Environmental influences on the piglets’ decision ‘where to eliminate’.

An observational study

Ollie van Hal
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Supervisors:
Dr. Inonge Reimert
Dr. ir. Liesbeth Bolhuis
Adaptation Physiology Group (ADP)
Wageningen University
Ollie van Hal (890705299120)

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**Supervisors:**

Dr. Inonge Reimert

Dr. ir. Liesbeth Bolhuis

March 16th 2015

Adaptation Physiology Group (ADP)

Wageningen University
Abstract

The pigs' natural behaviour to use separate areas for lying and eliminating, is often applied in commercial pig housing to direct the pigs to eliminate in a selected toilet area, that is provided with a slatted floor. Pigs, however, do not always display the desired behaviour, leading to displaced eliminations on the solid floor, and thus a decreased pen hygiene. The reduction in pen hygiene increases environmental pollution and the farmers' workload, while reducing animal health and welfare. To minimise the amount of displaced eliminations, understanding of the eliminative behaviour in pigs and its development is needed. This observatory study, with excessive literature review, was performed to assess how pigs decide 'where to eliminate' and how their eliminative behaviour can be directed.

Previous studies indicated that the eliminative preferences of piglets develop in the first days after birth. Whether these preferences are innate or learned from the sow, however, is not known. Therefore, the first research question was: "How does the eliminative behaviour of piglets develop?". The literature review revealed many factors that influence the piglets’ decision 'where to eliminate'. In the second research question; "What factors influence the eliminative behaviour of piglets?", three factors that suit the observatory nature of this study were studied, namely: smell, social environment and the location of functional areas. Additionally, for the third research question; “Do changes in the physical and social environment influence the eliminative behaviour of piglets?”, the effect of two different environmental changes on the eliminative preferences were studied. The environmental changes implied, mixing the piglets and mixing the sows of two adjoining pens, are common practice on the observation farm.

To answer the research questions, nine sows and their piglets were observed. When the piglets were 18 days old, the partition between the nests of two adjoining pens was removed enabling the piglets to move freely in both pens. On day 25 after birth another, and slatted fence between two adjoining pens was removed enabling the sows to move freely in both pens as well.

For research question one, video observations were made on three sows and their piglets on day one, three and five after birth. To statistically compare the location of the eliminations on the three days, the pen was divided in five areas based on the function of the area. Analysis of the observations showed that the fastest piglet eliminated on the toilet area 12 min after his last sibling was born. In the first five days after birth the total amount of eliminations increased each day, in agreement with earlier findings. Moreover, the amount of eliminations in the toilet area increased over time (P<0.0001), while the amount of eliminations in the nest decreased (P<0.0001). This indicates that development of the eliminative behaviour occurred in the first five days after birth as found in other studies. On multiple occasions the sow was seen to push an eliminating piglet to the toilet area, indicating that the sow influences this development.

To analyse the influence of smell on the piglets’ decision 'where to eliminate' live observations were made on four sows and their piglets on the day before, of, and after mixing the piglets and mixing the sows, and on the day before weaning. Analysis of the observations showed that sniffing occurred both before and after eliminating, but less than observed in a former study, which can be explained by the high amount of piglets observed at once in the current study. The proportion of eliminations with associated sniffing [sniffing occurring 2 min before or after elimination] was higher on the day before mixing the sows than on the day before mixing the piglets (P<0.0001), and remained equal on the day before weaning (P=0.1291). This indicates that the importance of smell in the piglets' decision 'where to eliminate' increased over time.

Whether pigs prefer to eliminate in solitude was analysed by comparing the location of the eliminations with the whereabouts of the piglets throughout the day. Analysis showed that the expected amount of eliminations in each area, based on the assumption that piglets eliminate in the area that they stay in, differed from the amount of observed eliminations in each area, for day one (P<0.0001), three (P<0.0001) and five (P<0.0001). The results do not show, however, whether the piglets were alone during elimination, but they do provide strong proof that piglets use separate areas for lying and eliminating. Closer examination of the results shows that on day one the majority of the piglets remained around the sow and eliminated there as well. On day three the piglets stayed in the nest but hardly eliminated there. On day five the time spent in the nest increased while eliminations there decreased even more. This is a strong indication of the development of the eliminative behaviour.

To analyse whether piglets avoid to eliminate in different functional areas, the two adjoining pens were divided in ten areas and each area in which eliminations were made during the live observations was noted. The analysis showed that the amount of eliminations made in the feeding area of the sow and the piglets' nests was lower than expected under the assumption of equal distribution of the eliminations over all areas (P<0.0001 and P<0.0001 resp.). Similar analysis did not show a difference between the expected and observed amount of eliminations in the lying area of the sow (P=0.0672). Eliminations in the lying area of the sow, however, occurred more often if the sow was lying on the slatted floor of the toilet area than when lying on the solid
floor (P<0.0001). Thus, piglets avoid to eliminate in the feeding area of the sow, their own lying area and in the lying area of the sow, but only when the sow is lying on the solid floor. Conversely, if the sow is lying on the slatted floor of the toilet area piglets tend to continue to use this as their elimination site.

For the last question, the two mixing events were used as a model to determine whether piglets changed their elimination site after a change in their environment. No difference was found in the proportion of eliminations made in each of the ten areas between the days around mixing the piglets. The piglets were found, however, to reduce the amount of eliminations on their own toilet area when provided with the ability to eliminate in the adjoining pen (P<0.001). This contradicts earlier statements that the elimination site is static. On the day of mixing the sows, the day after mixing the sows and the day before weaning, the proportion of eliminations made in the two areas between which the slatted fence was removed, decreased. At the same time, the amount of eliminations in the other two toilet areas increased. The slatted fence, therefore, seemed to make these areas more attractive to eliminate in, which can be explained by the areas containing more surface near a wall or corners before removal of the fence. Additionally, the proportion of piglet eliminations in the toilet area of the adjoining pen increased on the day of mixing, probably caused by the eliminations made by their mothers in this area directly after mixing. This could suggest that the area where the sow eliminates influences the piglets’ decision. On the day before weaning the amount of displaced eliminations was significantly reduced, contradicting with literature. In the current study, however, the pig density was much lower.

This study provided insights in the pig’s choice ‘where to eliminate’ and the development of eliminative preferences. First of all, development of eliminative preferences occurred during the first five days after birth as the piglets increasingly eliminated on the preselected toilet area and near the walls and avoided to eliminate in the nest. Additionally, the sow influenced the piglets decision “where to eliminate” both directly, by pushing eliminating piglets on the toilet area, and indirectly as the piglets tended to eliminate where their mother eliminated. Secondly, smell influences the pig’s choice ‘where to eliminate’ as sniffing occurred both before and after eliminating. How smell influences the decision, however, remains unknown. Thirdly, piglets avoid to eliminate in the feeding area, their nest and the lying area of the sow when she was lying on the solid floor, but continue to eliminate on the toilet area if the sow is lying there. Lastly, changes in the environment affect the pig’s decision where to eliminate as the piglets changed their elimination site after both mixing events. Furthermore, this study provided knowledge on how to study the eliminative behaviour in pigs.
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1. Introduction

This study into the influences of the social and physical environment of the piglet on its decision “where to eliminate”, is largely based on the extensive literature review that forms the introduction of this report. The research questions subtracted from this review are mentioned in the last section of this chapter. The methods used to answer these questions, the found results and discussion of the results are discussed thoroughly in the following chapters.

1.1 Pigs’ eliminations

The eliminative posture and the behaviour around elimination have been thoroughly described in literature. On average a healthy pig defaecates four times a day (Van Putten, 1978). During defaecation, the pig stands in a squatting position in which the hind legs are bended to lower the hind, causing the back to bulge (Altmann, 1969; Buchenauer et al., 1982; Whatson, 1985; Ekesbo, 2011) as shown in Figure 1. Additionally, the tail is raised (Buchenauer et al., 1982), the ears point back and the eyes are squinted or closed (Whatson, 1985). During urination, female pigs take the same posture as during defaecation (Buchenauer et al., 1982; Whatson, 1985), but do not show the typical facial expression (Whatson, 1985). Male pigs urinate in the normal standing position (Altmann, 1969; Buchenauer et al., 1982; Ekesbo, 2011) with an upright tail (Buchenauer et al., 1982) and their front legs slightly more forward causing their back to hollow (Whatson, 1985). Piglets’ eliminations often occur after suckling (Buchenauer et al., 1982; Fraser and Broom, 1997), and before elimination pigs often root, while after elimination they often shake their tail, body or head (Buchenauer et al., 1982).

The pig’s natural behaviour to use separate areas for elimination and lying (Signoret et al., 1975; Pflug, 1976; Whatson, 1978; Baxter, 1982; Petherick, 1983; Whatson, 1985; Fraser and Broom, 1997; Damm and Pedersen, 2000; Olsen et al., 2001; Ekesbo, 2011) is used in the design of industrial pig housing systems (Simonsen, 1990; Schmid, 1994). For direct removal of the eliminations slatted floors are often applied (Aarnink et al., 2006; Banhazi, 2013). The urine and small manure particles fall through the slats directly and larger particles of manure fall through when trampled on (Banhazi, 2013). Housing pigs in a pen where the whole floor is slatted, however, is stated to restrict animal welfare as it provides no comfortable lying area (Van Veen et al., 1985). Therefore, partly slatted floors are applied more frequently, where pigs should lie on the solid floor and eliminate on the slatted floor area (Aarnink et al., 2006; Banhazi, 2013). Pigs do not always show this desired behaviour, however, leading to displaced eliminations on the solid floor (Hacker et al., 1994). These displaced eliminations negatively influence environmental pollution, animal welfare and health and the working environment (Aarnink et al., 2006).

Displaced eliminations increase environmental pollution as they reduce the hygiene level in the pen, leading to an increase in ammonia emission (Aarnink, 1997; Philippe et al., 2011). Ammonium [NH₄⁺] and ammonia [NH₃] in pig housing systems are mainly formed when the urea present in pigs’ urine is hydrolysed by urease, an enzyme present in the pigs’ faeces (Aarnink and Verstegen, 2007). Ammonia emission, causing acidification of the environment and pollution of ground- and surface water, has been of increasing societal concern (Van der Peet-Schwering et al., 1999).

Additionally, the increased ammonium emission and pen soiling reduce animal health and welfare (Aarnink et al., 2006) and might reduce productivity (Banhazi, 2013). Pigs find areas with high doses of ammonia in the air aversive, making these areas less comfortable to live in (Jones et al., 2000). Furthermore, high doses of aerial ammonia are shown to impair the sense of smell (Jones et al., 2000), cause acute infections in the tracheal epithelium and decrease growth (Drummond et al., 1980) in pigs. The soiling of the lying area is abnormal behaviour in pigs (Reisner, 1991), indicating that the housing system does not facilitate pigs to express natural behaviour and that the welfare is reduced (Śpinka, 2006). Conjointly, the pen soiling increases contact with eliminations and, thereby, the risk of infectious diseases (Stanged and Jensen, 1991; Tuytten, 2005).

Soiling of the pen also influences the quality and quantity of work for the farmer (Aarnink et al., 2006). The amount of work and the labour costs increase when the eliminations are dispersed throughout the pen and the self-cleaning property of the slatted floor are not optimally used (Randall et al., 1983). Moreover, high levels of aerial ammonia in pig housing systems are shown to be one of the main causes for the increased risk of respiratory diseases in pig farmers (Reynolds et al., 1996).
To minimise the amount of displaced eliminations, and the burdens associated with it, the eliminative behaviour of pigs should be directed by the design of the pen (Banhazi et al., 2002). To do so, understanding of the eliminative behaviour in pigs and its development is needed (Wechsler and Bachmann, 1998). This literature study provides an overview of the diverse explanations provided and current discussions on why pigs use separate areas for resting and elimination. Firstly, Buchenauer et al. (1982) suggest that pigs prefer to eliminate in an area with specific characteristics, while others state that pigs simply avoid to soil the area they prefer to lie in (Whatson, 1985; Damm and Pedersen, 2000; Ekesbo, 2011). Secondly, Meynhardt (1978) showed that wild boar mark their territory by eliminating around the edges. Many researchers, therefore, suggest that scent marking may also play a role in the eliminative behaviour in confined pigs (Signoret et al., 1975; Buchenauer et al., 1982). Thirdly, a discussion remains on whether the natural eliminative behaviour of the pig is innate (Grauvogel, 1970) or learned from their mother (Hafez and Signoret, 1969). Lastly several factors are found to influence the eliminative behaviour such as: environmental temperature (Aarmink et al., 2006) and pig density (Yicui et al., 2008).

1.2 Why do pigs not eliminate in their lying area

Early literature states that pigs create a specific elimination site (Signoret et al., 1975; Buchenauer et al., 1982) in preferably a cold, moist (Baxter, 1982; Simonsen, 1990; Hacker et al., 1994; Banhazi et al., 2002), bright area (Taylor et al., 2006), with the smell of other eliminations (Buchenauer et al., 1982). Baxter (1982) found that pigs preferred to eliminate in the area wetted by spilled drinking water and that they tended to lie away from this wet area to avoid heath loss. Taylor et al. (2006) found that piglets prefer to eliminate on a brightly lit area and to rest in a warm dimly lit area. Buchenauer et al. (1982) found that piglets prefer to eliminate in a site that smells of other eliminations as they often eliminate where others have done so as well. Additionally, pigs were found to prefer eliminating near the walls (Baxter, 1982; Petherick, 1983; Whatson, 1985; Bate et al., 1988), which may be for safety reasons as they are vulnerable in the eliminative posture (Baxter, 1982; Petherick, 1983) or to avoid interactions (Bate et al., 1988). Contact with the neighbouring pen, however, seems to be appreciated during elimination (Hacker et al., 1994).

Later on, Whatson (1985) stated that pigs do not use a specific elimination site but use the area that is least uncomfortable for other activities. When placed in a new pen, pigs are found to first select a lying area, which they prefer to be warm and clean (Marx and Buchholz, 1989). As pigs spend about eighty percent of their time lying, their lying comfort is important (Ekkel et al., 2003). Factors making an area uncomfortable for lying are draught (Boon, 1982; Geers et al., 1986), low temperature (Geers et al., 1986), moistness and soiling (Yicui et al., 2008). To avoid soiling of the lying area, pigs prefer to eliminate far away from it (Whatson, 1985; Ekesbo, 2011). In large outdoor paddocks, pigs eliminate minimally five metres away from their lying area (Stolba and Wood-Gush, 1984), whereas this distance was only a metre and a half in indoor farrowing pens where space is limited (Whatson, 1985). This provides an alternative explanation for the high number of eliminations near the wall, as the wall restricts the pig from moving further from the lying area (Whatson, 1985; Wechsler and Bachmann, 1998). Combined with the fact that the proximity of other piglets didn’t affect the elimination site (Whatson, 1978), this alternative explanation seems more valid than the earlier suggestion of Buchenauer et al. (1982) that pigs seek protection and isolation.

Besides the lying area, the location of the drinker (Signoret et al., 1975), feeder (Fraser, 1978; Andersen and Pedersen, 2011) and playing area (Banhazi, 2013) influence the eliminative behaviour as well. Pigs prefer to keep their feeding area clean from eliminations (Simonsen, 1990). During eliminations pigs keep their head far away from their feeding and lying area, but they seem to be unaware of where their hind is (Andersen and Pedersen, 2011). Furthermore, piglets were found to relocate their eliminations when play chains were applied in their elimination area, indicating that piglets do not eliminate where they play or where other piglets might be playing (Banhazi, 2013).

1.3 Territory marking with eliminations

Wild boar (Meynhardt, 1978) and free ranging domestic pigs (Signoret et al., 1975; Marcellis et al., 2002) are found to eliminate near the edge or their territory which may be a form of scent marking. Territorial marking is a form of intra species olfactory communication (Eisenberg and Kleiman, 1972) by the use of pheromones (Wilson, 1970). Eisenberg and Kleiman (1972) defined olfactory communication as “the process whereby a chemical signal is generated by a presumptive sender and transmitted [generally through the air] to a presumptive receiver who by means of adequate receptors can identify, integrate, and respond [either behaviourally or physiologically] to the signal”. Pheromones present in the urine or faeces of an animal may provide
the receiver information on the identity of the depositor without having direct contact (Eisenberg and Kleiman, 1972).

Most pheromones are detected in the vomeronasal organ which is present in many mammals (Liman, 2006) including pigs (Guiraudie et al., 2003), but known to regenerate after birth in humans (Liman, 2006). The vomeronasal organ is located at the bottom of the nasal cavity, as displayed in Figure 2, and connected to the olfactory bulb in the brain with the vomeronasal nerve (Eisenberg and Kleiman, 1972). In rats and mice, it is shown that the olfactory bulb sends its input to the amygdaloid nucleus which projects to the hypothalamus (Jeppesen, 1982; Chamero et al., 2012). The input to the vomeronasal organ, therefore, has the potential to influence for instance sexual and feeding behaviour (Eisenberg and Kleiman, 1972). The activity of stimulating the vomeronasal organ is called flehmen (Schneider, 1930) and is expressed by behaviours such as altered breathing, increased salivation, tongue movements (Poduschka and Firbas, 1968) and specific facial expressions (Schneider, 1930).

The pigs’ olfactory system is known to be well developed (McGlone and Anderson, 2002). Therefore, many pheromones are expected to influence their behaviour and physiology (McGlone and Anderson, 2002). Piglets are known to use smell to find ‘their teat’ (Jeppesen, 1982) and can discriminate between familiar and unfamiliar pigs based on their smell alone (Jones et al., 2000).

Additionally, piglets can discriminate between the smell of their mothers faeces and the faeces of other sows (Morrow-Tesch and McGlone, 1990). Adult gilts were found to avoid a feeder if it was sprayed with urine of a pig that had just been in an aversive situation but not when it was sprayed with urine of a pig that had not been in an aversive situation (Vieuille-Thomas and Signoret, 1992; Amory and Pearce, 2000). This indicates that the urine of the pig in the aversive situation may contain alarm pheromones (Amory and Pearce, 2000). Pigs could use these alarm pheromones to warn others for risks in the environment and thus enabling them to avoid potential danger (Vieuille-Thomas and Signoret, 1992). Moreover, the skin of the sow is known to excrete pheromones (Pageat and Teyssier, 1998) that reduce agonistic behaviour when perceived by the piglets (Morrow-Tesch and McGlone, 1990). These pheromones can be synthetically reproduced (Pageat, 2001) to reduce aggression after weaning in commercial pig farming (McGlone and Anderson, 2002; Guy et al., 2009).

There are indications that smell plays a role in a pig’s decision ‘where to eliminate’ (Buchenauer et al., 1982). When studying the sequence of behaviour around elimination, Wechsler and Bachmann (1998) found that pigs generally sniff, i.e. “pulling back the sides of the nose twice or more”, before and after eliminating in the area that was known to be the preferred elimination site. The observed sequence contained: entering the elimination site, sniffing, changing posture, eliminating, sniffing and exiting the elimination site. Before elimination, sniffing was mostly directed to the wall (Wechsler and Bachmann, 1998), although sniffing the floor was expected to precede elimination because the smell of other eliminations may be important as stated by (Buchenauer et al., 1982). Possibly, the pigs are interested in the wall because it keeps them from moving further away from the lying area (Wechsler and Bachmann, 1998) which is in agreement with Whatson (1985) explanation for the eliminations near the wall. Just before elimination, pigs changed their posture by either a 90 degree turn to be parallel to the wall or by walking a few steps forward (Wechsler and Bachmann, 1998). Sniffing after elimination was usually directed at the piglets’ own elimination (Wechsler and Bachmann, 1998).

How smell influences the pig’s decision in where to eliminate remains unclear. The fact that sniffing occurs before elimination makes it likely that the smell of the environment influences the piglets’ decision on where to eliminate. But what smell pigs prefer to eliminate in and what that specific smell is, is still unknown. For example, is an area with the smell of eliminations of an unknown pig attractive to eliminate in, and if so, why? Is it because of territorial marking or just because they found an used eliminative area? Furthermore, it remains unclear what time elapses between sniffing and elimination and whether the pig searches for an eliminative area by smell [i.e. does it smell at different sites before picking an elimination site?].
1.4 Development of eliminative behaviour

The development of the eliminative behaviour in new born piglets remains unclear as discussion exists on whether the eliminative behaviour of piglets is innate (Grauvogel, 1970) or learned from the mother (Hafez and Signoret, 1969) and at what age the piglets start eliminating out of the nest. In the first day after birth, the eliminative behaviour is more scattered around the pen than in the following days, indicating that learning probably takes place (Schmid, 1991; Schmid, 1997). The sow and littermates, however, do not seem to directly affect the eliminative behaviour of the piglet as they do not actively direct the piglet to the area where it should eliminate (Whatson, 1985).

Indirectly, the sow and littermates do influence the eliminative behaviour as piglets do not eliminate in the lying area of the sow (Whatson, 1985) and prefer to eliminate in the same area as the sow and other piglets (Buchenauer et al., 1982; Whatson, 1985). The fact that artificially raised pigs also eliminate away from their lying area and preferably near the wall (Marx, 1969) indicates that the behaviour is largely innate but needs to develop over time. The age at which piglets are found to eliminate out of the nest varies much between studies, from two days post-partum (Pflug, 1976; Petherick, 1983), four days post-partum (Whatson, 1978), five days post-partum (Buchenauer et al., 1982) to six days post-partum (Whatson, 1985).

On the other hand, in wild boar and free ranging domestic pigs, piglets remain in the nest for the first nine days after birth (Jensen, 1986). In this period the sows keep the nest clean (Stolba and Wood-Gush, 1984; Stanged and Jensen, 1991) by never dunging in the nest (Stanged and Jensen, 1991) and by eating the faeces of their young in the first few days (Whatson and Bertram, 1983). This behaviour is functional as a clean nest reduces the risk of infection and provides better insulation (Stanged and Jensen, 1991). As the sow keeps the nest clean, the piglets may learn to eliminate away from the nest by social and observational learning (Nicol, 1995). Therefore, piglets of sows with displaced eliminations may learn the wrong behaviour, especially as previous housing and the eliminative behaviour there are known to affect the eliminative behaviour of the pig throughout life (Damm and Pedersen, 2000).

1.5 Factors influencing eliminative behaviour

Besides the factors discussed above [i.e. functional areas, smell and sow and pen mates], the eliminative behaviour of pigs is also influenced by environmental factors such as, lighting (Taylor et al., 2006), pig density (Yicui et al., 2008) and environmental temperature (Aarnink et al., 2006). Knowledge of these factors could help directing the eliminative behaviour. Lighting is shown to influence the pigs’ eliminative behaviour as pigs were found to prefer the low illuminated areas to rest in and the high illuminated areas to defaecate in (Taylor et al., 2006).

Pig density is shown to influence the eliminative behaviour (Heitman et al., 1961; Baldwin, 1969; Grauvogl and Buchenauer, 1976; Bate et al., 1988; Hacker et al., 1994; Fraser and Broom, 1997; Aarnink et al., 2006; Yicui et al., 2008) as a high density, for instance, increases the amount of displaced eliminations (Randall et al., 1983). Cleanest lying areas were found at a stocking density of about 120 kg/m² (Randall et al., 1983) and small differences in pig density [within the ranges of commercial pig housing] did not alter the pen hygiene (Jensen et al., 2012). A good parameter to assess pig density is the allometric space allowance which relates the space available per pig to its scaled Body Weight [BW] and is expressed as m² per kilogram of BW * 0.668 (Baxter, 1982; Petherick, 1983). As pigs grow the allometric space allowance in the pen decreases, making it more difficult for the pigs to eliminate in isolation (Bate et al., 1988). This may explain the increased soiling in the lying area towards the end of the finishing period (Aarnink, 1997).

Another factor influencing the eliminative behaviour of pigs is environmental temperature (Fraser, 1978; Aarnink et al., 2006), as pigs generally seek to rest in an area with a high temperature and excrete in an area with a low temperature (Fritschen, 1975; Baxter, 1982; Olsen et al., 2001). How pigs perceive the environmental temperature depends on the Inflection Temperature [IT] that varies with the pigs body weight [25 °C at 25kg and 20 °C at 100 kg]. Temperatures below the IT are perceived as cold while temperatures above the IT are perceived as warm. Under what is perceived as cold conditions, pigs use separate areas for resting, feeding and eliminating, with above 80% of each activity occurring on a particular side of the pen (Fraser, 1985). In most cases, resting and feeding was performed in the warmer bedded area and eliminating away from this area. When the lying area of the pen was 6 °C warmer than the elimination area, soiling of the lying area occurred in only 2% of the cases, while soiling of the lying area occurred in 36% of the cases if the lying area was marginally cooler than the elimination area (Randall et al., 1983).
If the pig perceives the environmental temperature as warm, the location of the activities is less consistent (Fraser, 1985). Above the IT pigs have difficulties losing their body warmth and search for a cool place to lie (Banhazi, 2013). As the slatted floor is often cooler than the solid floor, pigs choose the former as their preferred lying area (Huynh et al., 2005) and thereby eliminate on the solid floor (Aarnink et al., 2006). Additionally, under warm conditions pigs tend to soil the solid floor to create a wallow in which they can cool themselves by evaporation (Huynh et al., 2005). Wallowing is the pigs’ natural response to lose body warmth under hot conditions (Bracke and Spoodle, 2011). Although wet faeces and urine might not be the ideal wallowing substrates, pigs use it to cope with high temperatures if no alternatives are offered (Jensen et al., 2012).

**1.6 Directing eliminative behaviour**

Knowledge of the eliminative preferences of pigs and the factors influencing eliminative behaviour can thus be used to direct the eliminative behaviour of pigs in indoor housing. For example, Stolba and Wood-Gush (1984) suggest that pigs might prefer to eliminate in a corridor like area that resembles the rides between bushes used by wild boar. And that the elimination area should be located near the outdoor part of the pen as pigs prefer to eliminate on the edge of their habitat (Stolba and Wood-Gush, 1984).

The eliminative behaviour should be directed by creating a comfortable lying area and an elimination area that is not comfortable to lie in (Banhazi, 2013). Researchers have suggested multiple options to do so. An early suggestion to wet the area you selected for elimination (Fritschen, 1975) is applied in some commercial stables as the drinkers are placed in the preselected elimination area, wetting this site with spilled drinking water. Later, Randall et al. (1983) suggested that cooling gradients can be used to direct the eliminative behaviour to a preselected area, for example by using floor heating and draught (Geers et al., 1986).

Yicui et al. (2008) suggest to use different kinds of pen partitions to direct draught and the eliminative behaviour. Sows select a nest near solid walls to avoid draught and contact with the neighbouring pen (Arey et al., 1992). Using slatted partitions at the preselected elimination area creates draught that makes the area uncomfortable for lying (Yicui et al., 2008) and enables contact with the neighbouring pen, making it an attractive elimination site (Hacker et al., 1994).

Aarnink et al. (1997) suggested to make the floor of the preselected elimination area uncomfortable to lie on. He found that different kind of slats provided a different degree of comfort and that a metal slatted floor with metal studs, displayed in Figure 3, was least comfortable (Aarnink et al., 1997). In addition, providing pigs with a metal slatted floor with metal studs in a preselected elimination area significantly reduced the amount of soiling on the solid floor (Aarnink et al., 1997).

When a play chain was applied in the preselected elimination area with a slatted floor, as displayed in Figure 4, the piglets in the pen relocated their elimination to an area on the solid floor. This change in behaviour is undesirable but the concept can be used to redirect the eliminative behaviour in other cases. As pigs do not seem to eliminate where they play or others might be playing, application of play chains may be useful to redirect displaced eliminative behaviour (Banhazi, 2013).

Moreover, to direct the eliminative behaviour discrimination between elimination, resting and activity areas could be more promoted (Damm and Pedersen, 2000). There are several features that can be used to distinguish the different areas such as: partition type, temperature, illumination, floor type, bedding and different floor levels. For example, Banhazi (2013) found that less soiling occurred if sawdust was applied in the lying area. Randall et al. (1983) found that the ability to discriminate between the different areas was promoted in a long and narrow pen with the elimination area on the narrow side.

![Figure 3 Metal slatted floor with studs with dimensions in mm (Aarnink et al., 1997).](image3)

![Figure 4 Play chain applied above the slatted floor of the eliminative area in a weaner pen (Banhazi, 2013).](image4)
1.7 Gaps of knowledge

In this literature review some important gaps of knowledge were identified that need to be studied to answer the research question: "How do the physical and social environment influence the piglets’ decision 'where to eliminate'"? First off all, different results were found on when eliminative behaviour of new born piglets develops (Pflug, 1976; Whatson, 1978; Buchenauer et al., 1982; Petherick, 1983; Whatson, 1985). We address this topic in our first sub question: "When does the eliminative behaviour of new born piglet develop?" where we study at what day after birth piglets start eliminating out of the nest.

Secondly, it remains unclear how smell, the proximity of other piglets and the eliminative behaviour of the sow influence the piglets’ eliminative behaviour. These topics are addressed in the second sub question: "What factors influence the eliminative behaviour of piglets?". Although it is known that piglets often sniff before eliminating (Wechsler and Bachmann, 1998), which indicates that smell may influence the eliminative behaviour, it remains unclear how smell influences the eliminative behaviour. By observing the sniffing behaviour around elimination we determined the object that was sniffed before eliminating and whether eliminating was performed in the same area as sniffing.

Although many scientists stated that pigs prefer to eliminate in isolation (Baxter, 1982; Petherick, 1983; Bate et al., 1988), no evidence to these statements is given and they are in conflict with Whatson (1985) findings that proximity of other piglets does not affect the eliminative behaviour. By noting the proximity of other piglets and the sow at the time of elimination we could analyse whether the piglets seek isolation to eliminate.

The sow does not seem to directly influence the eliminative behaviour of her piglets (Whatson, 1985). The piglets, however, are expected to be indirectly influenced by the sow as they do not eliminate in the sow’s lying area and prefer to eliminate where the sow has eliminated before (Whatson, 1985). The current study analysed whether piglets avoid eliminating in functional areas such as the feeding or lying area of the sow and their own lying area.

Lastly, a good method to study whether the physical and social environment affect the eliminative behaviour is by observing the effect of changes in the environment on the eliminative behaviour; and this has never been studied before. This topic is addressed in the third sub question: "Do changes in the physical and social environment influence the eliminative behaviour of piglets?". Changes in the environment were induced twice. First by removing a partition by which the piglets could move freely to the adjoining pen and later by removing another partition by which also the sows could go to the adjoining pen.

This literature review is followed by the materials and methods in chapter two that describes how this study will provide answers to the three sub questions and with that the research question. The results of this study are provided in chapter three and discussed in chapter four. Additionally, chapter four provides suggestions for further research and conclusions on each sub question.
2. Materials and methods

2.1 Animals and housing

The piglets of eight crossbreed sows were observed on the pig farm VAIR in Erp, the Netherlands. During their dry and gestation period these sows were housed in a paddock with a shelter shed, in stable groups of six. About a week before farrowing, the sows moved to the farrowing pens where they remained for the six week long suckling period. During the suckling period the sows were fed a pelleted lactation feed at 8.30 AM and 6.00 PM each day. The amount of feed was based on the sows condition and litter size that varied between 9 and 15 piglets. The environmental temperature in the farrowing pens was around 17 °C, but varied slightly between and within the pens.

The pens in which the sows and their litter were housed are as displayed in Figure 5.A. The slatted floor, displayed in grey was elevated with 10 centimetres. When the piglets were about 18 days old, the partition wall, that separates the nests of two adjoining pens, was removed as displayed in Figure 5.B. Removing the wall provided the piglets with the opportunity to move freely in the two adjoining pens while the sow remained in her own pen. One week later, when the piglets were about 25 days old, the slatted fence separating the sows was removed as well, as displayed in Figure 5.C. This enabled the sows to move freely in the two pens. From this day onward the piglets received starter pellets in a piglet silo feeder placed in their nest. Each morning, before feeding, the pen hygiene was examined and the locations of the sows’ eliminations were noted. Afterwards, the pen was cleaned by scooping all eliminations and soiled sawdust found on the solid floor onto the slatted floor and a thin layer of fresh sawdust was provided.

The piglets of two different rounds were observed. The first round contained three sows with their litters, born around August 16th 2014 and weaned on September 25th 2014. Round two contained six sows with their litters, born around November 15th 2014 and weaned on December 30th 2014.
2.2 Experimental procedures

During the live observations, one observer observed two pens simultaneously. The observations in round one were, therefore, made by two trained and involved observers on the day of mixing the piglets (age: 18 days) and mixing the sows (age: 25 days) and the day before weaning (age: 39 days). In the second round live observations were made by four trained observers on the days around mixing the piglets (age: 17, 18 and 19 days), mixing the sows (age: 24, 25 and 26 days) and the day before weaning (age: 44 days). Not on all these days, three trained observers were available, therefore only four of the six sows in round two were observed on all days. During all live observations one observer constantly observed two adjoining pens for one hour after which observers switched pens. The observations were made during five consecutive hours between 12.00 and 5.00 PM.

During the live observations, individual piglets were followed. To enable discrimination between the piglets, a number or sign was applied on the back of the piglets with human hair dye of the brand Schwarzkopf using a small paint brush. As the markings quickly faded of the skin, they were reapplied each week. On the weeks in which live observations took place the markings were reapplied on the morning of the first day of observations. The piglets of each of two adjoining pens received markings in different colours to facilitate discrimination between the piglets of the different pens after removal of the nest separation. On the day of the removal of the slatted fence the sows received a marking with Raidex animal marking spray matching with colour of their piglets’ markings. These markings facilitated discrimination between the sows as they were able to move freely in the two adjoining pens.

To enable statistical analysis of the data, two adjoining pens were divided in 10 different areas as displayed in Figure 6. In this deviation, area 1, 2, 3 and 4 are together the preselected toilet area with a slatted floor and area 7 and 8 are the piglet nests. All analyses were performed with SAS 9.3 software and tested on significance with \( \alpha = 0.05 \).

2.2.1 How does the eliminative behaviour develop?

Scientists have not yet reached a consensus on when the piglets start to eliminate out of the nest. They did, however, indicate that the eliminative behaviour of piglets develops in first few days after birth (Pflug, 1976; Whatson, 1978; Buchenauer et al., 1982; Petherick, 1983; Whatson, 1985). Therefore, the three pens of round one were video observed on day one, three and five after birth to establish at what age piglets start leaving the nest to eliminate. On these days, the time and area of all of the piglets’ eliminations were recorded for thirteen consecutive hours starting at 7.00 AM and finishing at 8.00 PM. On day one, which is the day of birth, observations started as soon as the last piglet was born. For the first of the three pens, additional observations were made on day one and two, resulting in observations of five consecutive days for this pen. All video observations were made using the Observer XT 10 software of Noldus Information Technology B.V., Wageningen, The Netherlands.

The data of the video observations was used for descriptive statistics such as the amount of eliminations per area, the percentage of eliminations on the preselected toilet areas and the time till the first elimination on the toilet area and on what day most of the eliminations were made outside the nest. Furthermore, Pearson’s chi-squared goodness of fit test was performed to analyse whether the total amount of eliminations on the three observation days were equal for the three observed pens. Additionally, this test was performed on the total amount of eliminations on the five observation days of the first pen.

Pearson’s chi-squared test of independence was used to analyse whether there was a significant change in elimination site during the first five days after birth. To statistically compare the location of the observed eliminations on the three days, the data of the three different pens were summed as if all pens were the same. Therefore, it was assumed that the fact that one of the pens was the mirror image of the other two pens did not affect the development of the eliminative behaviour of the piglets. The adjusted numbering of the different areas in the pens for the video observations is displayed in Figure 7. In this deviation, area 1 and 2 are the preselected toilet area and area 5 is the nest.

![Figure 6 Numbering of the different areas in two adjoining pens.](image)

![Figure 7 Adjusted numbering of the different areas in two adjoining pens.](image)
Additionally, for the last of the three pens the exact location of each elimination was recorded on a map of the pen to visualise the eliminative behaviour for day one, three and five after birth in more detail. Comparison of the three pen maps displayed the development of the eliminative behaviour over these days. From these maps it was noted where in each area eliminations took place.

2.2.2. What factors influence the piglets’ decision on where to eliminate?

To get more understanding on how pigs decide where to eliminate, the behaviour sequence of piglets around elimination was studied. The study included three factors that were expected to influence the eliminative behaviour, smell (Wechsler and Bachmann, 1998), social environment (Baxter, 1982; Buchenauer et al., 1982; Petherick, 1983) and distance to functional areas (Whatson, 1985; Damm and Pedersen, 2000; Ekesbo, 2011).

2.2.2.1. Smell

Wechsler and Bachmann (1998) suggested that smell is an important factor in the pig’s decision ‘where to eliminate’ as they observed piglets sniffing before and after eliminating. The current study focussed on what proportion of the eliminations was preceded or followed by sniffing and whether this proportion increased as the piglets got older. Additionally, we analysed what the sniffing was directed to; the sow’s excretions, other piglets’ excretions or their own excretions. This provided insights in how smell influenced the piglets’ decision ‘where to eliminate’. Because sniffing behaviour is very subtle and knowledge on the producer of the excretions present in the pen was needed, live observations were found to be most suitable. During the live observations the piglets’ behaviour was observed only around elimination; the ethogram of these observations is provided in appendix 1.

To analyse whether the proportion of eliminations that was preceded or followed by sniffing changed over time, Pearson’s chi-squared goodness of fit test was performed, on observations of the day before -mixing the piglets, –mixing the sows and –weaning. In this test, the amount of observed eliminations on each day was compared with the expected amount of eliminations if the total amount of eliminations on these three days together was equally distributed over the three days. Thus, this test analyses whether the total amount of eliminations was equally distributed over the three days. These specific days were selected, as on these days the piglets had not recently experienced an induced change of environment that could have influenced their sniffing behaviour. Hence, only the live observations of round two were used here. Sniffing was associated to an elimination if it occurred within the time frame of two minutes before or after the elimination; this limit was set based on preliminary analysis of our own data. The following hypotheses were tested:

- H0: The proportion of eliminations that was preceded or followed by sniffing is equal on the day before mixing the piglets, the day before mixing the sows and the day before weaning.
- Ha: The proportion of eliminations that was preceded or followed by sniffing differs between the day before mixing the piglets, the day before mixing the sows and the day before weaning.

In case this test showed a significant difference, all possible pairwise comparisons were made using the same test.

2.2.2.2. Social environment

In the first round, the social environment piglets preferred to eliminate in was analysed. To do so, the presence of other piglets in the same area was noted for each elimination observed during the live observations. These data provided insights on the number of eliminations made in solitude.

In the first round the location of all eliminations on day one, three and five after birth were noted to answer sub research question one. Additionally, the whereabouts of the piglets during these days was recorded by 20 min scan sampling. With this method, the pen was scanned every 20 min and the whereabouts of the sow and the piglets [as in presence in which area] at that exact time was noted. Based on these scans, the average percentage of piglets present in each area throughout the day was calculated. The expected amount of eliminations, under the assumption that piglets eliminate where they are, was calculated for each area on each day. In this calculation the total amount of eliminations for each day was multiplied with the average percentage of piglets in each area; this outcome was divided by 100. Pearson’s chi-squared goodness of fit test was used to analyse whether the expected number of eliminations based on the average presence of the piglets throughout the day for each area was equal to the observed number of eliminations in each area. The hypotheses for this test are the following:

- H0: The number of observed eliminations per area per day is equal to the expected amount of eliminations under the assumption that piglets eliminate where they are.

14
• Ha: The number of observed eliminations per area is not equal to the expected amount of eliminations under the assumption that piglets eliminate where they are. Thus, piglets move to a more or a less crowded area to eliminate.

As the data of question one, in which the pen was divided in 5 areas as displayed in Figure 6, was used in this analysis, the same area division was applied.

2.2.2.3. Functional areas

Andersen and Pedersen (2011) stated that pigs intend to keep their lying and feeding areas clean and eliminate with their head as far away from these sites as possible. Additionally, Whatson (1985) found that piglets keep their own and the sow’s lying area clean; piglets eliminated more than a metre away from their lying area. The influence of the location of the sows lying and feeding areas, and the piglets’ lying area on the piglets’ decision ‘where to eliminate’, was studied in the second round. During the live observations, the lying area of the sow was recorded for every observed elimination. If a piglet eliminated while the sow was not lying, the area that she last lay in was recorded as her lying area. After mixing the piglets, the lying area of both the own sow and the sow of the adjoining pen were taken in account. The feeding area was constant; the sows were always fed in area 6 for the uneven numbered pens and area 10 for the even numbered pens. The lying area of the piglets was assumed to be in the nest [area 7 and 8], although sometimes the piglets remained in the lying area of the sow after suckling.

Pearson’s chi-squared goodness of fit was used to analyse whether the observed amount of eliminations in each functional area was lower than the expected amount of eliminations under the assumption that eliminations were divided over the areas equally. For this test the following hypotheses were tested:

- H0: the amount of observed eliminations in each functional area is equal to the amount of eliminations expected under equal distribution of the total amount of eliminations observed.
- Ha: the amount of observed eliminations in each functional area is lower than the amount of eliminations expected under equal distribution of the total amount of eliminations observed.

Additionally, Pearson’s chi-squared test of independence was performed to analyse whether the piglets eliminated in the lying area of the sow more often when she chose to lie on the slatted floor of one of the toilet areas with the following hypotheses:

- H0: the amount of eliminations in the lying area of the sow does not differ between sows lying on the slatted floor of one of the toilet areas and sows lying on the solid floor of the pen.
- Ha: the amount of eliminations in the lying area of the sow is higher for sows lying on the slatted floor of one of the toilet areas than for sows lying on the solid floor of the pen.

2.2.3. What is the effect of changes in the physical and social environment on the eliminative behaviour?

An interesting method to study environmental influences on the pigs’ preferred elimination site, is to observe the effect of changes in the physical and social environment on the eliminative behaviour. The environmental changes applied in this study are, [a] mixing the piglets of two adjoining pens and [b] mixing the sows of two adjoining pens.

To answer the question "Do piglets change the preferred elimination site after [a] they are provided with the ability to move into the adjoining pen and mingle with the unknown sow and piglets and [b] the sows are provided with the ability to move into the adjoining pen?", live observations were made on the pigs in the second round. The eliminative behaviour of the piglets and sows was observed live in four pens on the day before, the day of and the day after [a] removing the wall that separates the piglets’ nests and [b] after removing the slatted fence that separates the sows, and on the day before weaning.

For statistical analysis of the results, the observations of the four pens were summed. Pearson’s chi-squared goodness of fit test was performed to analyse whether the total amount of eliminations on the three observation days were equal. To assess whether the piglets changed their elimination site after mixing, the elimination frequency on the three consecutive days [thus separately for mixing of the piglets and mixing of the sows] was compared for each area using Pearson’s chi-squared test of independence with the following hypotheses:

- H0: The elimination frequency for each area is equal on the days before, of and after mixing.
- Ha: The elimination frequency in each area differs between the day before, of and after mixing.
Additionally, this analysis was used to compare the day after mixing the sows with the day before weaning to see how the eliminative behaviour stabilises in time. In case the test showed a significant difference, all possible pairwise comparisons were made using the same test.

To enable statistical analysis for changes in the elimination site, three different methods to divide the pen in areas were performed. Firstly, the areas were divided as proposed in Figure 6. The second division method divided the pen in a toilet area \([T]\) containing area 1, 2, 3 and 4 of Figure 6 and non-toilet area \([NT]\) containing area 5, 6, 7, 8, 9 and 10. The last method divided the pen in four areas, namely:

- the own toilet area \([OT]\) is the toilet area of the pen in which the piglet is born, containing area 1 and 2, or 3 and 4;
- the own non-toilet area \([ONT]\) is the non-toilet area of the pen in which the piglet is born, containing area 5, 6 and 7, or 8, 9 and 10;
- the not own toilet area \([NOT]\) is the toilet area of the adjoining pen, containing area 1 and 2, or 3 and 4;
- the not own non-toilet area \([NONT]\) is the non-toilet area of the adjoining pen, containing area 5, 6 and 7, or 8, 9 and 10;

Thus, which of the original areas were part of these new four areas, depended on in which pen the piglets were born.

Additionally, the role of smell in the observed changes of the preferred elimination site on the days around mixing was analysed. Pearson’s chi-squared goodness of fit test was used to analyse whether the proportion of eliminations that was preceded or followed by sniffing differed on the day before, of and after mixing. Furthermore, non-statistical comparisons were made to detect differences in the origin of the producer of the sniffed eliminations between the days around mixing. Results on this comparison will show whether piglets find the smell of eliminations of unknown pigs interesting.
3. Results

During the live observations of round one and two, the piglets on average eliminated 0.68 times per hour. Of these eliminations, 0.42 were urinations and 0.26 defaecations. Most of the eliminations [70%] were made in the preselected toilet areas with slatted floor (P<0.0001). Moreover, 65% of the eliminations occurred within 10 min after a suckling bout.

3.1 Development of the eliminative behaviour in piglets

During the video observations of round 1, the piglets on average eliminated 0.99 times per hour. The video observations did not provide enough detail to differentiate between urination and defaecation. After eliminating, the piglet often shook its head causing its ears to flap. Eliminations often occurred after or during suckling bouts; during the suckling bouts the piglets individually visited the sow’s head and often eliminated there. In two of the three pens, the sow was seen to actively push the piglets onto the slatted floor.

The 10 piglets of pen 1 were born on August 16th 2014, the observations on that day started at 8.20 AM, directly after the last piglet was born. On day one, therefore, the video observations of pen 1 only lasted for 11 h and 40 min. On the morning of day two, one of the piglets died, reducing the litter size to 9 piglets. The litter of pen 2, containing 14 piglets, was born in the night from August 12th to August 13th 2014. As all piglets were already born, the observations on day one started at 7.00 AM and lasted for 13 hours. The litter of pen 3 contained 11 piglets and was born on the morning of August 14th 2014. After the last piglet was born, at 9.00 AM, the observations started causing the video observations for pen three to last for 11 hours.

Eliminations on the slatted floor of the preselected toilet area occurred relatively early after birth. The quickest piglet to do so was a piglet from pen three, only 12 minutes after its last sibling was born. In pen 1 the first elimination on the preselected toilet area occurred much later, seven and a half hours after the start of observation. In pen 2 the first elimination on the toilet area occurred 45 minutes after the start of observation. Of this pen, however, the time of birth of the piglets is unknown as it took place during the night. On day five after birth, the majority [64%] of the eliminations was made in the two toilet areas [area 1 and 2].

Analysis of the eliminations made by the piglets in pen 1, of which all 5 days after birth were examined, showed an increase in the total number of eliminations on each day as displayed in Table 1. Pearson’s chi-squared goodness of fit test proved that the total amount of eliminations made by de piglets significantly differed between the days (P<0.0001). The most significant increase in the total amount of eliminations made by the piglets was from day 2 to day 3.

Comparison of the total amount of eliminations the piglets of all three pens together made, on day one, three and five after birth, displayed in Table 2, showed a steady increase for each day (P<0.0001). Additionally, the proportion of eliminations [i.e. the percentage of the day’s total amount of eliminations made in each area] differed between day one, three and five after birth for all areas (P<0.0001). On both toilet areas [area 1 and 2] the amount of eliminations increased tremendously. Although part of this increase was caused by the increase in the total amount of eliminations, a significant difference in the proportion of eliminations made in these areas was found for all days, except for day one and three in area 2 for which the increase was only close to significance (P=0.0534).

The increase in the number of eliminations made in area 3 is largely caused by the difference in total eliminations. Therefore, there was no significant difference in the proportion of eliminations made in this area between day one [37.8%] and three [41.4%] (P=0.3029). In this same area, however, a significant decrease was found in the proportion of eliminations between

<table>
<thead>
<tr>
<th>Area/Day</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>2</td>
<td>25</td>
<td>34</td>
<td>20</td>
<td>82</td>
</tr>
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<td>2</td>
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<td>3</td>
<td>8</td>
<td>6</td>
<td>69</td>
<td>26</td>
<td>21</td>
<td>130</td>
</tr>
<tr>
<td>4</td>
<td>17</td>
<td>30</td>
<td>53</td>
<td>26</td>
<td>18</td>
<td>144</td>
</tr>
<tr>
<td>5</td>
<td>18</td>
<td>66</td>
<td>52</td>
<td>17</td>
<td>3</td>
<td>156</td>
</tr>
<tr>
<td>Total</td>
<td>49</td>
<td>113</td>
<td>220</td>
<td>137</td>
<td>89</td>
<td>608</td>
</tr>
</tbody>
</table>

Table 1 The number of eliminations made in each area in pen 1 in the first 5 days after birth.

<table>
<thead>
<tr>
<th>Area/Day</th>
<th>1</th>
<th>3</th>
<th>5</th>
<th>Total</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>26</td>
<td>95</td>
<td>168</td>
<td>289</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>2</td>
<td>18</td>
<td>43</td>
<td>174</td>
<td>235</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>3</td>
<td>122</td>
<td>191</td>
<td>133</td>
<td>446</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>4</td>
<td>104</td>
<td>93</td>
<td>46</td>
<td>243</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>5</td>
<td>53</td>
<td>39</td>
<td>12</td>
<td>104</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Total</td>
<td>323</td>
<td>461</td>
<td>533</td>
<td>1317</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

Table 2 The amount of eliminations made in each area on day 1, 3 and 5 after birth of pen 1, 2 and 3 together.

Frequencies with different letters [abc]: the proportion of eliminations differs significantly with P<0.05.
day three [41.4%] and five [25%] (P<0.0001). In both area 4 and area 5 a significant decrease in the proportion of the total amount of eliminations was found between all days.

In addition to the statistical analysis, for pen three, the exact location of each elimination was recorded on a map of the pen to visualise the eliminative behaviour on day one, three and five after birth in more detail. The maps, displayed in Figure 8, show that the number of eliminations increased throughout time. Most of the piglets’ eliminations on day one were made in area 3 and 4 and are quite dispersed. On day three most eliminations were made in area 4, where the corner seemed most attractive. Additionally, more of the eliminations were now made near the walls of the pen and on the toilet area. On day five most eliminations were made on the toilet areas [area 1 and 2], and especially in the corner of area 1 where a pile of eliminations developed throughout the day. Furthermore, the amount of eliminations near the walls seemed to increase further. On day three and five most eliminations in area 5 [nest] were made at the far end. The sow made displaced eliminations throughout the whole observation period.

![Maps of pen](image)

**Figure 8** Location of the piglets’ [dots] and the sow’s [crosses] eliminations on A) day 1, B) day 3 and C) day 5 after birth.

### 3.2 Factors influencing the eliminative behaviour in piglets

#### 3.2.1. Smell

During the live observations of round one and two together, sniffing directed towards eliminations was observed 1227 times, 78.0% of these sniffs were directed towards faeces, the rest was directed towards urine. Of all sniffs observed, 52.0% was directed towards an elimination made by a sow, and 29.8% towards an elimination made by a piglet, and for the rest of the sniffs the origin of the elimination was unknown. In 47.6% of the sniffs, it was unknown from which pen the producer of the elimination originated, 28.3% of the sniffs were directed towards an elimination of a pig of the same pen as the sniffer, while 23.3% of the sniffs were directed towards an elimination of a pig from the adjoining pen, and the remaining 2.0% of sniffs was directed towards eliminations made by the piglet itself.

Piglets were found to sniff both within the two minutes preceding and following elimination. On average, sniffing associated to elimination was found in 38.7% of the eliminations on the days of the live observations for both rounds as displayed in Table 3. Sniffing before eliminating was observed in 29.3% of the eliminations and therefore occurred more frequently than sniffing after eliminating which was only observed in 14.9% of the eliminations. In round one the proportion of eliminations that were preceded or followed by sniffing seemed to be lower than in round two. In round two, the proportion of eliminations preceded or followed by sniffing seemed...
to be highest on the days around mixing the sows. On these days sniffing associated to elimination was observed for more than 50% of the eliminations.

From Table 3 it also seems that in round 2 the proportion of eliminations that is preceded or followed by sniffing is lower when the piglets are younger. Pearson’s chi-squared goodness of fit test proved this observation right as it showed that the proportion of eliminations that were preceded or followed by sniffing differed between the day before mixing the piglets, the day before mixing the sows and the day before weaning (P<0.0001). The proportion of eliminations which were preceded or followed by sniffing was significantly lower on the day before mixing the piglets [31.5%] than on the day before mixing the sows [65.7%] (P<0.0001) and the day before weaning [44.0%] (P=0.0059). The proportion of sniffing related to eliminations did not differ significantly between the day before mixing the sows and the day before weaning (P=0.1291).

### Table 4
The average percentage of piglets present in each area throughout the day for day 1, 3 and 5 after birth.

<table>
<thead>
<tr>
<th>Day/Area</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observed</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>0.00</td>
<td>0.32</td>
<td>41.74</td>
<td>43.66</td>
<td>14.29</td>
<td>323</td>
</tr>
<tr>
<td>3</td>
<td>0.63</td>
<td>0.08</td>
<td>17.84</td>
<td>24.68</td>
<td>56.77</td>
<td>1223</td>
</tr>
<tr>
<td>5</td>
<td>0.57</td>
<td>2.25</td>
<td>15.45</td>
<td>17.92</td>
<td>63.80</td>
<td></td>
</tr>
</tbody>
</table>

### Table 5
The expected number of eliminations in each area for each day under the assumption piglets eliminate where they are, and the observed eliminations in each area.

<table>
<thead>
<tr>
<th>Day/Area</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observed</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>310</td>
<td>694</td>
<td>1004</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>42</td>
<td>177</td>
<td>219</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>352</td>
<td>871</td>
<td>1223</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 3.2.2. Social environment

During the live observations of round one, 63% of the eliminations was made while others were present in the same area as the eliminating piglet.

The results of the 20 min scan samples [based on video observations of round two] are displayed in Table 4 as the average percentage of piglets present in each area throughout the day. These results show that on day one, the piglets mostly stayed in area 3 and 4 [lying area sow], while on day three and five they spent most of the time in area 5 [nest]. In both toilet areas [area 1 and 2] hardly any piglets were present throughout the days.

The expected amount of eliminations, under the assumption that piglets eliminate in the area that they are, and the observed amount of eliminations in each area are displayed in Table 5. Pearson’s chi-squared goodness of fit test showed that the observed and expected values not equal for day one (P<0.0001), day three (P<0.0001) and day five (P<0.0001). The eliminations are not distributed over the areas as expected. Therefore, the alternative hypothesis is accepted; the piglets do not eliminate in the area that they stay in most of the time. Piglets are likely to seek a quieter area to eliminate in.

### Table 6
Frequency analysis of eliminations in the Lying area of the sow.

<table>
<thead>
<tr>
<th>Lying area</th>
<th>Toilet area</th>
<th>No</th>
<th>Yes</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>310</td>
<td>694</td>
<td></td>
<td>1004</td>
</tr>
<tr>
<td>Yes</td>
<td>42</td>
<td>177</td>
<td></td>
<td>219</td>
</tr>
<tr>
<td>Total</td>
<td>352</td>
<td>871</td>
<td></td>
<td>1223</td>
</tr>
</tbody>
</table>

### 3.2.3. Functional areas

Of the eliminations made during the live observations in round two, 3.8% was made in the feeding areas of the sow. This was significantly less than the expected 20% under the assumption that the total amount of eliminations is equally distributed over the areas (P<0.0001). The lying area of the piglets was used a bit more, as 12.4% of all eliminations was made in the piglets’ nest. Nevertheless, this as well was significantly less than the expected 20% (P<0.0001). 17.9% Of the eliminations was made in an area where a sow was lying, but this was not significantly different to the expected 20% under the assumption of equal distribution (P=0.0672). The piglets are thus found to avoid to eliminate in the feeding area of the sow and their own lying area, but not in the lying area of the sow.

In most of the cases that a piglet eliminated in the lying area of a sow [62.2%], this was the piglet’s own mother. Additionally, most of the eliminations in the lying area of the sow [80.8%] were made while the sow was lying on the slatted floor of the toilet area, as displayed in Table 6. This was significantly more than the 19.2% of eliminations in the sows lying area when she was lying on the solid floor (P=0.0005). Therefore, the alternative hypothesis is accepted; piglets were found to eliminate in the lying area of the sow more often when the sow was lying on the slatted floor of the toilet area than when the sow was lying on the solid floor. Only 3.4% of all eliminations was made in the lying area of the sow while she was lying on the solid floor of the pen.
3.3 Effects of changes in the physical and social environment on the eliminative behaviour in piglets

3.3.1. Mixing piglets

Although a small difference was found in the total amount of eliminations between the day before, the day of and the day after mixing the piglets, Pearson’s chi-squared goodness of fit test did not prove that the total amount of eliminations differed between the three days (P=0.4721) as displayed in Table 7.

When the pen was divided in the ten areas displayed in Figure 6, it was shown that most of the eliminations [more than 70 %] were made in the toilet areas [area 1 to 4] and the proportion of eliminations made on the toilet areas [T] did not differ between the three days around mixing (P=0.2470). Areas 6, 8 and 10 were least favourite to eliminate in; the amount of eliminations in these areas was too low to make a valid chi-squared test. The proportion of eliminations [i.e. the percentage of the day’s total amount of eliminations made in each area] remained relatively stable over the three consecutive observation days. Therefore, in none of the areas a significant change in the elimination frequency was found.

When the pen was divided in four areas, it was shown that most of the eliminations in the days around mixing were made in the own toilet area as shown in Table 8. On the day of mixing, however, the proportion of eliminations in the own toilet area was significantly reduced from 75.7% on the day before mixing to 49.2% on the day of mixing (P<0.0001), and remained lower on the day after mixing. Additionally, the proportion of eliminations in the own non-toilet area was also reduced from 24.3% on the day before mixing to 21.1% on the day of and 18.7% on the day after mixing although not significantly (P=0.1523).

When separating the eliminations in urinations and defaecations, the results are similar to the results of all eliminations together, for all methods of dividing the areas. The only difference in the results is that on the day of mixing, the proportion of defaecations in both the own toilet area and the own non-toilet area decrease significantly [P=0.0075 and P=0.0208, respectively] after which they remained stable.

### Table 7. Eliminations around mixing piglets /10 areas.

<table>
<thead>
<tr>
<th>Area/Day</th>
<th>Before</th>
<th>Of</th>
<th>After</th>
<th>Total</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>29</td>
<td>19</td>
<td>13</td>
<td>61</td>
<td>0.0739</td>
</tr>
<tr>
<td>2</td>
<td>27</td>
<td>30</td>
<td>27</td>
<td>84</td>
<td>0.6539</td>
</tr>
<tr>
<td>3</td>
<td>54</td>
<td>40</td>
<td>42</td>
<td>136</td>
<td>0.5364</td>
</tr>
<tr>
<td>4</td>
<td>21</td>
<td>15</td>
<td>28</td>
<td>64</td>
<td>0.0890</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
<td>9</td>
<td>13</td>
<td>27</td>
<td>0.0955</td>
</tr>
<tr>
<td>6</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>7</td>
<td>NV*</td>
</tr>
<tr>
<td>7</td>
<td>14</td>
<td>15</td>
<td>11</td>
<td>40</td>
<td>0.6961</td>
</tr>
<tr>
<td>8</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>7</td>
<td>NV*</td>
</tr>
<tr>
<td>9</td>
<td>17</td>
<td>18</td>
<td>12</td>
<td>47</td>
<td>0.5044</td>
</tr>
<tr>
<td>10</td>
<td>2</td>
<td>2</td>
<td>5</td>
<td>9</td>
<td>NV*</td>
</tr>
<tr>
<td>Total</td>
<td>173</td>
<td>154</td>
<td>155</td>
<td>482</td>
<td>0.4721</td>
</tr>
</tbody>
</table>

*: no valid chi-squared analysis could be performed

### Table 8. Eliminations around mixing piglets /4 areas.

<table>
<thead>
<tr>
<th>Area/Day</th>
<th>Before</th>
<th>Of</th>
<th>After</th>
<th>Total</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>OT</td>
<td>131</td>
<td>65</td>
<td>66</td>
<td>262</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>ONT</td>
<td>42</td>
<td>28</td>
<td>25</td>
<td>95</td>
<td>0.1523</td>
</tr>
<tr>
<td>NOT</td>
<td>0</td>
<td>39</td>
<td>43</td>
<td>82</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>NONT</td>
<td>0</td>
<td>22</td>
<td>21</td>
<td>43</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Total</td>
<td>173</td>
<td>132</td>
<td>134</td>
<td>439</td>
<td>0.4721</td>
</tr>
</tbody>
</table>

OT: own toilet
ONT: not own toilet
NONT: not own non-toilet

Frequencies with different letters [ab]: the proportion of eliminations differs significantly with P<0.05

On the day before mixing, the piglets were not yet able to eliminate in the adjoining pen (displayed by the red zero in the table), therefore a significant increase was found in the proportion of eliminations in both the toilet area and the non-toilet area of the “not own” pen on the day of mixing (P<0.0001). On the day after mixing, however, the proportion of eliminations made in the toilet area and the non-toilet area of the adjoining pen remained equal (P=0.6304 and P=0.8515, respectively).

When separating the eliminations in urinations and defaecations, the results are similar to the results of all eliminations together, for all methods of dividing the areas. The only difference in the results is that on the day of mixing, the proportion of defaecations in both the own toilet area and the own non-toilet area decrease significantly [P=0.0075 and P=0.0208, respectively] after which they remained stable.
3.3.2. Mixing sows

The total amount of eliminations on the day before mixing was somewhat lower than on the following two days. This difference in total eliminations, however, was not significant (P=0.3027) as displayed in Table 9.

When the pen was divided in the ten areas displayed in Figure 6, it was shown that most eliminations [more than 65%] were still made on the toilet areas [area 1 to 4] and the proportion of eliminations made on the toilet areas [T] together did not differ between the three days around mixing (P=0.9214). In area 10 the number of eliminations was lowest, even too low to produce a valid chi-square test.

For most areas, the number of eliminations observed remained relatively stable over the three days around mixing. In area 1 and 4, an increase in the number of eliminations was found on the day of mixing and the day after mixing. This increase, however, is partly explained by the higher total amount of eliminations on the day of mixing and the day after mixing. Therefore, only in area 1 the proportion of eliminations on the day before mixing [7.4%] was found to be significantly lower than on the day of mixing [14.4%] (P=0.0490) and the day after mixing [19.4%] (P=0.0020). In area 3, the proportion of the eliminations on the day after mixing [5.3%] was significantly lower than the proportion on the day before mixing [18.9%] (P=0.0002) and the day of mixing [17.2%] (P=0.0005).

When the pen was divided in four areas, the own toilet area was found to have the highest eliminative frequency on the day before mixing as displayed in Table 10. On the day of mixing, however, the proportion of eliminations in the not-own toilet area significantly decreased from 43.2% to 24.7% (P=0.0004), while the proportion of eliminations in the not-own toilet area significantly increased from 23.6% to 42.5% (P=0.0004) causing the eliminative frequency on the day of mixing to be highest in the not-own toilet area. On the day after mixing the amount of eliminations in both toilet areas were between the extremes found on the day before and the day of mixing, causing these areas to be equally used to eliminate in on this day.

When comparing the day after mixing the sows with the day before weaning the piglets, it was found that the proportion of eliminations in area 2, 5 and 8 were significantly reduced, as displayed in Table 11 (P=0.0174, P=0.0012 and P=0.0061, respectively). Contrarily, the proportion of the daily eliminations increased significantly in area 1 (P=0.0458) and area 4 (P=0.0048). On the day after mixing the sows, more than 65% of the eliminations was made in one of the toilet areas [T] and this is comparable to all other live observation days. On the day before weaning, however, more than 83% of the eliminations was made in one of the toilet areas [T], and the proportion of eliminations in other areas in the pen [NT] was significantly reduced (P=0.0012). When the pen was divided in four areas, similar results were found, as displayed in Table 12. The proportion of eliminations in the own non-toilet and the not own non-toilet areas were significantly reduced (P=0.0225 and P=0.0052, respectively) on the day before weaning and the proportion of eliminations in the own toilet area was significantly increased on the day before weaning (P=0.0376) as compared to the day after mixing the sows.

### Table 9: Eliminations around mixing sows /10 areas.

<table>
<thead>
<tr>
<th>Area/Day</th>
<th>Before</th>
<th>Of</th>
<th>After</th>
<th>Total</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>11 a</td>
<td>25 b</td>
<td>33 b</td>
<td>69</td>
<td>0.0089</td>
</tr>
<tr>
<td>2</td>
<td>37</td>
<td>33</td>
<td>31</td>
<td>101</td>
<td>0.2695</td>
</tr>
<tr>
<td>3</td>
<td>28 a</td>
<td>30 a</td>
<td>9 b</td>
<td>67</td>
<td>0.0004</td>
</tr>
<tr>
<td>4</td>
<td>22</td>
<td>29</td>
<td>38</td>
<td>89</td>
<td>0.1862</td>
</tr>
<tr>
<td>5</td>
<td>10</td>
<td>12</td>
<td>15</td>
<td>37</td>
<td>0.7274</td>
</tr>
<tr>
<td>6</td>
<td>4</td>
<td>9</td>
<td>2</td>
<td>15</td>
<td>0.0939</td>
</tr>
<tr>
<td>7</td>
<td>17</td>
<td>15</td>
<td>19</td>
<td>51</td>
<td>0.6406</td>
</tr>
<tr>
<td>8</td>
<td>5</td>
<td>9</td>
<td>12</td>
<td>26</td>
<td>0.3416</td>
</tr>
<tr>
<td>9</td>
<td>11</td>
<td>7</td>
<td>9</td>
<td>27</td>
<td>0.4043</td>
</tr>
<tr>
<td>10</td>
<td>3</td>
<td>5</td>
<td>2</td>
<td>10</td>
<td>NV*</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>148</td>
<td>174</td>
<td>170</td>
<td>492</td>
<td>0.3027</td>
</tr>
</tbody>
</table>

Frequencies with different letters (ab): the proportion of eliminations differs significantly with P<0.05

*: no valid chi-square analysis could be performed

### Table 10: Eliminations around mixing sows /4 areas.

<table>
<thead>
<tr>
<th>Area/Day</th>
<th>Before</th>
<th>Of</th>
<th>After</th>
<th>Total</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>OT</td>
<td>64 a</td>
<td>43 b</td>
<td>55 b</td>
<td>162</td>
<td>0.0020</td>
</tr>
<tr>
<td>ONT</td>
<td>23</td>
<td>22</td>
<td>30</td>
<td>75</td>
<td>0.5084</td>
</tr>
<tr>
<td>NOT</td>
<td>35 a</td>
<td>74 b</td>
<td>57 a</td>
<td>166</td>
<td>0.0016</td>
</tr>
<tr>
<td>NONT</td>
<td>26</td>
<td>35</td>
<td>28</td>
<td>89</td>
<td>0.7912</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>148</td>
<td>174</td>
<td>170</td>
<td>492</td>
<td>0.3027</td>
</tr>
</tbody>
</table>

OT: own toilet
ONT: not own non-toilet
NONT: not own toilet

Frequencies with different letters (ab): the proportion of eliminations differs significantly with P<0.05

The proportion of eliminations in the not-own toilet area significantly increased from 43.2% to 24.7% (P=0.0004), while the proportion of eliminations in the not-own toilet area significantly increased from 23.6% to 42.5% (P=0.0004) causing the eliminative frequency on the day of mixing to be highest in the not-own toilet area. On the day after mixing the amount of eliminations in both toilet areas were between the extremes found on the day before and the day of mixing, causing these areas to be equally used to eliminate in on this day.

When comparing the day after mixing the sows with the day before weaning the piglets, it was found that the proportion of eliminations in area 2, 5 and 8 were significantly reduced, as displayed in Table 11 (P=0.0174, P=0.0012 and P=0.0061, respectively). Contrarily, the proportion of the daily eliminations increased significantly in area 1 (P=0.0458) and area 4 (P=0.0048). On the day after mixing the sows, more than 65% of the eliminations was made in one of the toilet areas [T] and this is comparable to all other live observation days. On the day before weaning, however, more than 83% of the eliminations was made in one of the toilet areas [T], and the proportion of eliminations in other areas in the pen [NT] was significantly reduced (P=0.0012). When the pen was divided in four areas, similar results were found, as displayed in Table 12. The proportion of eliminations in the own non-toilet and the not own non-toilet areas were significantly reduced (P=0.0225 and P=0.0052, respectively) on the day before weaning and the proportion of eliminations in the own toilet area was significantly increased on the day before weaning (P=0.0376) as compared to the day after mixing the sows.

### Table 11: Eliminations of mixing and weaning/10 areas.

<table>
<thead>
<tr>
<th>Area</th>
<th>Mix</th>
<th>Wean</th>
<th>Total</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>33</td>
<td>49</td>
<td>82</td>
<td>0.0458</td>
</tr>
<tr>
<td>2</td>
<td>31</td>
<td>16</td>
<td>47</td>
<td>0.0174</td>
</tr>
<tr>
<td>3</td>
<td>9</td>
<td>15</td>
<td>24</td>
<td>0.2093</td>
</tr>
<tr>
<td>4</td>
<td>38</td>
<td>62</td>
<td>100</td>
<td>0.0048</td>
</tr>
<tr>
<td>5</td>
<td>15</td>
<td>2</td>
<td>17</td>
<td>0.0012</td>
</tr>
<tr>
<td>6</td>
<td>2</td>
<td>3</td>
<td>5</td>
<td>NV*</td>
</tr>
<tr>
<td>7</td>
<td>19</td>
<td>15</td>
<td>34</td>
<td>0.4587</td>
</tr>
<tr>
<td>8</td>
<td>12</td>
<td>2</td>
<td>14</td>
<td>0.0061</td>
</tr>
<tr>
<td>9</td>
<td>9</td>
<td>6</td>
<td>15</td>
<td>0.4215</td>
</tr>
<tr>
<td>10</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>NV*</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>170</td>
<td>171</td>
<td>341</td>
<td>0.9568</td>
</tr>
</tbody>
</table>

*: no valid chi-square analysis could be performed

### Table 12: Eliminations of mixing and weaning/4 areas.

<table>
<thead>
<tr>
<th>Area</th>
<th>Mix</th>
<th>Wean</th>
<th>Total</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>OT</td>
<td>55</td>
<td>74</td>
<td>129</td>
<td>0.0376</td>
</tr>
<tr>
<td>ONT</td>
<td>30</td>
<td>15</td>
<td>45</td>
<td>0.0225</td>
</tr>
<tr>
<td>NOT</td>
<td>57</td>
<td>69</td>
<td>126</td>
<td>0.1557</td>
</tr>
<tr>
<td>NONT</td>
<td>28</td>
<td>13</td>
<td>41</td>
<td>0.0052</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>170</td>
<td>171</td>
<td>341</td>
<td>0.9568</td>
</tr>
</tbody>
</table>

OT: own toilet
ONT: own non-toilet
NOT: not own toilet
NONT: not own non-toilet
3.3.3. Sniffing and mixing

Mixing the piglets did not change the proportion of eliminations that were preceded or followed by sniffing (P=0.7250). Sniffing general, however, was almost doubled on the day of mixing the piglets, and remained higher on the day after mixing as displayed in Table 13 and Table 14. The amount of sniffing directed to eliminations of pigs from the adjoining pen were highest on the day of mixing the piglets as displayed in Table 13.

Comparably, mixing the sows did not change the proportion of eliminations that were preceded or followed by sniffing (P=0.1471), but sniffing in general was more than doubled on the day of mixing the sows, and remained higher on the day after mixing as displayed in Table 13 and Table 14. On the day before and after mixing the sows, piglets directed most of the sniffing to eliminations of pigs from their own pen, while on the day of mixing the sows, most of the sniffing was directed to eliminations of pigs originating from the adjoining pen, as shown in Table 13. Additionally the amount of sniffs directed towards eliminations of which the identity and origin of the producer was unknown increased.

On the day before weaning, significantly less eliminations were preceded or followed by sniffing (P=0.0114) and the sniffing in general was decreased with 33% compared to the day after mixing the sows, as displayed in Table 13 and Table 14. On the day after mixing the sows, most of the sniffs were directed towards eliminations of the sow, while on the day before weaning most sniffs were directed towards elimination of piglets, as displayed in Table 14.

Table 13 frequency of sniffing directed to eliminations of pigs originating from different pens on the days of live observation.

<table>
<thead>
<tr>
<th>Day/Origin</th>
<th>Own</th>
<th>Other</th>
<th>Self</th>
<th>Unknown</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before mix piglets</td>
<td>79</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>82</td>
</tr>
<tr>
<td>Mixing piglets</td>
<td>41</td>
<td>101</td>
<td>3</td>
<td>12</td>
<td>157</td>
</tr>
<tr>
<td>After mix piglets</td>
<td>47</td>
<td>44</td>
<td>4</td>
<td>18</td>
<td>113</td>
</tr>
<tr>
<td>Before mix sow</td>
<td>41</td>
<td>24</td>
<td>3</td>
<td>31</td>
<td>99</td>
</tr>
<tr>
<td>Mixing sows</td>
<td>47</td>
<td>56</td>
<td>7</td>
<td>154</td>
<td>264</td>
</tr>
<tr>
<td>After mix sow</td>
<td>21</td>
<td>14</td>
<td>1</td>
<td>188</td>
<td>224</td>
</tr>
<tr>
<td>Before weaning</td>
<td>18</td>
<td>15</td>
<td>1</td>
<td>116</td>
<td>150</td>
</tr>
<tr>
<td>Total</td>
<td>294</td>
<td>254</td>
<td>22</td>
<td>519</td>
<td>1089</td>
</tr>
</tbody>
</table>

Table 14 frequency of sniffing directed to eliminations of piglets or sows on the days of live observation.

<table>
<thead>
<tr>
<th>Day/Identity</th>
<th>Piglet</th>
<th>Sow</th>
<th>Unknown</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before mix piglets</td>
<td>17</td>
<td>64</td>
<td>1</td>
<td>82</td>
</tr>
<tr>
<td>Mixing piglets</td>
<td>32</td>
<td>124</td>
<td>1</td>
<td>157</td>
</tr>
<tr>
<td>After mix piglets</td>
<td>36</td>
<td>70</td>
<td>7</td>
<td>113</td>
</tr>
<tr>
<td>Before mix sow</td>
<td>32</td>
<td>58</td>
<td>9</td>
<td>99</td>
</tr>
<tr>
<td>Mixing sows</td>
<td>73</td>
<td>118</td>
<td>73</td>
<td>264</td>
</tr>
<tr>
<td>After mix sow</td>
<td>77</td>
<td>95</td>
<td>52</td>
<td>224</td>
</tr>
<tr>
<td>Before weaning</td>
<td>70</td>
<td>44</td>
<td>36</td>
<td>150</td>
</tr>
<tr>
<td>Total</td>
<td>337</td>
<td>573</td>
<td>179</td>
<td>1089</td>
</tr>
</tbody>
</table>

Own: elimination of pig of the own pen
Other: elimination of pig of adjoining pen
Self: own elimination
Unknown: producer of sniffed elimination unknown
4. Discussion

This study showed changes in the eliminative behaviour of the piglets during the first five days after birth, indicating that development of the eliminative preferences during these days occurred. This was indicated by the increase of eliminations near the wall and in the toilet area, and the decrease of eliminations in the nest and crowded areas. Additionally, sniffing was observed both before and after eliminating, but not very frequent, indicating that smell has some influence on the piglets’ decision where to eliminate. Piglets were found to avoid eliminating in the feeding area of the sow and their own nest. Additionally, the piglets avoided to eliminate in the lying area of the sow, but not if she was lying in one of the toilet areas. Both mixing events, induced as a change in the piglets’ environment, affected the piglets’ preferred elimination site.

During the live observations, the piglets on average eliminated 0.68 times per hour. Of these eliminations, 0.42 were urinations and 0.26 defaecations. When assuming equal distribution of the amount of eliminations over the day, this would sum up to 16.3 eliminations in 24 hours, which is similar to the 16.4 eliminations found by Buchenauer et al. (1982). Of these daily eliminations, 6.4 would be defaecations which is somewhat more than the 4 defaecations per day found by Van Putten (1978). Whatson (1985) found that piglets older than 15 days on average defaecated 0.2 times per hour, which is also lower than the observations in the present study. The urination rate in the present study, however, is similar to the 0.4 urinations per hour found by Whatson (1985).

Possible explanations for the difference in defaecation rate could be: defaecations being not equally distributed over the day, differences in management practice and differences in suckling rate. Firstly, Buchenauer et al. (1982) found that 59% of the eliminations were made during daytime. The current study only observed the piglets during daytime, while both Whatson (1985) and Van Putten (1978) also made nightly observations. Secondly, Whatson (1985) suggested that management practices may influence the defaecation rate as the water and solid feed intake may vary. The higher defaecation rate in the current study, may thus be caused by a high solid feed intake as the piglets were provided with a piglet starter feed from two weeks of age. Additionally, the sows were floor fed, enabling the piglets to eat along, and sawdust and straw were provided as rooting material, which were possibly ingested by the piglets. Lastly, the majority of eliminations (>65%) occurred directly after a suckling bout, in accordance with earlier studies (Buchenauer et al., 1982; Whatson, 1985; Fraser and Broom, 1997). The suckling rate may, therefore, be a major influence of the defaecation rate (Whatson, 1985).

The majority of the piglets’ eliminations (65%) were made in the preselected toilet area with slatted floor [area 1, 2, 3 and 4]. The pen hygiene scores [not presented in the current study] showed that that is about equal to the percentage of soiling of the toilet areas by the sow. This indicates that piglets may have eliminated where their mother had eliminated as suggested by Buchenauer et al. (1982) and Whatson (1985).

4.1 Development of the eliminative behaviour in piglets

During the video observations the piglets on average eliminated 12.9 times in 13 hours. When equal distribution of the amount of eliminations is assumed, this counts up to 23.8 eliminations per day which is much higher than the 16.3 eliminations per day found during the live observations and the 16.4 eliminations per day found by Buchenauer et al. (1982). This difference in eliminative frequency can be explained by the piglets’ age, as Whatson (1985) found piglets to eliminate about once an hour between day 3 and 5 of age, as displayed in Figure 9. Interestingly, this graph of Whatson (1985) shows an increase in the amount of eliminations in the first few days after birth similar to the results of the video observations.
The time elapsed before the first piglet made an elimination on the slatted floor of the preselected toilet area varied largely between the pens. The fastest piglet eliminated in the toilet area only 12 minutes after its last sibling was born. The piglet in question was hardly able to walk as it was unstable due to its young age and fell multiple times. This was also observed by Whatson (1985) on the first day after birth. In another pen, however, seven and a half hours had elapsed between the last piglet was born and the first elimination in the toilet area occurred. For the third pen, the latency of the first defaecation in the preselected toilet area could not be calculated as the time of birth was unknown. The average time between birth and the first elimination in the toilet area was 3 h and 36 min. This average, however, is based on only two observations and its accuracy is thus doubtful. Further research into the time between birth and the first elimination on a preselected toilet area is therefore needed. The six pens of round two, of which the videos only recently became available, provide a good opportunity for that. For more accurate observations, also marking of the piglets directly after birth is advised. These markings enable calculation of the time between birth and the first elimination, and between birth and the first elimination on a preselected toilet area, for each piglet in the pen.

Analysis of the video observations of the three pens showed how much the piglets eliminated in each of the five areas on day one, three and five. The number of eliminations made on the toilet areas increased significantly over time, while the eliminations made in the nest decreased significantly. This indicates that development of the piglets’ preferences to eliminate in a specific part of the pen occurred in the five days after birth, and this is in line with former studies (Pflug, 1976; Whatson, 1978; Buchenauer et al., 1982; Petherick, 1983; Whatson, 1985). Additionally, the results clearly show that on day five, the majority (64%) of the piglets’ eliminations were made on the slatted floor of the preselected toilet area.

The first day after birth, the majority of the eliminations was made on the solid floor of area 3 and 4. On this day, the piglets spent most of their time in these areas as it was observed that all suckling bouts took place there. After the suckling bouts, they often fell asleep near the udder and made only short travels for their eliminations, which is in agreement with Titterington and Fraser (1975). On the second day after birth, the majority of the eliminations was still made in area 3 and 4. The pen maps displayed in Figure 8, however, show that the eliminations became less dispersed than on day one, which is in agreement with Schmid (1991; 1997). On day five, the number of eliminations near the wall increased further, strengthening the conclusion that the development of the elimination location preferences of piglets occurred in the first five days after birth.

The pen maps indicate a major downside of the use of the relatively large areas in this study. Without the pen maps, for example, the increase of eliminations near the walls of the pen on day three would have been missed. This downside also occurred during the live observations where it was observed that piglets often eliminated on almost the same spot near the wall, but just on the edge of different areas. Eliminations that were very close together could thus be scored for different areas, while eliminations scored in the same area could actually have been further away.

The amount of eliminations in the piglets’ nest decreased over time. The pen maps in Figure 8 show that most of the eliminations in the nest were made at the far end of the nest, as far away from the heat lamp as possible. As the nest area is rather large and the piglets usually lie directly under the heat lamp, it is questionable whether the piglets perceived the whole area we indicated as the nest area, as their actual nest. Whatson (1985) found similar results, as displayed in Figure 10, and indicated that the size of the nest is the cause for the displaced eliminations in
the nest area. This hypothesis is based on the minimum distance to what the piglet perceives as the nest. Whatson (1985) found piglets preferably to eliminate minimally a metre and a half away from their lying area, which is less than the length of the nest area in both studies.

For the statistical analysis of the results the three pens were assumed to be the same, while in reality one of the three pens was the mirror image of the other two. In the current study it could not be tested whether the side of the nest had any effect on the results as only one pen with the nest on the left side was observed.

In two of the three pens, the sow was seen actively pushing a piglet that was eliminating on the solid floor onto the elevated slatted floor of the toilet area. This contradicts the observations of Whatson (1985) whom did not observe any direct influence of the sow on the piglets’ choice ‘where to eliminate’. Possibly this behaviour occurred in the study of Whatson (1985) as well, but was not observed in the three hour observation periods. An alternative explanation for this behaviour is that the sows in the current study are more strict in using the toilet area, as they have been raised to do so themselves. The pen maps displayed in Figure 8, on the other hand, showed that the sow herself did make displaced eliminations. While making these displaced eliminations, however, the sow always had her head in the corner of area 1. The sow may thus have intended to eliminate on the toilet area as Andersen and Pedersen (2011) suggested that pigs are unaware of where their hind is during elimination. After eliminating, piglets often shook their head which is in agreement with Buchenauer et al. (1982).

Conclusions

As the proportion of the piglets’ eliminations on the toilet areas increased and the proportion of eliminations in the nest decreased in the first 5 days after birth, it can be concluded that the development of the eliminative behaviour occurs in the first five days after birth. This analysis, however, was performed on only three pens from the same round. To increase the validity of the results, additional analysis of the now available videos of round 2 is advised. Dividing the pen in smaller areas and observing all pens for five days may increase the precision of the analysis even further. Additionally, for future observations the results should be checked for effect of the nest on the left or right side of the pen.

4.2 Factors influencing the eliminative behaviour in piglets

4.2.1. Smell

Sniffing before or after elimination was on average observed with 38.7% of the eliminations on the days of the live observations. This differs with Wechsler and Bachmann (1998) findings that sniffing occurred both before and after elimination in most of the cases. This difference is likely to be caused by a difference in observation methods. In the current study, one observer observed two litters, about twenty piglets, at the same time. As most piglets eliminated directly after suckling, in agreement with earlier findings (Buchenauer et al., 1982; Fraser and Broom, 1997), and as the suckling bouts were highly synchronised between the sows, many piglets eliminated at once. Therefore, it is very likely that the observers missed some of the subtle sniffing behaviour or even eliminations. In the study of Wechsler and Bachmann (1998), however, one observer observed the sequence of behaviour of one piglet at a time after the piglet entered the predetermined elimination area. As the observer could focus on one piglet at the time, the chance of behaviours being missed is much smaller. Their method, however, did not fit with the broad scope of this observational study.

The piglets’ behaviour was observed only around elimination. For this method, it would have been nice for the observer to know in advance when the piglet was going to eliminate, so to be ready to observe the sniffing behaviour that occurs before the elimination. Unfortunately, this was not the case. Thus, the observer did not know when the observation would have started and what type of sniffing behaviour should have been noted. This in contrast to Wechsler and Bachmann (1998) methods that have a clear starting point: when the piglet enters the area. Therefore, it is likely that in the current study sniffing before elimination is missed more often than sniffing after elimination as the observer then knows which piglet to observe. The results indicate that sniffing occurred more often before elimination [29.3%] than after [14.9%], while Wechsler and Bachmann (1998) stated it occurs equally before and after eliminating. The higher occurrence of sniffing before elimination, combined with the theory that sniffing before elimination is more
likely to be missed, indicates that the low amount of sniffing observed after elimination in the current study is caused by a low occurrence of sniffing after elimination.

In the current study, sniffing was stated to be related to an elimination if it was observed within a time window of two minutes before or after the elimination was observed. This time window was set based on preliminary analysis of our own data. Both the sniffing and eliminative behaviour, however, varied largely in duration. One piglet displayed sniffing behaviour for over five min in different areas before it transitioned to elimination. Consequently, it is possible that the sniffing behaviour was observed when the piglet started sniffing and the elimination five minutes later. In the analysis, however, the sniffing behaviour was not related to the elimination as the observations were 5 min apart, although the sniffing was performed right up to the start of the elimination.

To study if and how smell influences the piglets’ decision ‘where to eliminate’, sniffing was used as the earlier study of Wechsler and Bachmann (1998) indicated that sniffing behaviour was observed around eliminating. The definition of sniffing used; “a pig withdraws the outer parts of the snout at least twice”, was copied from Wechsler and Bachmann (1998) and found to describe the actual sniffing behaviour well. Sniffing according to this definition, though, is not the only way pigs can perceive smell of the environment. During the observations pigs were often found to root in faeces or soiled sawdust before elimination, and this is in accordance with the findings of Buchenauer et al. (1982) that piglets often root before elimination. By means of this rooting behaviour, the piglets might have perceived smell, taste or even pheromones from their environment; but as this rooting behaviour does not fit within the definition of sniffing, these observations were not noted. To include rooting behaviour into studies on the environmental influences on the eliminative behaviour of pigs, knowledge of smell, taste and pheromone perception during the rooting behaviour of pigs is needed.

The observations of this study could not prove that sniffing was related to eliminating as the occurrence of sniffing around elimination was relatively low. Additionally, the ethogram used did not provide the data needed to perform a sequential analysis like Wechsler and Bachmann (1998) [i.e. more than 2 behaviours that could occur in random order (Haccou and Meelis, 1992)]. The results showed that proportion of eliminations which were preceded or followed by sniffing was significantly lower on the day before mixing the piglets than on the day before mixing the sows and the day before weaning. This could indicate that sniffing occurred more often as the piglets grew older. On the other hand, this increase in observed sniffing could also be explained by the fact that the observers became more experienced and could therefore observe a larger proportion of the occurred sniffs. This, however, seems unlikely as the amount of sniffing seems to have decreased again after the day of mixing the sows.

To establish how smell influences the piglets’ decision ‘where to eliminate’ it is not only important whether piglets sniff around elimination, but also at what this sniffing is directed to. Of all sniffs observed, 52.0% was directed towards an elimination made by a sow, and 29.8% towards an elimination made by a piglet, for the rest of the sniffs the origin of the elimination was unknown. The faeces of a sow and a piglet are easy to tell apart due to their difference in colour and size. But as the piglets tended to eliminate where the sow had eliminated before, as also described in literature (Buchenauer et al., 1982; Whatson, 1985), it was impossible to determine what smell the piglets perceived when sniffing on a pile of eliminations.

Even for observations for which the object that was sniffed was known, a degree of uncertainty exists about the smell the piglet perceived from sniffing it. Piglets are known to have the ability to accurately distinguish the smell of separate faecal samples (Morrow-Tesch and McGlone, 1990). How piglets perceive smells of mixed faecal/urine samples, however, and if they can still distinguish the separate smells, is unknown. Therefore, it is unknown how the piglets of the current study perceived the smell of piles of faeces or faeces that was urinated over. Furthermore, the smell of the visible eliminations might have been mixed with the smell of eliminations lying under the slatted floor or with the smell of the faeces and soiled saw dust thrown on the slatted floor when cleaning the pen.

Table 15 Origin of the eliminations sniffed on the days around mixing the sows.

<table>
<thead>
<tr>
<th>Day</th>
<th>Known</th>
<th>Unknown</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before mixing</td>
<td>68</td>
<td>31</td>
</tr>
<tr>
<td>Mixing sows</td>
<td>110</td>
<td>154</td>
</tr>
<tr>
<td>After mixing</td>
<td>36</td>
<td>188</td>
</tr>
<tr>
<td>Total</td>
<td>214</td>
<td>373</td>
</tr>
</tbody>
</table>

When analysing whether the producer of an elimination that was sniffed at, originated from the same pen as the sniffer or from the adjoining pen, results showed that for many of the sniffed eliminations [47.7%] the origin of the producer was unknown. Some of this uncertainty is caused by the hourly switch of observers; the new observer does not know who made the eliminations lying in the pen. Without the switching, however, it remains questionable whether the observer would have been able to remember the origin of the producer of each elimination.

Around mixing the sows, uncertainty about the origin of the producer of the sniffed eliminations increased as shown in Table 15. This increase is likely to be caused by the increase of sniffing in general and the fact that the sow can now eliminate in both sides of the pen.
4.2.2. Social environment

To analyse whether piglets preferred to eliminate in seclusion, two different methods were used. During the live observations of round one, only 37% of the eliminations was made while the piglet was alone in an area. This indicates that the piglets do generally not seek seclusion. The analysis, however, is largely dependent on the definition of seclusion. As the areas used in the analysis are rather large, a piglet may still feel secluded when another piglet is sleeping in the same area. Therefore, our definition of seclusion in this analysis [i.e. a piglet being alone in the area] might not be the same as the piglet’s perception of seclusion. Additionally, it remains unknown whether a piglet that eliminates in isolation wants to be alone or just simply avoids eliminating in its lying area where its siblings are sleeping, as suggested by many scientists (Signoret et al., 1975; Pflug, 1976; Whatson, 1978; Baxter, 1982; Petherick, 1983; Whatson, 1985; Fraser and Broom, 1997; Damm and Pedersen, 2000; Olsen et al., 2001; Ekesbo, 2011).

In the other method, the performed analysis showed that piglets do choose a quiet area to eliminate in as they eliminate more in the areas where the average percentage of piglets throughout the day is low. The results, however, do not show whether the piglets are alone in that area when they eliminate. Although in general piglets do not spend much of their time in the areas where many eliminations occur, they often go there together to eliminate at the same time after suckling. Furthermore, it remains unclear whether the piglets chose to eliminate on the toilet area because it was a quiet area or because it was not suitable for any other activity as suggested by Whatson (1985). The found results are, therefore, not a good indicator that piglets prefer to eliminate in seclusion. Nevertheless, they do show accurately that piglets use separate areas for elimination and other activities, which is in agreement with many previous studies (Signoret et al., 1975; Pflug, 1976; Whatson, 1978; Baxter, 1982; Petherick, 1983; Whatson, 1985; Fraser and Broom, 1997; Damm and Pedersen, 2000; Olsen et al., 2001; Ekesbo, 2011). Table 5 shows that many more eliminations were made in area 1 and 2 than would be expected by the average percentage of piglets that were present in these areas throughout the day. Conversely, although piglets spend a lot of time in the nest, they hardly ever eliminate there.

The number of observed eliminations in each area differed very significantly with the number of eliminations expected under the assumption that piglets eliminate in the area that they are, between all days. When examining the whereabouts and the eliminations of the piglets more closely, a change in the eliminative behaviour of the piglets is visible, which is not shown in differences in the level of significance, as the observed and expected values differed with P<0.0001 for all days. Table 16 shows that on day one the piglets spent most of their time in area 3 and 4, where also most eliminations were made. On day one, the piglets were thus found to spend the majority of their time around the sow which is in agreement with the findings of Titterington and Fraser (1975) that piglets spent most of their time in proximity of the sow on the first day after birth. Additionally, they eliminated mostly in the area where they stayed, and did not seem to avoid eliminating in the area they wanted to sleep in which is in agreement with the findings of Whatson (1985) and Schmid (1991; 1997).

On day three, the piglets spent most of their time in the nest [area 5]. This is in agreement with Titterington and Fraser (1975) findings that only after day 2 piglets spent most of their time under the heat lamp. Most eliminations, however, were made in area 3, 4 and 1, and the pen maps show that the piglets increasingly eliminated near the walls of the pen. Therefore, the results show that on day three the piglets more actively avoided to eliminate in the area they want to sleep in which is somewhat sooner than indicated by Whatson (1985), whom found these results on day four.

On day five after birth the piglets spent even more time in the nest [area 5] which corresponds to the findings of Pedersen et al. (2007) that the amount of time spent in the artificially heated area increases in the first five days after birth. The eliminations made in the nest, however, decreased, and all eliminations found in the nest area were all near the far end of the nest, which the piglets possibly not perceived as lying area as explained in paragraph 4.1. The amount of eliminations on the toilet areas [area 1 and 2] increased further, while eliminations on the solid floor decreased. These observations indicate that the piglets’ preference to not eliminate in the lying area grows stronger between day three and five.
4.2.3. Functional areas

Results showed that piglets avoided to eliminate in both the feeding area of the sow and their own nest as these areas were eliminated in less than expected if the eliminations were distributed equally over all areas. This is in line with statements found in literature (Yicui et al., 2008; Andersen and Pedersen, 2011; Ekesbo, 2011) and indicates that pigs use separate areas for eliminating, eating and sleeping as suggested by Whatson (1985). To calculate the expected values, however, equally sized areas were assumed, but which was not the case in this study as the pen was divided in areas based on the function of those areas. Area 5, 6, 9 and 10 had a slightly smaller surface than area 1, 2, 3, and 4 while area 7 and 8 where slightly larger. As the differences in surface are only small and the significance of the results is very high, correcting for area size would probably not affect the results.

The feeding areas of the sow [area 6 and 10] were least eliminated in; only 3.8% of the eliminations was made there. This supports Andersen and Pedersen (2011) findings that pigs keep their feeding area clean, but may also be partly explained by its large distance to the toilet areas, so no accidental soiling occurred. In spite of it being the largest area, only 12.4% of the eliminations were made in the piglets’ nest. There was an unexplainable difference between the amount of eliminations in the nest for pens with the nest on the left or right side. If the nest was on the right side of the pen, this area [area 8] was hardly ever eliminated in, while the nests on the left side of the pen [area 7] were soiled more often. Most eliminations in the nest were made on one end, furthest away from the heating lamp. Causes for this have already been discussed in section 4.1.

The results did not prove that piglets avoid to eliminate in the lying area of the sow, in contradiction to Whatson (1985) statements. This can be partly explained by the presence of two sows in the current study, as but only one sow, that was always the mother of the piglet, in the study of Whatson (1985). Possibly, piglets feel less need to avoid eliminating in the lying area of an unfamiliar sow. In the majority [62.2%] of the cases that a piglet eliminated in the lying area of the sow, however, it was in the lying area of its own mother.

Further analysis of the eliminations made in the lying area of the sows showed that the majority of these eliminations were made while the sow was lying on the slatted floor of the toilet area. Only 3.4% of the total amount of eliminations was made in the lying area of the sow when she was lying on the solid floor, indicating that piglets avoid to eliminate in the lying area of the sow, but only when she is lying on the solid floor of the pen. Piglets do not avoid eliminating in the lying area of the sow when the she is lying in the toilet area. This illustrates that piglets continue to use their preferred elimination site even if the sow is lying on the solid floor, indicating that piglets avoid to eliminate in the lying area of the sow, but only when she is lying on the solid floor of the pen. Piglets do not avoid eliminating in the lying area of the sow when the she is lying in the toilet area. This illustrates that piglets continue to use their preferred elimination site even if the sow is lying there. This agrees with the findings of Buchenauer et al. (1982), that piglets have a preferred elimination site. Furthermore, it weakens Whatson (1985) that pigs avoid to eliminate in the functional areas as the lack of eliminations in these areas could as well be explained by the pigs preference to eliminate in the toilet area.

Conclusions

The results show that the smell of other eliminations does play a role in the piglets’ decision ‘where to eliminate’, as [some] piglets sniffed eliminations before eliminating themselves. It remains unknown, however, how the smell of other eliminations directs the eliminative behaviour. An experiment in which piglets are given the choice where they want to eliminate based on different smells may answer this question.

Both methods used to assess whether piglets prefer to eliminate in seclusion did not provide a satisfying answer to this question, therefore we could not prove that piglets prefer to eliminate in isolation. Combining knowledge on the whereabouts of the piglets with the observed location of their eliminations, however, did provide other interesting insights. For example on the first day after birth the piglets spent most of their time near the sow and often eliminate where they are. On day three the piglets were found to avoid eliminating in their lying area. This behaviour was shown even more profoundly on day five after birth, which strengthens the conclusion in section 4.1 that the development of eliminative behaviour occurs in the first five days after birth.

The results show that piglets avoid to eliminate in the feeding of the sow and their own lying area. Eliminations in the lying area of the sow are only avoided when the sow is lying on the solid floor. Conversely, if the sow is lying on the slatted floor of the toilet area piglets tend to continue to use this as their elimination site. Additionally, the eliminative behaviour of the pigs seems to be directed adequately by the pen design as the toilet areas were eliminated in most often and the other functional areas were hardly soiled.
4.3. Effects of changes in the physical and social environment on the eliminative behaviour in piglets

Slight variation was found in the total number of eliminations observed in the five consecutive hours on the different live observation days. A strong line of increase or decrease was not found, as the amount of eliminations seemed to fluctuate. Additionally, the differences were found to be not significant. After both the mixing events, that were used as a change in the piglets’ physical and social physical environment, distinct behavioural changes were observed. After mixing, the piglets became very active and showed an increase of exploring and play behaviour that according to Hillmann et al. (2003) is normal for piglets that are at ease in a novel environment.

The increase in exploratory behaviour is likely to be displayed by the found increase in the total amount of sniffing and the sniffing related to eliminations on the day of mixing the piglets and the day of mixing the sow displayed in Table 13 and Table 3 respectively. The amount of sniffing seemed to subdue on the day after the mixing event which could be due the novelty of the situation wearing off, as indicated by Hillmann et al. (2003), and even more so on the long term as was visible on the day before weaning.

The increased activity made it harder to observe the eliminations and the sniffing behaviour related to it. Due to all the activity in the pen, it is very likely some eliminations and sniffing behaviour was missed by the observers on the day of mixing. Therefore, the results may not show changes in eliminative and sniffing behaviour as strongly as they were present. Additionally, the increased activity due to mixing greatly increased the uncertainty about the origin of the producer of the sniffed eliminations in the pen as shown in Table 13 and Table 14.

4.3.1 Mixing the piglets

The proportion of eliminations made in each of the ten areas did not significantly differ between the days around mixing the piglets. The differences found in frequency, for example the decrease from 29 to 13 eliminations in area 1, are mostly explained by the difference in the total amount of eliminations on those days. Results did show that the toilet areas were used most as elimination site, while area 6, 10 [feeding area] and 8 [nest] were hardly ever used. As the expected amount eliminations in area 6, 8 and 10, when assuming equal distribution, was below five for one or more of the days around mixing, no valid chi-square test could be performed (Ott and Longnecker, 2008). Additionally, changes in the eliminative behaviour in these areas have a low relevance as the amount of eliminations in these areas remained low on all three observation days around mixing the piglets.

When the pen was divided in four areas, some difficulty arose with the analysis. Namely, on the day before mixing the piglets, the piglets were not yet able to eliminate in the adjoining pen. On this day, the amount of eliminations in the not own non-toilet area [NONT] and the not own toilet area [NOT], therefore, was zero as displayed in Table 8. The significant difference found between the day before and the day of mixing the piglets was, thus, caused by restriction of the piglets and not the piglets’ choice. The results do, nevertheless, show that the piglets changed their elimination site after provided with the opportunity to eliminate in the adjoining pen as the amount of eliminations in the own pen was reduced with almost 50%. This indicates that the piglets are flexible in their elimination site and do not create a specific elimination site as stated by Buchenauer et al. (1982). Earlier conclusions have shown, however, that piglets have a strong preference to eliminate on the preselected toilet area.
### 4.3.2 Mixing the Sows

An outstanding result on the days around mixing the sows is the increase in the proportion of eliminations made in area 1, while the proportion of eliminations made in area 3 decreased throughout the three consecutive days. Additionally, in the period between mixing the sows and weaning, the proportion of eliminations made in area 2 decreased, while the proportion of eliminations made in area 1 and 4 increased. Thus, the amount of eliminations made in area 1 and 4 increased between mixing the sows and weaning, while they decreased in area 2 and 3. This change of elimination site within the preselected toilet area, can be explained by the removal of the slatted fence that separated area 2 and 3, and withheld the sow from moving to the adjoining pen.

First of all, with the fence still in place, area 2 and 3 both contained two corners. Baxter (1982) stated that pigs prefer to eliminate in the corner of the pen. This statement is backed up by the eliminations drawn in pen maps for both the current study displayed in Figure 8 and the study of Whatson (1985) displayed in Figure 11 where many eliminations are placed in the corners of the pen. After removal of the slatted fence to enable the sows to move freely to the adjoining pen, both area 2 and 3 no longer have any corners, and thus become less attractive to eliminate in.

Secondly, the slatted fence itself may have been attractive to eliminate near to. Many scientists found pigs often to eliminate near a wall or stated that pig prefer to eliminate near the wall (Baxter, 1982; Petherick, 1983; Whatson, 1985; Bate et al., 1988). As the slatted fence is a type of wall, it increases the floor area that is near a wall in area 2 and 3. Furthermore, Yicui et al. (2008) found pigs often to eliminate near slatted fences as they create draught that makes the area uncomfortable for lying (Hacker et al., 1994; Yicui et al., 2008). Additionally the slatted fence enables contact with pigs in the neighbouring pen, which appears to be appreciated during elimination (Hacker et al., 1994). Which of the suggested reasons stated above is the cause for the decrease in eliminations in area 2 and 3 after removal of the slatted fence remains unknown. An experiment using the same mixing strategy but using slatted or non-slatted fences for different pens may provide insight in the attractiveness of the slatted fence in this study. Attractiveness of the corner can be studied by an experiment using the same mixing strategy but maintaining the corners when providing the sows with access to the adjoining pen.

Another remarkable observation on the day of mixing the sows, is that the amount of eliminations made on the own toilet significantly decreased, while the eliminations made on the not own toilet area increased. Closer examination of the data revealed that all the sows, immediately after removal of the slatted fence, eliminated in the toilet area of the adjoining pen. Buchenauer et al. (1982) and Whatson (1985) found that piglets often eliminate where their mother has eliminated before. The sows’ elimination in the not own toilet area, therefore, is a likely cause for the increase in the piglets’ eliminations in the not own toilet area. The results, thus, indicate that when the sow changes her elimination site, the piglets likely follow her initiative.

The question remains, why do the sows immediately after removal of the fence eliminate in the toilet area of the adjoining pen? A possible explanation for this observation is the scent marking behaviour found in the wild boar whom are found to eliminate near the edge of their territory (Signoret et al., 1975; Meynhardt, 1978). Removal of the slatted fence enlarged the area the sows could reach. Therefore, the elimination made directly after removal of the fence is possibly a territorial marking in the newly discovered area. This suggests that also domesticated pigs use eliminations to mark their territory as was suggested in earlier studies (Signoret et al., 1975; Marcellis et al., 2002).

In the period between mixing the sows and weaning, the proportion of eliminations that were made outside the preselected toilet area decreased significantly. These results contradict the conclusion of Bate et al. (1988) that growth of the piglets increases the pig density in the pen which increases the amount of displaced eliminations (Heitman et al., 1961; Baldwin, 1969; Grauvogl and Buchenauer, 1976; Bate et al., 1988; Hacker et al., 1994; Fraser and Broom, 1997; Aarnink et al., 2006; Yicui et al., 2008). The threshold density of 120 kg/m², above which Randall et al. (1983) found pen soiling increased, was however not reached yet in the current study as the farrowing pen was large and provided the sow and piglets with 8.45 m².
Conclusions

The mixing events, that were used as a model for change in the physical and social environment, affected the piglets’ sniffing behaviour and where they eliminated. Therefore, the mixing events as induced in this study show to be a suitable method to study the effect of changes in the physical and social environment on the piglets’ eliminative behaviour. To obtain more precise results, however, observations of one piglet at a time around the mixing events is advised. The fact that the piglets both after mixing the piglets and after mixing the sows changed their elimination site indicated that they are flexible and do not create a specific toilet. The theory that pigs eliminate in an area that is not used for another activity, therefore, seems more likely. Earlier conclusions in this study showed, however, that piglet prefer to eliminate in the toilet area even if the sow is lying there.
References


Aarnink, A. J. A. 1997. Ammonia emission from houses for growing pigs as affected by pen design, indoor climate and behaviour, Wageningen University, Wageningen.


Fraser, A. F., and D. M. Broom. 1997. Farm animal behaviour and welfare. 3 ed. CABI.


## Appendix 1

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
<th>Where</th>
<th>Piglets nearby (only round 1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SUSU</td>
<td>smelling urine of an unfamiliar sow</td>
<td>#area</td>
<td>#piglets in same area</td>
</tr>
<tr>
<td>SUSO</td>
<td>smelling urine of own sow</td>
<td>#area</td>
<td>#piglets in same area</td>
</tr>
<tr>
<td>SUS?</td>
<td>smelling urine of a sow (unknown which)</td>
<td>#area</td>
<td>#piglets in same area</td>
</tr>
<tr>
<td>SUPS</td>
<td>smelling own urine</td>
<td>#area</td>
<td>#piglets in same area</td>
</tr>
<tr>
<td>SUPU</td>
<td>smelling urine of an unfamiliar piglet</td>
<td>#area</td>
<td>#piglets in same area</td>
</tr>
<tr>
<td>SUPO</td>
<td>smelling urine of a piglet of their own litter</td>
<td>#area</td>
<td>#piglets in same area</td>
</tr>
<tr>
<td>SUP?</td>
<td>smelling urine of a piglet (unknown which)</td>
<td>#area</td>
<td>#piglets in same area</td>
</tr>
<tr>
<td>SU?</td>
<td>smelling urine (unknown who’s)</td>
<td>#area</td>
<td>#piglets in same area</td>
</tr>
<tr>
<td>SFSU</td>
<td>smelling faeces of an unfamiliar sow</td>
<td>#area</td>
<td>#piglets in same area</td>
</tr>
<tr>
<td>SFSO</td>
<td>smelling faeces of own sow</td>
<td>#area</td>
<td>#piglets in same area</td>
</tr>
<tr>
<td>SFS?</td>
<td>smelling faeces of a sow (unknown which)</td>
<td>#area</td>
<td>#piglets in same area</td>
</tr>
<tr>
<td>SFPS</td>
<td>smelling own faeces</td>
<td>#area</td>
<td>#piglets in same area</td>
</tr>
<tr>
<td>SFPU</td>
<td>smelling faeces of an unfamiliar piglet</td>
<td>#area</td>
<td>#piglets in same area</td>
</tr>
<tr>
<td>SFPO</td>
<td>smelling faeces of a piglet of their own litter</td>
<td>#area</td>
<td>#piglets in same area</td>
</tr>
<tr>
<td>SFP?</td>
<td>smelling faeces of a piglet (unknown which)</td>
<td>#area</td>
<td>#piglets in same area</td>
</tr>
<tr>
<td>SF??</td>
<td>smelling faeces (unknown who’s)</td>
<td>#area</td>
<td>#piglets in same area</td>
</tr>
<tr>
<td>F</td>
<td>Defaecating</td>
<td>#area</td>
<td>#piglets in same area</td>
</tr>
<tr>
<td>U</td>
<td>Urinating</td>
<td>#area</td>
<td>#piglets in same area</td>
</tr>
</tbody>
</table>