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How is feed-related behaviour in growing pigs affected by total mixed ration feed with intensively treated silage?

Hur påverkas växande grisars ätbeteende av fullfoder med intensivbearbetat ensilage?

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Abstract

In Nordic countries, roughage e.g. silage from ley crops is mainly provided in the daily feed rations to pigs within organic production systems. Grass-clover silage brings multiple advantages in letting pigs perform natural behaviours and reduces aggressive social interactions. Although, pigs' consumption of roughages such as silage varies and thus affect the nutrient utilization and their behaviour. The aim of this study was to examine feed-related behaviours in growing pigs fed total mixed ration (TMR) diets with inclusion of either chopped and intensively treated silage or solely chopped silage. In total 64 growing female and immuno-castrated male pigs (Yorkshire x Hampshire), thus 32 pigs from two batches (40 and 80 kg live weight), were included in the study and divided into four groups of eight pigs per pen in each stable. Two groups of pigs from each batch were fed treatment SI where the silage had been chopped and thereafter intensively treated in a bio-extruder, while two groups were fed treatment SC where the silage had been chopped with no further treatment. Pigs were observed for two days per batch by direct observations three times per day, in the morning prior to and after feeding, in the middle of the day separate from feeding, and in the afternoon prior to and after feeding. Data was collected by instantaneous (scan) and continuous sampling to estimate feed-related behaviours and social interactions. Statistical analyses were performed using Minitab 18 and pigs' behaviour differences were analysed with ANOVA using general linear models. Pigs in treatment SI were eating from the feed trough more frequent ($p < 0.01$) while pigs in treatment SC spent a greater extent on rooting behaviour ($p < 0.01$). After feeding and separate from feeding, SC pigs were more active compared with SI pigs ($p = 0.003$ and $p = 0.002$, respectively). Weight of the pigs did not have any clear effect on feed-related behaviours or social interactions (n.s), however 80 kg pigs were more active before feeding ($p = 0.05$). Based on the results of this study, pigs seemed to spend longer time eating, presumably also with greater feed consumption, when fed TMR with inclusion of intensively treated silage. This feeding strategy might therefore benefit the nutrient utilization from silage and have a positive effect on pig behaviour in growing pigs.

Sammanfattning

Grovfoder så som ensilage från vallgrödor ges främst till grisar inom ekologisk produktion i nordiska länder. Att ge gräs-klöverensilage medför flera fördelar för grisar i att utföra naturliga beteenden och minskar aggressiva sociala interaktioner. Dock kan grisarnas konsumtionsgrad av grovfoder så som ensilage variera och därmed påverka deras näringsutnyttjande samt beteende. Syftet med denna studie var att undersöka foderrelaterade beteenden hos växande grisar som fick ett fullfoder med antingen hackat och intensivbearbetat ensilage eller enbart hackat ensilage. I studien ingick totalt 64 växande grisar (Yorkshire x Hampshire) från två kullar (40 eller 80 kg levande vikt) indelade i fyra grupper per stall om åtta grisar per box. Två grupper av grisar i varje stall utfodrades med behandling SI där ensilaget först hackats och sedan intensivbearbetats i en bioextruder, medan två grupper fick behandling SC där ensilaget hackats utan vidare bearbetning. Beteendeobservationer utfördes under två dagar per stall och grisarna observerades tre gånger per dag på morgonen, före och efter utfodring, mitt på dagen, inte sammanhängande med utfodring, och slutligen på eftermiddagen före och efter utfodring. De statistiska analyserna utfördes i Minitab och skillnader i grisarnas beteenden analyserades med ANOVA med hjälp av generella linjära modeller. Grisarna i behandling SI åt i större utsträckning ($p < 0.01$) än grisarna i behandling SC som istället bökade mer ($p < 0.01$). SC grisar utförde mer sociala interaktioner än SI grisar före utfodring ($p = 0.029$), men inga skillnader fanns mitt på dagen eller efter utfodring ($p > 0.05$). Efter utfodring och inte sammanhängande med utfodring, var SC grisar mer aktiva jämfört med SI grisar ($p = 0.003$ och 0.002, respektive). Grisarnas vikt hade ingen tydlig påverkan på ät-relaterade beteenden eller sociala interaktioner (n.s), dock var 80 kilos grisar mer aktiva före utfodring ($p = 0.05$). Baserat på resultaten i den här studien, spenderar grisar längre tid på att äta, troligen också med en högre konsumtionsgrad, när de fick ett fullfoder med intensivbearbetat ensilage. Denna utfodringsstrategi kan troligtvis därför verka som fördel för växande grisars näringsutnyttjande från ensilage och ha en positiv inverkan på deras beteenden.

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1 Introduction

1.1 Background

Roughage to pigs is interesting for several reasons. In organic production systems, pigs' should have access to high quality roughage e.g. silage which is important since it enables them to perform highly motivated behaviours and the intention of these regulations is to improve the welfare of pigs (EU Commission Directive, 2001/93/EC). Ley with grass and leguminous plants in crop rotations are positive for soil fertility and increased biodiversity. According to restrictions in use of artificial fertilizers, the leguminous crops are important in organic production due to its' N-fixing ability (Wallenbeck, 2012). Ley crops can be used as a locally produced feed source of good protein quality for pigs (Jordbruksverket, 2011; Presto et al., 2013) and to some extent replace other sources of protein e.g. imported soya (Jordbruksverket, 2011). In Nordic countries, roughage e.g. silage from ley crops is mainly provided in the daily feed rations to pigs within organic production systems (Thamsborg, 2001). Although, pigs' consumption of roughages such as silage varies according to the type of roughage, nutrient properties, feeding technique and form of the silage, and these will influence their ability to sort out desirable parts and thus affect the nutrient utilization and their behaviour (Bikker et al., 2014; Jordbruksverket, 2011; Jordbruksverket, 2013; Kelly et al., 2007; Høøk Presto et al., 2009; Wallenbeck et al., 2014).

1.2 Behaviour of pigs

Under natural conditions, possible feed stuff is geographically spread over large areas (Stolba and Wood-Gush, 1989). Pigs spend a large proportion of their active time exploring, foraging and rooting (Høøk Presto et al., 2009; Studnitz et al., 2007). They explore their surroundings by performing rooting, sniffing, biting and chewing behaviours (Studnitz et al., 2007). Pigs' rooting behaviour has high priority (Day et al., 1995). The exploratory behaviours are based on the search for feed with purpose to locate feed, to find a place to lay down or to gather general information about their surroundings (Berlyne, 1960; Wood-Gush and Vestergaard, 1989). Materials that are complex, manipulative and edible are shown to stimulate appetitive explorative and foraging behaviours inpigs (Studnitz et al., 2007). Pigs spend much of their time rooting and foraging in enriched housing systems (Beattie et al., 2000; Morrison et al., 2007; Presto et al., 2013; Scott et al., 2006) and are not as involved in social interactions such as nosing, biting and aggressive encounters with other pigs compared with pigs housed in barren environments (Beattie et al., 2000; Presto et al., 2013). Within conventional production systems, when pigs are housed in conventional pens, they have limited possibilities to perform natural behaviours such as rooting and foraging. Instead, these behaviours are re-directed towards other pigs and pen surroundings (EFSA, 2007; Lyons et al., 1995; Presto et al., 2013; Van Putten et al., 1969). Among growing pigs, the occurrence of aggressive social interactions can depend on the limited space allowance as well as the low occurrence of enrichment (Beattie et al., 2000; Beattie et al., 1996). In case of an insufficient environment, unwanted behaviours directed to other pen-mates increases (Beattie et al., 1996). Environmental changes could also influence pigs' behaviour (Quiniou et al., 1998).

1.3 Roughage to pigs

Provision of roughage, in addition to straw, meets pigs' behaviour needs to a greater extent compared with provision of only straw (Høøk Presto et al., 2009; Olsen et al., 2000). Additional roughage allow pigs to perform highly motivated and natural feed-related behaviours (Høøk Presto et al., 2009), the motivation to explore and forage increases and is positively affected by roughages (Høøk Presto et al., 2009; Roberts et al., 1993). This leads to increased occupation among pigs and they spend a larger extent of time eating (Jordbruksverket, 2013; Olsen et al., 2000; Presto et al., 2013; Studnitz et al., 2007). At the same time, stress and unwanted behaviours such as aggression among individuals decreases which can improve animal welfare (Høøk Presto et al., 2009; Jordbruksverket, 2013). Furthermore, roughages have a positive impact on the development of the micro flora in the intestinal epithelium in the gut, due tothe high fibre content of the feed (Fernandez and Danielsen, 2002; Jordbruksverket, 2013). Roughage can influence pigs' activity pattern and social interactions. It occupies the pigs by increasing the extent of time spent on feed-related behaviours. Most likely this will reduce stress and aggression between pigs. Several studies have shown a reduction in aggressive and harmful behaviours when enrichments such as roughage has been supplied (Beattie et al., 2000; Høøk Presto et al., 2009; Petersen et al., 1995). However, pigs' behaviours can be influenced in different ways depending on how and in which form roughage is fed (Bikker et al., 2014; Jordbruksverket, 2011; Jordbruksverket, 2013; Kelly et al., 2007; Høøk Presto et al., 2009; Wallenbeck et al., 2014).

1.4 Nutrient utilization from roughage

Roughage could have a nutritive value for pigs as energy and protein source (Andersson and Lindberg, 1997a,b; Lindberg and Andersson, 1998). Properly harvested and stored roughage such as grass-clover silage can contribute with dietary protein (Jordbruksverket, 2018a,b). Among ley crops, red clover in animal feed can be profitable, due to the protein content (Jordbruksverket, 2018b) and red clover is considered to be palatable and increase feed consumption (Crawley, 2015). Research have emphasized that higher dietary fibre content provided through roughage leads to longer periods of satiety (Presto et al., 2013). Danielsen et al. (1998) investigated the effect on production when part of the pigs' diet was replaced with roughage. The results showed that the meat content in the carcass was higher and the pigs had an improved feed efficiency, although slower growth rate was obtained. Furthermore, studies have shown that roughage in diets can be included for up to 18-19% of dry matter (DM) without refusals (Carlsson et al., 1999) and pigs weighing 60 kg or over are able to consume 10% of their energy from roughage (Jensen and Andersen, 2002). In order to increase consumption, silage used for feeding should be finely chopped and mixed with other components so that the pigs do not select and sort out the silage (Gård & Djurhälsan, 2009). In that way, pigs' nutritional utilization of silage would probably increase.

1.5 The aim and hypothesis of the study

In this study, the aim was to examine feed-related behaviours in growing pigs fed total mixed ration (TMR) diets where silage had been pre-treated differently, either chopped and intensively treated or solely chopped. The idea was that a TMR feed with intensively treated silage can minimize the pigs' ability to sort out the silage, for increased consumption and improved nutrient utilization and at the same time still provide the pigs' with occupation in longer time spent eating. By utilizing the silage to a greater extent (compared with if silage was solely chopped) it should give the pigs a higher sense of satiety and reduced aggressions.

The objective was to answer the following questions:

- Will feed consumption and feed-related behaviours differ between pigs fed TMR with intensively treated silage and TMR with solely chopped silage?
- How will social interactions among pigs be affected when they receive the different diets?
- Are there any differences in feed-related behaviours and social interactions between younger (40 kg) and older (80 kg) pigs?
- Will pigs' fed TMR with intensively treated silage have a lower activity level in between the feeding occasions?

Our hypothesis was that pigs fed the TMR diet with intensively treated silage would finish the feed and thus consume more of the silage, than pigs fed the TMR diet with chopped silage. We also hypothesized that the pigs fed TMR with intensively treated silage would spend more time eating, be kept occupied, be calmer and have reduced aggressive social interactions.

2 Materials and methods

2.1 Animals and housing

The study was part of a project about inclusion of intensively manipulated silage in total mixed ration feed to growing pigs and its influence on nutrient utilization and behaviour (Presto Åkerfeldt et al., manuscript). The study was performed at the pig stable of the Swedish Livestock Research Centre at Lövsta outside of Uppsala and took place from the 17th of May until the 25th of May 2018. In total, 64 growing female and immuno-castrated male pigs of breed Yorkshire x Hampshire from two batches were included in the study. The two batches were housed in two different stables and each batch included 32 pigs divided into four pens, with eight pigs per pen. Before the experimental period started, the growing pigs were weighed. Batch one had an average start weight of 40.2 kg (± 12.1 kg) and batch two of approximately 79.3 kg (± 13.6 kg). The total area of one pen was 3.6 m x 2.9 m = 10.4 m^2 giving the floor area of 1.3 m^2 per pig. The largest part of the pen (about 2/3) consisted of concrete floor where the feed trough was placed in the front of the pen. The pigs had access to one water nipple, placed on the wall in the slatted floor area (figure 1).

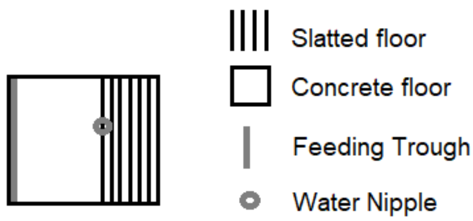

Figure 1. The formation of the pens.

In the laying area, solid walls were separating the different pens from each other. Although, in the slatted floor area there were bars in between separating the pens from each other, which allowed sight and contact with pigs in the neighbouring pens. The experiment was performed under conditions for conventional production systems, with exception for lower animal density (the pens are constructed for 10 pigs) and the provision of roughage during the period of the study. Cleaning of the pens and individual inspection of the pigs was carried out by the staff daily. During the experiment, the pigs received no straw.

2.2 Experimental design

2.2.1 Treatments and diets

The growing pigs in this study received two different TMR diets, treatment SI and SC, which both included commercial cereal-based feed and inclusion ofsilage. The commercial cereal-based feed that was used was Slaktfor (Lantmännen, 2018). The silage used in this experiment was a mixture of grass and red clover. On dry matter (DM) basis, both treatments had 80% inclusion of cereal-based crushed pelleted feed and 20 % inclusion of silage. In treatment SI the silage had been chopped to about 1-3 cm and thereafter intensively treated in a bio-extruder. During the process of bio-extrusion, the silage was decomposed into its cell structure caused by pressure and high temperature of a double screw extruder and this resulted in smaller silage particles (Lehmann Maschenbau). Treatment SC constituted of silage that was chopped to about 1-3 cm but with no further treatment. Treatment SI and SC are shown in figure 2. The chemical composition and energy value of the commercial Slaktfor feed and silages in SI and SC are presented in table 1.

Figure 2. Treatment SI with intensively treated silage (to the left) and treatment SC with chopped silage (to the right).

Table 1. *Chemical composition and energy value of the commercial feed, chopped and intensively treated silage (SI) and solely chopped silage (SC).*

	Commercial feed [a]	SI[b]	SC[b]
Dry matter (DM, %)	88.0	33.2	32.5
Net Energy (NE), MJ^{-1} kg DM	10.6	7.3 [c]	7.2 [c]
Gross Energy (GE), MJ^{-1} kg DM	-	19.6	19.6
Crude protein (CP), g^{-1} kg DM	150	187	190
Crude fat, g^{-1} kg DM	38	-	-
Ash, g^{-1} kg DM	52.3	98	95
NDF, g^{-1} kg DM	-	459	462

[a] Nutrient content according to product declaration (Lantmännen, 2018).
[b] Analysed nutrient content according to Presto Åkerfeldt et al., (manuscript).
[c] Estimated according to Lindberg and Andersson (1998), where energy digestibility (dE%) = 94.8 + (- 0.93x NDF %) Digestibility energy (DE) = dE x Ge, ME = 0.95 x DE and NE = 0.75 x ME.

The experimental period was in total six days with an adaptation period, for pigs to adapt to the TMR diets, for the first four days, and behaviour observations the following two days (table 2). Two groups of pigs in each batch were fed treatment SI and two groups were fed treatment SC (figure 3).

Table 2. *Schedule presenting period of adaptation = A, and behaviour observations = B.*

Date	17/5	18/5	19/5	20/5	21/5	22/5	23/5	24/5	25/5
Weekday	Thu	Fri	Sat	Sun	Mon	Tue	Wed	Thu	Fri
Stable 800 (pig weight, 40 kg)	A	A	A	A	B	B			
Stable 500 (pig weight, 80 kg)				A	A	A	A	B	B

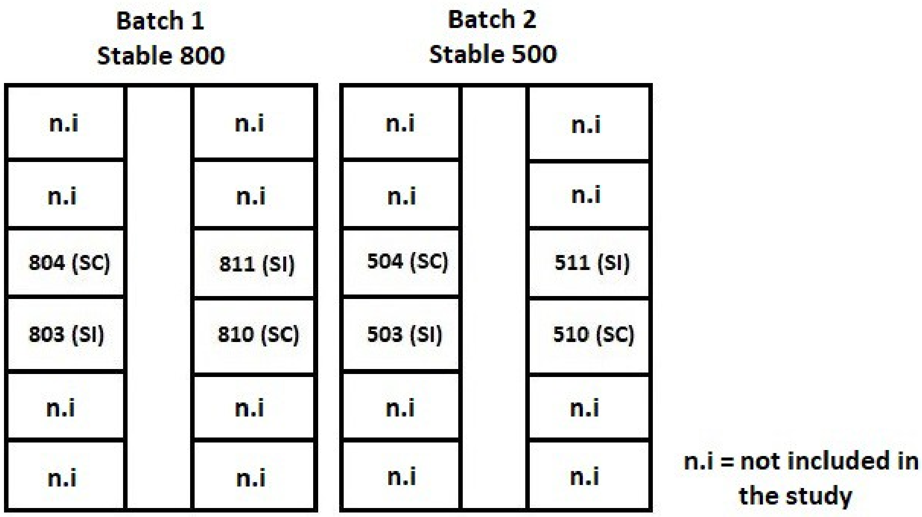

Figure 3. Sketch over the eight pens included in the study with the distributed treatments.

2.2.2 Preparation of silage and feed rations

Prior to the start of the study, silage was taken out of a silo at Lövsta research station. Half of the silage was then weighed and portioned into rations (per pen and feeding occasion) and stored in plastic bags in a freezer (-20˚C) while half of the silage was packed and transported to be run through a bio-extruder (Lehmann Maschenbau) for the intensive treatment. After receiving the intensively manipulated silage (smaller silage particles), it was weighed and portioned into rations according to the same procedure as the chopped silage. Silage rations were taken out from the freezer daily to enable defrosting until the feeding occasions the next coming day. Prior to every feeding, the TMR diets for each treatment were prepared. Rations of the crushed pellet commercial cereal-based feed was mixed with the silage rations in a concrete mixer. Table 3 shows the feed rations for each pen, treatment and feeding occasion. The estimated feed rations were based on the Swedish nutrient recommendations for growing pigs (Andersson et al., 1997) and based on average pen body weight of the pigs in the study. The average pig weight in pen 811 was lower compared with in the other pens, therefore those pigs received a reduced amount of crushed pellet feed. However, it was still mixed with the whole silage ration. Pigs included in the study were manually fed in the feed troughs, three times per day at; 08:35, 12:00 and 15:05. About 90 minutes after the pigs had been fed, a visual estimation of the amount of feed residues was made. Feed residues were not collected in the experiment. Approximately two hours after the feeding occasion, remaining feed residues were removed from the feed troughs and pen floor preparing for the up-coming feeding occasion.

Table 3. *Feed rations for each feeding occasion and for the different batches, showing the amount in kg of the commercial crushed pellet feed Slaktfor, chopped (SC) and intensively (SI) treated silage.*

Pen	Slaktfor (kg)	Silage SI (kg)	Silage SC (kg)
803	4.2	3.2	-
804	4.2	-	3.2
811	3.8	3.2	-
810	4.2	-	3.2
503	6.2	4.1	-
504	6.2	-	4.1
511	6.2	4.1	-
510	6.2	-	4.1

2.3 Behaviour observations

Direct behaviour observations of the growing pigs were performed during the last two days of the experimental period. Data was collected by instantaneous (scan) and continuous sampling. Relevant behaviours were chosen and tested prior to the start of the study and the behaviour observations were performed according to an ethogram (table 4).

Table 4. *Ethogram used for behaviour observations.*

Category	Behaviour	Definition
Instantaneous and continuous observations		
	Laying	Laying down on the stomach or side
	Sitting	Front legs and the back part in contact with the floor
	Standing	Standing at all four feet or walking
	Eating	Snout in contact with feed trough, eating from feed trough or moving around feed
	Rooting	Snout in contact with floor, eating from the floor or moving around feed residues without eating
	Drinking	Snout in contact with water nipple
	Social interactions	Snout in contact with other pig, bites other pig somewhere on body, pushes away other pig, climbing on other pig or persistent fighting with other pig
	Manipulating the surroundings	Snout in contact with fittings or surroundings such as walls, fence, chains or grid

The pigs were observed by direct observations, in the morning, prior to and after feeding, in the middle of the day separate from feeding, and in the afternoon prior to and after feeding. Observations started with a scan sampling of all pigs in each pen, looking at pen 1, 2, 3 and 4 separately. This was then followed by one minute of continuous observation of the eight pigs in pen 1. Thereafter, scan sampling was performed of all pigs in the four pens again, followed by one minute of continuous sampling of pen 2, and so it continued until pen 4. This procedure was called a ‘session’ and it took about 8 minutes. In the morning and afternoon the behaviour observations were performed with one session prior to feeding and one session repeated four times (8 minutes x 4 rounds = 32 minutes) after feeding, with start directly when all pigs had received the diets in the feed troughs. In the middle of the day, separate from feeding the observations were performed with a session that was repeated four times (8 minutes x 4 rounds = 32 minutes). A timeline over a session is shown in figure 4.

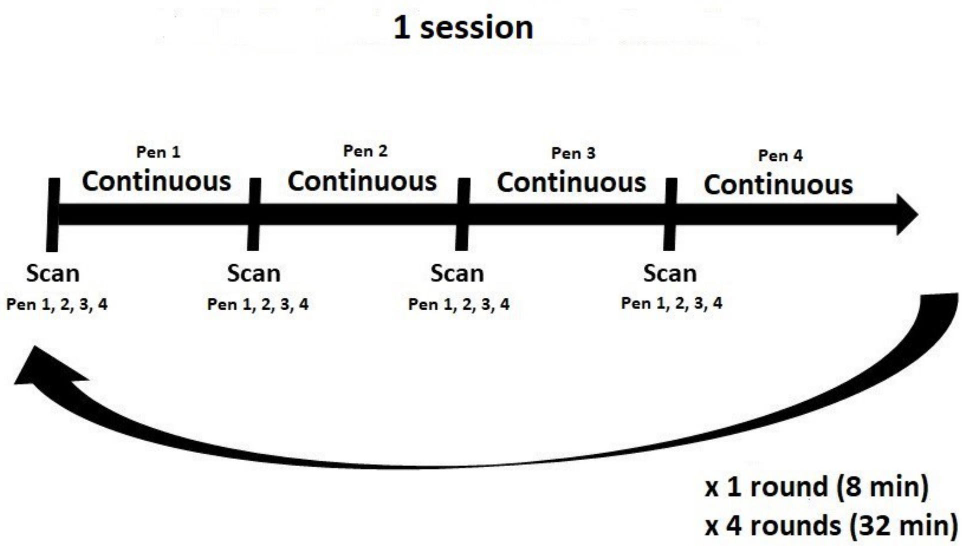

Figure 4. Timeline over how instantaneous (scan) and continuous observations were performed.

During the scan sampling all occurring behaviours for each pig in that exact moment of observation were noted and during the continuous sampling all upcoming behaviours that occurred during the one minute were recorded. Feed-related behaviours as well as social interactions were given priority to body position as laying, standing or sitting down. If for example a pig was laying down and rooting at the same time, then rooting was the behaviour that was recorded, or if a pig was standing and drinking, then drinking was the behaviour recorded.

2.4 Statistical analysis

Statistical analysis was performed using Minitab 18 (Minitab, 2018) in three steps. From the continuous sampling, the variables used were ‘eating’, ‘rooting’, ‘drinking’, ‘social interactions’ and ‘manipulate surroundings’. When analysing the data from the scan sampling, the variables ‘eating’, ‘rooting’, ‘drinking’, ‘social interactions’ and ‘manipulate surroundings’ were merged into a new variable named ‘active’, while ‘laying’, ‘sitting’ and ‘standing’ were merged into a new variable named ‘non-active’. In the first step, the behaviour variables for continuous and scan sampling were examined on the basis of treatment (SI and SC), pig weight (40 and 80 kg) and observations occasion (previous to feeding, after feeding and separate from feeding). Calculations for descriptive statistics; mean values and standard deviation were performed from all direct observations. Thereafter, the obtained data were studied without tests by histogram plots in Minitab and not all variables showed to be normally distributed, although, there was a good variation in the variables and a relatively large sample (n > 30). Due to this, variables which were not clearly normally distributed were considered to be approximately normally distributed (Olsson et al., 2010).

In the second step, behaviour differences were analysed separately for different observation occasions; previous to feeding, after feeding and separate from feeding. Data were analysed with ANOVA using general linear models with the response (y) behaviour variables 'eating', 'rooting', 'drinking', 'social interactions, 'manipulate surroundings' and 'active'. In the development of the final statistical models the predicting (x) effects of 'day' (class: 1 or 2), 'treatment' (class: SI or SC), 'weight' (class: 40 or 80) and 'time of day' (class: am or pm) were assessed. Interactions between 'day*treatment', 'day*weight', 'day*time of day', 'treatment*weight' and 'treatment*time of day' were examined. As the observations that occurred separate from feeding only occurred in the middle of the day, the effect 'time of day' and interactions with 'time of day' was not included in those analyses.

The third step was performed in the same way as in the second step, but with the difference that interactions were included in the final models for analysis only if they were shown to be significant ($p < 0.05$). For each variable the model 'y = day + treatment + weight + time of day + the significant interactions + e' was used (table 5). P-values, fitted mean values and standard errors (SE) were collected from the last runs of the final models. Tables were used to summarize and present these values. Interval plots were made to present the data and enable interpretation. The statistical unit in the analysis of the continuous sampling was expressed as the number of times the different behaviours occurred for each observation occasion per minute and effect (day/treatment/weight/time of day). For the scan sampled data, the frequency of 'active' or 'non-active' were expressed as a percentage of the total time for each observation occasion.

Table 5. *All final models used for analyses are shown and which interactions that were included for each variable in the final models are presented.*

Occasion	Models with the (x) effects used for each (y) variable
Before feeding	'Rooting = day + treatment + weight + time of day + treatment*time of day + e'
	'Drinking = day + treatment + weight + time of day + e'
	'Social interactions = day + treatment + weight + time of day + e'
	'Manipulate = day + treatment + weight + time of day + day*weight + e'
	'Active = day + treatment + weight + time of day + e'
After feeding	'Eating = day + treatment + weight + time of day + e'
	'Rooting = day + treatment + weight + time of day + day*time of day + e'
	'Drinking = day + treatment + weight + time of day + treatment*time of day + e'
	'Social interactions = day + treatment + weight + time of day + e'
	'Manipulate surroundings = day + treatment + weight + time of day + e'
	'Active = day + treatment + weight + time of day + day*treatment + treatment*weight + e'
Separate from feeding	'Rooting = day + treatment + weight + e'
	'Drinking = day + treatment + weight + e'
	'Social Interactions = day + treatment + weight + e'
	'Manipulate Surroundings = day + treatment + weight + e'
	'Active = day + treatment + weight + day*weight + treatment*weight + e'

3 Results

3.1 Consumption of silage

Based on direct visual observations, about 90 minutes after the pigs had been fed, an estimation of the amount of feed residues was made. According to this rough estimation and in general, pigs in treatment SI finished almost all feed while pigs in treatment SC had more feed residuals. Older pigs (80 kg) in treatment SI finished all the feed while younger pigs (40 kg) in treatment SC had the largest amount of feed residues. Thus, it seemed that older pigs consumed more silage than the younger ones based on these visual observations.

3.2 Continuous sampling

Before feeding, eating did not occur. No significant differences were seen in rooting behaviour between treatments or pig weight, $p > 0.05$ for both (table 6). However, rooting occurred more frequent on the second day of observation (5.0 vs 10.5 for day 1 and 2 respectively; $p = 0.045$, $SE = 0.23$). Social interactions occurred more frequent before feeding among pigs' in treatment SC compared with pigs in treatment SI ($p = 0.029$). Pig weight (40 and 80 kg respectively) had no significant effect on the occurrence of the observed behaviours ($p > 0.05$ for all; table 6).

Table 6. *P-values, SE and number of times behaviours occurred per 8 minutes in the different treatments and pig weights before feeding, N = 16.*

Before feeding	Treatment				Pig weight			
	SI	SC	P	SE	40	80	P	SE
Eating	-	-	-	-	-	-	-	-
Rooting	9.5	6.0	0.217	0.25	7.0	8.5	0.592	0.25
Drinking	4.5	2.5	0.410	0.21	4.5	2.5	0.410	0.21
Social interactions	8.5	13.0	**0.029**	0.17	10.0	11.5	0.449	0.17
Manipulating	9.5	8.5	0.742	0.27	8.0	10.0	0.512	0.27

After feeding, pigs in treatment SI spent more time eating than pigs in treatment SC ($p < 0.01$). Pigs in treatment SC spent more time rooting compared with pigs in treatment SI ($p < 0.01$). No significant differences were however found between treatments in the occurrence of social interactions ($p = 0.834$) or in manipulating surroundings ($p = 0.734$). Pig weight (40 and 80 kg respectively) had no significant effect on none of the behaviours ($p > 0.05$ for all). All figures shown in table 7.

Table 7. *P-values, SE and number of times behaviours occurred per 8 minutes in the different treatments and pig weights after feeding, N = 64.*

After feeding	Treatment				Pig weight			
	SI	SC	P	SE	40	80	P	SE
Eating	53.6	35.9	< **0.01**	0.32	46.4	43.2	0.486	0.32
Rooting	15.6	37.8	< **0.01**	0.25	27.2	26.4	0.620	0.25
Drinking	5.5	5.0	0.680	0.11	5.6	4.8	0.536	0.11
Social interactions	5.8	5.5	0.834	0.11	6.4	5.6	0.531	0.11
Manipulating	0.6	0.5	0.734	0.03	0.6	0.5	0.734	0.03

Separate from feeding, eating did not occur. Pigs in treatment SC spent more time rooting compared with pigs in treatment SI ($p = 0.016$). No significant difference for rooting was however found between pigs with different weight ($p = 0.292$). There was no significant difference in the occurrence of social interactions between SI and SC pigs ($p = 0.466$), or between pigs with different weights ($p = 0.309$). However, there was a significant difference between the different observation days. During the first day of observation social interactions occurred to a greater extent (9.0 vs 2.8 for day 1 and day 2 respectively; $p = 0.001$, SE = 0.15). No significant differences in the occurrence of manipulating the surroundings was seen between pigs in treatment SI and SC ($p = 0.545$) although pigs with a weight of 80 kg performed this behaviour to a greater extent than pigs with a weight of 40 kg ($p < 0.01$). See table 8.

Table 8. *P-values, SE and number of times behaviours occurred per 8 minutes in the different treatments and pig weights separate from feeding, N = 32.*

Separate	Treatment				Pig weight			
	SI	SC	P	SE	40	80	P	SE
Eating	-	-	-	-	-	-	-	-
Rooting	1.8	5.3	**0.016**	0.13	2.8	4.3	0.292	0.13
Drinking	1.0	6.4	0.696	0.06	0.5	1.3	0.243	0.06
Social interactions	6.5	5.3	0.466	0.15	6.8	5.0	0.309	0.15
Manipulating	3.3	4.0	0.545	0.11	1.3	6.0	< **0.01**	0.11

3.3 Scan sampling

In general, the pigs were most active during the observations after feeding, however after feeding they were found to be more active during the observations in the morning than in the afternoon (95.7 vs 88.4 % for in the morning and in the afternoon respectively; $p < 0.01$; SE = 0.01), and pigs' were least active in the middle of the day separate from feeding. Before feeding, no significant differences in pigs' active behaviours were found for pigs in treatment SI and SC ($p > 0.05$; figure 5) but with an effect for pig weights with higher activity level among 80 kg pigs ($p = 0.05$; figure 6). Pigs in treatment SC were more active after feeding compared with pigs in treatment SI ($p = 0.003$; figure 5). No significant differences were found in activity level between pigs with different weights ($p = 0.288$; figure 6). The pigs were more active after feeding during the second day of observations (90.5 vs 93.6 % for day 1 and 2 respectively; $p = 0.012$, SE = 0.01). In the middle of the day, separate from feeding, pigs in treatment SC were active to a greater extent than pigs in treatment SI ($p = 0.002$; figure 5). No significant differences in activity were however seen between pigs with different weights ($p = 0.224$; figure 6) at this observation occasion. The pigs were more active in the middle of the day on the first day of observation (10.3 vs 6.2 % for day 1 and day 2 respectively; $p = 0.011$; SE = 1.13).

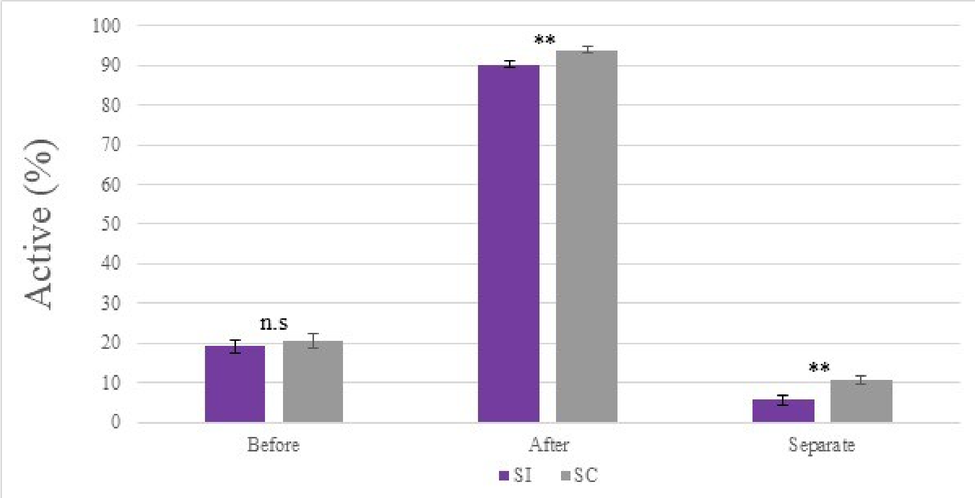

Figure 5. Percentage of active pigs in the different treatments before feeding, N = 64, after feeding, N = 256, and separate from feeding, N = 128.

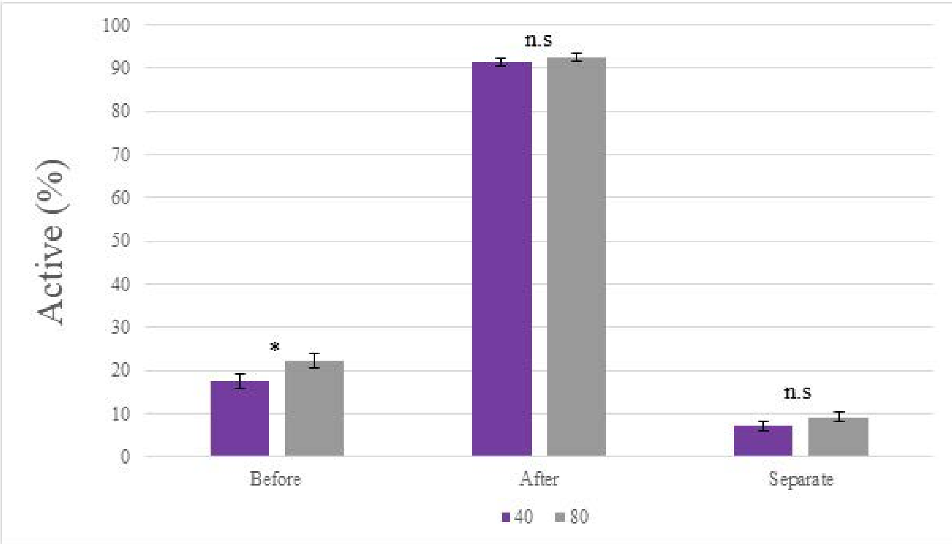

Figure 6. Percentage of activity in pigs with different weights before feeding, N = 64, after feeding, N = 256 and separate from feeding, N = 128.

4 Discussion

In commercial pig production, cereals are the main source of energy and nutrients in the diet (Wallenbeck et al., 2014). Presto et al. (2013) showed that pigs fed chopped or intact silage in addition to straw spent a larger proportion of their time foraging compared with pigs fed only pelleted feed and straw. Several studies have found that provision of silage let pigs express their natural foraging and exploratory behaviours (Høøk Presto et al., 2009; Olsen et al., 2000; Roberts et al., 1993). In this study, the results showed that pigs that received a diet with inclusion of intensively treated silage (SI) spent more time eating from the feed trough and less time rooting on the floor compared with pigs that were fed a diet with inclusion of solely chopped silage i.e. having larger silage particles (SC). They instead spent more time rooting on the floor and less time eating from the feed trough. Furthermore, based on our visual estimations, it seemed like pigs in treatment SC left more feed residues than pigs in treatment SI. This can partially confirm that certain feeding techniques (using a TMR feed and a certain shape of the silage) can benefit the nutrient utilization from silage in growing pigs (Bikker et al., 2014; Jordbruksverket, 2011; Jordbruksverket, 2013; Kelly et al., 2007; Høøk Presto et al., 2009; Wallenbeck et al., 2014). Based on the results of this study, if the silage is managed in a certain way (in this case intensively treated in a bio-extruder) pigs seem to spend longer time eating, presumably also with greater feed consumption. This could be due to the reduced ability for the pigs to sort out the silage (Gård & Djurhälsan, 2009). However, the occupation provided through the ability to sort out the silage is reduced when the silage is intensively treated. Although, silage that is intensively treated can, unlike to silage with longer particles, be considered positive to include in feed rations to pigs, in order for them to utilize the nutrients from the silage better and not only as enrichment. Inclusion of silage in a TMR diet can be a good option to serve as energy and protein source (Andersson and Lindberg, 1997a,b; Lindberg and Andersson., 1998). In agreement with previous studies, the results in this experiment indicates that for pigs to consume silage the form of the silage fed is significant (Høøk Presto et al., 2009; Rundgren, 1988; Wallenbeck et al., 2014) and probably affect their ability to utilise it as a nutrient source (Danielsen et al., 2000). The results of the present study together with previous studies emphasise that grass-clover silage partially can function as nutrient supply for growing pigs (Andersson and Lindberg, 1997a,b; Bikker et al., 2014; Kelly et al., 2007; Høøk Presto et al., 2009; Wallenbeck et al 2014).

Previous studies have shown large differences in behaviour between pigs reared in barren respectively enriched environments (Beattie et al., 1996; Beattie et al., 2000; Petersen et al., 1995). Pigs housed in barren environments often lack the opportunity to perform natural behaviours e.g. to forage and explore, which causes that these behaviours might be re-directed towards other pigs or pen surroundings (Beattie et al., 2000; Lyons et al., 1995). In this experiment, pigs in treatment SC had a higher occurrence of social interactions compared with pigs in treatment SI before feeding. Possibly because the SC pigs were more hungry. Since the pigs in treatment SI seemed to consume more of the silage, this might indicate that SI pigs had a greater gut filling, higher satiation and therefore were more satisfied. Although, the frequency of social interactions between pigs in the different treatments did not differ after feeding nor in the middle of the day, separate from feeding, which do not support the theory. Not either did the frequency of manipulating the surroundings differ between treatments. This might be due to various reasons, since pigs often are kept in a barren environment there is not much else that keeps them occupied, the insufficient environment might cause social interactions to occur even though all pigs received enrichment in form of silage. However, Høøk Presto et al. (2009) showed that access to silage can reduce the frequency of social interactions and the occurrence of these behaviours did not seem to differ to any great extent from in the present study, therefore the frequency of social interactions can still be assumed to be lower compared with if the pigs had not received additional silage. Beattie et al. (1996) concluded that enrichment plays a greater role in determining pig behaviour than space allowance. Another reason to why the frequency of social interactions didn’t differ between pigs in the different treatments might have been due to that disregarding the shape of the silage, all pigs were occupied to a greater extent since they were all fed a TMR feed with silage inclusion. The present study focused on evaluating how the intensively treated silage affected feed-related behaviours and social interactions in comparison with silage that was only chopped. Thus, the aim was not to perform a comparative study with pigs that were not fed silage inclusions. Provision of silage have previously been shown to have a positive influence on social behaviours of pigs (Presto et al., 2013). For instance, Presto et al. (2013) showed that pigs fed chopped or intact silage had a lower proportion of social interactions compared with pigs fed pelleted feed, both with and without silage inclusion. Additionally, in a study by Presto et al. (2009) it was found that the frequency of aggressive behaviours was lower for pigs with access to roughage than for pigs in the control treatment. Studies confirm that environmental enrichment can improve welfare of pigs by reducing the frequency of aggressive social interactions (Beattie et al., 2000).

Heavier thus older pigs (80 kg) seemed to have a greater appetite, since they overall consumed more of the TMR feed and left less residues of silage both in SI and SC groups, than lighter, younger pigs did (40 kg). However, these results were based on a rough visual estimation and actual feed consumption was not registered. Furthermore, 40 and 80 kg pigs were eating from the feed trough and rooting on the floor on a similar level which is contradictory to our estimation. Additional studies on TMR feed and inclusion levels of silage is needed in order to determine optimal feeding strategy for pigs with different live weights. Jensen and Andersen (2002) showed that pigs with a live weight of 60 kg or more, are able to consume 10 % of the energy from roughage and Wallenbeck et al. (2014) concluded that an inclusion level of 20 % (on energy basis) was appropriate.

In the present study, pigs in treatment SC were more active after feeding (both in the morning and in the afternoon) and in the middle of the day, separate from feeding, compared with pigs in treatment SI. The increased activity could both indicate increased feed-related behaviours as well as increased social interactions. Pigs being active could thus be positive as they expressed more feed-related behaviours, but also negative as it might indicate more aggressive social interactions. Therefore, it is difficult to draw any conclusions about it, other than that pigs fed TMR with intensively treated silage were less active after feeding and in the middle of the day, separate from feeding, than pigs fed the TMR with longer silage particles. Additionally, SI pigs were eating from the feed trough more and rooting on the floor less after feeding, and were also rooting less in the middle of the day, compared with the SC pigs. This might support a higher satiety among pigs in treatment SI, even though it overall did not result in lower frequency of social interactions compared with pigs in treatment SC. Research have emphasized that higher dietary fibre content provided through roughage leads to longer periods of satiety, which might decrease the occurrence of aggressive social interactions (Presto et al., 2013).

Differences found between the observation days could depend on the condition of the animals e.g. health status or environmental changes like in temperature. There were some hot days in May which contributed to higher temperatures in the stables. Quiniou et al. (1998) indicate that exposure to heat have a negative effect on pigs' feed-related behaviour. During higher temperatures, pigs' ingestion time per day was shown to be reduced and they spent less time at the feeding station. Moreover, the presence of the observer may have affected the pigs' behaviour to some extent. In case of a longer adaptation period there would have been more time for the pigs to get used to the TMR feed and silage, this could have affected their consumption and behaviours. As well as additional behaviour observations and collection of feed residues could have provided different and more correct results. The practical way of managing this type of feeding strategy on farm level also needs to be considered, e.g. feed preservation, handling and feeding technique, costs and co-operation between farms. Additionally, studies on nutrient utilization and effects on production and animal health also needs to be emphasized.

5 Conclusions

- Providing growing pigs with a TMR feed with inclusion of intensively treated silage can increase the consumption level and benefit the nutrient utilization from silage and at the same time occupy the pigs.

- Pigs fed a TMR feed with inclusion of intensively treated silage spent more time eating from the feed trough while pigs fed a TMR feed with inclusion of chopped silage spent more time rooting on the floor, probably due to that the longer silage particles are easier to sort out.

- Before feeding, pigs with a weight of 80 kg were more active, and separate from feeding, they were manipulating the surroundings to a greater extent. No other differences in behaviours were found between younger and older pigs.

- Pigs fed a TMR feed with intensively treated silage had a lower activity level between feeding occasions, in the middle of the day. Thus, inclusion of intensively treated silage might influence the satiety of pigs, even though the frequency of social interactions did not differ between treatments in the present study, except from that social interactions occurred more frequent before feeding among pigs' fed silage with longer particles.

References

Andersson, C., and Lindberg, J.E. (1997a). Forages in diets for growing pigs, part 1. *Animal Science*, 56, 483-491.

Andersson, C., and Lindberg, J.E. (1997b). Forages in diets for growing pigs, part 2. *Animal Science*, 56, 493-500.

Andersson, K., Schaub, A., Andersson, K., Lundström, K., Thomke, S, and Hansson, I. (1997). *Livestock Production Science*, 51, 131-140.

Beattie, V.E., O'Connell, N.E., and Moss, B.W. (2000). Influence of environmental enrichment on the behaviour, performance and meat quality of domestic pigs. *Livestock Production Science*, 65, 71-79. (Beattie et al., 2000).

Beattie, V.E., Walker, N., and Sneddon, I.A. (1996). An investigation of the effect of environmental enrichment and space allowance on the behaviour and production of growing pigs. *Applied Animal Behaviour Science*, 48, 151-158.

Berlyne, D.E. (1960). Conflict, arousal, and curiosity. New York, NY, US: McGraw-Hill Book Company.

Bikker, P., Binnendihj, G., Vermeer, H., van der Peet-Scwering, C. (2014). Grass silage in diets for organic growing-finishing pigs. *4th ISOFAR Scientific Conference* (Istanbul, Turkey: IFOAM [International Federation of Organic Agriculture Movements]), 815-818.

Carlsson, D., Laerke, H.N., Poulsen, H.D., Jørgensen, H. (1999). Roughages for growing pigs, with emphasis on chemical composition, ingestion and faecal digestibility. *Animal Science*, 49, 129-136.

Crawley, K. (2015). *Fulfilling 100% organic pig diets: Feeding roughage and foraging from the range.* ICCOP-Technical Note 5. Organic Research Centre, UK: ICOPP Consortium 2015. Available: http://orgprints.org/28088/7/28088.pdf [2019-01-01]

Danielsen, V., Hansen, L.L., Moller, F., Bejerholm, C., and Nielsen, S. (2000). Production results and sensory meat quality of pigs fed different amounts of concentrate and ad lib clover grass or clover grass silage. *Ecological animal husbandary in the Nordic countries, proceedings from NJF-seminar No. 303* (Denmark; Horsens).

Day, J.E.L., Kyriazakis, I., and Lawrence, A.B. (1995). The effect of food deprivation on the expression of foraging and exploratory behaviour in the growing pig. *Applied Animal Behaviour Science*, 42, 193-206.

EFSA. (2007). The risks associated with tail biting in pigs and possible means to reduce the need for tail docking considering the different housing and husbandry systems. *The EFSA Journal*, 611, 1-13.

EU Commission Directive. (2001/93/EC).

Fernandez, J.A., and Danielsen, V. (2002). Grovfoder til svin, hvad er det? Danmarks Jordbrugs Forskning. Grøn Viden Husdyrbrug nr, vol. 29. Ministeriet for Fodervarer, Landbrug og Fiskeri (Regulations for organic farmin in Denmark).

Gård & Djurhälsan. (2009). Foder till ekologiska grisar. Available: https://www.gardochdjurhalsan.se/sv/gris/kunskapsbank/foder/utfodring/ [2018-11-16]

Høøk Presto, M., Algers, B., Persson, E., and Andersson, H.K. (2009). Different roughage to organic growing/finishing pigs - influence on activity behaviour and social interactions. *Livestock Science*, 123, 55-62.

Jensen, T., Nielsen, C.K., Vinther, J., and D'Eath, R.B. (2012). The effect of space allowance for finishing pigs on productivity and pen hygiene. *Livestock Science*, 149, 33-40. (Jensen et al, 2012).

Jensen, M.B., and Pedersen, L. (2007). The value assigned to six different rooting materials by growing pigs. *Applied Animal Behaviour Science*, 108, 31-44.

Jensen, M.B., Studnitz, M., Halekoh, U., Pedersen, L.J. and Jørgensen., E. (2007). Pigs' Preferences for rooting materials measured in three-choice maze-test. *Applied Animal Behaviour Science*, 112, 270-283. (Jensen et al., 2007).

Jensen, H.F., and Andersen, B.H. (2002). Grovfoder till økologiske slagtesvin. Danmarks JordbrugsForskning. Grøn Viden Husdyrbrug nr, vol. 27. Ministeriet for Fodervarer, Landbrug of Fiskeri (Regulations for organic farming in Denmark).

Jordbruksverket (2018a). *Skörd och konservering av vall*. Available: https://www.jordbruksverket.se/download/18.../Skörd+och+konservering+av+vall.pdf [2018-11-16]

Jordbruksverket (2018b). *Vallarter*. Available: http://www.jordbruksverket.se/amnesomraden/odling/jordbruksgrodor/vall/vallarter.4.23f3563314184096e0d7cb1.html [2018-11-24]

Jordbruksverket (2013). *Vägen till ekologisk produktion*. Available: http://www.jordbruksverket.se/webdav/files/SJV/trycksaker/Pdf_jo/jo13_2.pdf [2018-12-03]

Jordbruksverket (2011). *Näringsförsörjning till grisar i ekologisk produktion.* Available: https://www.jordbruksverket.se/download/18 [2018-12-03]

Kelly, H.R., Browning, H.M., Day, J.E.L., Martins. A., Pearce, G.P., Stopes, C. and Edwards, S.A. (2007). Effect of breed type, housing and feeding system on performance of growing pigs managed under organic conditions. *Journal of the Science of Food and Agriculture*, 87, 2794-2800.

Lindberg, J.E., and Andersson, Christel. (1998). The nutritive value of barley-based diets with forage meal inclusion for growing pigs based on total tract digestibility and nitrogen utilization. *Livestock Production Science*, 56, 43-52.

Lyons, C.A.P., Bruce, J.M., Fowler, V.R., and English, P.R. (1995). A comparison of productivity and welfare of growing pigs in four intensive systems. *Livestock Production Science*, 43, 265-274.

Morrison, R.S., Johnston, L.J., and Hilbrands, A.M. (2007). The behaviour, welfare, growth performance and meat quality of pigs housed in deep-litter, large group housing system compared to a conventional confinement system. *Applied Animal Behaviour Science*, 103, 12-24.

Olsen, A.W., Vestergaard, E.M., and Dybkjaer, L. (2000). Roughage as additional rooting substrates for pigs. *Animal Science*, 70, 451-456.

Olsson, U., Englund, J.E., and Engstrand, U. (2010). *Biometri - grundläggande biologisk statistik.* Upplaga 2:4. Studentlitteratur AB, Lund, 120.

Petersen, V., Simonsen, H.B., and Lawson, L.G. (1995). The effect of environmental stimulation on the development of behaviour in pigs. *Applied Animal Behaviour Science*, 45, 215-224.

Presto, M., Rundgren, M., and Wallenbeck, A. (2013). Inclusion of grass/clover silage in the diet for growing/finishing pigs – influence on pig time budgets and social behaviour. *Animal Science*.

Presto Åkerfeldt., M., Nihlstrand, J., Neil., M, Lundeheim, N., Andersson, H.K., and Wallenbeck, A. (2018). Chicory and red clover silage in diet to finishing pigs – influence on performance, time budgets and social interactions. *Organic Agriculture*, 1-12.

Quiniou, N., Dubois, S., and Noblet, J. (1998). Voluntary feed intake and feeding behaviour of group-housed growing pigs are affected by ambient temperature and body weight. *Elsevier*, 65, 245-253.

Roberts, S., Matte, J.J., Framer, C., Girar, D.I., and Martineau, G.P. (1993). High-fibre diet for sows: effects on stereotypies and adjunctive drinking. *Applied Animal Behaviour Science*, 37, 297-309.

Rundgren, M. (1988). *Growing pig performance: effects of dietary fibre, the halothane gene, transportation and mixing. Report 172.* Uppsala: Department of Animal Nutrition and Health. Swedish University of Agricultural Sciences.

Scott, K., Chennells, D.J., Campbell, F.M., Hunt, B., Armstrong, D., Taylor, L., Gill, B.P., and Edwards, S.A. (2006). The welfare of finishing pigs in two contrasting housing systems: Fully-slatted versus straw-bedded accommodation. Livestock Science, 103, 104-115. (Scott et al., 2006).

Stolba, A., and Wood-Gush, D.G.M. (1989). The behaviour of pigs in a seminatural environment. *Animal Science*, 48, 419-425.

Studnitz, M., Jensen, M.B., and Pedersen, L.J. (2007). Why do pigs root and in what will they root? A review on the exploratory behaviour of pigs in relation to environmental enrichment. *Applied Animal Behaviour Science*, 107, 183-197.

Thamsborg, S.M. (2001). Organic Farming in the Nordic Countries – Animal Health and Production. *Acta vet. scand*, 95, 7-15.

Van Putten, G. (1969). An investigation of tail biting among fattening pigs. *British Veterinary Journal*, 125, 511-517.

Wallenbeck, A. (2012). Foder till grisar i ekologisk produktion. Uppsala: SLU, EPOK – Centrum för ekologisk produktion och konsumtion. Available: http://www.slu.se/Documents/externwebben/centrumbildningar-projekt/epok/gris-fodersyntes_web.pdf [2019-01-03]

Wallenbeck, A., Rundgren, M., and Presto, M. (2014). Inclusion of grass/clover silage in diets to growing/finishing pigs – Influence on performance and carcass quality. *Acta Agriculturae Scandinavia*, 64, 145-153.

Wood-Gush, D.G.M., and Vestergaard., K. (1989). Exploratory Behaviour and the Welfare of Intensively Kept Animals. *Journal of Agricultural Ethics*, 2, 161-169.