Feeding systems for lactating sows:

Effects on welfare and productivity of sows and piglets

Master thesis

submitted by

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AFFIDAVIT

I hereby declare that I am the sole author of this work. No assistance other than that which is permitted has been used. Ideas and quotes taken directly or indirectly from other sources are identified as such. This written work has not yet been submitted in any part.

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My path changed from horses to pigs and I'm glad that I could get to know such great animals!

Table of Contents

1. Introduction

Feeding both, lactating and pregnant sows has always been a challenge in the swine industry. In nature, sows spend much of their day searching for food and chewing (Stolba and Wood-Gush, 1989). However, this is not the case for domesticated swine on commercial farms where feeding times are scheduled and short. A consequence of the feeding system not meeting the requirements of the sows' behavioral needs is that the sow can develop stereotypies (Lawrence and Terlouw, 1993) or other health issues (e.g. shoulder lesions). Furthermore, nutritional requirements also change from gestation to lactation, which needs to be considered, when calculating feeding quality and quantity.
To date, lactating and pregnant sows are fed using different feeding regimes: either ad libitum (continuous access to food over 24h) or restricted feeding (fixed amount of feed on fixed feeding times). Modern ad libitum feeding systems rely on mechanisms that require the sow to actively trigger access to feed by moving a ball or lever. This enables the sow to gain access to food whenever she wants and needs. With a manual ad libitum feeding system the exact amount of dispensed feed is not recorded and therefore inaccessible to the farmer. Delivery and recording of the exact amount of dispensed feed are already implemented in some restricted feeding systems, when regulated by a computer program. The computer program allows the farmer to plan the feed ration of the sow over the lactation. A new ad libitum feeding system was developed, where a computer program delivers and records exact amounts of feed and feeding times.
These feeding systems support farmers to find a balance between fulfilling the sows' behavioral needs, production traits (e.g. weight gain, mortality) and profitability (feed costs, labor time). Currently, there are just very few studies which compare different feeding regimes and systems regarding productivity, welfare and behavior of sows and piglets: Poulopoulou et al. (2018) looked at the productivity and reproductive performance of lactating sows. Shoulder lesions were included but no further clinical or behavioral welfare indicators. To expand our knowledge about lactation feeding systems, the following study was conducted.

2. Objectives of the thesis

The objective of the study was to examine the impact of different feeding systems (non-ad libitum and a manual/automated ad libitum feeding system) on the productivity, clinical welfare indicators and behavior of lactating sows and their piglets.

Research Questions:

Do the different feeding systems differ regarding productivity and welfare of sows and piglets? The hypothesis is, that automated ad libitum feeding systems can improve productivity, clinical welfare indicators and behavior of piglets and sows as measured by:

1. Daily feed disappearance, litter and sow weight (gain/loss)
2. Clinical data of sows and piglets (e.g. lesions, body condition)
3. Behavior of the sow (e.g. stereotypies)

3. Literature

3.1 Productivity

3.1.1 Feeding management

The transition between gestation and lactation is challenging for both, sows and farmers. Nutrient requirements are increasing at the end of gestation, when the fetal growth is predominant. At the time of farrowing, sows reduce their feed intake and after farrowing, sows need continuously more nutrients to produce sufficient milk for the growing piglets (Baxter et al., 2017; Cools et al., 2014; Guillemet et al., 2006). Furthermore, an optimal diet is important to keep the sows' body condition. The goal is to maintain a minimum score of 2 on a scale from 1 to 5 (Coffey et al., 1999) at the end of lactation to prevent shoulder lesions and subsequent impairment of fertility (Fitzgerald et al., 2009; Zurbrigg, 2006). Therefore, the diet needs to be adapted to the number of piglets and the stage of lactation regarding nutrient (esp. protein and amino acids) and energy content, but also regarding quantity of feed, optimally distributed over several meals per day. As pigs spend usually a large percentage of their active time with searching for food, chewing and eating (Stolba and Wood-Gush, 1989), feeding smaller portions over multiple meals per day can better fulfil behavioral needs in this respect and prevent the occurrence of oral stereotypies (Lawrence and Terlouw, 1993). However, the most common feeding management schemes for lactating sows comprise fixed feeding times with a fixed amount of feed combined with step-up feeding management, where the amount of feed increases with the day of lactation; but frequently they cannot sufficiently fulfil the energy requirements of the sow (Solà-Oriol and Gasa, 2017). There are studies showing, that ad libitum feeding in multiparous lactating sows increases the feed intake or results in an equal intake as restricted feeding (Sulabo et al., 2010; Thingnes et al., 2012).
In another study, three different amounts of feed were compared within the first days after farrowing to prepare the sow for ad libitum feeding. It was concluded, that increasing feed by 1.4 kg daily for the first five days after farrowing and then feeding ad libitum improved performance of the sow the most (Lei et al., 2018). Ad libitum feeding during the perinatal period led to an increased feed intake, which improved litter growth and weaning weight compared to restricted feeding, when sow back fat in late gestation was under 22mm

(Cools et al., 2014). Comparing a dry meal that was offered two times a day only for 30 min ad libitum with a liquid meal offered ad libitum the whole day, the liquid fed sows had higher body weight of piglets at weaning. Additionally, the sows spent more time standing, engaged in eating and had an increased feed intake (Scipioni et al., 2005). All studies show an improvement of performance when sows are fed ad libitum. Similarly, increasing feeding frequency to three times a day can increase the body condition score (BCS) (Poulopoulou et al., 2018).

Many factors influence the feed intake of sows: internal factors like parity and litter size but also external factors such as ambient temperature (O'Grady et al., 1985). In particular, more piglets require more milk and therefore sows need more feed and energy to produce enough milk (Eissen et al., 2000). In addition to that, sows with a higher parity consume more feed than sows with a low parity (O'Grady et al., 1985). Regarding room temperature O'Grady et al. (1985) found that sows eat more during winter and spring and that an increased ambient temperature of 6°C can lead to a drop in feed intake of 12%. However, Imaeda and Yoshioka (2007) showed no difference in feed intake in sows fed multiple times a day in the hot season compared to once a day feeding. A possible explanation is that the appetite is generally lower in the hot season and feeding frequency did not have an effect on feed intake. This work demonstrates the importance of adequate feed intake during lactation and accordingly the role that feeding systems can play during this stage of production.

3.1.2 Piglet mortality, sow weight loss, and conception rate

Similarly, an estimated protein mass loss (using live weight and the back fat depth) of the sow of 10 to 12% reduced piglet growth (Clowes et al., 2003). Body mass loss can be reduced by feeding a high protein diet during lactation (Revell et al., 1998) and by feeding the sows multiple times over the day (Pedersen et al., 2016), which also increases piglet growth (Kruse et al., 2011). Sulabo et al. (2010) showed reduced body weight loss when the sows were fed ad libitum. Furthermore, parity can have an influence on the weight loss as sows from parity one can have a lower feed intake and a higher body weight loss (Thingnes et al., 2012).

Piglet mortality during lactation is a challenge on most farms. It is influenced by sow (e.g. behavior), the piglet, but also environmental factors (e.g. pen design) (Edwards, 2002). Larger litter size (increased number of piglets born alive) also increases the risk of pre-weaning mortality as piglets can be smaller and uneven in size. As piglets fight more over the milk, they can starve or be crushed by the sow (Edwards and Baxter, 2015). Commercial farms tried to solve the problem with farrowing crates which are installed to prevent the sow from crushing the piglets and to reduce pre-weaning mortality (Edwards and Baxter, 2015). Nicolaisen et al. (2019) showed a higher piglet mortality in free farrowing pens. In organic farms free farrowing is mandatory (farrowing crates are not allowed), however, the variation of piglet mortality within farming systems is higher than between (Leeb et al., 2019; Melišová et al., 2014). Genetic solutions to this problem also have been studied looking at factors such as piglet vitality and maternal traits in sows (Edwards, 2002; Pfeiffer et al., 2018). One behavioral trait, which is connected to reduced mortality is nest building activity: Sows which stand and root more in the first days after farrowing show a lower number of crushed and dead piglets (Valros et al., 2003). Feeding systems have the potential to impact piglet mortality as well: Spanlang (2011) showed a relation between the sows body condition and the number of weaned piglets. The highest number of piglets were weaned from sows that were neither over- nor under conditioned.

Increased rates of return to estrus following breeding can result from a variety of reasons. First, problems with estrus detection, insemination and semen quality have to be considered as well as reproductive health issues (e.g. ovarian cysts). Secondly, increased weight loss during lactation (more than 0.5 decrease in BCS) can lead to an increased return to estrus rate (Vargas et al., 2009). It was shown, that return to estrus rate can be improved by feeding sows multiple times a day (Poulopoulou et al., 2018).

3.2 Clinical data

3.2.1 Piglets

Skin lesions are very common in newborn piglets and can be the entrance for infections (Zoric et al., 2008), e.g. lameness (Zoric et al., 2008).

Facial lesions can arise already during the first hours after birth when a teat order is developed. Piglets use their teeth to establish control of a teat which can lead to facial lesions of their siblings. Some farms grind these teeth to reduce the severity of lesions. However, this may not always be sufficient to prevent lesions, especially when sows produce insufficient milk or have malfunctioning teats (Hansson and Lundeheim, 2012).

Housing can also be another risk factor for piglet lesions. Floor type is an important risk factor for carpal lesions. During suckling, piglets are in contact with the floor and depending on the floors roughness, the carpi can be abraded, especially when piglets fight for access to milk. Straw in the first week of life can decrease or even prevent carpal lesions (Baxter et al., 2011). One study showed that piglets from sows housed in free farrowing boxes have less face and carpal lesions than piglets from sows housed in crates (Lohmeier et al., 2019). This may be an indirect effect of housing as piglets are always free to move independent of the farrowing housing system, but they fought more and were more restless in crates. Furthermore, the nursing was shorter and less calmer.

Another welfare issue is the presence of runts in a litter. Runts are piglets with a low birth weight which will never achieve the same weight as the other piglets at the same age (Ritacco et al., 1997). They are more prevalent in large litters. Runts are more likely to have infections and have an increased risk to die (Schrader et al., 2016). Runts are characterized by smaller size, a visible spine and long bristles (Schrader et al., 2016).

3.2.2 Sows

Skin lesions in sows are multifactorial. Many lesions found on the neck and body of sows in farrowing rooms originate in gestation due to e.g. fighting in group housing. The housing environment including the floor type also contribute to the development of injuries during lactation such as shoulder and body lesions (KilBride et al., 2009). For instance, 12.1% of the indoor housed lactating sows suffered from shoulder lesions whereas 35.4% of sows kept indoor and outdoor had scars or new body lesions (KilBride et al., 2009).

Shoulder sores are especially common in sows kept in a farrowing crate with perforated floor as sows spend a large amount of time lying in the same location and position. Bonde et al. (2004) reported a prevalence of approximately 20% of lactating sows affected by shoulder lesions, especially in thin sows. These shoulder lesions can develop due to pressure between the sows' body (spine of shoulder blade) and the floor. A risk factor for shoulder lesions is a low BCS (Maschat et al., 2020; Spanlang, 2011), caused by insufficient feed quantity or quality (Poulopoulou et al., 2018). Sows with a BCS under three have a higher prevalence of shoulder lesions (Zurbrigg, 2006). If the low feed intake is due to illness, lameness or other health problems, then the animal is also more likely to increase the time spent lying (Zurbrigg, 2006). Furthermore, shoulder sores can specifically occur in primiparous sows, as they are still growing, additionally to the nutritional demands of lactation. This can result in insufficient feed intake and a lower BCS (Eissen et al., 2000). Straw as bedding can decrease the prevalence of shoulder lesions, as the pressure is reduced (Baxter et al., 2017).

Teat lesions are mainly caused by slatted floors, when teats get caught in the gaps between slats (Baxter et al., 2017), but also results from sows stepping on their teats when trying to stand up (Ceballos et al., 2020). Free farrowing can possibly reduce the incidence of udder lesions of sows, as the lying area is mostly solid floor (Lohmeier et al., 2019). Additionally, teat and udder lesions can be caused by piglets fighting over the milk: Especially when the sow does not have enough milk (e.g. due to lack of feed intake and energy) piglets fight over the teats(Hansson and Lundeheim, 2012).

The occurrence of head, snout, ear and neck lesions can be caused by parts of the pen or other objects in the farrowing environment. Maschat et al. (2020) investigated sow lesions in different pen types and for different confinement periods. It was observed that the prevalence of head, ear, neck and shoulder lesions ranged between 2 to 10%. Lameness also is not uncommon in lactating sows. Maschat et al. (2020) observed between 2 and 10% lame sows in their study. In a different study,15% of sows were observed as lame (Bonde et al., 2004). In addition, thin sows are more often lame than fat sows. Furthermore, sows with shoulder lesions are more likely to be lame (Bonde et al., 2004). More studies will be required to elucidate, if poor BCS is a cause or a result of lameness, given that lameness can reduce feed intake.

3.3 Behavior

The traditional definition of stereotypies describes them as repetitive, invariant behaviors without any function (Mason, 1991). However, this definition is outdated, as new definitions include, that stereotypies may help an animal to deal with frustrations in its environment or can also arise from dysfunctions of the central nervous system (Mason and Rushen, 2006). Almost all (91.5 %) of confined sows in Europe and North and Central America show stereotypies (Mason and Rushen, 2006). Stereotypies can be caused by many different factors (Mason and Rushen, 2006), of which the most important is restriction of food. Due to a sow’s natural need to search and eat feed during most of her active day (Stolba and Wood-Gush, 1989), restricted feed fails to fulfill a sow’s natural needs and stereotypies can develop (Terlouw et al., 1991). Stereotypies can be sham chewing, bar biting or tongue rolling. Those are the stereotypies which are strongly related to feed restriction (Lawrence and Terlouw, 1993). If a stereotypy occurs over 10% of the time the welfare of the sow suffers (Broom, 1983). An inverse relationship between vacuum chewing and total piglets born was shown: Sows with an increased incidence of vacuum chewing produced less total piglets born (Sekiguchi and Koketsu, 2004). A possible explanation of this finding is, that shame chewing identifies sows that were exposed to stress leading to a decreased ovulation rate and/or increased embryo mortality. Chidgey et al. (2016) compared behavior of sows in conventional farrowing crates to sows in farrowing pens where the crate was opened on day four. From day one to six, vacuum chewing and biting fixtures and standing increased, whilst lying decreased independently of the treatment. In a different study three feeds with different amounts of fiber fed restrictively were compared to an ad libitum group (Bergeron et al., 2000). Sows with a very high fiber diet and the ad libitum fed sows spent more time standing than the other treatment groups. The sows in the three different fiber groups spent more time performing stereotypies than the ad libitum control group but there was no difference between the three groups (Bergeron et al., 2000). Stereotypies are caused not just by the type of feed and the feeding system but can also be decreased, when bedding (e.g. straw) is provided (Broom, 1983; Yin et al., 2016). Stereotypies developed in gestation are not always easily reversible and may persist during farrowing and lactation (Bergeron et al., 2000; Mason and Rushen, 2006).

Additional exploring behavior is seen before farrowing. Sows also are very motivated to perform nest building behaviors prior to farrowing. In the wild, sows will carry tens of kilos of material (grass, sticks, leaves etc.) to a site to build a nest (Zanella and Zanella, 1993). In the absence of straw or another suitable substrate, it can be helpful to provide commercial sows prior to farrowing with just something to manipulate such as a jute bag.

4. Animals, Materials and Methods

The study was conducted from July until November 2019 at the Swine Teaching and Research Center on the New Bolton Center campus of the School of Veterinary Medicine at the University of Pennsylvania. Data were collected initially from 77 Landrace × Yorkshire sows in 4 identical farrowing rooms of 10 farrowing pens each and corresponded to two replicates of data collection in each room. In order to evaluate the ad libitum feeding systems, different on-farm parameters describing productivity and welfare of sows and piglets were examined. Sow behavior was recorded and analyzed using video cameras.

Each farrowing pen was equipped with a hinged farrowing crate having a size of 2.0 m × 2.1 m (4.2 m^2 in total) and allowed the space to convert between a conventional farrowing crate and a free farrowing pen. The floor was perforated plastic flooring (MIK, International, Ransbach-Baumbach, Germany) with a water filled heat pad (0.8 x 0.6 m) embedded in the flooring and maintained at a temperature of approximately 32°C during the whole period of observation. The crates were closed the afternoon before the calculated farrowing day and opened at day four post farrowing. Twenty-four hours before the calculated farrowing day a small amount of straw (~1 kg) was provided as nest building material. The farm utilized a two weeks batch farrowing system and the piglets were weaned on day 28 to 37 (mean 33.51 days). The piglets had access to creep feed from ~10 day post-farrowing. Sows were allocated by parity (P) to treatments (T). The parity ranged between zero and eight. For analysis, sows were divided in three groups: parity zero, parity one and two, and parity three or greater. The average parity of the study animals was 2.16 (+/-0.32 (SEM)) and the average pre-weaning piglet mortality over all treatments was 20.7%. On average 15.16 piglets were born with 3.13% of dead piglets per litter.

The room temperature was recorded continuously and values were entered as minimum and maximum temperature per each room daily (Table 1).

Table 1: Average minimum and maximum temperature for each farrowing room (°C)

Room	1	2	3	4
Minimum (°C)	22.45	20.67	21.22	21.43
Maximum (°C)	26.4	26.3	26.303	25.9

4.1 Feeding technology

4.1.1 Automated sow-controlled ad libitum feeding system (Treatment 1 and 2)

The automated, sow-controlled ad libitum feeder was a system where the sow had access to feed at all times. The feeding system included a hopper for feed storage which was filled by a feed delivery system that drew feed from a feed bin located adjacent to the barn. For the sow to get feed, she needed to touch a metal rod which was connected to a sensor. If the sensor was triggered five times (could be adapted), an auger dispensed 100 gram of feed from the hopper and dropped it through a tube into the trough. The sensitivity of the trigger (number of times the sow needed to touch the metal rod) and the amount of food dispensed could be adjusted via the computer program but stayed always the same during the experimental phase. Additionally, the computer generated a feeding protocol, which recorded all feeding events (time and total amount of food). Water was dispensed via a computer controlled solenoid with each portion of feed through a separate pipe entering the feed trough. The amount of water delivered was controlled by the duration of time the solenoid was open. Taken together, this technology comprised treatment 1. Treatment 2 utilized the same feeding technology but employed one additional feature: The automated sow-controlled ad libitum feeder also had the capability to dispense a so called “attraction portion”. At user specified times across the day, a 100 gram portion of feed was dispensed independent of the sow’s behavior in an effort to motivate the sow to initiate feeding.

4.1.2 Manual sow-controlled ad libitum feeding system (Treatment 3)

The manual sow-controlled ad libitum feeder allowed the sow 24-hour access to feed. Similar to feeding systems 1 and 2, feeding system 3 also included a hopper for feed storage such that feed was always available to the sow and the hopper was filled by a feed delivery system that drew feed from a feed bin located adjacent to the barn. From the hopper a tube led into the trough. At the end of the tube a ball was integrated, which could be lifted by the sow, so that feed fell down between the ball and the tube. The sensitivity of the ball could be manually adjusted to control how much feed the sow could release. In most applications, the manual sow-controlled ad libitum feeder cannot record the timing or amount of feed intake. For this study, the system was implemented such that feed delivery to the feed hopper was tracked through the computer program but no details about when or how much the sow ate during individual feeding bouts. Water was also always available in the trough at a fixed level.

4.1.3 Non-ad libitum feeding system (Treatment 4)

The non-ad libitum feeding system was managed as challenge feeding (increasing the number of feeding according to the feed intake), with the feed delivered via an automated feed system. At pre-determined feeding times a fixed amount of feed was delivered and water was added upon delivery.

4.2 Feeding regime

All sows were fed the same organic lactation diet which meets or exceeds the United States National Research Council’s recommended requirements for lactating sows. The composition of the diet was: 16% crude Protein (min.), 0.85 % of Lysine (min), 3.5 %

crude Fat (min.), 5 % crude Fiber (max.), between 0.5 % and 1.0 % Ca, 0.45 % P, 0.3 ppm Se and 230 ppm Zn.

It is common practice to restrict feed supply prior to and shortly after farrowing. Sows were fed 2.7 kg of feed per day using the treatment specific feeding technology to which a sow was assigned. This also provided time for the sows to adapt to the new feeding systems as none of the animals had previous experience with the ad libitum feeding technologies. On day three, the feed amount was changed to one of the four treatment groups: Treatment 1 (T1) was the basic automated ad libitum strategy (n=18). Treatment 2 (T2) was the same system with an additional attraction portion four times a day, i.e., at 8:05, 11:20, 15:40 and 20:00 100 grams of feed were dispensed into the trough (n=19). Treatment 3 (T3) consisted of the manual sow-controlled ad libitum strategy where the sow had to lift a ball to get the feed (n=12). Treatment 4 (T4) was the non-ad libitum feeding system where sows were fed 2.7 kg per feeding time, but the number of feedings per day was adjusted by the farm manager based on the stage of lactation, litter size and the feed disappearance from the previous day. Treatments were allocated evenly across all farrowing rooms with each room being equipped with three farrowing pens of T1, three with T2, two with T3 and another two with T4. The location of the different treatments within a room was varied between rooms to minimize any possible effect of farrowing pen location on the data. Other management practices (e.g. farrowing management, piglet castration) were the same for all treatment groups.

4.3 Data collection

For the analysis of feed disappearance, performance and clinical data of sows and piglets, 61 sows and their litters from the original 77 sows were studied. Exclusion criteria for sows included confounding health issues: severe lameness, mastitis or euthanasia (7 sows), or extreme values regarding production parameters: less than six weaned or live born piglets (5 sows); litter weaning weight less than 45 kg (2 sows); low sow body weight at farrowing (1 sow) and one sow was excluded because she did not farrow.

4.3.1 Productivity

Feed delivery was recorded by the computer programs controlling the four feeding systems. In addition, the daily feeding pattern was recorded for the automated sow-controlled ad libitum feeding systems (T1 and T2). Daily feed disappearance was measured as daily recorded feed delivered minus feed removed (defined as the amount of feed which was left over by the sow and removed from the trough once a day if necessary (e.g. too old). For further analysis, the average daily feed disappearance was calculated from day three when the ad libitum feeding started until weaning day. To calculate the piglet growth, the average weight of a piglet 24 hours after birth was subtracted from the average weight of a piglet at weaning. Feed efficiency ratio was calculated using the feed disappearance during the treatment divided by the average piglet growth over that same time interval.

The following assessments were carried out (Figure 1): All sows were weighed twice (day of entering the farrowing room, weaning day) using a scale in the hallway in front of the farrowing rooms. For further analyzes, body weight loss in percentage was used. It was calculated by subtracting the body weight before entering the farrowing room from the body weight on weaning day. The BCS was scored from 1 to 5 (Coffey et al., 1999) and sows were always encouraged to stand up for BCS scoring. The litter weight was measured three times (Day 1, 7 and at weaning) and piglet weight gain over the duration of lactation was used for further calculations. The number of piglets per litter was adjusted by cross-fostering during the first 24 hours after farrowing. After weaning, the sows who returned to estrus were counted and the conception rate was used for further calculations. Additionally, the piglet mortality was calculated based on the piglets born alive and the number of piglets which died until weaning piglets.

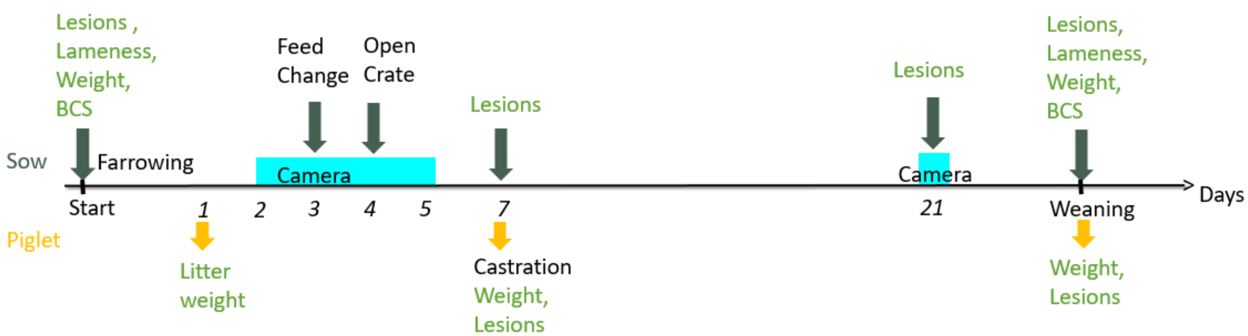

Figure 1: Timeline of assessed parameters

4.3.2 Clinical data

The protocol for the clinical data collection was based on previous projects (Leeb et al., 2010; Welfare Quality®, 2009). Clinical data were collected up to five times per farrowing period:

- Observation (O) 1: on the day the sow entered the farrowing room
- O 2: during the first 24 hours after farrowing
- O 3: between day 6 and day 8 during the castration of the piglets
- O 4: between day 20 and day 23
- O 5: on weaning day

4.3.2.1 Sow

Snout, ear, head, neck, teat and shoulder lesions of the sow were scored (during O1, O3, O4, O5) using score 0 to 2. The assessment of all lesions is shown in Appendix 1 and 2. For analyzes, the lesions score 1 and 2 were combined and converted into a binary outcome. For the teat lesions, score 1 included scratches small enough not to affect the suckling behavior whereas score 2 required more than 50% of the teat to be damaged. In the end only score 2 was used for analyzes.

Lameness was scored as the sow approached and walked away from the observer during scaling when the sow walked on and off the scale (Appendix 2). Prevalence of slightly lame sows (Score1) was low and was therefore not further analyzed. Additionally, all medical treatments during lactation were recorded during the trial. Only 12 sows were treated with oxytocin because of difficult farrowing and one sow got repeated doses of a non-steroidal anti-inflammatory drug (four injections) before she farrowed (unknown reasons). Vaccination of the sow against ileitis, circovirus and parvovirus were carried out about three weeks after farrowing. Piglets were vaccinated against circovirus twice during lactation period.

4.3.2.2 Piglet

Clinical data were collected twice (O3 and O5): the number of runts, lame piglets and piglets with carpal lesions were counted and calculated as prevalence., Head lesions were scored (O3, O5) using the score 0 to 2 (see definitions in Appendix 1). Prevalences of runts (26 litters with one or two runts) and lame piglets (two litters) were not that common and we elected not to pursue further analysis.

4.3.3 Behavior

Sows were recorded with a camera (IPX DDK-1700D Infrared IP Dome Camera, Farmingdale, New Jersey - USA) mounted on the ceiling 2m above each farrowing pen during lactation. As in our study, stereotypies including vacuum chewing and biting fixtures were in focus, the camera was installed above the farrowing pen to ensure visibility of those behaviors.

It was planned to record ten sows per batch. However, only 35 sows and their litters from the original 60 sows could be included: 16 sows were excluded as explained above. Additionally, nine videos could not be used due to technical issues. The first period of recording was 72 hours from day 2 post farrowing until day five post-farrowing. The second period was 24 hours between day 20 and day 23 post farrowing. The crate was opened on day 4.

To analyze the data, the first 72 hours were separated into three 24-hour days. The Observer XT (Noldus, version 11.5, Wageningen, the Netherlands) was used to code and analyze the videos.

Table 2: Ethogram used - definitions of the behavioral categories (Chidgey et al. 2016)

	Behavior	***Definition***
Posture	Standing/Walking	Standing still with all four claws on the floor and not moving. The body is not touching the floor. Walking through the farrowing pen.
	Sitting	Sitting on its rear part with the front legs straight.
	Lying	Laterally lying: Shoulder on the floor and udder exposed. Sternal lying: Resting with her sternum and udder in contact with the farrowing crate floor.
Activity	Nursing	Over 50% of the litter is suckling on the teats.
	Drinking/Manipulating the drinker	Mouth on nipple drinker. The sow can drink or manipulate/bite the drinker. In all three postures possible.
	Head in the trough	Snout is not visible Including eating & playing with feed/sensor.
	Vacuum chewing	Chewing actions (more than two) performed without the presence of feed in the oral cavity
	Vacuum chewing/ Nursing	Vacuum chewing during nursing
	Exploring the environment	Touching the boards or fixtures of the box with the snout. In all 3 postures possible.
	Biting fixtures	Biting the fixtures in the farrowing box (Trough or Crate). The fixture is in the mouth of the sow
	Interaction with piglet	Sow is facing the piglet and is touching the piglet with its snout. The sow is in interaction with the piglet. Doesn’t include if a piglet walks over her face/body.
	Resting/Sleeping	The sow stays in one of the three postures and doesn’t do any activity. If she is at the trough, the snout must be visible.
	Piglet in the trough	A piglet is in the sows’ trough with a minimum of two legs and half its body. The piglet can trigger the sensor from the feeding system, eat out of the trough or stay/sleep in the trough.
	Unsure	Head is not visible or camera view is not clear enough.
	Human 1 & 2	A human is in the farrowing pen.

The ethogram used in this study (Table 2) was based on Chidgey et al. (2016). Instantaneous sampling was applied with a sample interval of one minute.

The coding scheme included two different behavioral classes: posture and activities (Table 2). Both behavioral classes had to be coded for each observation. Intra-observer and inter-observer tests were also carried out using the Observer XT provided test package. An intra-observer test was completed three times. One observation day of one randomly chosen sow was assessed three times by the same observer (Sarah). A different observer (Observer 1) evaluated the same day for an inter-observer test (Table 3). All tests revealed an excellent percentage of agreement.

Table 3: Intra - and Inter-observer test: percentage of agreement and kappa value

Test		**Percentage of agreement %**	**Kappa**
Intra-observer test	Sarah 1 – Sarah 2	98.55	0.98
	Sarah 1 – Sarah 3	97.22	0.96
	Sarah 2 – Sarah 3	97.99	0.97
Inter-observer test	Sarah 1 - Observer 1	96.78	0.95
	Sarah 2 - Observer 1	96.57	0.94
	Sarah 3 - Observer 1	96.02	0.95

4.4 Statistical analyses

The data was calculated and analyzed using SAS statistical software. As a first step normal distribution of the outcome variables was tested. If there was a normal distribution the data was further analyzed. The significance level was determined with $P \leq 0.05$.

Clinical data of piglets and the behavioral data were analyzed using a linear mixed model (procedure mixed) with the fixed effects of treatment and assessment and the interaction between treatment and assessment. For weight loss, piglet mortality and piglet growth just the fixed effect of treatment was used. As random effect the sow number identifier nested in group was used. Vacuum chewing and nursing were not normally distributed, therefore vacuum chewing, vacuum chewing during nursing and biting fixtures were summarized as “stereotypies” and analyzed using a linear mixed model (procedure mixed).

$$y_{ijkl} = \mu + a_i + \beta_j + a_i * \beta_j + G_k(S_l) + \varepsilon_{ijklm}$$

y_{ijk}	=	dependent variable
μ	=	Intercept
a_i	=	fixed effect of treatment
β_j	=	fixed effect of assessment
$a_i * \beta_j$	=	interaction effect treatment*assessment
$G_k(S_l)$	=	random effect of sow identifier nested in group
ε_{ijkl}	=	residual

The number of weaned piglets can impact the outcome variables such as feed per day and the feed efficiency (piglet growth / feed disappearance per day) and thus were included in the following model as a covariate.

$$y_{ijkl} = \mu + a_i + \beta_j + a_i * \beta_j + G_k(S_l) + \gamma + \varepsilon_{ijklm}$$

y_{ijk} = dependent variable

μ = intercept

a_i = fixed effect of treatment

β_j = fixed effect of assessment

$a_i * \beta_j$ = interaction effect treatment*assessment

$G_k(S_l)$ = random effect of sow identifier nested in group

γ = covariate of number of weaned piglets

ε_{ijkl} = residual

For each of the different types of sow lesions (see Appendix 2) a binary score (combining score 1 and 2) for each sow at each assessment period was used. In the next step, the initial assessment was used as a baseline value for the other assessments and the difference between the baseline and number of lesions at each subsequent assessment was calculated. The difference was converted into a binary outcome where zero means the lesions in subsequent assessments were less than or equal to baseline levels whereas one means the lesions on subsequent assessments increased compared to the baseline. Lesions were relatively rare and thus we chose not to carry out statistical analysis on these variables. A binary system was used as well for the conception rate.

5. Results

In this section, all results (as mean values) are presented in the order of research questions (see Tables 4-10 and Figures 2-4). All values are indicated as a least square means (LSM) +/- its standard error (SEM).

5.1 Productivity

5.1.1 Feed disappearance and piglet growth

Several outcomes regarding productivity were compared across the four feeding regime treatments: The average feed disappearance was significantly impacted by treatment ($p<0.001$) with sows exposed to the challenge feeding paradigm (Least squares mean=LSM (Standard error= SEM): T4=10.08 (0.98) kg/day) having greater feed disappearance compared to the others (Figure 2, LSM (SEM): T1=6.55 (0.81) kg/day, T2=6.55 (0.78) kg/day, T3=7.4 (1.00) kg/day, p-value<0.001) (Appendix 3: Table 11, Table 12).

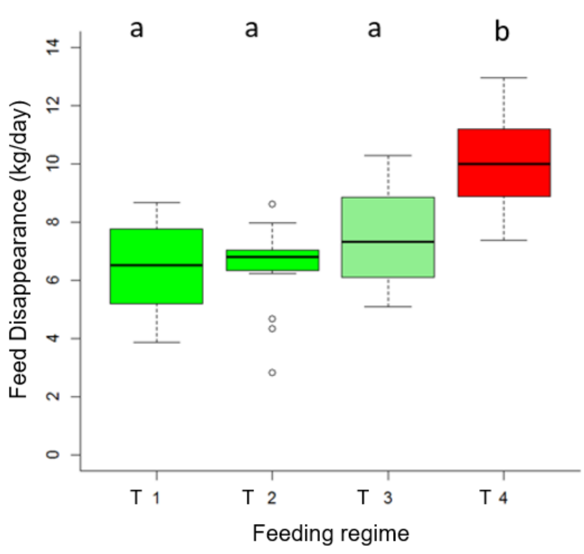

Figure 2: Boxplot for feed disappearance (mean kg per day) per treatment; horizontal line is the median, the colored box is showing quartile 1 to 3 (25 %-75 %), top and bottom line are the minimum and maximum values; T1=automated ad libitum, T2=automated ad libitum with attraction portion, T3=manual ad libitum,T4=non-ad libitum, significant values ($p<0.001$) are indicated by different letters (a, b)

There also was a tendency for feeding paradigm to impact piglet growth over lactation (Figure 3, p-value= 0.0544) with litters reared on sows fed by automated ad lib feeding systems (LSM (SEM): T1=8.23 (0.84) kg/day and T2=7.83 (0.85) kg) having numerically greater growth than the others (LSM (SEM): T3=7.1 (0.98) kg, T4=6.92 (0.99) kg (see also Appendix 3: Table 13, Table 14). The piglets across all 4 treatments averaged a litter weaning weight of 103.9 kg (SEM: 2.85) with a lactation length of 33.5 (SEM: 0.25) days. Total feed delivered per litter was on average 226.5 (SEM: 18.5) kg per litter.

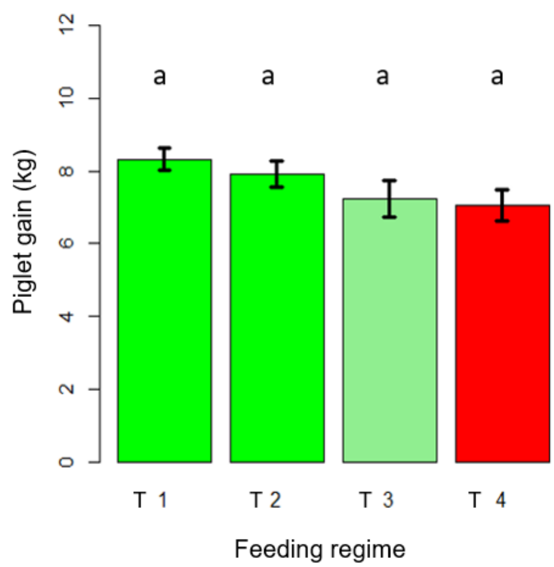

Figure 3: Mean piglet weight gain over lactation (kg) and SEM per treatment; T1=automated ad libitum, T2=automated ad libitum with attraction portion, T3= manual ad libitum, T4= non-ad libitum, significant values ($p \leq 0.05$) are indicated by different letters (a, b)

The ratio of piglet growth per sow feed disappearance was significantly impacted by feeding paradigm (Figure 4; $p<0.001$, Appendix 3: Table 15, Table 16). Treatment 1, 2 and 3 (LSM (SEM): T1=0.46 (0.03), T2=0.45 (0.03), T3=0.35 (0.04)) were significantly more efficient in feed utilization than Treatment 4 (LSM (SEM): T4=0.24 (0.04)).

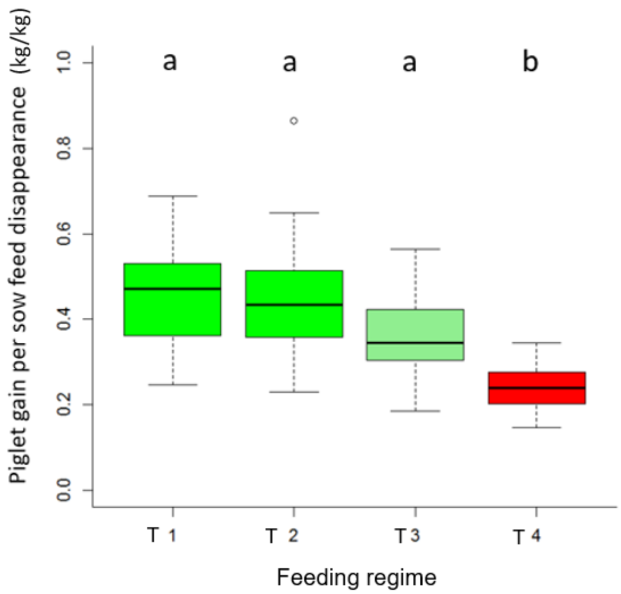

Figure 4: Piglet gain per sow feed intake, vertical line is the median, the colored box is showing quartile 1 to 3 (25 %-75 %), top and bottom line are the minimum and maximum values; T1=automated ad libitum, T2=automated ad libitum with attraction portion, T3= manual ad libitum, T4= non-ad libitum, significant values (p≤0.05) are indicated by different letters (a, b)

5.1.2 Piglet mortality, sow weight loss and conception rate

Sow weight loss during lactation did not differ between treatments: compared to the pre-partum weight, the average weight loss as percentage during lactation was less than 4 % for all four groups. On average, per litter there were 15.2 piglets born alive, 3.1 piglets died before weaning and 11.5 piglets were weaned. Differences between treatments were also not noted for pre-weaning piglet mortality or conception rate of the sows (Table 4).

Table 4: Least squares mean and standard error for piglet mortality (%), weight loss (%) and conception rate (%) for Treatment 1 to 4, p-value T1=automated ad libitum, T2=automated ad libitum with attraction portion, T3= manual ad libitum, T4= non-ad libitum

Parameter	**Least squares mean (standard error of the mean)**				**p-value**
	T1	T2	T3	T4	
Weight loss %	-0.78 (1.67)	-2.50 (1.73)	0.31 (1.85)	-1.31 (1.90)	0.57
Piglet mortality %	20.7 (4.01)	22.1 (3.94)	17.4 (4.87)	23.1 (4.87)	0.83
Conception rate % n=44	81.8	84.6	100	100	0.13

5.2 Clinical data

5.2.1 Piglets

Both, head wounds and lesions were significantly impacted by day of assessment: On the second assessment day, piglets had less head wounds and lesions (p=<0.05, Figure 5, Appendix 3: Table 17,Table 18, Table 19, Table 20, Table 21) than on the first day. The percentage of piglets without head lesions and wounds (“head sound”) was significantly higher in T1 and T2 than in T3 and T4 (p=0.01) and there was a tendency that piglets from the ad libitum systems had less head lesions (p=0.06).

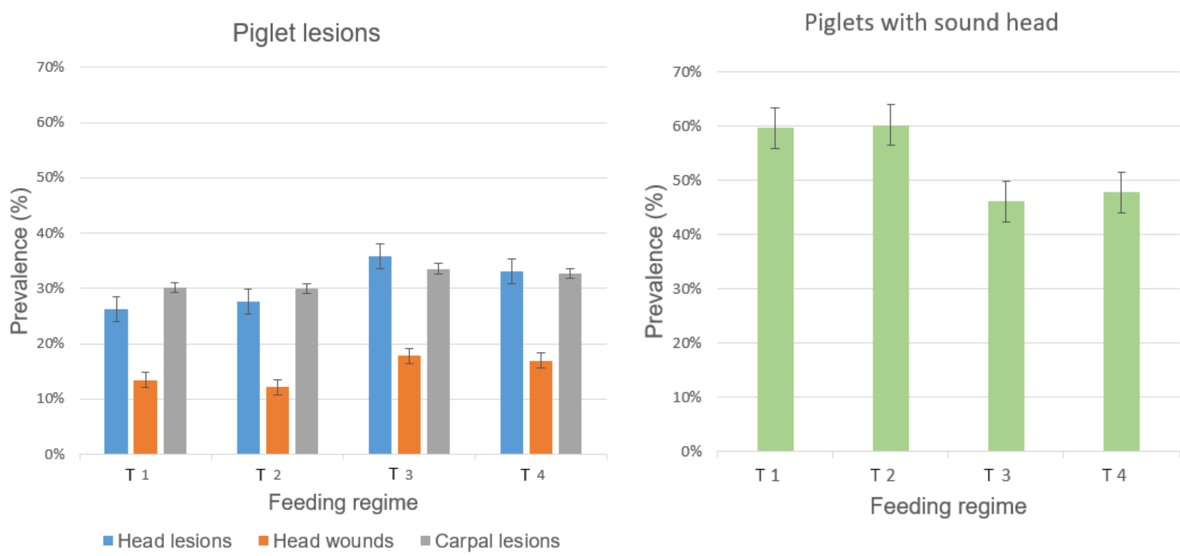

Figure 5: Prevalence (LSM and SEM) and standard error of piglet lesions and piglets with sound head in Treatment 1 to 4; T1=automated ad libitum, T2=automated ad libitum with attraction portion, T3= manual ad libitum, T4= non-ad libitum

5.2.2 Sows

A total of 61 sows were scored on five different days during lactation. The mean number of lesions (Table 5) and the development of those (Table 6) were examined. In general, there were few lesions found (snout and head). Teat and ear lesions were most frequent. There was no numerically difference between treatments.

Table 5: Mean number of sow lesions over all five assessments for Treatment 1 to 4; T1=automated ad libitum, T2=automated ad libitum with attraction portion, T3= manual ad libitum, T4= non-ad libitum (n=61 sows)

Sow lesions	**Mean number of sow lesions**			
	T1	T2	T3	T4
Snout lesions	1.6	1.2	2.0	1.5
Head lesions	3.6	3.2	3.5	3.3
Ear lesions	7.0	5.6	6.3	6.8
Teat lesions	**7.2**	**8.0**	**8.1**	**7.9**

On weaning day, eleven sows had developed shoulder lesions on one or both shoulders. When entering the farrowing room, three sows were slightly lame with a score of one and four sows when leaving (Table 6). Teat lesions first decreased and then increased over time whereas snout and head lesions decreased. Ear lesions developed different in every treatment group: T1 and T3 had an increase and then a decrease whereas T2 and T4 decreased until assessment 4.

Table 6: Overview of change in mean number of sow lesions for Treatment 1 to 4; T1=automated ad libitum, T2=automated ad libitum with attraction portion, T3= manual ad libitum, T4= non-ad libitum (n=61 sows)

Treat -ment	**Δ of mean number of sow lesions**											
	T1			T2			T3			T4		
Assess ment	2	3	4	2	3	4	2	3	4	2	3	4
Snout	-0.4	-0.5	-0.6	**0.3**	-0.3	-0.3	**0.3**	-0.2	-0.7	-1.6	-2.4	-2.2
Head	-3.8	-4.5	-3.7	-2.3	-2.1	-2.6	-4.0	-3.5	-3.8	-3.6	-4.1	-3.9
Ear	-2.8	**1.7**	**1.2**	-2.3	**1.2**	**1.7**	-1.0	**4.5**	**2.6**	-2.3	**0.7**	**2.6**
Teat	**3.5**	**3.1**	**4.2**	**4.6**	**4.4**	**5.1**	**4.9**	**5.0**	**5.1**	**3.9**	**3.2**	**4.1**

5.3 Behavior
Posture and Activity

Sows spent nearly 90 % of their time lying and about one tenth of time standing and even less time sitting. No treatment effects were observed on sow posture. However, posture did change over the course of lactation as on day 21 the sows were lying less and standing more compared to the three previous days of observation (Table 7, Appendix 3: Table 23,Table 24,Table 25).

Table 7: Least squares mean, standard error and p-values for the posture for the proportion of observations the sows spent in different postures for Treatment 1 to 4; p-values are also given for the effects of day and the interaction term day*treatment; T1=automated ad libitum, T2=automated ad libitum with attraction portion, T3= manual ad libitum, T4= non-ad libitum

Posture	**Least squares mean (standard error of the mean)**				Day p-value	Treat-ment (p)	Day * Treatment (p)
	T1	T2	T3	T4			
Standing	7.12 (0.01)	8.35 (0.01)	7.52 (0.01)	6.34 (0.01)	<.001	0.204	0.462
Lying	91.5 (0.01)	89.9 (0.01)	90.0 (0.01)	92.5 (0.01)	<.001	0.179	0.718
Sitting	1.29 (0.001)	1.70 (0.002)	1.39 (0.002)	1.04 (0.001)	0.856	0.556	0.394

Stereotypic behavior during lactation was rare and no effect of treatment or day of observation was found. However, there was a significant interaction between day and treatment (Table 8, Appendix 3: Table 26, Table 27, Table 28, Table 29), as only in Treatment 1 far fewer stereotypies were observed on day 21 than on the days one to three. For Treatment 3 the stereotypies were higher on day 21 compared to the other days. For biting of fixtures no significant effects were found (Table 8).

Table 8: Least squares mean, standard error and p-value for the posture for the proportion of observations the sows spent with different stereotypies for Treatment 1 to 4, p-values are also given for the effects of day and interaction term day*treatment, T1=automated ad libitum, T2=automated ad libitum with attraction portion, T3= manual ad libitum, T4= non-ad libitum

	Least squares mean and standard error of the mean (in brackets)				Day	Treatment	Day * Treatment
	T1	T2	T3	T4			
Stereotypies	1.80 (0.01)	1.54 (0.002)	1.90 (0.01)	1.65 (0.002)	0.676	0.975	0.011
Vacuum chewing	1.41 (0.01)	1.05 (0.002)	1.29 (0.003)	1.22 (0.002)	0.552	0.964	0.050
Vacuum chewing/ Nursing	0.26 (0.001)	0.29 (0.001)	0.54 (0.002)	0.33 (0.001)	0.335	0.594	0.021
Biting fixtures	0.13 (0.0003)	0.20 (0.0004)	0.07 (0.0002)	0.01 (0.0002)	0.481	0.279	0.239

Treatment did not affect most behaviors, however the amount of time the sow spent with her head in the trough was higher in T1, T2 and T3 than in T4. Day of assessment had an effect on all behaviors: exploring the environment, head in trough and sow interaction with piglets increased during the course of lactation, whereas resting and sleeping were reduced significantly until day 21. For drinking behavior an effect of day and a tendency for an interaction between day and treatment was found: Drinking behavior increased for all treatments from assessment day one to the last assessment day whereas the change from first day to last day was higher for T1 and T2 than for T3 and T4 (Table 9, Appendix 3: Table 31, Table 30, Table 32, Table 33, Table 34, Table 35).

Table 9: Behavior: Least squares mean, standard error and p-value for the proportion of observations the sows spent in different activities for Treatment 1 to 4; p-values are also given for the effects of day and the interaction term day*treatment; T1=automated ad libitum, T2=automated ad libitum with attraction portion, T3= manual ad libitum, T4= non-ad libitum, significant values (p≤0.05) are indicated by different letters (a, b)

	Least squares mean and standard error of the mean (in brackets)				Day	Treat-ment	Day * Treat-ment
	T1	T2	T3	T4			
Head in the trough	4.28 (0.003) **a**	5.11 (0.003) **a**	5.35 (0.004) **a**	2.73 (0.003) **b**	<.001	**<.001**	0.267
Drinking	1.32 (0.002)	1.57 (0.002)	1.24 (0.002)	1.17 (0.001)	<.001	0.819	**0.064**
Nursing	18.5 (0.01)	18.1 (0.01)	17.9 (0.01)	18.5 (0.009)	0.058	0.965	0.857
Interaction with piglet	0.77 (0.001)	0.95 (0.001)	0.75 (0.001)	0.90 (0.001)	<.001	0.710	0.378
Resting/ Sleeping	71.2 (0.01)	70.4 (0.01)	70.3 (0.014)	72.6 (0.10)	0.021	0.631	0.455
Exploring the environment	1.88 (0.003)	2.10 (0.004)	1.39 (0.002)	2.07 (0.003)	<.001	0.445	0.501

6. Discussion

Our findings address the effects of four different feeding systems on welfare and productivity of sows and piglets. How these different parameters were impacted by the feeding systems are discussed here in the order of the research questions: productivity, clinical data of sows and piglets and behavior. The strength of this work was, that it focused for the first time on a novel automated ad libitum feeding system for lactating sows and compared both, a challenge feeding regime with three different ad libitum feeding systems. Especially the possibility to record the amount of all feeding events provided an opportunity to collect exact data. All treatments were balanced per room to exclude room effects. However, behavior of sows might be influenced across treatments because sows react to the noise of the feeding system.

6.1 Productivity

Overall it can be said, that the feed disappearance in our study (multiparous sows: 6.43 to 7.54 kg/day) was similar to two other studies (Neil, 1996; Zushi et al., 2018 Table 10). In contrast to our study, slightly higher results were found in three other projects (Burke et al., 2000; Thaker and Bilkei, 2005; Thingnes et al., 2012). Four studies observed a lower daily feed intake in ad libitum fed sows (Peng et al., 2007; Revell et al., 1998; Sulabo et al., 2010; Thaker and Bilkei, 2005).

Table 10: Comparison of daily feed intake in ad libitum fed sows form different sources, including average lactation length, blue and green arrows indicating if the feed intake was higher or lower as compared to our study

Feeding management	Feed intake (kg/day)	Average lactation length	Source
Ad libitum	8.2 ↑	33.7	Thingnes et al., 2012
Ad libitum	4.9 ↓	21.1	Sulabo et al., 2010
Hand-fed feed-water system	5.4 ↓	19.8	Peng et al., 2007
Self-fed wet/dry	5.9 ↓	20.0	Peng et al., 2007
Ad libitum primi-parous sows	5.2 ↓	27.1	Thaker and Bilkei, 2005
Ad libitum multiparous sows	7.6 ↑	27.1	Thaker and Bilkei, 2005
Ad libitum small pen	7.7 ↑	21.0	Burke et al., 2000
Ad libitum large pen	7.7 ↑	21.0	Burke et al., 2000
Ad libitum with high protein	5.2 ↓	28.0	Revell et al., 1998
Ad libitum introduced on day 3	6.6	35.0	Neil, 1996
Ad libitum introduced before day 3	7.2	35.0	Neil, 1996
Ad libitum	6.6	17.0	Zushi et al., 2018

In contrast to our study, Thingnes et al. (2012) found no difference among treatments regarding daily feed consumption. In a different study it was observed, that ad libitum fed sows had a higher feed intake than restricted fed sows (Sulabo et al., 2010). Our results show a lower feed intake in ad libitum fed sows. It needs to be considered that we did not compare with a restricted feeding system but with a feeding system which should challenge the sow to her maximum feed intake. There are no other studies which used a challenge feeding system, therefore it is difficult to interpret these findings. Furthermore, the lactation length needs to be considered. Neil (1996) found a similar daily feed intake for a similar lactation length .

Many studies did not compare ad libitum with restricted feeding. Instead, they focused on the number of feeding times per day. Comparing four times to two times feeding, a study concluded, that the rate of feed consumption was higher in the former (Imaeda and Yoshioka, 2007). Comparing three with two feeding times, the former increased daily feed intake by 0.5 kg per day (5.8 kg compared to 5.3 kg) (Poulopoulou et al., 2018). In our study, feed intake from treatment group four (T4= challenge feeding) was exceptionally high, but as already mentioned above, it aims at challenging the sow to eat as much as possible.

Previous studies have not reported such high daily feed consumption (10.08 kg per day) as we observed in the challenge feeding regime. This feeding paradigm (T4) gives us some insight into what a maximum feed intake can be for a lactating sow. Barn staff was instructed to increase the number of times a day a sow was fed based on litter size, the day of lactation and the previous day's feed disappearance. On average, a sow was fed 3.7 times a day, with up to 5 times a day for a total of nearly 14 kg feed delivered per day. From this study, we cannot discern, if the feed consumed was beyond their nutritional requirements and how the results can be transferred to other farms. However, T4 sows' change in body condition or weight loss was not different than for the other treatment groups. It is also possible, that high feed disappearance was partly due to feed wastage. More controlled studies need to be carried out on challenge feeding to better understand its' potential as a lactation feeding regime. Also care must be taken, when interpreting the results compared to the other treatments.

In our study piglet weight gain during lactation for the automated ad libitum systems was on average about 8 kg. Several other studies (Sulabo et al., 2010; Zushi et al. 2018; Thingnes et al., 2012) also report piglet weight gain measures reared by sows with ad libitum feeding systems. However, the length of lactation must be considered and thus it is hard to make direct comparisons as the weaning age in this study farm averaged 33 days, which was longer than in many of the other studies.

For evaluating the feed conversion ratio, litter growth per feed disappearance was calculated. The daily weight gain of the piglets from day three, when the feeding regime was changed, until weaning day was used for calculation of feed conversion ratio. Ad libitum feeding system (T1-T3) required less feed per unit of piglet gain than the non-ad libitum feeding system (T4). At the same time, there was no difference in weight loss of sows between the treatments. The lower feed intake does not lead to a lower sow weight during lactation. Ad libitum fed sows seemed to use the feed more efficiently than the challenge fed sows, suggesting, that their feed conversion ratio is lower and therefor better and that they convert the feed more efficiently into piglet growth. Other studies include back fat loss of sows and digestible energy of the feed for calculating the conversion ratio (Bergsma et al., 2009; Pedersen et al., 2019). These two parameters were not used in our study, but would be beneficial for further research.

Feed intake can be influenced by external and internal factors. The temperature in the farrowing room is an important external factor. It was shown, that the feed intake was decreased during the hot summer months (Imaeda and Yoshioka, 2007). Our study was conducted between July and November, thus including both, summer and autumn. Therefore, we cannot differentiate between seasons or look into season effects, which would probably influence feed intake if the experiment was conducted during either the winter months or summer months. Also parity is an important internal factor for feed consumption: Sows from parity one and two showed lower feed consumption than older sows (Thingnes et al., 2012). In our study, the sows were allocated by parity to minimize any parity effects across treatment and thus the effect of parity was not analyzed.

It is shown that a body mass loss of 10 to 12 % can affect litter growth (Clowes et al., 2003). In this study, no difference was observed in percent body weight loss between treatment groups despite the lower feed intakes for the ad libitum group. Weight loss can lead to e.g. shoulder lesions in sows and can affect sows' health which can then influence the piglets' health. However, we also failed to observe any differences in shoulder lesions. Similar to our findings, Thingnes et al. (2012) observed no difference in weight loss between ad libitum and step-up feeding. Step-up feeding in this study meant an increase of feed allowance of 0.8 kg every two days until the maximum feed intake was reached which was when the feed started to pile up in the trough after feeding. That feeding regime is different to a restricted feeding program. Similar to our study, Imaeda and Yoshioka (2007) did not see a difference in body weight loss between ad libitum and restricted feeding. Furthermore, two other studies found similar results to ours. Kruse et al. (2011) showed a weight gain for parity one and weight losses from 1.5 to 2.2 % for parity two and three with a challenge feeding system. The same calculation for body weight loss was used than we did. Another study showed as well a weight loss of under 5 % comparing a high-protein diet with a low-protein diet (Revell et al., 1998). Pedersen et al., (2016) documented 5 to 7 % weight loss comparing two different feeding managements using different feed ingredients. Poulopoulou et al. (2018) showed a body mass loss of 12.7 % in three times fed sows and 13.7 % in sows fed twice. The study shows a higher body mass loss than our study. One reason could be that we did not weigh the sows after farrowing but instead when they entered the room and subtracted the birth litter weight where inaccuracy can occur.

The percentage of piglet mortality is typically between 16 to 20 % from birth to weaning (Edwards and Baxter, 2015) and can be caused by many factors: Also, the feeding regime can have an effect: If the sow produces more milk due to the feeding regime and therefore has stronger piglets with a higher survival rate, piglet mortality can be reduced. In our study the feeding regime did not influence piglet mortality. A piglet mortality (related to piglets born alive) of 20.67 % was found which was higher than in a study which investigated piglet performance on a farm in Sweden with 24 sows in free farrowing pens, resulting in a piglet mortality of 15 % (Valros et al., 2003). Leeb et al. (2019) found a similar result with 21.3 % (total mortality including dead born) in indoor housed organic sows. Possible explanations for the pre-weaning mortality observed in this study include management (opening the crate at 4 days post-farrowing, flooring, housing (e.g. relatively small area) or the highly prolific sows (large number of piglets born alive).

Post-weaning conception rates can be influenced by several factors including feed intake during lactation. We found no statistical difference between feeding regimes for post-weaning conception rates consistent with the notion that all four of the feeding systems in this study were able to meet the nutritional needs of lactating sows. It is interesting that the conception rate for T 1 was numerically lower than for the other treatments. Parity has been shown to influence post-weaning conception rates (Vargas et al., 2009). Poulopoulou et al. (2018) reported that sows in parity three or older had reduced conception rates. Interestingly, two of the three sows in T1 that failed to conceive on their first mating after weaning were parity three or older. Given the similarity between T1 and 2, it is likely that any numerical differences arise from stochastic variation in the relatively small number of sows in each treatment group rather an underlying biological difference.

6.2 Clinical data piglets and sows

Lesions are often multifactorial, e.g. flooring (Norring et al., 2006), lactation length and body condition. 63 percent of all piglets showed carpal lesions on new concrete, partially slatted floor (Zoric et al., 2008). The incidence of carpal lesions in our study was much lower (~30 %) possibly because the floor in our study was plastic which would be less abrasive and decrease the carpal lesions. In our study, piglets' head lesions and wounds decreased from birth until weaning whereas carpal lesions did not. Carpal lesions could not heal over time, most likely due to ongoing exposure to the source of the lesions, the floor.

A sound head (no lesions) was assessed in all treatments and more piglets with sound head were found in T1 and T2. Studies comparing the effect of different feeding systems on piglet lesions are rare. One study observed face lesions in piglets with intact or ground teeth (Hansson and Lundeheim, 2012) and found that 69.8% of the piglets had lesions in week one and 43.5 % in week two. Contrasting two different floors, it was observed, that head lesions, but not carpal lesions decreased with on both flooring types (Lohmeier et al., 2019). Both studies are consistent with our observation, that piglets' head lesions can heal during lactation. The differences in head lesions between the four feeding regimes could be explained by less fighting of the piglets in the first two systems (T1, T2) due to better milk production from the sow, more productive teats or less piglets. Compatible with that there was a tendency that the piglet weight gain was higher in the ad libitum systems which supports the assumption of a better milk production. However, additional research will be needed to better understand these differences.

Our study did not provide evidence to support the development of sow lesions due to feeding systems (e.g. by hitting equipment in the feeding trough when eating) or a treatment effect: Overall the number of sows with snout and head lesions developed during lactation was very low. Sows may have entered farrowing rooms with lesions developed during gestation, but those did not increase during lactation. However, initially 3 sows in T1 and T2 developed a wound on their neck due to the metal rod of the automated ad libitum feeding system. The system was adapted by changing how the metal rod was installed and prevented injuries in subsequent groups. The prevalence of ear lesions was quite high. Most of the lesions in the beginning came from gestation whereas the increase of ear lesions over lactation is not explainable.

Teat lesions can develop through a large litter size and the lack of milk or through perforated flooring. The prevalence of teat lesions was high and increased over time which could be explainable due to the type of floor. In gestation they could decide if they lay down on a straw bed, concrete or slatted floor whereas in lactation there is just the slatted floor where the teats can be trapped between the slats. The increase might happen because of the piglets which get older and stronger and damage the teats more. The high percentage of teat lesions is similar to the findings of (Maschat et al., 2020) and might arise from the fact that piglet teeth were not clipped in this herd together with the confinement period and the flooring material. Crated sows showed more postural changes during lactation compared to not crated sows which can lead to more teat lesions. In Denmark Bonde et al. (2004) a range of udder and teat lesions ranged between 2 to 12 % which is lower than in our study. It could be that these differences in findings also arise from differences in how teat lesions were scored in different studies.

Low feed intake during lactation leads to a lower BCS and increases the likelihood of lesions (Baxter et al., 2017). Similar to our study, where 11 of 61 sows (18 %) had shoulder lesions on weaning day, Bonde et al. (2004) found shoulder lesions to range between 3 and 25 %. Few studies are focusing on shoulder lesions with regard to the feeding system: Poulopoulou et al. (2018) compared the feed intake with shoulder lesions and concluded, that a higher feed intake led to fewer shoulder lesions. Maschat et al., 2020 observed a prevalence for shoulder lesions between 2 and 10 %. We had a higher prevalence which could be also due to different floor types. In contrast to ours and other studies, no shoulder lesions were observed in a study comparing sows housed in organic systems including outdoor and indoor systems (Leeb et al., 2010). Four sows (6.6 %) were lame in our study. Our prevalence of lameness is similar to a study by Maschat et al., 2020 where pen types and confinement periods were compared in similar husbandry systems using temporary crating of sows. The study showed a prevalence of 2 to 10 % for lameness.

6.3 Behavior

Across all treatments groups, sow spent almost all of their time lying (90.95 %) and the remainder of their time standing (7.33 %) or sitting (1.36 %). The percentage of lying decreased over time, whereas the percentage of standing increased. Overall, our observations regarding postures are comparable to other studies (Chidgey et al., 2016; Yin et al., 2016). As an example, Yin et al. (2016) observed the behavior from lactating sows in free farrowing pens with straw and in crates without straw (with fixed feeding times three times a day). For the free farrowing pen, sows were lying 90.9 %, standing 8.26 % sitting only 0.63 %. Comparing general activities in different feeding systems, gestating sows in ad libitum feeding systems spent more time lying than in the other treatments (Bergeron et al., 2000). However, in our study no difference was found between the feeding regimes, which could be due to the fact, that we observed lactating sows fed ad libitum or with a challenge feeding regime and the difference was not as much as if it would be compared to a restricted regime. In addition, we did not compare ad libitum to a restricted feeding system but to a challenge feeding system (with a high amount of feed) which could be an explanation for the difference in daily feed intake. Furthermore, in our study we used sows from parity zero to eight and not just parity two. Older sows can have a different feeding pattern, as it was shown that young sows eat less than old sows (Poulopoulou et al., 2018).

If the behavioral needs of the sows are not fulfilled, stereotypies can develop. One reason for developing stereotypies can be the feeding regime, e.g. restricted feeding systems. In our study we could not see a difference in stereotypies among treatments but generally, there was a very low (under 5 %) prevalence of stereotypies. Comparing different amounts of fibers fed restricted with a control group fed ad libitum in gestation, it was found that the ad libitum group showed less stereotypies (Bergeron et al., 2000). However, only 21 sows were included in the study and instantaneous samples of five minutes were used. As already mentioned above, it is important that we did not compare to a restricted group like Bergeron et al. (2000) but to a challenge feeding regime, which is more similar to ad libitum and could explain the missing difference between the treatment groups. Yin et al. (2016) analyzed the occurrence of stereotypies, where crated sows showed significantly more oral stereotypies than sows in free farrowing pens. Furthermore stereotypies can develop and become irreversible over time (Mason and Rushen, 2006), so that a change of feed system does not affect the display of stereotypies straight away (or at all). Sows spend a longer period in gestation where they can be fed using different feeding systems, and the animals in our study were limited feed which can promote the onset of stereotypies. So if stereotypies developed during gestation are maintained in lactation, it can be hard to understand the impact of lactation practices on stereotypic behavior.

Sekiguchi and Koketsu (2004) found a higher percentage of vacuum chewing (12.7 %) in gestating sows but roughly the same occurrence of bar biting (0.2 %). Unlike in our study they used instantaneous samples of 15 min and sows in gestation. Furthermore, they recorded the sows immediately after feeding and only during day time. As sows show stereotypies mostly before and after eating this could explain the higher percentage of vacuum chewing. A different study (Chidgey et al., 2016), also observed a much higher percentage in vacuum chewing than in our study with percentages for biting fixtures similar to ours. There, sows were kept in farrowing crates during the whole lactation or just until day four as in our study and behavior was observed only during daytime. In contrast to this, we analyzed 24 hours as the ad libitum sows could also eat during the night. It should be noted, that during night time a sow is more likely to be immobile which leads to a lower percentage of stereotypies over the 24 hours period. The feeding paradigm did not affect any other observed behavior (e.g. nursing, drinking).

There are two most common observational methods: Instantaneous sampling and continuous recording. Continuous recording records the behavior of the sow over the whole time period. In instantaneous sampling, different preselected events during the day are observed (Altmann, 1974). This method is a simple way to reduce the time of observation (Martin and Bateson, 2007). Additionally, the time budget of different behaviors over a large amount of time can be calculated. In our study instantaneous sampling was used. The disadvantage of this approach is that - depending on the time interval – especially brief behaviors can be missed. The smaller the sample interval, the closer it is to continuous recording (Engel, 1996). Especially when stereotypies have a short duration instantaneous sampling might fail to detect the behavior. In a bachelor thesis (Bicanic and Schmitt, 2020), continuous recording was compared with instantaneous sampling for 20 sows from our study. Additionally, the camera position from above the sow was compared to the side of the farrowing pen. In contrast to the method used in my study, vacuum chewing was best visible from the side and with continuous recording. That means that it is possible that we missed frequencies with vacuum chewing and it could be higher using continuous recording. There was no difference for vacuum chewing from the camera above between the observation methods. However, it was difficult to see bar biting from above and with scan sampling, but the frequency of sows which showed bar biting was very low. It could be possible that we missed behavior what could be seen from a camera on the side of the farrowing pen. For bar biting continuous recording would be better. Further research is needed to evaluate the behavior of the sow for a longer period of time. Furthermore, looking at the behavior using continuous observation and during day time could lead to different results. The percentage could be higher but also better comparable to other studies because most of them used just the day time.

One effect of treatment was seen regarding the activity “head in the trough”. This behavior includes playing with the sensor or the food and eating, as those behaviors could not be distinguished. In the ad libitum treatments (T1-T3), the sows spent more time with their head in the trough, which might be explained with the increased playing with the sensor/ball or more frequent eating than the challenge feeding group (T4). Spending most of their active time with eating and searching for food corresponds to sows’ natural behavior (Stolba and Wood-Gush, 1989). If sows are actually eating and searching for food, when their head is in the trough this can be interpreted as an indicator for improved welfare. However, this behavior could also be interpreted as negative, when sows spent more time with their head in the trough due to boredom or frustration by the limited amount of feed being dispensed. In our study it is impossible to say what sows actually did when they performed this behavior and further research is needed to investigate this behavior closer including some way of assessing the valence of it (e.g. via heart rate variability).

7. Conclusion

In summary, findings from this work support some, but not all of the original hypotheses that automated ad libitum feeding regimes can improve productivity, health and behavior of piglets and sows. Automated ad libitum feeding improved the productivity of sows and piglets: piglet growth per feed disappearance increased and more piglets with a sound head were found, but the health of sows did not improve. There were differences in the behavior: sows in ad libitum systems spend more time with their head in the trough.

One important outcome of our study was, that automated ad libitum systems had a positive effect regarding productivity: The feed disappearance of sow feed was lower in ad libitum strategies T1-T3, and the piglet growth was higher. The piglet growth per feed disappearance was the highest in the automated ad libitum treatment groups (T1 and T2) without any differences in weight loss of sows between the treatments. Also the higher prevalence of piglets without head lesions in T1 and T2 could support this finding, as these lesions are caused by increased fighting over access to milk. The results lead to the conclusion, that the sows in the ad libitum system consumed feed according to their requirements, whereas the sows in the challenge feeding system ate more than they required. Further research is necessary to get a better understanding of the impact of different feeding regimes on piglet growth per feed disappearance. Furthermore, ad libitum fed sows seem to eat more meals over several times per day and spend more time with their head in the trough. More research addressing the effects on sow welfare of different feeding systems as well as the sows feeding behavior is needed to understand the meaning of the changed feeding behavior for the sow. Ad libitum feeding could improve not only the economic performance, but also the welfare of sows.

8. Abstract

Feeding lactating sows is difficult due to their changing nutrient demands from gestation to and during lactation. The present study evaluated the effect of four different feeding systems on productivity and welfare of 62 sows and their piglets allocated by treatment and parity. An automated ad libitum feeding system without (T1) and with attraction portion four times a day (T2) and a manual ad libitum feeding system (T3) were compared with a non-ad libitum system (T4). Daily feed disappearance, piglet growth, piglet growth per feed disappearance as well as other productivity data were recorded. Furthermore, health indicators (e.g. lesions and lameness) of sows and piglets were scored and behavior (e.g. stereotypies) was analyzed using in total 96 hours of video recording from 35 sows. Sows from the ad libitum systems (T1 to T3) showed a lower feed disappearance than T4 (T1=6.55 kg, T2=6.55 kg, T3= 7.4 kg, T4= 10.08 kg, $p<0.001$). There was a tendency, that average daily piglet growth was higher in T1 to T3 than T4 (T1=8.23 kg, T2=7.83 kg, T3=7.1 kg, T4=6.92 kg, $p=0.054$) and in T1 and T2 a higher piglet growth per feed disappearance (T1=0.46, T2=0.45, T3=0.35, T4=0.24, $p<0.001$) in was found. Furthermore, more piglets without head lesions were found in T1 and T2 ($p=0.006$). No treatment effect was seen for piglet mortality, sow weight loss and conception rates. Sows in ad libitum systems (T1 to T3) spent more time with their head in the trough than in the non-ad libitum system T4 (T1=4.28 %, T2=5.11 %, T3=5.35 %, T4=2.73%, p=<0.001) but no effect regarding the occurrence of stereotypies was seen. Our data suggest, that sows fed ad libitum eat what they need and can convert this better into the piglets' growth without any additional weight loss. The good nutritional status of sows in the ad libitum systems could be an explanation for less head lesions of their piglets due to sufficient milk production and therefore little fighting among the piglets. Furthermore, the increased time sows spent in ad libitum systems with their head in the trough points towards longer feeding times, which could be positive for sows' welfare, but needs further, more detailed observations. In conclusion, automated ad libitum feeding systems improve the productivity, especially the piglet growth per feed intake. Further research in the area of feeding behavior and piglet growth per feed disappearance is

needed to contribute to the development of feeding systems, which improve the welfare of sows and piglets as well as economic costs.

9. Zusammenfassung

Die Fütterung laktierender Sauen erweist sich als schwierig durch den sich ändernden Nährstoffbedarf am Übergang von der Tragezeit zur bzw. während der Laktation. In der vorliegenden Studie wurden die Effekte von vier verschiedenen Fütterungssystemen auf die Produktivität und das Tierwohl von 62 Sauen und ihren Ferkeln beurteilt, die unter Berückstichtigung der Wurfzahl zufällig den Versuchsgruppen zugeteilt wurden. Ein automatisches ad libitum Fütterungsystem ohne Anlockportion (T1), mit einer Anlockportion viermal am Tag (T2) und ein manuelles ad libitum Fütterungssystem (T3) wurden mit einem nicht ad libitum Fütterungsystem (T4) verglichen. Dazu wurden die Futteraufnahme, die täglichen Zunahmen der Ferkel, die Ferkelzunahmen pro Futteraufnahme der Sau und weitere Produktionsdaten wurden erhoben. Außerdem wurde die Gesundheit (z.B. Läsionen und Lahmheit) der Sauen und Ferkel beurteilt und das Verhalten (z.B. Stereotypien) anhand von 96 Stunden Videomaterial von 35 Sauen beobachtet. Sauen in den ad libitum Systemen (T1 bis T3) nahmen weniger Futter auf als die nicht ad libitum (T4) Sauen (T1=6.55 kg, T2=6.55 kg, T3= 7.4 kg, T4= 10.08 kg, $p=<.0001$). Es gab eine Tendenz, dass die Ferkel der Sauen in T1 bis T3 mehr zunahmen als in T4 (T1=8.23 kg, T2=7.83 kg, T3=7.1 kg, T4=6.92 kg, $p=0.054$) und somit eine höhere Zunahme der Ferkel pro kg Futteraufnahme der Sau (T1=0.46, T2=0.45, T3=0.35, T4=0.24, $p<0.001$). Außerdem wurden in T1 und T2 mehr Ferkel ohne Kopfverletzungen ($p=0.006$) gefunden. Kein Effekt wurde bei der Umrauschrate, der Ferkelsterblichkeit und dem Gewichtsverlust der Sau festgestellt. Der Kopf von Sauen in T1, T2 und T3 war länger im Trog zu beobachten als bei den nicht ad libitum Sauen in T4 (T1=4.28 %, T2=5.11 %, T3=5.35 %, T4=2.73%, $p<0.001$), aber es gab keinen Unterschied bei den hinsichtlich des Auftretens von Stereotypien. Unsere Daten zeigen, dass die Sauen in den ad libitum Systemen so viel Futter aufnehmen konnten, wie sie brauchten, dies bei den Ferkeln zu guten Wachstum führte, ohne dass die Sauen übermäßigen Gewichtsverlust erlitten. Die gute Körperkondition der Sau könnte ein Grund für die weniger häufiger auftretenden Gesichtsläsionen bei den Ferkeln sein: da die Sauen ausreichend Milch produzierten, mussten die Ferkel weniger darum kämpfen und wuchsen besser. Die längere Zeit, die die Sauen in den ad libitum Systemen mit dem

Kopf im Trog verbrachten, kann auf längere Fresszeiten deuten, was für das Wohlergehen positiv wäre, aber umfangreichere Beobachtungen benötigen würde. Zusammenfassend kann man sagen, das automatische ad libitum Fütterungsstrategien die Produktivität steigern, insbesondere die Zunahmen der Ferkel pro Futteraufnahme der Sau. Weitere Forschung auf dem Gebiet des Fressverhaltens und des Ferkelwachstums pro Futteraufnahme der Sau ist erforderlich, um Fütterungssysteme zu entwickeln, die das Wohlergehen von Sauen und Ferkeln steigern, sowie die Wirtschaftlichkeit verbessern.

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Table of figures

List of tables

Appendix 1 – Sow & Piglet Parameter

Sow	Parameter	Method and Definition	Based on	Time
	Body Condition Score (BCS)	Score 1 to 5 1: visually thin, hips and backbone very prominent 2: hips and backbone slightly covered 3: hips and back well covered, rear view oval shape 4: fat layers on hips and back, rear view nearly round 5: thick fat layers on hips and back, clearly visible “trousers”	(Coffey et al., 1999)	D1, D3, D4, D5
	Lameness	Score 0 to 1 0: no lameness 1: lameness	(Leeb et al., 2010) (D’Eath, 2012)	D1, D5
	Snout Lesion	Region from the snout to the end of the bridge, Score 0 to 2 0: no injuries 1: < 3cm length, <4mm wide 2: injuries > 3cm length, >4mm wide	(Welfare Quality®, 2009) /adapted	D1, D3, D4, D5
	Shoulder lesion	Score 0 to 2 0: No pressure lesion or only reddening on sow’s shoulder 1: <3 Diameter pressure lesion <3cm 2: >3 Diameter obvious pressure lesions on sow	(Welfare Quality®, 2009)	D1, D3, D4, D5
	Head and ear lesion	region from the end of the snout to the beginning of the neck, including the ears Score 0 to 2 0: no injuries 1: < 3cm length, <4mm wide 2: injuries > 3cm length, >4mm wide	(Welfare Quality®, 2009) /adapted	D1, D3, D4, D5
	Teat lesions	Score from 0 to 2 0: no injuries 1: small scratches < 50% of the teat 2: injuries on > 50% of the teat		D1, D3, D4, D5
	Neck lesion	Region from 10 cm from the end of the ears in the direction of the back Score from 0 to 2 0: no injuries 1: < 3cm length, <4mm wide 2: injuries > 3cm length, >4mm wide		D1, D3, D4, D5

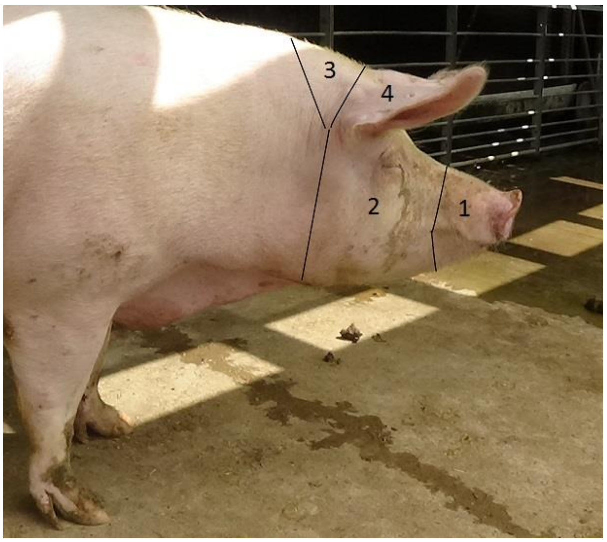
Piglet	Carpal lesions	Score 0 to 1 0: No swelling 1: Obvious swelling on at least one of the carpal joints, diameter ≥1cm	Pro Sau /adapted	D3, D5
	Lameness	0 to 1 0: no lameness 1: obvious lameness= clearly visibly reduced weight bearing on one limb (“limping”) or animals being unable to walk	Pro Sau /adapted	D3, D5
	Head lesions	Score 0 to 2 0: no lesions 1: more than 2 scratches 2: wounds diameter ≥ 1 cm	Pro Sau /adapted	D3, D5
	Runts	Score 0 to 1 0: normal piglet 1: runt 1= runt with at least two of the following indicators: long face, large ears, sunken flank, visible spin, hairy coat, obviously smaller, under 3 lb	Pro Sau /adapted	D3, D5

Appendix 2 – Sow & Piglet Assessment
Sow and Piglet Assessment

Veterinary treatments

1. Piglet: Assess farm veterinary records for number and type (Diarrhia,lameness,..) of treatments per litter until weaning.
2. Sow: Assess farm veterinary records for number and type (MMA,lameness,..) of treatments per litter until weaning.

Sow



<u>Injuries on snout 1</u>

Assess both sides. Consider the **region** from snout to the end of bridge. Sows (individual): Score from 0 to 2 Score 0: **no injuries** Score 1: **< 3cm length, <4mm wide** Score 2: **injuries > 3cm length, >4mm wide**

<u>Injuries on head 2&4</u>

Assess both sides. Consider the **region** from the end of the snout to the beginning of the neck, including the ears. Count all **scratches** (= a **wound** penetrating the skin, fresh or crust). Count the number of lesions on the ears separated. Score 0: **no injuries** Score 1: **< 3cm length, <4mm wide** Score 2: **injuries > 3cm length, >4mm wide**

Injuries on neck Nr.3

Assess both sides. Consider a **region** from 10 cm from the end of the ears in the direction of the back. Count all **scratches** (= a **wound** penetrating the skin, fresh or crust).

Score 0: **no injuries**
Score 1: **< 3cm length, <4mm wide**
Score 2: **injuries > 3cm length, >4mm wide**

Teat lesions

Assess both sides. Consider all teats. (= a **wound** penetrating the skin, fresh or crust).

Sows (individual): Score from 0 to 2
Score 0: **no injuries**
Score 1: **small scratches < 50% of the teat**
Score 2: **injuries on > 50% of the teat**

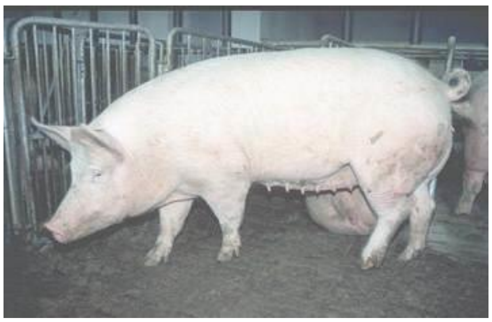
Score 1

Score 2

Lameness

Assess for lameness during walking to the scale.

Score every sow:
0 Normal gait
1 Difficulties walking, but still using all legs
2 Severely lame, minimum weight-bearing on affected limb
3 Non-weight-bearing on the affected limb or unable to walk



Score 1: Lame = **reduced** weight bearing on left **hind** leg

Body condition score (sows)

(Adapted from DEFRA, 1998; training material at: http://sauwohl.weebly.com)

To score the sows individually, encourage them to **stand up**.

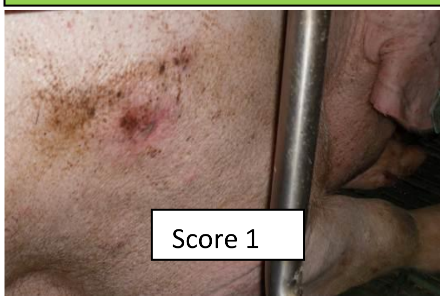
Sows (individual level)**: Score 1 to score 5** (see below)

Score 1	Score 2	Score 3	Score 4	Score 5
visually thin, **hips** and **backbone** very prominent	hips and backbone slightly covered, rear view **roof like** shape	hips and back well covered, rear view **oval shape**	fat layers on hips and back, rear view nearly **round**	thick fat layers on hips and back, clearly visible "**trousers**" (red arrow)

Shoulder lesions (sows)

Assess whether there is evidence of a **pressure lesion (ulcer)** on the shoulders (typical location on spine). Include any penetration of the tissue, like open wound, healing lesion or scar tissue. **Do NOT include reddening** of the area without penetration of the tissue.

<u>**Sows** (individual level):</u>
Score 0: **No** pressure lesion or only reddening on sow's shoulder
Score 1: <3 Diameter pressure lesion <3cm
Score 2: >3 Diameter **obvious** pressure lesions on sow



Piglet

Lameness

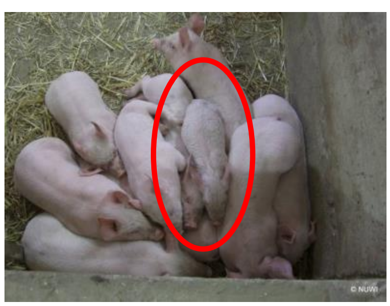
Encourage all animals to **stand up and walk** some steps. Assess for obvious lameness = **clearly** visibly **reduced weight bearing** on one limb ("limping") or animals being unable to walk. Do **not** count slight aberration or stiff gait.

Count the number of piglets for score 1
Score 0: no lameness
Score 1: obvious lameness

Lame: can't stand up reduced weight on one leg

Runts

Count number of piglets in the pen with at least **two** of the following indicators: obviously **smaller** (less than 4 lb) than the other animals, **spine** is obviously visible, **pale**, **hairy coat**, **long face**, **large ears** and/or **sunken flank**. Weight less than **4** pounds.



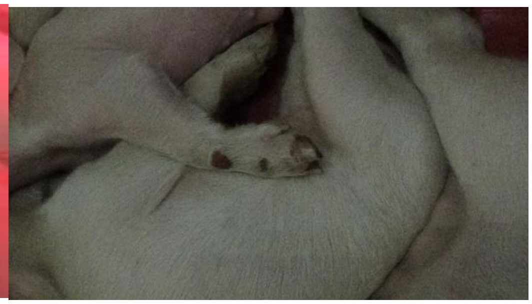
Runt: >2 indicators present: Long face, large ears, sunken flank

Runt: >2 indicators present: Visible spine, hairy coat, obviously smaller

Carpal Lesions

Assess for obvious swellings (**≥ 1 cm** diameter) on at least one of the **carpal joints**.

Count Piglets with score 1:
Score 0: **No** swelling
Score 1: Obvious **swelling** on at least one of the **carpal joints**

Injuries on head

Assess both sides. Consider the **region** from the end of the snout to the beginning of the neck, including the ears. Percentage in every litter of every score. Score every animal:

Score 0: no lesions
Score 1: more than 2 scratches
Score 2: wounds diameter ≥ 1 cm


Cradle Cap

Wound

Scratches

Appendix 3 – Results tables

For every table: T1=automated ad libitum, T2=automated ad libitum with attraction portion, T3= manual ad libitum, T4= non-ad libitum.

Feed disappearance

Table 11: Feed disappearance, least squares mean, estimated value, standard error, degrees of freedom and p-value

Least squares mean						
Effect	**Treatment**	**Estimated value**	**Standard-error**	**DF**	**t-Value**	**Pr > |t|**
Treatment	**1**	14.41	0.81	50	17.71	<.001
Treatment	**2**	14.41	0.78	50	18.46	<.001
Treatment	**3**	16.29	0.99	50	16.29	<.001
Treatment	**4**	22.18	0.98	50	22.58	<.001

Table 12: Feed disappearance, differences least squares mean, estimated value, standard error, degrees of freedom and p-value corrected by Tukey-Kramer Test

Differences Least Squares Mean						
Effect	**Treatment**	**Treatment**	**Estimated value**	**Standard-error**	**DF**	**Korr. P**
Treatment	**1**	**2**	-0.009	1.13	50	1
Treatment	**1**	**3**	-1.885	1.308	50	0.480
Treatment	**1**	**4**	-7.778	1.274	50	<.001
Treatment	**2**	**3**	-1.876	1.266	50	0.456
Treatment	**2**	**4**	-7.768	1.255	50	<.001
Treatment	**3**	**4**	-5.892	1.404	50	0.001

Piglet growth

Table 13: Piglet growth, least squares mean, estimated value, standard error, degrees of freedom and p-value

Least squares mean						
Effekt	**Treatment**	**Estimated value**	**Standard-error**	**DF**	**t-Value**	**Pr > |t|**
Treatment	**1**	18.110	0.839	51	21.58	<.001
Treatment	**2**	17.216	0.847	51	20.33	<.001
Treatment	**3**	15.632	0.978	51	15.98	<.001
Treatment	**4**	15.232	0.987	51	15.43	<.001

Table 14: Piglet growth, differences least squares mean, estimated value, standard error, degrees of freedom and p-value corrected by Tukey-Kramer Test

Differences Least Squares Mean						
Effect	**Treatment**	**Treatment**	**Estimated value**	**Standard-error**	**DF**	**Korr. P**
Treatment	**1**	**2**	0.894	1.024	51	0.819
Treatment	**1**	**3**	2.479	1.168	51	0.160
Treatment	**1**	**4**	2.878	1.161	51	0.076
Treatment	**2**	**3**	1.585	1.153	51	0.521
Treatment	**2**	**4**	1.984	1.152	51	0.323
Treatment	**3**	**4**	0.399	1.269	51	0.989

Piglet growth per feed disappearance

Table 15: Piglet growth per feed disappearance, least squares mean, estimated value, standard error, degrees of freedom and p-value

Least squares mean						
Effekt	**Treatment**	**Estimated value**	**Standard-error**	**DF**	**t-Wert**	**Pr > |t|**
Treatment	**1**	0.464	0.030	50	15.32	<.001
Treatment	**2**	0.454	0.030	50	15.21	<.001
Treatment	**3**	0.350	0.035	50	9.88	<.001
Treatment	**4**	0.239	0.035	50	6.78	<.001

Table 16: Piglet growth per feed disappearance, differences least squares mean, estimated value, standard error, degrees of freedom and p-value corrected by Tukey-Kramer Test

Differences Least Squares Means						
Effect	**Treatment**	**Treatment**	**Estimated value**	**Standard-error**	**DF**	**Korr. P**
Treatment	**1**	**2**	0.010	0.038	50	0.994
Treatment	**1**	**3**	0.114	0.044	50	0.058
Treatment	**1**	**4**	0.224	0.042	50	<.001
Treatment	**2**	**3**	0.104	0.042	50	0.079
Treatment	**2**	**4**	0.214	0.042	50	<.001
Treatment	**3**	**4**	0.111	0.047	50	0.096

Piglet lesions

Table 17: Piglet lesion: Least squares mean with standard error in brackets and p-value for Treatment 1 to 4

Piglet lesions	Treatment: Least squares mean				Assessment: Least squares mean		Assessment: p-value	Treatment: p-value	Assessment *Treatment
	T1	T2	T3	T4	1	2			
Head sound	60.6 a (0.04)	61.1a (0.04)	46.8 b (0.04)	48.3 b (0.04)	41.0 (0.03)	67.4 (0.03)	<.05	0.01	0.63
Head wound	13.4 a (0.03)	12.1 a (0.03)	17.8 a (0.03)	16.9 a (0.03)	24.0 (0.02)	0.06 (0.02)	<.05	0.46	0.62
Head lesions	25.7 a (0.03)	26.9 a (0.03)	34.9 a (0.03)	32.6 a (0.03)	34.4 (0.02)	25.7 (0.02)	<.05	0.06	0.06
Carpal lesions	30.3 a (0.03)	30.1 a (0.03)	34.0 a (0.04)	33.2 a (0.04)	32.0 (0.03)	31.8 (0.03)	0.97	0.81	0.38

Head wound

Table 18: Head wound, least squares mean, estimated value, standard error, degrees of freedom and p-value corrected by Tukey-Kramer Test

Least Squares Mean						
Effekt	**Treatment**	**assessment**	**Estimated value**	**Standard-error**	**DF**	Pr > |t|
Treatment	**1**		0.134	0.027	108	<.001
Treatment	**2**		0.121	0.026	108	<.001
Treatment	**3**		0.178	0.033	108	<.001
Treatment	**4**		0.169	0.033	108	<.001
assessment		**1**	0.240	0.021	108	<.001
assessment		**2**	0.061	0.021	108	0.004
Treatment*assessment	**1**	**1**	0.214	0.038	108	<.001
Treatment*assessment	**1**	**2**	0.054	0.038	108	0.152
Treatment*assessment	**2**	**1**	0.195	0.037	108	<.001
Treatment*assessment	**2**	**2**	0.047	0.037	108	0.203
Treatment*assessment	**3**	**1**	0.304	0.046	108	<.001
Treatment*assessment	**3**	**2**	0.052	0.046	108	0.259
Treatment*assessment	**4**	**1**	0.248	0.046	108	<.001
Treatment*assessment	**4**	**2**	0.091	0.046	108	0.051

Head lesions

Table 19: Head lesions, least squares mean, estimated value, standard error, degrees of freedom and p-value corrected by Tukey-Kramer Test

Least Squares Mean						
Effect	**Treat ment**	**assess ment**	**Estimated value**	**Standard-error**	**DF**	**Pr > |t|**
Treatment	**1**		0.257	0.028	108	<.001
Treatment	**2**		0.269	0.028	108	<.001
Treatment	**3**		0.350	0.033	108	<.001
Treatment	**4**		0.326	0.033	108	<.001
assessment		**1**	0.344	0.023	108	<.001
assessment		**2**	0.257	0.023	108	<.001
Treatment*assessment	**1**	**1**	0.326	0.037	108	<.001
Treatment*assessment	**1**	**2**	0.187	0.037	108	<.001
Treatment*assessment	**2**	**1**	0.308	0.037	108	<.001
Treatment*assessment	**2**	**2**	0.230	0.037	108	<.001
Treatment*assessment	**3**	**1**	0.329	0.045	108	<.001
Treatment*assessment	**3**	**2**	0.371	0.044	108	<.001
Treatment*assessment	**4**	**1**	0.413	0.045	108	<.001
Treatment*assessment	**4**	**2**	0.239	0.045	108	<.001

Carpal lesions

Table 20: Carpal lesions, least squares mean, estimated value, standard error, degrees of freedom and p-value corrected by Tukey-Kramer Test

Least Squares Mean						
Effect	**Treat ment**	**assess ment**	**Estimated value**	**Standard-error**	**DF**	**Pr > |t|**
Treatment	**1**		0.303	0.032	108	<.001
Treatment	**2**		0.301	0.032	108	<.001
Treatment	**3**		0.340	0.039	108	<.001
Treatment	**4**		0.332	0.039	108	<.001
assessment		**1**	0.320	0.026	108	<.001
assessment		**2**	0.318	0.026	108	<.001
Treatment*assessment	**1**	**1**	0.301	0.045	108	<.001
Treatment*assessment	**1**	**2**	0.305	0.045	108	<.001
Treatment*assessment	**2**	**1**	0.309	0.044	108	<.001
Treatment*assessment	**2**	**2**	0.294	0.044	108	<.001
Treatment*assessment	**3**	**1**	0.292	0.055	108	<.001
Treatment*assessment	**3**	**2**	0.389	0.055	108	<.001
Treatment*assessment	**4**	**1**	0.378	0.055	108	<.001
Treatment*assessment	**4**	**2**	0.286	0.055	108	<.001

Head sound

Table 21: Head sound, least squares mean, estimated value, standard error, degrees of freedom and p-value corrected by Tukey-Kramer Test

Least Squares Mean						
Effect	**Treat ment**	**assess ment**	**Estimated value**	**Standard-error**	**DF**	**Pr > |t|**
Treatment	**1**		0.606	0.036	108	<.001
Treatment	**2**		0.611	0.036	108	<.001
Treatment	**3**		0.468	0.042	108	<.001
Treatment	**4**		0.483	0.043	108	<.001
assessment		**1**	0.410	0.030	108	<.001
assessment		**2**	0.674	0.030	108	<.001
Treatment*assessment	**1**	**1**	0.449	0.048	108	<.001
Treatment*assessment	**1**	**2**	0.762	0.048	108	<.001
Treatment*assessment	**2**	**1**	0.495	0.048	108	<.001
Treatment*assessment	**2**	**2**	0.728	0.048	108	<.001
Treatment*assessment	**3**	**1**	0.367	0.0583	108	<.001
Treatment*assessment	**3**	**2**	0.569	0.0583	108	<.001
Treatment*assessment	**4**	**1**	0.328	0.05843	108	<.001
Treatment*assessment	**4**	**2**	0.638	0.05843	108	<.001

Sow lesions

Table 22: Percentage (%) of sows where lesions increased for Treatment 1 to 4; T1=automated ad libitum, T2=automated ad libitum with attraction portion, T3= manual ad libitum, T4= non-ad libitum

Treat -ment	**% of sows where Δ increased**											
	T1, n=18			T2, n=19			T3, n=12			T4, n=12		
Asses sment	2	3	4	2	3	4	2	3	4	2	3	4
Snout	38.9	27.8	33.3	42.1	26.3	31.6	41.2	33.3	25.0	16.7	0	16.7
Head	22.2	16.7	22.2	10.5	26.3	21.1	8.33	8.33	8.33	33.3	8.33	25.0
Ear	16.7	50.0	50.0	15.8	47.4	42.1	16.7	75.0	75.0	0.33	41.7	83.3
Teat	72.2	72.2	83.3	84.2	73.7	89.5	91.7	100	83.3	91.7	83.3	83.3

Behavior: Standing

Table 23: Behavior: Standing, least squares mean, estimated value, standard error, degrees of freedom and p-value corrected by Tukey-Kramer Test

Least Squares Mean						
Effect	**Treatment**	**Day**	**Estimated value**	**Standard-error**	**DF**	**Pr > |t|**
Treatment	**1**		0.071	0.007	93	<.001
Treatment	**2**		0.084	0.007	93	<.001
Treatment	**3**		0.075	0.007	93	<.001
Treatment	**4**		0.063	0.007	93	<.001
Day		**1**	0.053	0.005	93	<.001
Day		**2**	0.069	0.005	93	<.001
Day		**3**	0.082	0.005	93	<.001
Day		**21**	0.089	0.005	93	<.001
Treatment*Day	**1**	**1**	0.055	0.010	93	<.001
Treatment*Day	**1**	**2**	0.074	0.010	93	<.001
Treatment*Day	**1**	**3**	0.080	0.010	93	<.001
Treatment*Day	**1**	**21**	0.076	0.010	93	<.001
Treatment*Day	**2**	**1**	0.061	0.010	93	<.001
Treatment*Day	**2**	**2**	0.085	0.010	93	<.001
Treatment*Day	**2**	**3**	0.088	0.010	93	<.001
Treatment*Day	**2**	**21**	0.100	0.010	93	<.001
Treatment*Day	**3**	**1**	0.059	0.010	93	<.001
Treatment*Day	**3**	**2**	0.071	0.010	93	<.001
Treatment*Day	**3**	**3**	0.080	0.010	93	<.001
Treatment*Day	**3**	**21**	0.091	0.010	93	<.001
Treatment*Day	**4**	**1**	0.037	0.010	93	0.002
Treatment*Day	**4**	**2**	0.048	0.010	93	<.001
Treatment*Day	**4**	**3**	0.079	0.010	93	<.001
Treatment*Day	**4**	**21**	0.090	0.010	93	<.001

Sitting

Table 24: Behavior: Sitting, least squares mean, estimated value, standard error, degrees of freedom and p-value corrected by Tukey-Kramer Test

Least Squares Mean						
Effect	**Treatment**	**Day**	**Estimated value**	**Standard-error**	**DF**	**Pr > |t|**
Treatment	**1**		0.013	0.003	93	0.003
Treatment	**2**		0.017	0.003	93	<.001
Treatment	**3**		0.014	0.003	93	<.001
Treatment	**4**		0.010	0.003	93	0.002
Day		**1**	0.014	0.002	93	<.001
Day		**2**	0.014	0.002	93	<.001
Day		**3**	0.013	0.002	93	<.001
Day		**21**	0.013	0.002	93	<.001
Treatment*Day	**1**	**1**	0.015	0.004	93	0.001
Treatment*Day	**1**	**2**	0.013	0.004	93	0.003
Treatment*Day	**1**	**3**	0.010	0.004	93	0.014
Treatment*Day	**1**	**21**	0.014	0.004	93	0.001
Treatment*Day	**2**	**1**	0.014	0.004	93	0.003
Treatment*Day	**2**	**2**	0.017	0.004	93	<.001
Treatment*Day	**2**	**3**	0.018	0.004	93	<.001
Treatment*Day	**2**	**21**	0.018	0.004	93	<.001
Treatment*Day	**3**	**1**	0.014	0.004	93	0.004
Treatment*Day	**3**	**2**	0.016	0.004	93	<.001
Treatment*Day	**3**	**3**	0.016	0.004	93	<.001
Treatment*Day	**3**	**21**	0.010	0.004	93	0.009
Treatment*Day	**4**	**1**	0.012	0.004	93	0.002
Treatment*Day	**4**	**2**	0.012	0.004	93	0.003
Treatment*Day	**4**	**3**	0.009	0.004	93	0.016
Treatment*Day	**4**	**21**	0.009	0.004	93	0.027

Lying

Table 25: Behavior: Lying, least squares mean, estimated value, standard error, degrees of freedom and p-value corrected by Tukey-Kramer Test

Least Squares Mean						
Effect	**Treatment**	**Day**	**Estimated value**	**Standard-error**	**DF**	**Pr > |t|**
Treatment	**1**		0.915	0.010	93	<.001
Treatment	**2**		0.899	0.010	93	<.001
Treatment	**3**		0.900	0.010	93	<.001
Treatment	**4**		0.925	0.010	93	<.001
Day		**1**	0.932	0.007	93	<.001
Day		**2**	0.915	0.007	93	<.001
Day		**3**	0.903	0.007	93	<.001
Day		**21**	0.888	0.007	93	<.001
Treatment*Day	**1**	**1**	0.929	0.015	93	<.001
Treatment*Day	**1**	**2**	0.913	0.015	93	<.001
Treatment*Day	**1**	**3**	0.907	0.015	93	<.001
Treatment*Day	**1**	**21**	0.909	0.015	93	<.001
Treatment*Day	**2**	**1**	0.924	0.015	93	<.001
Treatment*Day	**2**	**2**	0.898	0.015	93	<.001
Treatment*Day	**2**	**3**	0.893	0.015	93	<.001
Treatment*Day	**2**	**21**	0.881	0.015	93	<.001
Treatment*Day	**3**	**1**	0.926	0.015	93	<.001
Treatment*Day	**3**	**2**	0.912	0.015	93	<.001
Treatment*Day	**3**	**3**	0.900	0.015	93	<.001
Treatment*Day	**3**	**21**	0.860	0.015	93	<.001
Treatment*Day	**4**	**1**	0.950	0.015	93	<.001
Treatment*Day	**4**	**2**	0.939	0.015	93	<.001
Treatment*Day	**4**	**3**	0.910	0.015	93	<.001
Treatment*Day	**4**	**21**	0.901	0.015	93	<.001

Stereotypies

Table 26: Behavior: Stereotypies, least squares mean, estimated value, standard error, degrees of freedom and p-value corrected by Tukey-Kramer Test

Least Squares Mean						
Effect	**Treatment**	**Day**	**Estimated value**	**Standard-error**	**DF**	**Pr > |t|**
Treatment	**1**		0.018	0.006	93	0.005
Treatment	**2**		0.015	0.006	93	0.011
Treatment	**3**		0.019	0.006	93	0.002
Treatment	**4**		0.016	0.006	93	0.007
Day		**1**	0.016	0.004	93	<.001
Day		**2**	0.015	0.004	93	0.002
Day		**3**	0.019	0.004	93	<.001
Day		**21**	0.019	0.004	93	<.001
Treatment*Day	**1**	**1**	0.017	0.008	93	0.036
Treatment*Day	**1**	**2**	0.020	0.008	93	0.013
Treatment*Day	**1**	**3**	0.027	0.008	93	0.001
Treatment*Day	**1**	**21**	0.007	0.008	93	0.399
Treatment*Day	**2**	**1**	0.023	0.008	93	0.004
Treatment*Day	**2**	**2**	0.014	0.008	93	0.068
Treatment*Day	**2**	**3**	0.011	0.008	93	0.143
Treatment*Day	**2**	**21**	0.014	0.008	93	0.079
Treatment*Day	**3**	**1**	0.011	0.008	93	0.144
Treatment*Day	**3**	**2**	0.012	0.008	93	0.128
Treatment*Day	**3**	**3**	0.016	0.008	93	0.040
Treatment*Day	**3**	**21**	0.037	0.008	93	<.001
Treatment*Day	**4**	**1**	0.013	0.008	93	0.105
Treatment*Day	**4**	**2**	0.014	0.008	93	0.072
Treatment*Day	**4**	**3**	0.022	0.008	93	0.006
Treatment*Day	**4**	**21**	0.018	0.008	93	0.023

Biting fixtures

Table 27: Behavior: Biting fixtures, least squares mean, estimated value, standard error, degrees of freedom and p-value corrected by Tukey-Kramer Test

Least Squares Mean						
Effect	**Treatment**	**Day**	**Estimated value**	**Standard-error**	**DF**	**Pr > |t|**
Treatment	**1**		0.001	0.001	93	0.014
Treatment	**2**		0.002	0.004	93	<.001
Treatment	**3**		0.001	0.004	93	0.136
Treatment	**4**		0.001	0.004	93	0.066
Day		**1**	0.001	0.002	93	<.001
Day		**2**	0.001	0.002	93	<.001
Day		**3**	0.001	0.002	93	0.004
Day		**21**	0.001	0.002	93	0.003
Treatment*Day	**1**	**1**	0.002	0.001	93	0.004
Treatment*Day	**1**	**2**	0.002	0.001	93	0.006
Treatment*Day	**1**	**3**	0.001	0.001	93	0.198
Treatment*Day	**1**	**21**	0.001	0.001	93	0.206
Treatment*Day	**2**	**1**	0.002	0.001	93	0.002
Treatment*Day	**2**	**2**	0.003	0.001	93	<.001
Treatment*Day	**2**	**3**	0.002	0.001	93	0.006
Treatment*Day	**2**	**21**	0.002	0.001	93	0.003
Treatment*Day	**3**	**1**	0.004	0.001	93	0.426
Treatment*Day	**3**	**2**	0.001	0.001	93	0.113
Treatment*Day	**3**	**3**	0.001	0.001	93	0.124
Treatment*Day	**3**	**21**	0.001	0.001	93	0.288
Treatment*Day	**4**	**1**	0.001	0.001	93	0.186
Treatment*Day	**4**	**2**	0.001	0.001	93	0.353
Treatment*Day	**4**	**3**	0.001	0.001	93	0.074
Treatment*Day	**4**	**21**	0.001	0.001	93	0.035

Vacuum Chewing

Table 28: Behavior: Vacuum Chewing, least squares mean, estimated value, standard error, degrees of freedom and p-value corrected by Tukey-Kramer Test

Least Squares Mean						
Effect	**Treatment**	**Day**	**Estimated value**	**Standard-error**	**DF**	**Pr > |t|**
Treatment	**1**		0.014	0.005	93	0.007
Treatment	**2**		0.012	0.005	93	0.030
Treatment	**3**		0.013	0.005	93	0.008
Treatment	**4**		0.012	0.005	93	0.012
Day		**1**	0.012	0.003	93	0.001
Day		**2**	0.011	0.003	93	0.001
Day		**3**	0.015	0.003	93	<.001
Day		**21**	0.012	0.003	93	<.001
Treatment*Day	**1**	**1**	0.013	0.006	93	0.039
Treatment*Day	**1**	**2**	0.015	0.006	93	0.019
Treatment*Day	**1**	**3**	0.023	0.006	93	0.001
Treatment*Day	**1**	**21**	0.005	0.006	93	0.391
Treatment*Day	**2**	**1**	0.017	0.006	93	0.007
Treatment*Day	**2**	**2**	0.009	0.006	93	0.152
Treatment*Day	**2**	**3**	0.008	0.006	93	0.213
Treatment*Day	**2**	**21**	0.009	0.006	93	0.122
Treatment*Day	**3**	**1**	0.009	0.006	93	0.145
Treatment*Day	**3**	**2**	0.008	0.006	93	0.192
Treatment*Day	**3**	**3**	0.013	0.006	93	0.037
Treatment*Day	**3**	**21**	0.022	0.006	93	0.003
Treatment*Day	**4**	**1**	0.009	0.006	93	0.116
Treatment*Day	**4**	**2**	0.010	0.006	93	0.085
Treatment*Day	**4**	**3**	0.016	0.006	93	0.007
Treatment*Day	**4**	**21**	0.013	0.006	93	0.038

Vacuum chewing and nursing

Table 29: Behavior: Vacuum chewing and nursing, least squares mean, estimated value, standard error, degrees of freedom and p-value corrected by Tukey-Kramer Test

Least Squares Mean						
Effect	**Treatment**	**Day**	**Estimated value**	**Standard-error**	**DF**	**Pr > |t|**
Treatment	**1**		0.003	0.002	93	0.113
Treatment	**2**		0.003	0.002	93	0.059
Treatment	**3**		0.005	0.002	93	0.001
Treatment	**4**		0.003	0.002	93	0.034
Day		**1**	0.003	0.001	93	0.032
Day		**2**	0.003	0.001	93	0.014
Day		**3**	0.003	0.001	93	0.011
Day		**21**	0.005	0.001	93	<.001
Treatment*Day	**1**	**1**	0.002	0.003	93	0.398
Treatment*Day	**1**	**2**	0.004	0.003	93	0.167
Treatment*Day	**1**	**3**	0.004	0.003	93	0.114
Treatment*Day	**1**	**21**	0.001	0.003	93	0.813
Treatment*Day	**2**	**1**	0.004	0.002	93	0.082
Treatment*Day	**2**	**2**	0.003	0.002	93	0.240
Treatment*Day	**2**	**3**	0.002	0.002	93	0.372
Treatment*Day	**2**	**21**	0.002	0.002	93	0.309
Treatment*Day	**3**	**1**	0.002	0.002	93	0.408
Treatment*Day	**3**	**2**	0.003	0.002	93	0.227
Treatment*Day	**3**	**3**	0.002	0.002	93	0.333
Treatment*Day	**3**	**21**	0.014	0.002	93	<.001
Treatment*Day	**4**	**1**	0.002	0.002	93	0.356
Treatment*Day	**4**	**2**	0.003	0.002	93	0.227
Treatment*Day	**4**	**3**	0.004	0.002	93	0.084
Treatment*Day	**4**	**21**	0.004	0.002	93	0.112

Head in the trough

Table 30: Behavior: Head in the trough, least squares mean, estimated value, standard error, degrees of freedom and p-value corrected by Tukey-Kramer Test

Least Squares Mean						
Effect	**Treatment**	**Day**	**Estimated value**	**Standard-error**	**DF**	**Pr > |t|**
Treatment	**1**		0.043	0.004	93	<.001
Treatment	**2**		0.051	0.004	93	<.001
Treatment	**3**		0.054	0.004	93	<.001
Treatment	**4**		0.027	0.004	93	<.001
Day		**1**	0.037	0.003	93	<.001
Day		**2**	0.047	0.003	93	<.001
Day		**3**	0.038	0.003	93	<.001
Day		**21**	0.053	0.003	93	<.001
Treatment*Day	**1**	**1**	0.036	0.007	93	<.001
Treatment*Day	**1**	**2**	0.049	0.007	93	<.001
Treatment*Day	**1**	**3**	0.038	0.007	93	<.001
Treatment*Day	**1**	**21**	0.049	0.007	93	<.001
Treatment*Day	**2**	**1**	0.044	0.007	93	<.001
Treatment*Day	**2**	**2**	0.063	0.007	93	<.001
Treatment*Day	**2**	**3**	0.040	0.006	93	<.001
Treatment*Day	**2**	**21**	0.057	0.006	93	<.001
Treatment*Day	**3**	**1**	0.048	0.006	93	<.001
Treatment*Day	**3**	**2**	0.054	0.006	93	<.001
Treatment*Day	**3**	**3**	0.053	0.006	93	<.001
Treatment*Day	**3**	**21**	0.059	0.006	93	<.001
Treatment*Day	**4**	**1**	0.020	0.006	93	0.002
Treatment*Day	**4**	**2**	0.021	0.006	93	0.001
Treatment*Day	**4**	**3**	0.022	0.006	93	0.001
Treatment*Day	**4**	**21**	0.046	0.006	93	<.001

Drinking

Table 31: Behavior: Drinking, least squares mean, estimated value, standard error, degrees of freedom and p-value corrected by Tukey-Kramer Test

Least Squares Mean						
Effect	**Treatment**	**Day**	**Estimated value**	**Standard-error**	**DF**	**Pr > |t|**
Treatment	**1**		0.013	0.003	93	0.001
Treatment	**2**		0.016	0.003	93	<.001
Treatment	**3**		0.012	0.003	93	0.001
Treatment	**4**		0.012	0.003	93	0.003
Day		**1**	0.010	0.002	93	<.001
Day		**2**	0.012	0.002	93	<.001
Day		**3**	0.015	0.002	93	<.001
Day		**21**	0.017	0.002	93	<.001
Treatment*Day	**1**	**1**	0.008	0.004	93	0.057
Treatment*Day	**1**	**2**	0.009	0.004	93	0.021
Treatment*Day	**1**	**3**	0.016	0.004	93	<.001
Treatment*Day	**1**	**21**	0.020	0.004	93	<.001
Treatment*Day	**2**	**1**	0.009	0.004	93	0.013
Treatment*Day	**2**	**2**	0.013	0.004	93	0.001
Treatment*Day	**2**	**3**	0.017	0.004	93	<.001
Treatment*Day	**2**	**21**	0.023	0.004	93	<.001
Treatment*Day	**3**	**1**	0.012	0.004	93	0.001
Treatment*Day	**3**	**2**	0.012	0.004	93	0.001
Treatment*Day	**3**	**3**	0.013	0.004	93	0.001
Treatment*Day	**3**	**21**	0.012	0.004	93	0.002
Treatment*Day	**4**	**1**	0.010	0.004	93	0.009
Treatment*Day	**4**	**2**	0.012	0.004	93	0.002
Treatment*Day	**4**	**3**	0.012	0.004	93	0.002
Treatment*Day	**4**	**21**	0.014	0.004	93	0.003

Nursing

Table 32: Behavior: Nursing, least squares mean, estimated value, standard error, degrees of freedom and p-value corrected by Tukey-Kramer Test

Least Squares Mean						
Effect	**Treatment**	**Day**	**Estimated value**	**Standard-error**	**DF**	**Pr > |t|**
Treatment	**1**		0.185	0.011	93	<.001
Treatment	**2**		0.181	0.010	93	<.001
Treatment	**3**		0.179	0.010	93	<.001
Treatment	**4**		0.185	0.010	93	<.001
Day		**1**	0.187	0.007	93	<.001
Day		**2**	0.190	0.007	93	<.001
Day		**3**	0.183	0.007	93	<.001
Day		**21**	0.169	0.007	93	<.001
Treatment*Day	**1**	**1**	0.193	0.015	93	<.001
Treatment*Day	**1**	**2**	0.195	0.015	93	<.001
Treatment*Day	**1**	**3**	0.187	0.015	93	<.001
Treatment*Day	**1**	**21**	0.165	0.015	93	<.001
Treatment*Day	**2**	**1**	0.184	0.014	93	<.001
Treatment*Day	**2**	**2**	0.182	0.014	93	<.001
Treatment*Day	**2**	**3**	0.192	0.014	93	<.001
Treatment*Day	**2**	**21**	0.166	0.014	93	<.001
Treatment*Day	**3**	**1**	0.188	0.014	93	<.001
Treatment*Day	**3**	**2**	0.190	0.014	93	<.001
Treatment*Day	**3**	**3**	0.174	0.014	93	<.001
Treatment*Day	**3**	**21**	0.161	0.014	93	<.001
Treatment*Day	**4**	**1**	0.183	0.014	93	<.001
Treatment*Day	**4**	**2**	0.192	0.014	93	<.001
Treatment*Day	**4**	**3**	0.178	0.014	93	<.001
Treatment*Day	**4**	**21**	0.185	0.014	93	<.001

Interaction with piglet

Table 33: Behavior: Interaction with piglet, least squares mean, estimated value, standard error, degrees of freedom and p-value corrected by Tukey-Kramer Test

Least Squares Mean						
Effect	**Treatment**	**Day**	**Estimated value**	**Standard-error**	**DF**	**Pr > |t|**
Treatment	**1**		0.008	0.002	93	<.001
Treatment	**2**		0.010	0.001	93	<.001
Treatment	**3**		0.008	0.001	93	<.001
Treatment	**4**		0.009	0.001	93	<.001
Day		**1**	0.006	0.001	93	<.001
Day		**2**	0.006	0.001	93	<.001
Day		**3**	0.010	0.001	93	<.001
Day		**21**	0.011	0.001	93	<.001
Treatment*Day	**1**	**1**	0.004	0.002	93	0.073
Treatment*Day	**1**	**2**	0.007	0.002	93	0.002
Treatment*Day	**1**	**3**	0.010	0.002	93	<.001
Treatment*Day	**1**	**21**	0.011	0.002	93	<.001
Treatment*Day	**2**	**1**	0.008	0.002	93	<.001
Treatment*Day	**2**	**2**	0.005	0.002	93	0.018
Treatment*Day	**2**	**3**	0.012	0.002	93	<.001
Treatment*Day	**2**	**21**	0.013	0.002	93	<.001
Treatment*Day	**3**	**1**	0.006	0.002	93	0.005
Treatment*Day	**3**	**2**	0.006	0.002	93	0.003
Treatment*Day	**3**	**3**	0.008	0.002	93	<.001
Treatment*Day	**3**	**21**	0.010	0.002	93	<.001
Treatment*Day	**4**	**1**	0.007	0.002	93	0.001
Treatment*Day	**4**	**2**	0.008	0.002	93	<.001
Treatment*Day	**4**	**3**	0.012	0.002	93	<.001
Treatment*Day	**4**	**21**	0.009	0.002	93	<.001

Resting and sleeping

Table 34: Behavior: Resting and Sleeping, least squares mean, estimated value, standard error, degrees of freedom and p-value corrected by Tukey-Kramer Test

			Least Squares Mean			
Effect	**Treatment**	**Day**	**Estimated value**	**Standard-error**	**DF**	**Pr > |t|**
Treatment	**1**		0.712	0.015	93	<.001
Treatment	**2**		0.704	0.014	93	<.001
Treatment	**3**		0.703	0.014	93	<.001
Treatment	**4**		0.726	0.014	93	<.001
Day		**1**	0.734	0.011	93	<.001
Day		**2**	0.716	0.011	93	<.001
Day		**3**	0.700	0.011	93	<.001
Day		**21**	0.696	0.011	93	<.001
Treatment*Day	**1**	**1**	0.729	0.022	93	<.001
Treatment*Day	**1**	**2**	0.705	0.022	93	<.001
Treatment*Day	**1**	**3**	0.685	0.022	93	<.001
Treatment*Day	**1**	**21**	0.731	0.022	93	<.001
Treatment*Day	**2**	**1**	0.721	0.021	93	<.001
Treatment*Day	**2**	**2**	0.709	0.021	93	<.001
Treatment*Day	**2**	**3**	0.689	0.021	93	<.001
Treatment*Day	**2**	**21**	0.696	0.021	93	<.001
Treatment*Day	**3**	**1**	0.727	0.021	93	<.001
Treatment*Day	**3**	**2**	0.714	0.021	93	<.001
Treatment*Day	**3**	**3**	0.711	0.021	93	<.001
Treatment*Day	**3**	**21**	0.661	0.021	93	<.001
Treatment*Day	**4**	**1**	0.758	0.021	93	<.001
Treatment*Day	**4**	**2**	0.736	0.021	93	<.001
Treatment*Day	**4**	**3**	0.714	0.021	93	<.001
Treatment*Day	**4**	**21**	0.695	0.021	93	<.001

Exploring

Table 35: Behavior: Exploring, least squares mean, estimated value, standard error, degrees of freedom and p-value corrected by Tukey-Kramer Test

Least Squares Mean						
Effect	**Treatment**	**Day**	**Estimated value**	**Standard-error**	**DF**	**Pr > |t|**
Treatment	**1**		0.019	0.004	93	<.001
Treatment	**2**		0.021	0.003	93	<.001
Treatment	**3**		0.014	0.003	93	0.001
Treatment	**4**		0.021	0.003	93	<.000
Day		**1**	0.009	0.003	93	0.001
Day		**2**	0.013	0.003	93	<.001
Day		**3**	0.030	0.003	93	<.001
Day		**21**	0.022	0.003	93	<.001
Treatment*Day	**1**	**1**	0.012	0.006	93	0.028
Treatment*Day	**1**	**2**	0.014	0.006	93	0.012
Treatment*Day	**1**	**3**	0.033	0.006	93	<.001
Treatment*Day	**1**	**21**	0.015	0.006	93	0.007
Treatment*Day	**2**	**1**	0.010	0.005	93	0.059
Treatment*Day	**2**	**2**	0.012	0.005	93	0.021
Treatment*Day	**2**	**3**	0.032	0.005	93	<.001
Treatment*Day	**2**	**21**	0.030	0.005	93	<.001
Treatment*Day	**3**	**1**	0.006	0.005	93	0.219
Treatment*Day	**3**	**2**	0.009	0.005	93	0.078
Treatment*Day	**3**	**3**	0.020	0.005	93	0.003
Treatment*Day	**3**	**21**	0.020	0.005	93	0.003
Treatment*Day	**4**	**1**	0.008	0.005	93	0.125
Treatment*Day	**4**	**2**	0.017	0.005	93	0.002
Treatment*Day	**4**	**3**	0.036	0.005	93	<.001
Treatment*Day	**4**	**21**	0.022	0.005	93	<.001