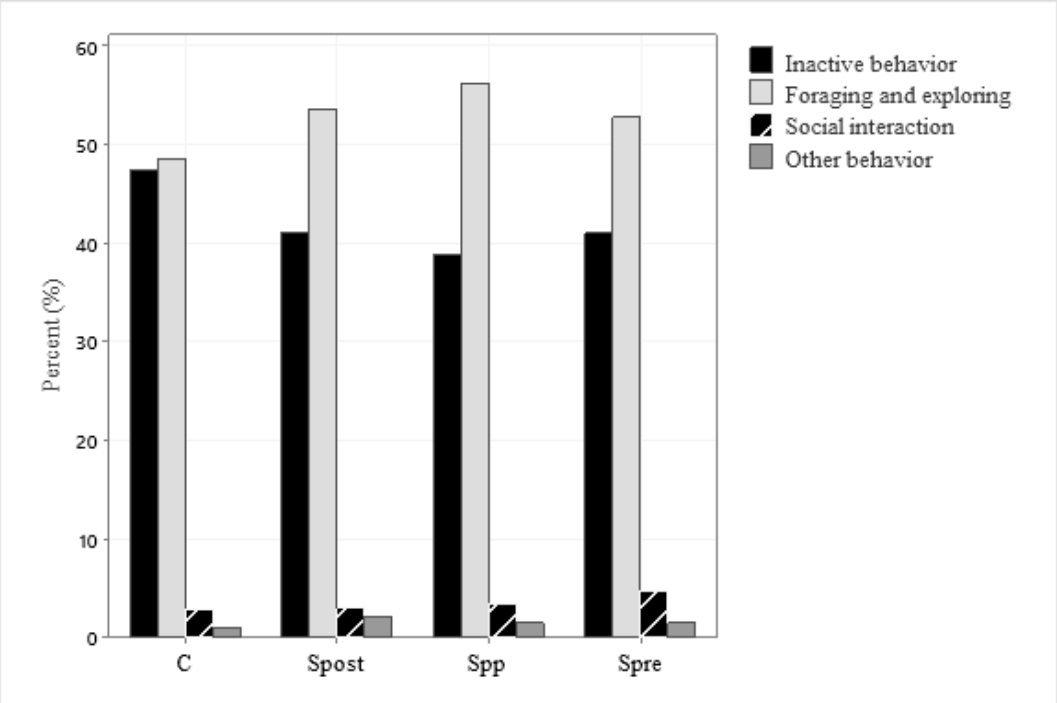

Figure 5. Mean (%) of scans (and time budget) piglets in the different treatments performed each behavioral category. N = 1 019.

3.2.2. Statistical analyses

Level of significance for effects, included in the statistical model, on piglets' behavior is presented in Table 7. There was no significant effect of treatment on the different behaviors. Exploring bedding material in creep area tended to be significant ($P = 0.063$). Observation period (pre- and post-weaning) differed significantly for eating behavior ($P < 0.001$) and suckling only occurred during pre-weaning. Time (am and pm) had a tendency to a significant effect on nosing object ($P = 0.094$) and eating ($P = 0.058$). Performing other behaviors was significantly higher in the second batch ($P < 0.023$).

Table 7. Level of significance (P-value) for the different effects in the statistical model for the scan sampling.

Response variable	Treatment	Observation period (pre- or post-weaning)	Time (am or pm)	Batch	Observation period * Treatment	Time * Treatment
Standing, sitting	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Lying down	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Exploring bedding material in pen	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Exploring bedding material in creep area	#	< 0.05	n.s.	n.s.	n.s.	n.s.
Nosing object	n.s.	n.s.	#	n.s.	n.s.	n.s.
Social interaction	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Eating	n.s.	< 0.001	#	n.s.	n.s.	n.s.
Suckling (pre-weaning)	n.s.	< 0.001	n.s.	n.s.	n.s.	n.s.
Other behavior	n.s.	#	n.s.	< 0.05	n.s.	n.s.

n.s. = not significant # = tendency to significance ($P < 0.1$)

Corrected means of the time that the piglets spent on each behavior is presented in Table 8. There was a significant effect of observation period (pre- and post-weaning) for eating, where the piglets spent more time eating post-weaning (Table 8).

Table 8. Corrected mean (%) of scans (and time budget) in the different treatments and observation periods the piglets performed each behavior. N = 1 019.

	Treatment					Observation period		
	C	S_{pre}	S_{post}	S_{pp}	P-value	Pre-weaning	Post-weaning	P-value
Standing, sitting	4.62	5.24	5.77	4.01	0.516	4.22	5.60	0.124
Lying down	42.8	35.8	35.4	34.9	0.881	41.5	32.9	0.296
Exploring bedding material in pen	22.8	21.1	21.5	22.0	0.992	18.3	25.4	0.101
Exploring bedding material in creep area	8.63	14.0	15.7	17.8	0.063	11.1^{A}	16.9^{B}	0.021
Nosing object	2.07	1.38	2.40	1.07	0.375	1.26	2.21	0.119
Social interaction	2.95	4.72	3.02	3.49	0.347	3.05	4.04	0.205
Eating	8.20	6.66	8.11	6.59	0.649	3.76^{A}	11.0^{B}	< 0.001
Suckling (pre-weaning)	6.87	9.63	5.89	8.78	0.168	15.6^{A}	0.00^{B}	< 0.001
Other behavior	1.10	1.52	2.23	1.49	0.179	1.27	1.90	0.092

Different letters$^{A\ B}$ in the same effect and row indicate pairwise differences of $P < 0.05$.

No effect of treatment on foraging and explorative behaviors between the treatments was found (P = 0.885). The time spent foraging and exploring was 48.6 % in C, 52.7 % in S_{pre}, 53.6 % in S_{post}, and 56.2 % in S_{pp}. Further, no difference was found on the time spent inactive (P = 0.860).

3.3. Continuous sampling

3.3.1. Descriptive statistics

Based on the behavior of the focal piglets, S_{pre} explored bedding material in pen the most (C: 3.50 ± 2.84; S_{pre}: 3.67 ± 1.58; S_{post}: 2.79 ± 2.09; S_{pp}: 2.92 ± 2.65). Exploring bedding material in the creep area was most seen among piglets in S_{post} (C: 1.67 ± 1.40; S_{pre}: 2.25 ± 1.03; S_{post}: 2.29 ± 2.00; S_{pp}: 2.00 ± 1.47). Mean number of times the piglets performed the different behavioral category are presented in Table 10.

Table 9. Mean number of times ± standard deviation (SD) a focal animal in every treatment performed each behavior per 3 minutes of observation. N = 765 minutes.

	Treatment			
	C	S_{pre}	S_{post}	S_{pp}
Foraging and exploring	6.88 ± 3.44	8.21 ± 1.91	7.83 ± 3.52	8.46 ± 3.91
Investigation social interactions	1.88 ± 1.80	1.54 ± 1.41	1.17 ± 1.24	1.96 ± 1.83
Undesirable social interactions	1.58 ± 2.54	2.21 ± 2.32	1.500 ± 2.06	2.17 ± 3.02
Other behaviors	5.04 ± 2.10	4.96 ± 1.65	5.58 ± 2.15	4.79 ± 2.50

The most performed behavior of foraging and exploring behaviors was exploring bedding material in pen, which occurred to 50.9, 44.7, 35.6 and 34.5 % of the total time that foraging and exploring behaviors occurred, for C, S_{pre}, S_{post} and S_{pp} respectively. This was followed by exploring bedding material in creep area (C: 24.2 %; S_{pre}: 27.4 %; S_{post}: 29.3 %; S_{pp}: 23.7 %) (Figure 6). The proportion of other behaviors performed, varied between the treatments (Figure 6).

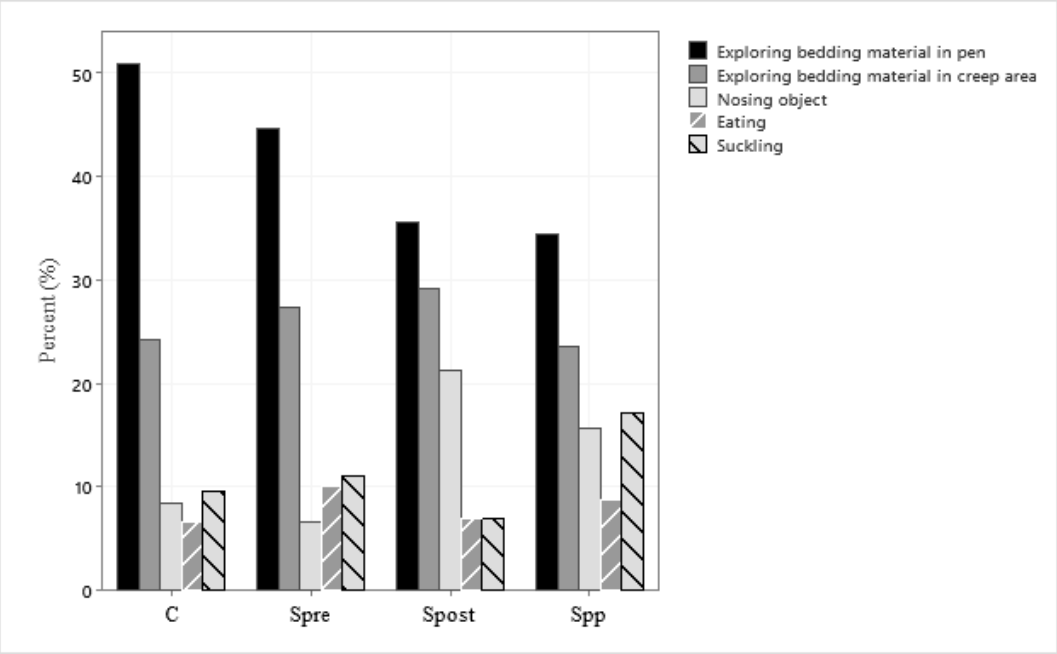

Figure 6. The proportion of times a piglet spent performing the different foraging and exploratory behaviors. N = 765 minutes.

Of all the social interactions, the most common social interaction was nosing pig (C: 54.2 %; S_{pre}: 41.1 %; S_{post}: 43.8 %; S_{pp}: 47.5 %), followed by head knock (C: 33.4 %; S_{pre}: 41.1 %; S_{post}: 34.4 %; S_{pp}: 32.3 %), and biting (C: 6.02 %; S_{pre}: 14.4

%; S_{post}: 10.9 %; S_{pp}: 12.1 %) (Figure 7). Other types of social interactions included in this study, was observed in a varying degree, and with a relatively small share of the time (Figure 7). Ear and tail biting occurred more among the pigs in S_{pp}, with 6.1 %.

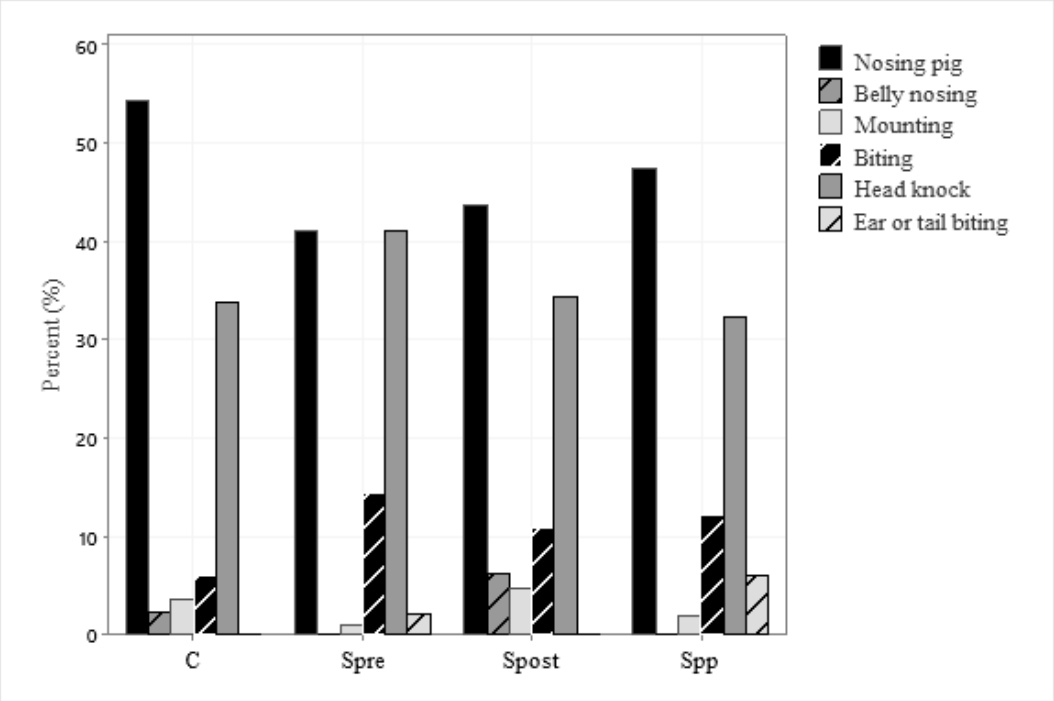

Figure 7. The proportion of times a piglet spent performing the different social behaviors. N = 765 minutes.

3.3.2. Statistical analyses

Level of significance for effects, included in the statistical model, on piglets' behavior can be found in Table 11. For example, treatment had a significant effect on nosing object ($P < 0.01$), ear or tail biting ($P < 0.05$), and suckling ($P < 0.001$). No significant effect was found on time of day or the different observation minutes. Like the scan samplings, the continuous sampling showed a significantly ($P < 0.05$) higher performance of exploring bedding material in creep area post-weaning, as well as nosing object, and nosing pig. Eating was significantly ($P < 0.05$) higher post-weaning. The category other behaviors in the ethogram, was significantly ($P < 0.01$) affected by observation period and batch (Table 11). These behaviors were most performed post-weaning ($P < 0.05$), and in the second batch.

Table 10. Level of significance (P-value) for the different effects in the statistical model for the continuous sampling.

Response variable	Treatment	Observation period (pre- or post-weaning)	Time (am or pm)	Batch	Minute	Observation period * treatment	Time * treatment
Exploring bedding material in pen	n.s.	#	n.s.	n.s.	n.s.	n.s.	< 0.05
Exploring bedding material in creep area	n.s.	< 0.01	n.s.	n.s.	n.s.	n.s.	n.s.
Nosing object	< 0.01	< 0.01	n.s.	n.s.	n.s.	n.s.	< 0.05
Nosing pig	n.s.	< 0.01	n.s.	n.s.	n.s.	n.s.	n.s.
Belly nosing	n.s.	< 0.05	n.s.	n.s.	n.s.	n.s.	< 0.05
Mounting	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Biting	n.s.	n.s.	n.s.	n.s.	n.s.	#	n.s.
Head knock	n.s.	n.s.	n.s.	< 0.01	n.s.	#	n.s.
Ear or tail biting	< 0.05	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Eating	n.s.	< 0.001	n.s.	#	n.s.	< 0.05	n.s.
Suckling (pre-weaning)	< 0.001	< 0.001	n.s.	< 0.05	n.s.	< 0.001	n.s.
Other behavior	n.s.	< 0.01	n.s.	< 0.01	n.s.	n.s.	< 0.05

n.s. = not significant # = tendency to significance ($P < 0.1$)

Nosing object was performed significantly more often ($P < 0.05$) in S_{post} and S_{pp} (Table 12). Regarding ear or tail biting, this was significantly less performed in C and S_{post}, compared to S_{pp} ($P < 0.05$). Further, suckling was significantly higher ($P < 0.05$) in S_{pp} compared with the other treatments. Observation period had an effect on nosing object, with more nosing in the post-weaning period.

Table 11. The corrected mean number of times a focal animal in every treatment, and observation period, performed each behavior per 3 minutes of continuous observation. N = 765 minutes.

	Treatment					Observation period		
	C	S_{pre}	S_{post}	S_{pp}	P-value	Pre-weaning	Post-weaning	P-value
Exploring bedding material in pen	3.50	3.67	2.79	2.92	0.434	2.83	3.60	0.089
Exploring bedding material in creep area	1.67	2.25	2.29	2.00	0.448	1.60^{A}	2.50^{B}	0.004
Nosing object	0.583^{A}	0.542^{A}	1.67^{B}	$1.33^{A\ B}$	0.008	0.667^{A}	1.40^{B}	0.009
Nosing pig	1.88	1.54	1.17	1.96	0.305	1.19^{A}	2.08^{B}	0.007
Belly nosing	0.0833	0.00	0.167	0.00	0.164	0.00^{A}	0.125^{B}	0.171
Mounting	0.125	0.0417	0.125	0.0833	0.794	0.0625	0.125	0.361
Biting	0.208	0.542	0.292	0.500	0.474	0.271	0.500	0.195
Head knock	1.17	1.54	0.917	1.33	0.608	1.08	1.40	0.357
Ear or tail biting	0.00^{A}	$0.0833^{A\ B}$	0.00^{A}	0.250^{B}	0.021	0.0417	0.125	0.194
Eating	0.458	0.833	0.542	0.750	0.268	0.271^{A}	1.02^{B}	< 0.001
Suckling (pre-weaning)	0.007^{A}	0.917^{A}	0.542^{A}	1.46^{B}	< 0.001	1.79^{A}	0.00^{B}	< 0.001
Other	5.04	4.96	5.58	4.79	0.513	4.54^{A}	5.65^{B}	0.006

Different letters$^{A\ B}$ in the same effect and row indicate pairwise differences of $P < 0.05$.

When all the behaviors were combined to the four categories foraging and exploring, investigation social interactions and undesirable social interactions and other behaviors no significant effect of treatment was found (Table 13).

Table 12. The corrected mean number of times a focal animal in each treatment performed each behavioral category per 3 minutes of continuous observation. N = 765 minutes.

	Treatment				
	C	S_{pre}	S_{post}	S_{pp}	P-value
Foraging and exploring	6.88	8.21	7.83	8.46	0.333
Investigation social interactions	1.88	1.54	1.17	1.96	0.305
Undesirable social interactions	1.58	2.21	1.50	2.17	0.620
Other behaviors	5.04	4.96	5.58	4.79	0.513

4. Discussion

4.1. Silage intake and body weight

The silage given had a low content of NDF, which is preferable to pigs. Since the crop is being lignified with delay of harvest, the NDF level increases, and thus the digestibility (Frame & Laidlaw, 2011). The content of lactic acid, as well as the pH, indicate that the silage was of good quality (Table 1). Further, as all silage was consumed the same day. This also indicates that the silage was palatable.

Regarding the BW of the piglets, S_{pp} weight the least when entering the study. This may be explained by the number of piglets reared in the same pen, where S_{pp} was the largest group (14-15 piglets) of all groups in both batches. Because of this, the competition for feed (i.e., milk from the sow, solid feed from the piglet feeder, and silage) was larger in these groups compared to the other, smaller groups. The silage had an effect on growth, where the growth was significant of piglets' receiving silage post-weaning (S_{post} and S_{pp}) from day 8 (day of weaning). No effect of silage on growth pre-weaning was found. The reason for this could be that older pigs have higher capacity to digest dietary fiber (Wallenbeck *et al.,* 2015), thus the piglets post-weaning could utilize the silage to a higher extent. Further, there was a difference on growth between the two batches throughout the study. Even though the start weight of the piglets was corrected for in the statistical analyses, this might have been affected by individual variations due to e.g., health status and feed consumption. There was a tendency that batch had an effect on the piglets' eating behavior, where eating was seen more in the second batch.

4.2. The effects of silage

The hypothesis was that a significant difference would be found in foraging and exploratory behaviors between pigs that had access to silage compared to pigs that only had access to straw, where piglets receiving silage will have an increased performance of foraging and exploratory behaviors. We could not find any

significant differences between the piglets in the different treatments regarding these behaviors. However, piglets receiving silage both pre- and post-weaning (S_{pp}) spent numerically most time performing foraging- and explorative-related behaviors. This confirms previous studies (Olsen *et al.,* 2002; Jensen & Pedersen, 2007; Presto *et al.,* 2013; Holinger *et al.*, 2018), where silage, in addition to straw, stimulates these behaviors. One reason for this could be that the rooting substrates becomes more varied and thus expands the behavior repertoire. Another reason could be the smell of the silage, which have a more distinctive smell than straw. Pigs have a well-developed sense of smell, which is used when the pigs are e.g., foraging and communication (Špinka *et al*., 2009), and silage may stimulate and pro-long foraging and exploring. Further, according to Jensen *et al.,* (2010), silage is more nutritious and heterogeneous compared to straw. This may explain why silage stimulated more foraging and exploratory behavior in S_{pp}. The other hypothesis was that the piglets who had access to silage both prior to and after weaning would interact more with the silage after weaning, compared to the piglets that did not receive silage prior to weaning. We found no significant difference in this behavior if the piglets had access to silage both pre- and post-weaning. In the study by Docking *et al.* (2008), the suckling piglets used the EEs to a smaller extent compared to the weaned piglets. In this present study, this could be confirmed, as the observation period, pre- or post-weaning, showed a significant effect on exploring bedding material in creep area, and a tendency to significance regarding exploring bedding material in pen.

Silage have a positive effect on pigs' behavior, though it may depend on how it is given and its properties. Silage in combination with straw may decrease aggression (Jensen & Pedersen, 2007), whereas silage as a single rooting material might be less effective preventing aggression, compared to peat and straw (Ocepek *et al.,* 2020a). In the present study, a significant difference was found in ear or tail biting, where it was performed the most among piglets in S_{pp}. According to previous studies, it could be expected that the results in this study would have been the opposite: where a mixture of different rooting substrates, which includes silage, increases the pigs' play behavior and decreased the manipulation of ears and tails of other pigs (Ocepek *et al.,* 2020a). Further, the piglets in this present study finished the silage very rapidly after it was given and did not occupy the piglets for such a long time. This goes in line with the results from the study by Ocepek *et al.* (2020a), where the silage was consumed to a high extent. Due to this, silage may not be a long-lasting rooting material for pigs to manipulate and explore throughout the whole day, and till a new silage ration is given to the piglets. Though, what can be discussed is the amount of silage given to the piglets in this master thesis. As 1 kg of silage is not an enormous amount, unsurprisingly that the piglets consumed it, and thus not had the possibility to redirect exploratory behaviors toward other

piglets as desired. In the study by Ocepek *et al.* (2020a), timothy silage was used, whereas Jensen & Pedersen (2007) used maize silage. Both these studies compared silage and straw as rooting materials provided to pigs, but the type of straw also differed between these two researches: long-stemmed oat straw and chopped barley straw respectively. This makes the two studies by Jensen & Pedersen (2007) and Ocepek *et al.* (2020a) less comparable to each other. Different silages have different e.g., properties and smell, depending on what crop has been used. At the same time, it enhances the importance of the outcome of the EE rather than the EE itself. This could have affected the pigs' behavior toward the substrate in both these studies. In this present study, the silage did not occupy the piglets for as long as expected, but it was consumed almost right away. If the piglets would have been provided with a larger amount, or silage with longer stems, the results regarding the social interaction might have been different.

In the study by Jensen *et al.,* (2010), the result indicated that both the rooting substrate itself and space allowance affect the animals' behavior toward the rooting substrate. In the present study, space allowance per piglet differed since the pens did not house the same number of piglets. Higher stocking density may decrease both the accessibility to the EE, as well as it increases the possibility for social interaction due to the piglets being closer to each other. This present study could neither confirm nor reject this theory, as the effect of group size on behavior was not investigated. However, S_{pp}, who spent numerically the most time foraging and exploring, compared to the other groups, had the highest stocking density in both batches (14-15 piglets), compared to i.e., C which had the lowest stocking density in both batches (10-12 piglets).

One positive aspect using silage as an EE is that it is not a 'fixed' substrate. Lewis *et al.* (2006) compared ropes and shredded paper as EE to piglets in farrowing crates. The same authors concluded that the piglets spent longer time interacting with the paper compared to the ropes. This was explained as the ropes were not as movable as the paper was and all piglets could not interact with the ropes at the same time. EE that piglets need to compete for to access stimulates aggression (Lewis *et al.,* 2006) and social competition, since pigs are synchronized in their behavior (Docking *et al.*, 2008). Though, another study has shown that fixed, hanging toys may stimulate more play behavior in piglets, compared to free toys on ground level (Blackshaw *et al.,* 1997). It has been discussed that free toys on ground level easily get caught under or between pen fittings, e.g., the feed trough, pushed into other pens or get soiled by faces (Blackshaw *et al.,* 1997), and thus is not an optimal EE. In this present study, the silage was placed on the floor but did not become dirty by feces. Further, no differences were found between the treatments regarding behaviors that could be related to aggression, e.g., biting and head

knocking. Reasons for this could be that the silage was, as mentioned above, placed on the floor, which made the EE accessible to multiple animals at the same time.

In previous studies, play behaviors are seen as positive behaviors (Martin *et al.,* 2015: Ocepek *et al*., 2020a) indicating increased welfare. Despite this, play behaviors were excluded from the ethogram as these behaviors were thought to not contribute to the research aims for this thesis. For example, when gamboling was seen during the observations, this was recorded as other behavior, as the definition of social interaction in the ethogram is defined as physical contact between two individuals.

The recording of the social interactions during the continuous sampling may not reflect the actual social interactions that took place. When recording a focal animal's behavior, other pen mates may have interacted socially, and thus not been recorded. For example, while a focal animal was sleeping in the creep area, other pen mates may have played and interacted socially. Further, at the same time a focal animal was lying down during the continuous observation, another piglet may have belly nosing this focal animal. When a social interaction was recorded, it was the piglet who performed the interaction that was recorded and not the piglet receiving the interaction. For example, if piglet A nosed piglet B, who was laying down, this was recorded as one piglet was socially interacting and one piglet was laying down. Further, if piglet A and B were head knocking against each other, this was recorded as two social interactions.

One of the questions asked in this study was to see if provision of silage would change the animals' behavior, regarding social interactions. Further, the objective was to see if the performance of undesirable behaviors, like biting, head knocks and ear or tail biting, would change if the piglets have access to silage. For example, these behaviors can cause wounds (Oostindjer *et al*., 2014) and thus, are undesirable. When losing an EE, the foraging and exploring that have been stimulated by the EE are being redirected towards other pigs (e.g., Munsterhjelm *et al.,* 2009). In this present study S_{pre}, who only had access to silage pre-weaning, could have developed redirected manipulating behavior toward other piglets housed in the same pen as they lost an EE, in this study silage, at weaning. This present study did not show a significant difference between groups regarding undesirable social behaviors as a behavioral category. However, these undesirable social behaviors were seen more frequently within S_{pre}, compared to the other groups. This goes in line with the study by Munsterhjelm *et al.* (2009), where pigs who lost their enrichment redirected their explorative behavior towards pen fittings and pen mates. If this present study would have been performed for a longer period, there might have been a different result. The relatively high number of head knocks observed among the control group (C), pre-weaning, might have resulted in a

greater number of exploring bedding material in creep area being recorded. This could be due to a subordinate piglet, who wanted to get away from a dominant piglet, and thus stopped exploring the bedding material in the pen and moved to the creep area to explore the bedding material in that area instead.

No significance between the groups was found regarding the social interactions in general. In growing-finishing pigs, chopped straw does not seem to decrease negative social interactions compared to silage (Jensen *et al*., 2010). The silage used in this present study was short stemmed, approximately 5-8 centimeters. If the piglets in this present study were provided with intact (long) silage, the negative social interactions may have been lower, and the differences might have been the opposite (having higher prevalence of undesirable social behaviors in C). Since the silage was short stemmed, it may primarily have been an additional feed source for the piglets and not an additional rooting substrate to keep them more occupied performing foraging and explorative behavior. The differences in ear and tail biting between the groups might have been caused due to individual personalities and group dynamics. Since ear and tail biting only was seen in two of the four groups, S_{pre} and S_{pp}, the explanations described above may be possible reasons for the result of these behavioral differences.

4.3. Social, ethical and sustainability aspects

From a social sustainability aspect, silage may be a better alternative than straw. Because silage contains more water and less DM than straw, it may also decrease the dust levels in the stable and thus improves the air quality for both the animals and the stable personnel. Straw is a commonly used rooting substrate, but it could cause problems with manure management (Scott *et al*., 2007; Jensen *et al*., 2010). Enrichments placed directly on the floor, in this study both straw and silage, may get the pigs to lose interest if these get dirty with feces and urine (Mkwanazi *et al*., 2019), and thus later on have to be cleaned out. This could lead to an overload in the manure management, by clogging the system, and increases the workload on the stable personnel who need to put time and effort to mend and reestablish the system to make it run again. As silage seems to be consumed to a higher extent compared to straw (e.g., Ocepek *et al.,* 2020a), less silage may be left and needs to be cleaned out the next day.

Pigs housed in barren environments are less active compared to pigs reared in environments provided with EE (McKinnon *et al.,* 1989; Bolhuis *et al.,* 2005). Further, animals kept in substrate-enriched environment have a more diverse behavior repertoire (Wemelsfelder *et al.,* 2000). From an ethical point of view, it

could be discussed how we want our domestic animals to behave. Do we want animals to be less active, and thus maybe less prone to explore their environment? Or the opposite, encourage their natural exploratory and foraging behaviors by providing suitable substrates they could chew on, manipulate and ingest? The first example may lead us into a path where the domestic animals are more viewed as 'animal machines' rather than actual living beings, or the latter, that might increase oral manipulative behaviors toward other pen mates causing various forms of body wounds. Some people might think that straw is good enough as a rooting substrate to pigs, as this keeps the animals occupied (to some extent), and that no additional rooting material needs to be added. On the other hand, other people might think the opposite: that only provide straw to pigs is not good enough, as in the wild there exists more than one type of rooting substrates and multiple more environmental factors than the environment in conventional production. Then, by providing pigs with silage, in addition to straw, foraging and exploratory behaviors are stimulated to a higher extent (Jensen & Pedersen, 2007; Presto *et al.,* 2013), and play behavior is increased (Olsen *et al.,* 2002; Ocepek *et al.,* 2020a). To conclude, a mixture of diverse rooting substrates, as mentioned above, enhances the foraging behaviors in these animals. As observed in this present study, behaviors related to foraging and exploring were seen numerically more frequent in groups receiving silage (S_{pre}, S_{post}, S_{pp}), compared to C that did not received silage.

Ley crops with clover and other legumes contribute to increase the carbon storage and lowers the risk of field nitrogen (N) and phosphor (P) losses, compared to if annual crops are grown (Aronsson *et al.,* 2007, Eriksson *et al*., 2010). They are important for increased soil fertility and biodiversity and in organic production systems, where the use of artificial fertilizers is banned, mixed leys are substantial as the system relies on the legumes for nitrogen supply. Legumes can substitute other protein sources for pigs as they show a favorable protein and amino acid composition (M. Åkerfeldt, SLU, personal message, 21st May 2021). Fermented silage can contribute with lactic acid bacteria and lower pH (M. Åkerfeldt, SLU, personal message, 21st May 2021). This can limit the growth of several potential pathogenic bacteria such as enterobacteria and have beneficial effects on gut health. Although this was not studied in the present work, it is an interesting aspect for improved gut health and less problems with weaning diarrhea. Ensiling of cut ley, makes the resource an all-year-round alternative.

4.4. Advantages and disadvantages with chosen study

While performing behavioral observations live, and being close to the animals, it is difficult to not affect the animals. During a few observations, some piglets were

curious about the observer and was standing and looking toward the observer. This may have affected the results to some extent, as a focal animal during the 3 minute-continuous recording could be standing and looking at the observer. This was then recorded as other behavior (standing). Additionally, some groups were easier to observe than others. This may be due to both the placement of the pens, as well as piglets are different individuals and react differently on humans. For example, when performing scans in the second batch, S_{post} was always the easiest scan to perform, as the piglets did not react, compared to observing S_{pp}, which was the most difficult group to observe as these piglets reacted on the observer very often. Even though the piglets seemed to be acclimatized toward the observer during the acclimatization period, there was always piglets reacting to the observer. No matter if the observer approached this pen the same way as during the acclimatization period, or quietly.

On the days of observation, the observer herself put the silage in the creep area before each observation. After the silage was given to the piglets, the observer continued to walk back and forth, 2-3 times, in the middle aisle (approximately 2 minutes) before the observation started. These additional 2 minutes of acclimatization was performed to try to get a general picture of the piglets' behavior toward the silage. Since pigs are naturally curious animals (Studnitz *et al.* 2007), the majority of the piglets in the pen explored the silage almost immediately after it was given. In general, there was always some silage left after the observation ended, indicating that the 2 extra minutes of acclimatization after the piglets were fed with silage did not jeopardize the piglets to finish the silage during the behavioral observation. Looking back at this method, including the observer's involvement as well as the few minutes before the recordings started, this may be an advantage for this study. If the stable personnel would have put the silage in the pen directly after cleaning it, the risk of having the piglets finish the silage during the observation could have been great.

Another strength was that this research included different treatments and scenarios: one control group receiving no silage (C) and three groups receiving silage pre- or postweaning (S_{pre}, S_{post}), and both pre- and post-weaning (S_{pp}). Even though regrouping is a common practice in pig production, there were no regroupings after weaning in this study. By not regrouping the piglets, the outcome of having access to silage could be made. Perhaps, if regrouping would have occurred, more interactions and stress, due to changes in the piglets' social structure, would have been observed. Regrouping may increase undesirable social interactions, like fighting and aggression (Weary *et al.,* 2008; Špinka, 2009), and regrouping would then have to be considered when evaluating the effect of silage.

This master thesis did not include the possible health aspects, e.g., feed-intake and post-weaning diarrhea, when providing silage to piglets. Neither did the sow have the possibility to interact with the silage (unless the piglets spread out the silage to the rest of the pen). Multiple studies (e.g., Cox & Cooper, 2001; Oostindjer *et al.,* 2014) discuss the sow's role in the pre-weaning period to show, and to be a part of the development of the piglets' foraging-related behaviors, also known as 'social learning'. In this present study, the silage was intentionally placed in the creep area to minimize the risk of having the sow eating it instead of the piglets. Looking at the aim and hypotheses of this study, the placement of the silage speaks to the study's advantage. Further, as the piglets interacted with the silage immediately after it was given, there did not seem to be a need of 'social learning' on how to eat silage.

What could be seen as a larger disadvantage is how short this study was carried out (15 days in total, one week post-weaning). Though, what needs to be considered is that this is a master thesis and, thus have a time limit. Further, the amount of silage, 1 kg, was quite small and was finished by the piglets rapidly. This makes it difficult to compare and draw conclusions about the long-term effect regarding behavior and social interaction between the different treatments.

4.4.1. Limitations

This study did not include evaluation of any possible effects due to the chemical composition or the properties of the silage, such as time of harvest or nutritional value. Further, as the main focus in this study was on the piglets' behavior, effects of the silage on the gut health and general health of the piglets were not included.

4.5. Application of this study

Multiple studies indicate that pigs are affected by earlier environment experiences, pre- and/or post-weaning (Cox & Cooper, 2001; Lewis *et al.,* 2006; Ko *et al.,* 2020). As the present study was carried out during a relative short time period, and the amount of silage given was small, it is difficult to draw reasonable conclusions about the effect of silage and the applicability of using it in commercial pig production. However, access to silage during the pre-weaning had an effect on increased suckling behavior. Providing piglets with silage during the post-weaning period increased growth rate during the same time period. In this present study, no effect of receiving silage both pre- and post-weaning were found on foraging and exploring behaviors. However, the piglets numerically increased their foraging and

exploring behaviors by being provided with silage in addition to straw, which might be an interesting aspect to take into account from an animal welfare perspective. Looking at these results in general, silage could be a beneficial input for improved growth and may increase foraging and exploratory behaviors in piglets. Further, silage may also enhance gut health (Abe *et al*., 1995; Guerra *et al.,* 2007).

This study is one of, relatively, few studies performed about silage's effect on piglets. Hopefully this master thesis rises the bigger question on how already established products in agriculture, like silage, could be applicated in pig production and increase the welfare of the piglets in connection to weaning.

4.6. Future studies

There are several future studies that are welcomed to be performed in this area. Some of these are:

- A more prolonged research like this present study, which perhaps enables to see the silage's long-term effects.
- Looking at the effects of silage in connection with weaning when regrouping the animals. In connection with weaning, several difficulties may arise, like fighting and aggression due to regrouping (Puppe *et al*., 1997; Weary *et al.,* 2008; Middelkoop *et al.,* 2019). Would these social difficulties decrease if piglets are provided with silage?
- Investigate if piglets have a preference regarding the length of the silage. For example, growing pigs seem to prefer long-stemmed straw than chopped straw, as they interact more with the rooting material when it is more intact (Day *et al.,* 2008; Bulens *et al.,* 2015).
- If silage has an effect on the piglets' gut health and possibly prevent, or decrease, post-weaning diarrhea. Though diarrhea is multifactorial (Madec *et al.,* 2000; Oostindjer *et al*., 2014; Ruiz *et al*., 2016), silage may promote gut health, as it contains LAB and act as a probiotic substance (Abe *et al.,* 1995; Guerra *et al.,* 2007) and increase the piglets' solid feed-intake pre-weaning.
- Are there any behavioral differences between breeds and/or individuals when providing silage? Previous studies, performing pig personality tests (back tests), in combination to enrichments, show individual behavior response on housing environment (Bolhuis *et al.,* 2006).
- How the farmer's conventional production is affected by providing the piglets silage, in addition to straw. Regarding the economy, workload as well as the technical functions installed in the stable, like the slurry system.

5. Conclusion

This study indicates that foraging and exploring behaviors increased in general, by giving the piglets access to silage in addition to straw. However, the study could not confirm any differences in behavior between piglets that were provided with silage pre-weaning, compared with those that only received silage post-weaning. Provision of silage in this study did not have any effect on the occurrence of social interactions between the piglets. Neither did it change the occurrence of unwanted behaviors among the piglets. Due to the silage's properties, i.e., scent and nutrient composition, it may be a good enrichment and have potential to promote pigs' gastric health.

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Appendix 1

The protocol used for the behavioral observations, created from the ethogram (Table 2).

Date: _____ Time: _____ Batch, stable: _____

Session 1

Scan, groups 1-4

Group	Standing, sitting	Lying down	Exploring bedding material in Pen	Exploring bedding material in Creep area	Nosing object	Social interaction	Eating	Suckling (pre-weaning)	Other behavior	Total
1										
2										
3										
4										

Continuous, group 1 Focal animal-ID (1st):

Time	Exploring bedding material in Pen	Exploring bedding material in Creep area	Nosing object	Social interaction: Nosing pig	Social interaction: Belly nosing	Social interaction: Mounting	Social interaction: Biting	Social interaction: Head knock	Social interaction: Ear/tail biting	Eating	Suckling (pre-weaning)	Other behavior
1st minute												
2nd minute												
3rd minute												

Scan, groups 1-4

Group	Standing, sitting	Lying down	Exploring bedding material in Pen	Exploring bedding material in Creep area	Nosing object	Social interaction	Eating	Suckling (pre-weaning)	Other behavior	Total
1										
2										
3										
4										

Continuous, group 2 Focal animal-ID (1st):

Time	Exploring bedding material in Pen	Exploring bedding material in Creep area	Nosing object	Social interaction: Nosing pig	Social interaction: Belly nosing	Social interaction: Mounting	Social interaction: Biting	Social interaction: Head knock	Social interaction: Ear/tail biting	Eating	Suckling (pre-weaning)	Other behavior
1st minute												
2nd minute												
3rd minute												

Scan, groups 1-4

Group	Standing, sitting	Lying down	Exploring bedding material in Pen	Exploring bedding material in Creep area	Nosing object	Social interaction	Eating	Suckling (pre-weaning)	Other behavior	Total
1										
2										
3										
4										

Continuous, group 3 Focal animal-ID (1st):

Time	Exploring bedding material in Pen	Exploring bedding material in Creep area	Nosing object	Social interaction: Nosing pig	Social interaction: Belly nosing	Social interaction: Mounting	Social interaction: Biting	Social interaction: Head knock	Social interaction: Ear/tail biting	Eating	Suckling (pre-weaning)	Other behavior
1st minute												
2nd minute												
3rd minute												

Scan, groups 1-4

Group	Standing, sitting	Lying down	Exploring bedding material in Pen	Exploring bedding material in Creep area	Nosing object	Social interaction	Eating	Suckling (pre-weaning)	Other behavior	Total
1										
2										
3										
4										

Continuous, group 4 Focal animal-ID (1st):

Time	Exploring bedding material in Pen	Exploring bedding material in Creep area	Nosing object	Social interaction: Nosing pig	Social interaction: Belly nosing	Social interaction: Mounting	Social interaction: Biting	Social interaction: Head knock	Social interaction: Ear/tail biting	Eating	Suckling (pre-weaning)	Other behavior
1st minute												
2nd minute												
3rd minute												

End of session 1.

Session 2

Scan, groups 1-4

Group	Standing, sitting	Lying down	Exploring bedding material in Pen	Exploring bedding material in Creep area	Nosing object	Social interaction	Eating	Suckling (pre-weaning)	Other behavior	Total
1										
2										
3										
4										

Continuous, group 1 Focal animal-ID (2nd):

Time	Exploring bedding material in Pen	Exploring bedding material in Creep area	Nosing object	Social interaction: Nosing pig	Social interaction: Belly nosing	Social interaction: Mounting	Social interaction: Biting	Social interaction: Head knock	Social interaction: Ear/tail biting	Eating	Suckling (pre-weaning)	Other behavior
1st minute												
2nd minute												
3rd minute												

Scan, groups 1-4

Group	Standing, sitting	Lying down	Exploring bedding material in Pen	Exploring bedding material in Creep area	Nosing object	Social interaction	Eating	Suckling (pre-weaning)	Other behavior	Total
1										
2										
3										
4										

Continuous, group 2 Focal animal-ID (2nd):

Time	Exploring bedding material in Pen	Exploring bedding material in Creep area	Nosing object	Social interaction: Nosing pig	Social interaction: Belly nosing	Social interaction: Mounting	Social interaction: Biting	Social interaction: Head knock	Social interaction: Ear/tail biting	Eating	Suckling (pre-weaning)	Other behavior
1st minute												
2nd minute												
3rd minute												

Scan, groups 1-4

Group	Standing, sitting	Lying down	Exploring bedding material in Pen	Exploring bedding material in Creep area	Nosing object	Social interaction	Eating	Suckling (pre-weaning)	Other behavior	Total
1										
2										
3										
4										

Continuous, group 3 Focal animal-ID (2nd):

Time	Exploring bedding material in Pen	Exploring bedding material in Creep area	Nosing object	Social interaction: Nosing pig	Social interaction: Belly nosing	Social interaction: Mounting	Social interaction: Biting	Social interaction: Head knock	Social interaction: Ear/tail biting	Eating	Suckling (pre-weaning)	Other behavior
1st minute												
2nd minute												
3rd minute												

Scan, groups 1-4

Group	Standing, sitting	Lying down	Exploring bedding material in Pen	Exploring bedding material in Creep area	Nosing object	Social interaction	Eating	Suckling (pre-weaning)	Other behavior	Total
1										
2										
3										
4										

Continuous, group 4 Focal animal-ID (2nd):

Time	Exploring bedding material in Pen	Exploring bedding material in Creep area	Nosing object	Social interaction: Nosing pig	Social interaction: Belly nosing	Social interaction: Mounting	Social interaction: Biting	Social interaction: Head knock	Social interaction: Ear/tail biting	Eating	Suckling (pre-weaning)	Other behavior
1st minute												
2nd minute												
3rd minute												

End of session 2.

Session 3

Scan, groups 1-4

Group	Standing, sitting	Lying down	Exploring bedding material in Pen	Exploring bedding material in Creep area	Nosing object	Social interaction	Eating	Suckling (pre-weaning)	Other behavior	Total
1										
2										
3										
4										

Continuous, group 1 Focal animal-ID (3rd):

Time	Exploring bedding material in Pen	Exploring bedding material in Creep area	Nosing object	Social interaction: Nosing pig	Social interaction: Belly nosing	Social interaction: Mounting	Social interaction: Biting	Social interaction: Head knock	Social interaction: Ear/tail biting	Eating	Suckling (pre-weaning)	Other behavior
1st minute												
2nd minute												
3rd minute												

Scan, groups 1-4

Group	Standing, sitting	Lying down	Exploring bedding material in Pen	Exploring bedding material in Creep area	Nosing object	Social interaction	Eating	Suckling (pre-weaning)	Other behavior	Total
1										
2										
3										
4										

Continuous, group 2 Focal animal-ID (3rd):

Time	Exploring bedding material in Pen	Exploring bedding material in Creep area	Nosing object	Social interaction: Nosing pig	Social interaction: Belly nosing	Social interaction: Mounting	Social interaction: Biting	Social interaction: Head knock	Social interaction: Ear/tail biting	Eating	Suckling (pre-weaning)	Other behavior
1st minute												
2nd minute												
3rd minute												

Scan, groups 1-4

Group	Standing, sitting	Lying down	Exploring bedding material in Pen	Exploring bedding material in Creep area	Nosing object	Social interaction	Eating	Suckling (pre-weaning)	Other behavior	Total
1										
2										
3										
4										

Continuous, group 3 Focal animal-ID (3rd):

Time	Exploring bedding material in Pen	Exploring bedding material in Creep area	Nosing object	Social interaction: Nosing pig	Social interaction: Belly nosing	Social interaction: Mounting	Social interaction: Biting	Social interaction: Head knock	Social interaction: Ear/tail biting	Eating	Suckling (pre-weaning)	Other behavior
1st minute												
2nd minute												
3rd minute												

Scan, groups 1-4

Group	Standing, sitting	Lying down	Exploring bedding material in Pen	Exploring bedding material in Creep area	Nosing object	Social interaction	Eating	Suckling (pre-weaning)	Other behavior	Total
1										
2										
3										
4										

Continuous, group 4 Focal animal-ID (3rd):

Time	Exploring bedding material in Pen	Exploring bedding material in Creep area	Nosing object	Social interaction: Nosing pig	Social interaction: Belly nosing	Social interaction: Mounting	Social interaction: Biting	Social interaction: Head knock	Social interaction: Ear/tail biting	Eating	Suckling (pre-weaning)	Other behavior
1st minute												
2nd minute												
3rd minute												

End of session 3.

Session 4

Scan, groups 1-4

Group	Standing, sitting	Lying down	Exploring bedding material in Pen	Exploring bedding material in Creep area	Nosing object	Social interaction	Eating	Suckling (pre-weaning)	Other behavior	Total
1										
2										
3										
4										

Continuous, group 1 Focal animal-ID (4th):

Time	Exploring bedding material in Pen	Exploring bedding material in Creep area	Nosing object	Social interaction: Nosing pig	Social interaction: Belly nosing	Social interaction: Mounting	Social interaction: Biting	Social interaction: Head knock	Social interaction: Ear/tail biting	Eating	Suckling (pre-weaning)	Other behavior
1st minute												
2nd minute												
3rd minute												

Scan, groups 1-4

Group	Standing, sitting	Lying down	Exploring bedding material in Pen	Exploring bedding material in Creep area	Nosing object	Social interaction	Eating	Suckling (pre-weaning)	Other behavior	Total
1										
2										
3										
4										

Continuous, group 2 Focal animal-ID (4th):

Time	Exploring bedding material in Pen	Exploring bedding material in Creep area	Nosing object	Social interaction: Nosing pig	Social interaction: Belly nosing	Social interaction: Mounting	Social interaction: Biting	Social interaction: Head knock	Social interaction: Ear/tail biting	Eating	Suckling (pre-weaning)	Other behavior
1st minute												
2nd minute												
3rd minute												

Scan, groups 1-4

Group	Standing, sitting	Lying down	Exploring bedding material in Pen	Exploring bedding material in Creep area	Nosing object	Social interaction	Eating	Suckling (pre-weaning)	Other behavior	Total
1										
2										
3										
4										

Continuous, group 3 Focal animal-ID (4th):

Time	Exploring bedding material in Pen	Exploring bedding material in Creep area	Nosing object	Social interaction: Nosing pig	Social interaction: Belly nosing	Social interaction: Mounting	Social interaction: Biting	Social interaction: Head knock	Social interaction: Ear/tail biting	Eating	Suckling (pre-weaning)	Other behavior
1st minute												
2nd minute												
3rd minute												

Scan, groups 1-4

Group	Standing, sitting	Lying down	Exploring bedding material in Pen	Exploring bedding material in Creep area	Nosing object	Social interaction	Eating	Suckling (pre-weaning)	Other behavior	Total
1										
2										
3										
4										

Continuous, group 4 Focal animal-ID (4th):

Time	Exploring bedding material in Pen	Exploring bedding material in Creep area	Nosing object	Social interaction: Nosing pig	Social interaction: Belly nosing	Social interaction: Mounting	Social interaction: Biting	Social interaction: Head knock	Social interaction: Ear/tail biting	Eating	Suckling (pre-weaning)	Other behavior
1st minute												
2nd minute												
3rd minute												

End of session 4. End of this observation.

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