Aarhus University
Science and Technology
Department of Agroecology

Paddock management systems for organic growing pigs

Effect of land allocation strategies on foraging activity and excretory behaviour

Økologiske slagtesvin på friland

Effekt af forskellige foldmanagement-strategier på fourageringsaktivitet og gødeadfærd

Master of Science Thesis

by Juliane Helmerichs

Matriculation number: 201301853

Supervisor
Anne Grete Kongsted, senior scientist

30 ECTS
Submitted July 1st 2014

Abstract

The EU regulations for organic farming require outdoor access for pigs, as one of the main organic principles is to establish sustainable farming systems including harmonious relationships between animals, plants and environment. Outdoor access for pigs provides benefits in terms of animal welfare as pigs are able to express their natural and social behaviour. However, it is still common to keep organic growing pigs indoors with access to outdoor concrete yards.

Main reasons for not keeping growing pigs on pasture are high nutrient inputs to the free-range area and high feed costs due to an increased energy demand in outdoor pigs. Reasons for the high nutrient loads on free range areas are the not-random excretory behaviour as well as the high input of supplemental feed. The reduction and better distribution of nutrients on the field can be achieved by different strategies. Considering the excretory behaviour and foraging activity of pigs the main focus in this study was to identify suitable environmental friendly paddock management systems for organic growing pigs with high animal welfare standards.

For identifying those, an experiment with growing pigs was conducted in Denmark. Within this experiment growing pigs got access to two strategies of land allocation. They got either access to 3x12 m of new land right away (allocation strategy 3) or to 1x12 m of new land on three days in a row (allocation strategy 1). In combination with new land they got one of the forage crops alfalfa or grass-clover and access to either high or low protein content in the supplemental feed. During the experiment behavioural observations were performed. Rooting, grazing, urinating and defecating were recorded to investigate the effect of management system on the pig’s behaviour.

It was shown that pigs are rooting and grazing significantly more often in new land. However, urinating in this study is performed to a significantly lower extent in new land compared to old land. The allocation strategy affects foraging activity and excretory behaviour when the three observation days are regarded separately.

From the present study it became clear that paddock management strategies should be based on mobile systems including frequent allocation of new land, e.g. strip grazing or pasture rotations and mobile huts, feeders and drinkers. An interesting approach is to establish mobile paddock systems such as the mobile organic piggery (MOP). Nevertheless, more research in the field of paddock management systems is required. In particular more knowledge on mobile fence systems is necessary to make these systems common on farms.

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1. Introduction

The consumer demand for organic food increased over the last years (European Comission, 2010). Therefore the sector of organic agriculture is growing rapidly. In the EU the area under organic agriculture has increased from 5.7 mio. ha in 2003 to 9.6 mio. ha in 2010. Also the number of organic holdings increased from 0.12 mio. in 2003 to 0.18 mio. in 2010 (European Comission, 2013). The overall aim in organic agriculture is to develop sustainable farming systems (Lund, 2006). To achieve those, support of biological cycles within the farm and a diversified production on farm are crucial principles (Hermansen et al., 2004). Consumers appreciate the way animals are raised under organic farming conditions as they expect the animal welfare to be higher than under conventional conditions. With animal welfare most consumers also associate high standards of food safety, quality and healthiness (Harper and Henson, 2001).

According to the EU regulations organic livestock farming should ensure that specific behavioural needs of animals are met. This includes specific housing conditions which should satisfy the needs of animals regarding space, comfort as well as the freedom of movement for each animal to maintain its natural and social behaviour. Additionally, IFOAM (2002) states “Organic livestock husbandry is based on the harmonious relationship between land, plants and livestock, respect for the physiological and behavioural needs of livestock and the feeding of good quality organically grown feedstuffs”. This shows that the combination of high welfare standards and environmental friendly farming is very important in organic agriculture. For animals the EU regulations require permanent access to an open air area for grazing with an appropriate system of rotation. Moreover, the feedstuff should preferably come from own holding and should take into account the physiological needs of the animal.

In the organic animal sector sheep and cattle production is developing faster compared to pig production. In 2010 2.9% of the total bovine produced was organic, 2.82% of the sheep and goats were organic. But only 0.33% of the pigs produced within the EU were organic (European Comission, 2013). This is probably due to the more fundamental difference between conventional and organic pig production than the differences in dairy production systems. Conventional pigs are usually kept indoors while organic pigs have to have outdoor access which leads to a more land dependent production (European Commission, 2013). Nevertheless the consumer demand for organic pork is increasing. The biggest producers for organic pig are Germany, Denmark and France. Even within these countries the supply cannot meet the high demand (Halberg et al., 2004).

Systems of organic pig production differ between the countries within the EU. In the UK the already existing conventional outdoor production systems could easily be converted to organic production systems. As those conventional systems are already very extensive it was not necessary for converting farmers to purchase more land, whereas it is more difficult to convert the more intensive conventional systems in Western Europe and Scandinavia (Hovi et al., 2003). In Germany pigs are usually kept indoors with access to an open yard while the common system in Denmark is to keep sows in outdoor systems all year round and to move the weaned piglets indoors with access to outdoor yards (Sundrum and Weißmann, 2005). A maximum of 14 fattening pigs per ha which is equivalent to 170 kg N ha^{-1} $year^{-1}$ are allowed according to the EU regulations. The Danish organic regulations allow a maximum of 140 kg N ha-[1] $year^{-1}$ or 280 kg N ha^{-1} every second year (Kongsted and Hermansen, n.d.). The original advantage of keeping pigs on pasture was the reduction of feed costs due to grazing. But it has been shown that reduced feed cost cannot be seen as an advantage any longer. Outdoor pigs do have a higher energy demand compared to pigs kept indoors (Edwards, 2003). Therefore they need more feed and the cost for feed increases (Worthington and Danks, 1992). However, the lower costs for buildings and equipment are seen as beneficial (Worthington and Danks, 1992).

Outdoor pig production provides benefits in terms of animal welfare as pigs are able to express their natural behaviour like rooting and wallowing (Laister and Konrad, 2005). But on the other hand a number of environmental costs have to be considered. With their rooting and wallowing behaviour pigs destroy pastures which leads to nutrient losses to water bodies and to the atmosphere and makes outdoor access difficult (Worthington & Danks, 1992). An uneven distribution of nutrients and nutrient hotspots were found on paddocks where pigs were grazing (Eriksen, 2001). A reason for this is the difficulty to maintain grass cover on those areas due to rooting and wallowing (Eriksen et al., 2006). The combination of nutrient hot-spots and the bare soil leads to nitrate leaching and ammonia volatilization (Eriksen, 2001; Sommer et al., 2001). Major drivers for nutrient hot-spots are a high input of supplemental feed as well as the defecation and urination pattern of pigs (Eriksen, 2001; Laister and Konrad, 2005). Outdoor pigs are provided with more feed compared to indoor sows as their energy requirement is approximately 15% higher compared to indoor pigs (Eriksen, 2001; Edwards, 2003) Moreover, the urination and defecation behaviour of pigs is not random; they excrete on certain areas and thereby create nutrient hot-spots (Stolba and Wood-Gush 1989). The high nutrient load on free range areas needs to be reduced to get a more environment friendly pig production with high welfare standards.

There are several possible ways for reduction and distribution. One way is to increase pasture consumption to get a higher nutrient uptake from free the range area. A main issue in pig production systems is to design cropping systems that allow pigs to forage a larger part of their requirements (Andresen, 2000). This can be achieved by decreasing the amount of supplement feed (Andresen et al., 2001), increasing foraging possibilities by offering suitable crops (Andresen and Redbo, 1999) and establishing strip grazing to offer new land (Andresen and Redbo, 1999). Another way to reduce environmental risk factors is to get a more even distribution of faeces and urine in the free range area. Moving huts and troughs and avoiding stationary equipment on pastures is a way to get a more even distribution (Andresen, 2000). Besides, the weekly rotation of paddocks (Quintern, 2005) and a reduced stocking density (Eriksen, 2001) are suggested possibilities.

Keeping in mind the overall aim of developing sustainable systems in organic agriculture and the need in livestock farming for harmonious relationships between land, plant and animal, it is necessary to improve the organic pig production systems. High nutrient loads on outdoor runs harm the environment. Moreover, keeping the growing pigs indoors without pasture access does neither follow the organic principles nor the regulations. Therefore it is necessary to find a suitable pasture management system for organic pigs and especially for growing pigs.

This thesis aims to identify suitable paddock management systems for growing pigs which ensure high animal welfare standards and at the same time an environmentally friendly production.

The first part of this thesis is a review of the available literature in this area. Environmental risk factors as well as approaches to reduce N input from concentrate and to distribute faeces and urine more equal in the free range area are described considering the natural behaviour of pigs. The objective of this review is to get an overview of the current state of knowledge on possible management strategies and the behaviour of pigs to evaluate the following experiment.

In the second part a strip grazing experiment, conducted with growing pigs in Denmark will be described and evaluated. Within the experiment different paddock management strategies were tested with a focus on the effect of allocation of new land on foraging activity and excretory behaviour in pigs. Based on the experimental results and the literature review suggestions for suitable paddock management systems for growing-finishing pigs will be given in the last part.

2. Literature Review

2.1 Environmental risk factors in outdoor pig production

Status

Organic farming aims to contribute to a high degree to animal welfare and to develop environmentally friendly and more sustainable farming systems. But the aim of an environmentally friendly development became a challenge in organic animal production, especially in outdoor pig production systems (Lund, 2006). Main environmental concerns arising from outdoor pig production are nutrient losses to the atmosphere and water bodies caused by high nutrient loads on the area and difficulties to maintain grass cover (Eriksen et al., 2006). In this term especially nitrogen plays an important role. Although nitrogen is a very important nutrient in agriculture, it contributes the most to environmental problems. In outdoor pig production the nitrogen inputs can be very high (Williams et al., 2000). In Europe the atmosphere is polluted by ammonium and nitrate which are easily available forms of nitrogen and mainly occur from livestock farming (Ferm, 1998). Leaching of nitrate (NO_3) to the groundwater is a major reason for N loss (Quintern and Sudrum, 2006; Rotz, 2004). Rotz (2004) reports that excess amounts of nitrate in the groundwater (50 mg NO_3 liter^{-1}) can be harmful for humans. However, also large losses of ammonia (NH_3) to the atmosphere occur from livestock farming (Ferm, 1998). Ferm (1998) concludes that in Western Europe around 25% of the nitrogen excreted by animals is lost to the atmosphere. Ammonia is a result of urea break down and is known to be a reason for eutrophication and acidification of natural ecosystems (Novak and Fiorelli, 2010). Furthermore, it was estimated that 5% of the global nitrous oxide emissions are a result of oxidized NH_3 in the atmosphere (Ferm, 1998). Nitrous oxide is a greenhouse gas which contributes to global warming to a large extent (Rotz, 2004). It is necessary to decrease the emissions of NO_3 and NH_3 to reduce environmental damage (Ferm, 1998).

According to the EU regulations an input of 170 kg N ha^{-1} year^{-1} are allowed. The Danish regulations allow 140 kg N ha^{-1} year^{-1} or 280 kg N ha^{-1} every second year. Eriksen (2001) investigated the N loss from paddocks with lactating sows. He found that on average nitrogen leaching was 320 kg N ha^{-1} over a period of 18 months. Close to the feeding area (10 m around) he found high values of 500 kg N ha^{-1}. Eriksen and Kristensen (2001) found that inorganic N in the soil was highest around the feeding area and decreased the further away from the feeding area. The cause for that was probably the large quantity of feed the lactating sows in this study obtained. Eriksen et al. (2006) did an experiment on the nutrient losses from growing pigs produced outdoors. They conducted an experimental design with a stocking density that was calculated to cause 280 kg N ha^{-1} year^{-1}. The N surplus was calculated by subtracting the N input by the N output (pig live weight gain).

They found that even the group fed restricted in supplemental feed produced a surplus of 388 kg N ha^{-1} year^{-1}. A surplus of 507 kg N ha^{-1} year^{-1} was found in the ad libitum group (Eriksen et al, 2006). Similar results were shown by Worthington and Danks (1992). They estimated feed N inputs for outdoor systems with a stocking density of 14 sow per ha to be 625 kg N ha^{-1}. The outputs in meat were calculated as 119 kg N ha^{-1} which means a surplus of 506 kg N ha^{-1} was left on the soil (Worthington and Danks, 1992). Andresen et al. (2000) did an experiment with two different stocking densities (10m² per pig and 20² per pig) and two different protein contents in the supplemental feed. The crude protein (CP) content in the low protein (LP) diet was 139 g kg^{-1} DM in and 197 g kg^{-1} DM in the high protein (HP) diet. They calculated the nitrogen balance per hectare and found a zero balance for the treatment with low stocking density in combination with low protein content in the supplemental feed. In this combination the N surplus did not increase over time whereas all other treatment combinations did show an increasing N surplus over time. The highest surplus was found in the treatment combination of high stocking density and high protein content (Andresen et al., 2000). This shows that feed consumption as well as excretory behaviour of pigs have a high influence on the N balance in outdoor systems (Eriksen et al, 2006).

Reasons

There are several factors contributing to the high environmental risk in organic pig production systems. One of the main reasons is the high nutrient input through concentrate supplements (Quintern and Sundrum, 2006; Eriksen et al., 2006). Another is the unequal distribution of nutrients and thus nutrient accumulation which are results of the pigs' excretory behaviour (Quintern and Sundrum, 2006). Additionally, the high stocking density in outdoor production systems contributes to the environmental risks (Eriksen et al., 2006). The stocking density can be reduced rather easily. However, the use of concentrate supplements and the unequal distribution of nutrients in the free range area are big challenges. Therefore this thesis focuses on the latter one.

2.2 Reduce N-input from concentrate

As mentioned before outdoor pigs do have an approximately 15% higher energy demand than indoor pigs under Northern European Conditions (Eriksen, 2001; Edwards, 2003). The reasons for this higher demand are a higher climatic energy demand due to changing weather conditions as well as a higher locomotory activity due to a higher space allowance in outdoor pigs compared to indoor pigs. Therefore, outdoor pigs are supplemented with high amounts of concentrate (Edwards, 2003; Stern and Andresen, 2003) without having higher demands for protein compared to indoor housed pigs. The high protein content increases the losses of nitrogen which contribute to a high degree to nutrient surpluses on pastures (Høøk Preso et al., 2007). Therefore, a reduction in supplemental feed would reduce the N input to pastures. There are several ways to reduce the N-input from concentrate. One is to provide pigs with the amount of concentrate needed to fulfill their energy requirements but with reduced protein content as discussed by Høøk Preso et al. (2007). Another way is to increase nutrient intake from free range area (Andresen, 2000; Andresen and Redbo, 1999).

2.2.1 Increase nutrient intake from free range area

Pigs are omnivores and are able to find their feed on the soil surface as well as below the soil surface (Stolba and Wood-Gush, 1989). Wild pigs ingest fruits, crops as well as roots and invertebrates (Graves, 1984). The composition of their diet depends on the season. In winter and autumn pigs mainly feed on nuts, roots and mast crops while they have more grasses, roots, tubers and invertebrates in their summer diet (Graves, 1984). Under natural conditions pigs spend a lot of time on searching available feed sources by exploring their surroundings (Studnitz et al., 2007). It is still necessary to supplement modern pig breeds with stored feed in addition, because those breeds are not able to fulfill their complete nutrient requirements by foraging (Andresen, 2000). However, they are able to find a part of their daily requirement from the range area, but their foraging capacity is often neglected in present pig production systems (Andresen, 2000). Better foraging possibilities would improve nutritional choices as well as direct feed intake from the field and at the same time reduce the need for supplemental feed (Andresen et al., 2000).

Most studies on pasture intake of pigs refer to sows. However, compared to growing pigs, sows are more adapted to use energy from fibrous feed. The more efficient fibre digestion is favoured by their greater intestinal volume and a slower digestive transit (Dierick et al., 1989). Sehested et al. (1999) performed a study on pasture intake of pregnant sows and found a daily grass intake of 2.4 kg of dry matter in early summer and an intake of 3.7 kg DM day^{-1} in late summer. Rivera Ferre et al. (1999) estimated the voluntary herbage intake of sows using the n-alkane technique. They did a spring and a summer study. In the spring study a mean herbage intake of 1.13 kg OM day^{-1} was found. In summer the mean herbage intake was 2.99 kg OM day^{-1}. Rivera Ferre et al. (1999) assumed that the reason behind the higher herbage intake in summer is a lower nutritive value of the herbage in summer which is compensated by a higher herbage intake. Thus, the nutritive value of pasture is an important factor for pasture intake.

Carlson et al. (1999) observed that growing pigs, with an average live weight of 30 kg, achieved an average roughage intake of 1.1 kg day^{-1}, corresponding to 18-19% of DM intake. A study by Mowat et al. (2001) on growing pigs showed a mean daily intake of 0.10 kg organic matter day^{-1}(0.5 kg fresh weight day^{-1}) when pigs had ad libitum access to concentrate feed. Moreover, Kanga et al. (2012) did a study on pasture intake in growing pigs. They fed growing pigs outdoors with access to Kikuyu grass 80% of the recommended amount of concentrate and estimated an intake of Kikuyu grass of 0.131 kg of organic matter day$^{-1.}$ For growing pigs with a live weight of 60 kg are able to consume 10% of their energy demand from roughage (Jensen and Andersen, 2002).

In the following different approaches for increasing pasture intake and parameters which do have an influence on pasture consumption are described.

Allocation of new land

The foraging behaviour of pigs includes grazing and rooting (Edwards, 2003). Andresen (2000) found that foraging in pigs does have nutritional as well as explorative purposes to collect information and to adapt to the environment. Thus, it is important to consider this exploratory behaviour of pigs to increase pasture consumption (Day et al., 1995). Andresen et al. (2000) state that pig herds should have a high degree of mobility to get a proper nutrient level in the field. Andresen and Redbo (1999) found that the longer time pigs spent in a paddock, the more passive their behaviour became, e.g. their foraging behaviour decreased. They concluded that offering pigs access to new land every week can stimulate foraging and explorative behaviour and therefore a major factor to increase pasture intake. This was confirmed by Stern and Andresen (2003) who found that pigs preferred grazing and rooting on newly allotted land over grazing and rooting on areas which has already been grazed. Day et al. (1995) also found that pigs visited an area where novel objects (coloured squares or cylinders) were presented more often, but this was independent of foraging motivation. Therefore, Day et al. (1995) concluded that appetitive foraging behaviour and explorative behaviour can be regarded separately. Rivero et al. (2013) compared the behaviour of European wild boar under continuous and rotational grazing systems. In the continuous system pigs entered the same pasture area for 5 days. In the rotational system pigs entered a new strip every day for 5 days. However, the results did not show any significant differences in pasture intake between the two treatments. Rivero et al. (2013) assumed that the European wild boar is probably very fast in adapting to pasture systems.

Suitable crops for foraging

An option in order to decrease supplemental feed might be to offer better foraging possibilities for pigs which could also lead to reduced costs for feed preparation and storage (Andresen and Redbo, 1999). To which extent pasture consumption can contribute to the nutritional requirements of pigs depends on several factors such as availability, nutrient composition, grazing intake as well as the digestive utilisation of herbage as main factors. Thus the quality of forage plays an important role (Andresen and Redbo, 1999). A suitable crop for outdoor pig production should have high nutritional value for the pig and at the same time it must ensure a groundcover to reduce N leaching (Rachuonyo et al, 2005). Suitable crops or pasture can offer the possibility for pigs to select a ration that meets their individual nutritional needs as it was shown that pigs are able to forage selective due to their needs

(Andresen and Redbo, 1999; Gustafson and Stern, 2003). Thus, it is important to investigate which crop might be most suitable.

Rachuonyo et al. (2005) established one of the crops: alfalfa, tall fescue, white clover or buffalograss as groundcover on pastures and kept groups of pregnant gilts on it. Groups of gilts on white clover and alfalfa were grazing significantly more compared to pigs on tall fescue or buffalograss. Moreover, pigs rooted more in white clover compared to the other types of forage. Subsequently, the reduction in groundcover was less in tall fescue and buffalograss than in alfalfa and white clover. In white clover the gilts grazed on the canopy and afterwards began to take out the roots and forage on them. In alfalfa they foraged the leaves and left the fibrous part of the stem (Rachuonyo et al., 2005). From this study it was concluded that pigs prefer legumes over grasses as they are easier to graze and probably have a better palatability compared to fibrous grasses which are harder to graze. Groundcover was maintained best in tall fescue and buffalograss which was probably due to the dense structure which made it difficult for pigs to root. These two grasses are therefore suitable to maintain groundcover on pastures where pigs are fed a balanced diet. Alfalfa and white clover may contribute to the nutritional needs of pigs as it was shown that pigs like to forage on them (Rachuonyo et al., 2005). Hodgkinson et al. (2011) found that growing European wild boars showed selective grazing behaviour in a semi-extensive environment. They preferred plantain and perennial ryegrass. Moreover, it was shown that plants with broader leaves were preferably grazed. Kongsted et al. (2013) investigated Jerusalem Artichokes as a crop for pigs to forage on below the soil surface. This crop does have a great potential as very high yields have been shown and it grows well in poor soils and does have a high frost tolerance compared to most conventional crops (Kosaric et al., 1984).

Reduced level of concentrate supplements

In an experiment by Andresen and Stern (2000), groups of pigs foraging on grass-clover were supplemented with either 100% of concentrate of the recommended amount according to the Swedish recommendations or just 80% of the recommended concentrate. A higher rooting and foraging frequency and a lower resting frequency in the groups fed less concentrate was observed. The reduction of concentrate feed by 20% led to an increase of nutrient intake from the field by 5%. Thus, pigs were not able to fully compensate for the missing concentrate by foraging. In a study by Kongsted et al. (2013) two groups of pigs foraging on Jerusalem Artichokes were compared. One group had ad libitum access to an organic standard diet while the other group had restricted access to an organic high protein mixture. The restricted group got access to a new area of land one more time than the ad libitum group. Both groups had ad libitum access to Jerusalem Artichokes in the soil. It was shown that the restricted fed group was foraging significantly more for Jerusalem Artichokes compared to the ad libitum group. The access to less supplemental feed and the allocation to new land were probably the reasons for the more intensive foraging behaviour in the restricted fed group. In this study pigs were able to get 60% of their daily energy requirement from feeding on Jerusalem Artichokes. This large contribution to the pigs' diet led to a low consumption of concentrate per kg weight gain (Kongsted et al., 2013). In a study by Day et al. (1995) pigs spent more time rooting while lying decreased as a result of restricted feeding. Rivera Ferre et al. (1999) found that herbage intake was unaffected by level of concentrate, but found huge individual variation. Moreover, with the marker technique used in their experiment complete consumption of the marker could not be guaranteed as it was fed in small pellets. This might be the reason for overestimation of herbage intake in some sows.

Reduction in Crude Protein level in concentrate

If pigs root or graze depends to some extent on the friction in the soil, the amount and quality of the above-foraging substrate and also the protein content of the feed (Andresen et al. 2000). Thus, the crude protein level in supplemental concentrate influences the pigs foraging behavior. In addition, pigs are able to compensate for limitations in crude protein and energy in the supplemental feed by foraging (Andresen, 2000).

Jensen et al. (1993) offered groups of pigs indoors three different supplemental feedstuffs with similar content of digestible energy (around 16 MJ kg^{-1}) but different in protein content. They were either fed a diet with low protein content (122 g of crude protein kg^{-1} fresh food), a diet with high protein content (240 g CP kg^{-1} fresh food) or a medium protein content of 206 g CP kg^{-1} fresh food. The groups were offered one of the foods ad libitum. The result showed that pigs in the low protein group spent more time standing, walking and rooting. But also the other two groups performed these activities to an appreciable amount. Jensen et al. (1993) suggests that the motivation to root and move may have different reasons. While pigs in the low protein group may have a higher motivation to perform appetitive foraging to meet their nutritional needs, the others may perform it as exploratory behaviour. This shows that specific nutritional needs can increase the motivation to search for feed (Jensen et al. 1993). The results of Jensen et al. (1993) in indoor pigs are not in line with the observations of Andresen and Redbo (1999) in outdoor pigs. Andresen and Redbo (1999) also fed groups of pigs with low or high amounts of protein in the supplemental feed (either 137 g kg^{-1} DM or 191 g kg^{-1} DM). They found that crude protein level did not influence the behaviour of pigs (foraging, rooting, and movement). A reason for this might be that the clover-grass did not contain enough crude protein to meet the requirement of the pigs and was therefore too low to reinforce foraging behaviour. Thus, foraging behaviour of pigs also depends on the quality of clover-grass herbage (Andresen and Redbo, 1999). Andresen et al. (2001) did an experiment where rooting of pigs was used as tillage work. They fed groups of pigs with low protein (139 g kg^{-1} DM) or high protein (197 g kg^{-1} DM) in the supplemental feed. There was no difference shown in tillage work (rooting) between the groups. Therefore they concluded that lower protein content does not increase the foraging activity under outdoor conditions. Jakobsen et al. (2014) found that pigs restricted in protein feed showed an increased rooting behaviour in comparison to non-restricted fed pigs. This effect was shown to be more dominant in pigs foraging on grass compared to pigs grazing on alfalfa.

Conclusion

From this literature review several possibilities to reduce the amount of supplemental feed and to increase pasture intake were shown. A restricted level of concentrate feed leads to a higher pasture intake while a reduced level of crude protein did not affect foraging activities. Feed intake from free range areas might also be increased by the daily allocation of new land, but studies on this were contradicting. Moreover, the crop established on pasture affects intake. Alfalfa, grass-clover and Jerusalem Artichokes were shown to be suitable crops for foraging pigs. Thus, it is possible to increase pasture intake by reducing the amount of supplemental feed and by establishing a suitable crop, e.g. white-clover, alfalfa or Jerusalem Artichokes.

2.3 Distribution of faeces and urine in the free-range area

Effects of uneven distribution

Even moderate stocking densities of sows have been shown to create nutrient hot-spots on the free-range area (Zihlmann et al., 1997). The inhomogeneous distribution leads to nutrient losses as well as to a less efficient utilization of nutrients by plants. As organic farms are not allowed to use mineral fertilizer it is very important that plants utilize these nutrients efficiently (Eriksen and Kristensen, 2001).

Excretory behaviour

A major reason for the uneven distribution of nutrients is the excretory behaviour of pigs which is very complex and depends on many factors (Hacker et al., 1994). Pigs are very systematic in their defecation and urination behaviour. They do not excrete randomly, but use well-defined areas for excretory behaviour (Andresen, 2000; Petherick, 1982). Moreover, Hacker et al. (1994) found that pigs prefer to lie in warmer areas and excrete in the coolest area of the pen. Stolba and Wood-Gush (1989) also observed a non-random excretory behaviour in pigs in a semi-natural environment. This non-random excretory behaviour has also been found in other animal species. Edwards and Hollis (1982) kept sheep, cattle and ponies together in the New Forrest and all three species performed non-random excretion behaviour. In general latrine areas were observed where all three species excreted and these areas remained stable during the three years of the experiment. Especially for ponies they found a clear separation of feeding and dunging area. The ponies avoided grazing in these latrine areas. Edwards and Hollis (1982) concluded that the observed pattern has been established by the selective grazing and excretory behaviour of the ponies as cattle usually tend to excrete at randomly. In addition they concluded that this separated behaviour was related to stocking density.

Results by Andresen and Stern (2000) confirmed that pigs did not distribute their feaces and urine evenly in the paddock. A higher frequency of defecating was observed in the dwelling area. The dwelling area in that study was the area that includes huts, water supply and wallowing area. Salomon et al. (2007) found that pigs do not defecate close to drinking water and feeding troughs. In a stationary system pigs excreted 43% of the total average amount of nutrients in the wallowing area (Salomon et al., 2007). Olsen et al. (2001) found that growing pigs used the wallow for 50% of their defecation and urination behaviours. The main part of the grazing area was covered with manure and the degree of cover was increasing the closer to the hut. Stolba and Wood-Gush (1989) found that most of the places where the pigs defecated in the morning after leaving the nest were located uphill from the nest and only a few downhill. They also observed that none of these defecation spots was closer to the nest than 5 m and none was farther away than 15m. At other times of the day pigs preferred to excrete in wide paths going through gorse bushes (Stolba and Wood-Gush, 1989). Furthermore, Petherick (1982) observed the excretory behaviour of piglets in straw-bedded pens and found that they never excreted in their nest area.

In terms of influencing excretory behaviour Horsted et al. (2012) did an experiment where pigs and energy crop production where combined. In their experiment growing-finishing pigs got access to zones of grass, miscanthus and willow. It was observed that pigs preferred to excrete in the willow zones, especially the zone between the feeding area and the hut. The finding that pigs prefer to excrete in willow zones might be a way to influence the area of excretion by establishing willow zones in the range area. Moreover, willows are able to take up high amounts of N which may help to reduce the nutrient leaching from free-range areas (Horsted et al., 2012). Horsted et al. (2012) observed that pigs prefer to defecate close to bushes, trees or higher vegetation and prefer to move away from huts and feeding areas for defecating.

It was also shown that pigs preferred certain locations close to the fence for excretory behaviour (Andresen and Redbo, 1999; Andresen et al., 2000). This behaviour was also shown indoors by Hacker et al. (1994). They found that pigs which can directly communicate with pigs in the neighbouring pen tend to excrete close to walls and other pen boundaries. A reason for this might be that pigs try to mark their territory. In a study by Salomon et al. (2007) it was confirmed that pigs tend to excrete close to the electric fence. Wiegand et al. (1994) tested the effect of different pen shapes on the behaviour of pigs and found that pigs preferred to defecate near corners or walls. Pigs in circular pens were using feeder edges as corners. Petherick (1982) observed the excretory behaviour of piglets indoors in conventional farrowing pens and found that they also prefer to excrete close to pen walls and especially in corners.

Management practice

Benfalk et al. (n.d.) compared mobile and stationary organic pig systems with a focus on excretory behaviour. In the mobile system pigs were kept on arable land and were transferred to a new area every year. In the stationary system pigs were kept in a barn with access to an outdoor area. For the stationary system it was shown that pigs preferred to excrete in the outdoor area which was close to the barn and in the rest of the outdoor area the manure was more even distributed. In the mobile system the majority of excretory behaviour was performed in the area between the hut and the trough. However, pigs did not defecate in the area around feeding trough and water facilities. Furthermore, they avoided defecating inside the huts in both systems (Benfalk et al., n.d.). Benfalk et al. (n.d.) concluded that a more even distribution of nutrients can be reached by manipulating the pigs excretory behaviour. This might be realized by shifting the feeding troughs and the huts and by a longer distance between huts and feeding troughs. These requirements are easier to fulfill in a mobile system as it is variable in its construction. Eriksen and Kristensen (2001) also suggest to regularly move the huts and feeders to get a more even nutrient distribution and to avoid hot-spots. Moreover, excretory behaviour was shown in a higher frequency in newly allotted land compared to already grazed areas (Andresen, 2000; Stern and Andresen, 2003). Hacker et al. (1994) found that pigs prefer to lie in warmer areas and like to excrete in the coolest area of the pen. Therefore partitioning of stables is an important factor to keep pens clean. It is possible to influence the defecation and urination area by providing a cool climate in the excretory area. Eriksen and Kristensen, 2001 suggest that a uniform distribution of nutrients on the area can be achieved by regularly moving huts and feeders. Small individual pens instead of common paddocks may be more suitable.

Conclusion

Excretory behaviour of pigs was shown to be not-random. Pigs clearly prefer to excrete close to fences, bushes and trees but not close to water and feeding areas. Moreover, it is possible to get a better distribution of faeces and urine in the free-range area by using mobile systems where fences, water and troughs can be moved regularly. The establishment of bushes or high vegetation can also be used to influence the excretory behaviour of pigs and can contribute to a reduction in nitrogen leaching.

2.4 Overall conclusion

The main causes for high nutrient inputs are the high amount of concentrate pigs are supplemented with and their not-random excretory behaviour. Within this first part the available literature on how to reduce nutrients and on how to distribute these more equal on the free range area was reviewed. A way to reduce N input from concentrate feed is to increase pasture intake as it has been shown that pigs are able to meet a part of their nutritional requirement from foraging. In some studies it has been shown that pasture intake could be increased by regular allocation of new land and by offering suitable forage crops such as Jerusalem Artichokes, alfalfa and clover-grass. Furthermore, a reduced level of concentrate supplements lead to an increased pasture intake by pigs in most of the studies reviewed. Moreover, in some studies reducing the amount of protein in the supplemental feed has been shown to increase foraging behaviour in pigs. However, other studies did not find an effect of protein level in the supplemental feed on foraging behaviour.

For a more even distribution of nutrients in the free range area excretory behaviour of pigs does play an important role. According to the reviewed literature pigs are very systematic in their excretory behaviour and do not excrete random. They prefer to excrete in the wallowing area, close to the nest and in higher vegetation, especially in willow zones. Furthermore pigs were shown to excrete mostly close to walls, fences, corners and in newly allotted land. Excretory behaviour close to fences and walls was often shown when pigs had visual contact to others in neighbouring pens, thus it was concluded that pigs were marking their territory. Furthermore it was shown that pigs prefer to excrete in cooler climates. However, pigs did usually avoid excreting in the nest as well as close to feeding areas and water facilities. Within the literature review mobile systems were suggested to reach a more even distribution of nutrients. Moving feeder, huts and establishing smaller pens instead of big common pens were suggested possibilities.

From the literature review it becomes clear that there are several possible ways to increase pasture intake and to get a better distribution of feaces and urine on the free-range area. However, knowledge on suitable management systems for growing pigs is lacking. Therefore, an experiment was conducted which considers some of the above mentioned strategies focusing on land allocation as the literature review showed that allocation of new land does have the potential to influence pasture intake and excretory behaviour.

3. Experiment

The following experiment is part of a larger main experiment conducted by Jakobsen et al. (2014). In the main experiment the focus was on the effect of feeding strategy (low vs. high protein content in the supplemental feed) and cropping system (alfalfa vs. grass) on foraging activity, nutrient intake from the range area and pig performance. Within the current project the focus is on the effect of land allocation strategy on foraging activity and excretory behaviour of pigs. Therefore, the effect of feeding strategy and cropping system are not discussed in detail later on. The literature review showed that allocation of new lead is a main driver for an increased pasture intake in pigs. Moreover, it has been shown that pigs preferred to excrete in new land and they probably excrete to mark their territory. Thus, allocation of new land might be a key factor for reducing nutrient input and for distributing nutrients on the free range area. However, from the literature review it did not become clear if providing access to a small area of new land every day or a bigger area of land for several days is more suitable. Thus, a strip grazing experiment with two strategies for land allocation was conducted. In land allocation stratgegy 1 pigs did get access to 1x12.5 m of land on three days in a row and in strategy 3 they got 3x12.5 m right away. According to the literature review alfalfa and clover-grass lead to an increase in pasture intake from above-ground. Besides, low protein content has also been shown increase pasture intake by pigs, however results here were contradicting. The objective of the following experiment is to gain more knowledge which can be used to design suitable paddock management strategies for organic growing pigs. Based on the knowledge available from the literature review, in this experiment two land allocation strategies (1 vs. 3) were tested in combination with two cropping systems (alfalfa vs. clover grass) and two feeding strategies (high vs. low protein content in the supplemental feed). Considering the knowledge available from the literature review the following hypothesis were tested within this experiment:

1. Foraging activity of pigs will be performed more often in 'new' land compared to 'old' land as pigs expect to find novelty and visit the new area more often compared to old.

2. In the 'new' land there will be a higher frequency of foraging activity when pigs get access to 1x12.5 m of land on three days in a row compared to 3x12.5m right away.

3. Pigs will defecate and urinate more in new land as they will mark their territory in unknown land.

3.1 Materials and Methods

Experimental site

The experiment was performed from 4th of September until 14th of October 2013 at the research station Foulumgaard belonging to Aarhus University in Denmark.

Experimental Design

The experimental design was a 2x2 treatment which was replicated in three blocks. Two forage treatments (alfalfa and clover-grass) were established and two different concentrate treatments (high and low protein) were used. The pigs were grouped according to their weight and gender and were then put into one of the four paddocks within one of the three blocks. Three pigs were grouped in every paddock; either one female and two male pigs or one male and two female pigs were put together. The experimental paddocks were directly next to each other and separated by two strand electric wire fences. In six paddocks alfalfa was growing and in six paddocks clover-grass was established. In each paddock pigs had access to a hut with a floor area of 4m². The huts were placed on pasture and straw was put inside. Moreover, each group of pigs had access to two feeding troughs and water tubs. Feeder, water tubs and hut were stationary throughout the whole experiment (Fig. 1). The main effects of crop and feed were investigated by Jakobsen et al. (2014) within this thesis the main focus is on the effect of paddock management systems (land allocation strategy).

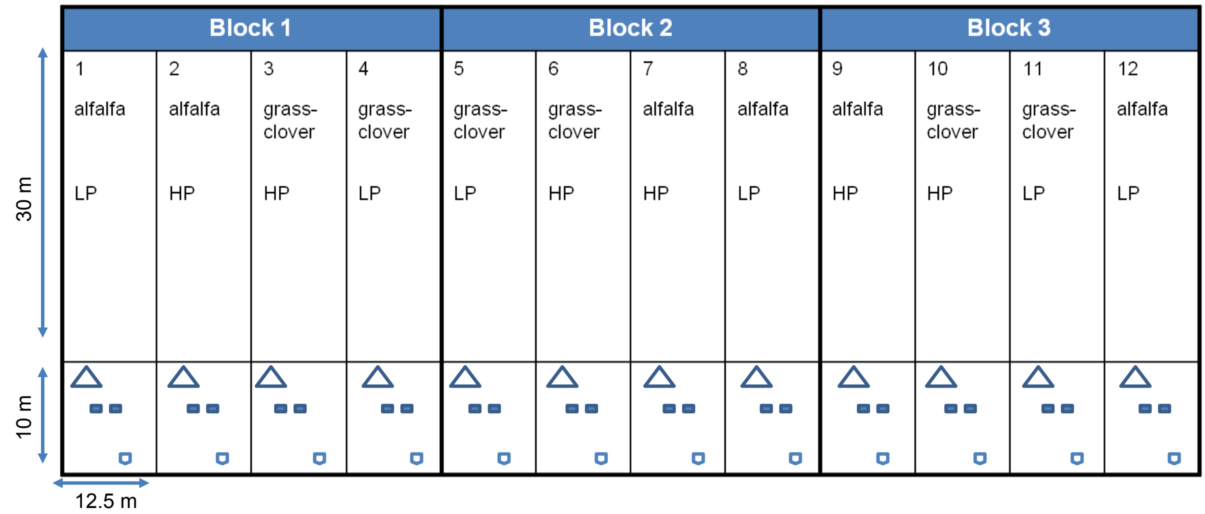

Fig. 1 Experimental Design. (Mod. a. Jakobsen **et al.**, 2014): a 2x2 treatment replicated in three blocks. LP =low protein, HP= high protein, △ = hut, ▯▯ = feed troughs, ⬡= water tub**.**

Land allocation strategies

In the beginning of the experiment the size of each paddock was 12.5x10 m, thus 125 m² which is equal to 42m² per pig. This area represented zone 1 in the experiment. Strip grazing was conducted and therefore the pigs got successive access to a new area of land (Table 1). The following zones were names subsequently 2, 3, 4... .Pigs got access to new land every week. In land allocation strategy 3 they got 3x12.5 m of land on Tuesdays and Fridays. In land allocation strategy 1 they got 1x12.5 m on Tuesdays, Wednesdays, and Thursdays as well as 3x12.5 m on Fridays.

Table 1 Experimental design including zones and treatment per week. The observations were taken in week 38-41. Coloured rows represent the zones observed. In allocation strategy 3 pigs got access to 3 x 12.5 m of land on one day and in land allocation strategy 1 they got 1 m x 12.5 m on 3 following days. (mod. a. Jakobsen et al., 2014).

Block no.		Block 1				Block 2				Block 3			
Paddock no.		1	2	3	4	5	6	7	8	9	10	11	12
Week	Zone	Allocation strategy				Allocation strategy				Allocation strategy			
42	11	3	3	3	3	3	3	3	3	3	3	3	3
41	10	3	3	3	3	3	3	3	3	3	3	3	3
	9	3	3	3	3	1	1	1	1	3	1	1	3
40	8	3	3	3	3	3	3	3	3	3	3	3	3
	7	1	1	1	1	3	3	3	3	1	3	3	1
39	6	3	3	3	3	3	3	3	3	3	3	3	3
	5	3	3	3	3	1	1	1	1	3	1	1	3
38	4	3	3	3	3	3	3	3	3	3	3	3	3
	3	1	1	1	1	3	3	3	3	1	3	3	1
37	2	3	3	3	3	3	3	3	3	3	3	3	3
36	1	hut area				hut area				hut area			

Animals

In this experiment 36 growing finishing crossbred pigs (Landrace x Yorkshire x Duroc) were included. 19 of them were female and 17 male. The pigs were reared on a conventional farm with free-range access where they had ad libitum access to a commercial diet for weaner and grower. The mean live weight of the pigs was 58kg (51-68 kg) in the beginning of the experimental period and 90kg (79-107 kg) in the end of the experiment. The pigs were not nose-ringed.

Forage Crop and soil

The forage crops in this experiment were a well-established alfalfa (*Medicago sativa*) and a newly established grass-clover containing 85% of rye grass (*Lolium perenne L.*) and 15% of white clover (*Trifolium repens*). The forage crops were randomized to the paddocks within the blocks. Due to weevils the clover content in the grass-clover paddocks was reduced to approximately 1%. Therefore, it is referred to grass instead of grass-clover in the following. There were no pesticides and artificial fertilizers applied on the field since autumn 2009. The soil was a fine loamy sand (Greve, 2014).

Supplemental feed

Once a day at 7.30 am the pigs were fed a supplemental feed. They got a mean of 2.23kg feed per pig per day. This was equivalent to 27.5 MJ ME in the high protein diet and 26.5 MJ ME in the low protein diet. This is equivalent to 80% and 78% of the Danish indoor recommendations for pigs (Anonymous, 2008).

The high protein was an organic standard diet for growing-finishing pigs containing 205g of crude protein (CP) and 10.55 g of lysine kg^{-1} DM. The low protein diet was a mixture of coarsely grinded and granulated organic wheat (42%), barley (30%) and oats (25%). It contained 107 g CP and 4.35 g lysine kg^{-1} DM. Regarding CP content pigs on low protein diet received 52% of the CP in the high protein diet. Both diets were optimized for minerals and vitamins.

Observations

Behavioural observations were performed to investigate the effect of management system, forage crop and protein content in the concentrate on behaviour. Observations were performed three days every week (Tuesdays, Wednesdays and Thursdays). Pigs were observed from 8.30 to 10.00 am, 10.30 to 12.00 am, 1.30 to 3.00 pm, 3.30 to 5.00 pm and from 5.30 to 7.00 pm. The behaviour was recorded as scan sampling in a 2 minute interval (Martin and Bateson, 2007). The behaviours recorded were: grazing, rooting, and other. Definitions are given below (Table 2). Moreover, urinating and defecating were recorded continuously. The observation of paddocks was randomized between blocks and within blocks. To randomize observations a dice was used to decide which block to observe first and also which paddocks within the blocks to observe first. The other blocks were then observed in numerical order. For each observation it was recorded in which zone it occurred (Table 1). Two neighbouring paddocks were observed at the same time for 15 minutes (1+2, 3+4, 5+6, 7+8, 9+10, 11+12). This means that seven scan samplings per pig were collected at five times during a day. In total every pig was scan sampled 420 times from day 13 to day 36. The same two observers recorded the behavioural elements during the whole experiment. The observers were placed outside the paddocks in a vehicle which was approximately seven meters away from the fence and did not intervene in the pig's behaviour. Three minutes were used to move to the paddock and for accustoming the pigs to the presence of the vehicle.

Table 2 Definitions of behavioural elements recorded during the scan sampling. (mod. a. Jakobsen et al., 2014).

Behaviour	Definition
Grazing	Pulling/biting of grass, alfalfa or other forages items with the mouth; chewing and/or swallowing grass, alfalfa or other forage items
Rooting	Snout in the soil with shovelling and forward headed movements; pig is rooting and right after the head is lifted and chewing is visible
Other activities	Eating concentrate, resting, being in the hut, drinking, walking, standing, social interaction, grooming, wallowing

Statistical Analysis

For the statistical analysis and for each behavioral element, the observations were first summed per week. The sum per week was divided by the frequency to get the average of each behavioural element. Afterwards these mean observations were calculated per square meter to make treatment 1 and 3 comparable (average frequencies per square meter are shown in Appendix I). For the statistical analysis the means across weeks were used. All behavioural elements were square root transformed to obtain approximately normal distribution. The effect of strip grazing on rooting, grazing and on foraging behaviour was investigated by a linear mixed model. A type 3 test of fixed effects was performed to get the overall level of significance of the effects. All statistical analyses were performed in SAS (SAS institute, 2013).

Models

1) $Y_{ijklm} = \mu + \alpha_i + \beta_j + v_k + \delta_l + \gamma_m + A_{ijm} + E_{ijklm}$

where Y_{ijklm} is the behaviour in frequency per square meter (n = 48), μ is the general intercept, α_i is the effect of crop (*i* = alfalfa, grass), β_j is the effect of feeding (*j* = high protein, low protein), v_k is the effect of land allocation strategy(*k* = 1, 3), δ_l = the effect of status (*l* = new land, old land), γ_m is the effect of block (*k* = 1-3). A_{ijm} is the normally distributed random effect of group (*i* = alfalfa, grass; *j* = high protein, low protein, *k* = 1-3). All interactions between crop, feeding, treatment and status were also included in the model (not shown in 1). All interactions and main effects with P-values above 0.05 were removed from the models one by one and the analyses were repeated.

3.2 Results

There were 15,116 observations recorded during the scan sampling. Of those recorded behaviours 8.32% were grazing and 28.1% were rooting. Thus pigs spent 36.42% of the day on foraging activities.

3.2.1 Effect of land allocation strategy on foraging activity and excretory behaviour

Foraging activity

There was no significant difference (p=0.91) in rooting frequency per m² when pigs got access to 1x12.5m (LSM: 0.57) on three days in a row or to 3x12.5m (LSM: 0.58) right away. The effect on grazing frequency per m² was also not significantly different (p=0.39) between 1x12.5m (LSM: 0.15) and 3x12.5m (LSM: 0.13). Thus, land allocation strategy did not influence rooting and grazing frequency when the three observation days per week were averaged. Likewise, there were no significant interactions between land allocation strategy and cropping system or between land allocation strategy and feeding strategy.

However, land allocation strategy did influence the rooting and grazing frequency when the three observation days per week were regarded separately (Fig. 2). For alfalfa it was shown that grazing frequency remained relatively constant over the three observation days when pigs got access to new land on three days in a row (land allocation type 1). Whereas the grazing frequency in alfalfa was higher on day 1 and decreased on day 2 and 3 when pigs got access to new land only on day 1 (land allocation type 3). For grass it was shown that rooting frequency in land allocation strategy 1 was lowest on day 1 and increased on day 2 and again on day 3 when pigs got access to new land on three days in a row (allocation type 1). However, when pigs got access to new land only on day 1 (allocation type 3) rooting frequency showed the opposite pattern. Rooting was highest on day 1 and decreased on day 2 and again on day 3. Total rooting frequency was highest on day 3 in land allocation strategy 1 and grass as forage crop (Fig. 2).

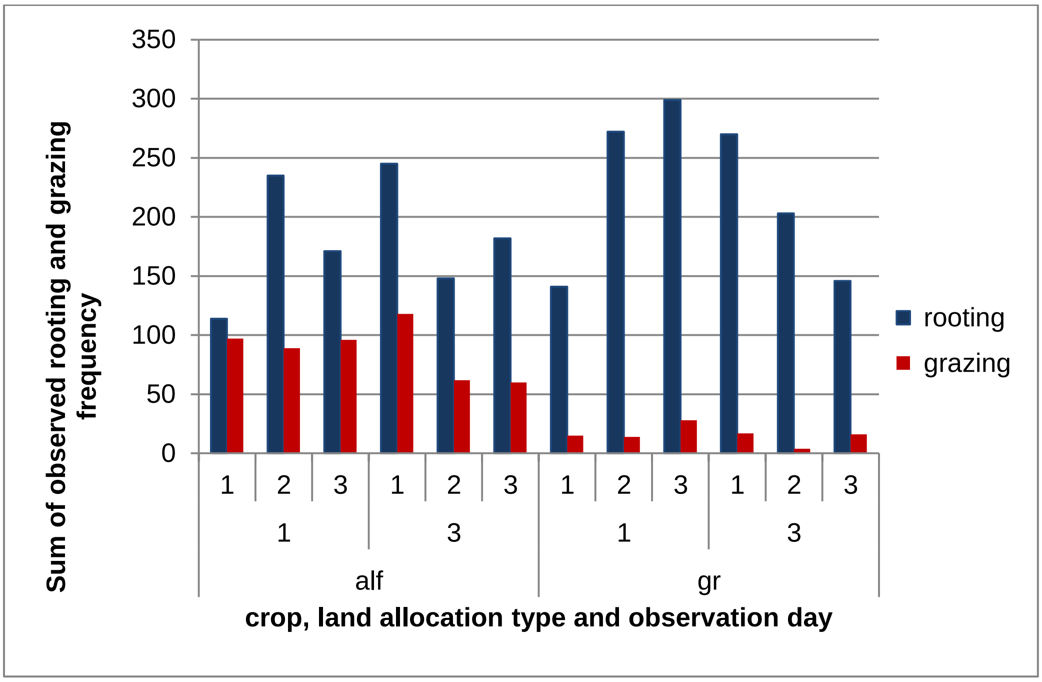

Fig. 2 Sum of observed rooting and grazing frequency per crop (alf=alfalfa vs. gr=grass), land allocation type (1=3x12.5m, 3=1x37.5m) and observation day (day 1= all pigs got access to new land, day 2+3= only pigs in land allocation type 1 got access to new land).

Excretory behaviour

There was no significant difference (p=0.57) when pigs got access to 1x12.5 m on three days in a row (LSM: 0.03) compared to 3x12.5 m right away (LSM: 0.03). Therefore, land allocation type did not have a significant effect when the three observation days per week were averaged. However, when the three observation days were regarded separately differences between the two land allocation strategies can be seen. In general pigs excreted more often per day on grass. Defecating was highest in land allocation strategy 3 in combination with grass on day 1. In land allocation strategy 1 in combination with alfalfa pigs did not urinate, however, they urinated in land allocation strategy 3. Defecating did not differ a lot between the two land allocation strategies on alfalfa, but on grass pigs defecated a lot on day 1 while pigs did not defecate on day 1 in land allocation strategy 1.

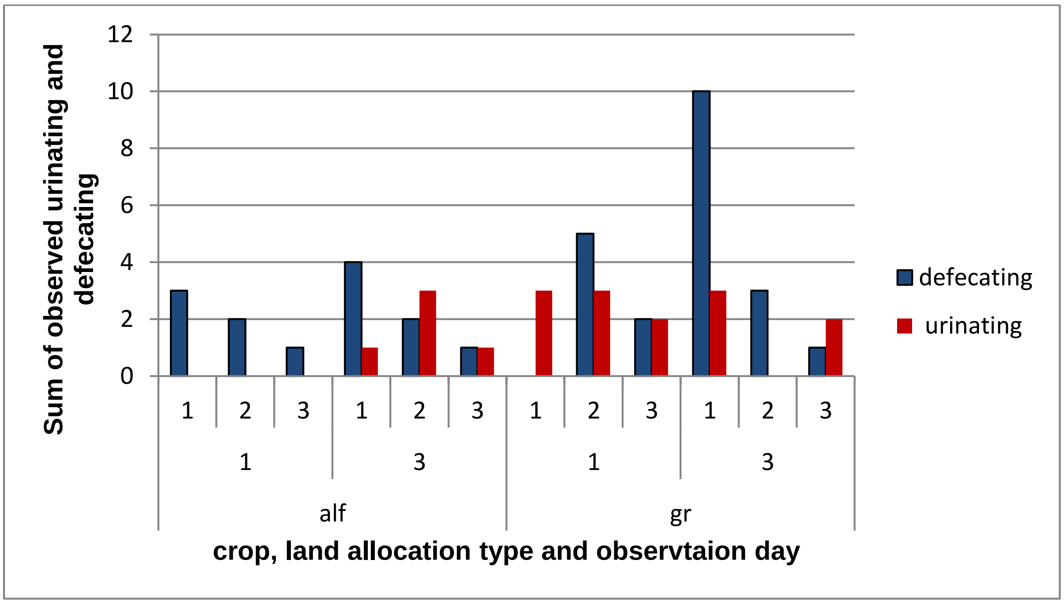

Fig. 3 Sum of observed urinating and defecating frequency per crop (alf= alfalfa vs. gr=grass), land allocation type (1x12.5 m on three days in a row, 3=3x12.5 m right away) and observation day (day 1= all pigs got access to new land, day 2+3= only pigs in land allocation type 1 got access to new land).

3.2.2 Effect of land status on foraging activity and excretory behaviour

Foraging activity

The interaction of feed (HP vs. LP) and status (old vs. new land) influenced rooting frequency significantly. For both feeding strategies rooting frequency was significantly higher on new compared to old land. However, the effect of status was much more pronounced in LP compared to HP diet. In new land combined with the LP diet pigs rooted 130% more compared to new land with HP diet. Thus, rooting frequency was highest when pigs got access to a low protein diet in combination with new land. The second highest rooting frequency was observed when pigs had access to a high protein diet in combination with new land. Low protein in combination with old land showed a significantly lower rooting frequency. The lowest rooting frequency occurred when pigs had access to a high protein diet in combination with old. However, effect of status was not significantly influenced by crop system (alfalfa vs grass) (Table 3).

Grazing frequency was significantly influenced by a two-way interaction of crop and status. Moreover, grazing frequency was highest when pigs had access to new land in combination with alfalfa. This combination showed a 12 times higher grazing frequency than the combinations of alfalfa*old land and grass*old land. The interaction of grass*new land resulted in a 7 times lower grazing frequency than alfalfa*new, but it was not significantly different from the treatments alfalfa*old and grass*old. Whereas, the interaction of feed*status did not have a significant influence on grazing frequency (Table 3).

Excretory behaviour

There was a significant effect of land status on urinating frequency. Pigs urinated more in the old land compared to new land. This effect could not be found on defecating frequency. The interaction between feed*status and crop*status did neither influence urinating nor defecating frequency significantly (Table 3).

Table 3 LS means back transformed as means of performed behaviour per m², standard errors (SE) and p values for effect of treatment: *main effect of land status (old vs. new), interaction of feed (HP vs. LP) and status as well as interaction of crop (alfalfa vs. grass) and status on rooting, grazing, defecating and urinating.*

Treatment	Mean Rooting/m²	SE	p	Mean Grazing/m²	SE	p	Mean Defecating/m²	SE	p	Mean Urinating/m²	SE	p
status												
new	1.27a			0.30a			0.03			0.01a		
old	0.15b			0.05b			0.04			0.03b		
		0.03	0.0001***		0.02	<0.0001***		0.02	0.25		0.01	<0.001**
feed*status												
*HP*new*	0.80a			0.25			0.03			0.02		
*HP*old*	0.12b			0.05			0.03			0.04		
*LP*new*	1.84c			0.31			0.02			0.01		
*LP*old*	0.20d			0.05			0.04			0.03		
		0.04	<0.0001***		0.03	0.22		0.03	0.50		0.02	0.16
crop*status												
*alf*new*	1.16			0.60a			0.02			0.01		
*alf*old*	0.11			0.05b			0.04			0.03		
*gr*new*	1.40			0.09b			0.03			0.02		
*gr*old*	0.20			0.05b			0.04			0.04		
		0.04	0.92		0.03	<0.0001***		0.03	0.49		0.02	0.20

3.2.3 Observed and expected behaviour

Foraging activity

In Table 4 the proportion of observed foraging behaviour compared to the proportion of area of new and old land in the four observation weeks is shown. Given that foraging frequency is randomly distributed over the whole area the proportion of land corresponds to the expected proportion of foraging behaviour in new and old land respectively. Due to successive allocation of new land the proportion of new to old land changed during the experiment. Every week the proportion of new land decreased while the proportion of old land increased.

Across cropping systems pigs performed 35-74% of all rooting in the new zone, although the new zone did account for only 16-32% of the total area. Additionally, the proportion of rooting in new land increased over time, although the proportion of new area decreased every week. Of total grazing observed pigs performed 58-70% in new land with alfalfa and only 13-31% in new land with grass. Thus, performed grazing in new land with alfalfa was very high in comparison with the area of the new zone (16-32%). The proportion of grazing in new land did fluctuate over time in both crops. In alfalfa the proportion of grazing in new land was a bit lower in week 2 and 4 compared to 1 and 2. In new land with grass the proportion of grazing decreased between week 1 and 3 with decreasing proportion of new land but increased in week 4 (Table 4).

Table 4 Proportions of observed and expected rooting and grazing frequency for alfalfa and grass on new and old land.

Observation week	Expected[1] proportion of rooting/grazing (%)		Observed proportion of rooting (%)				Observed proportion of grazing (%)			
			alfalfa		grass		alfalfa		grass	
	New land	Old land	New land	Old land	New land	Old land	New land	Old land	New land	Old land
1	32	68	45	55	35	65	70	30	24	76
2	24	76	63	37	50	50	58	42	19	81
3	19	81	74	26	55	45	65	35	13	87
4	16	84	66	34	72	28	58	42	31	69

[1]Equal to relative area of new and old land respectively.

Excretory behaviour

In Table 5 the proportion of observed excretory behaviour in alfalfa and grass are shown in comparison to the proportions of area of new and old land for the four observation weeks, respectively. Across cropping systems the proportion of defecating and urinating in new land was low compared to the proportion of new land area (16-32%). The proportion of defecating in new land was 3-21% of total defecating and urinating in new land had a proportion of 0-16% of total urinating behaviour. The proportion of defecating frequency in new alfalfa decreases until week 3 as it was expected, but it increases again in week 4. In new grass the propoprtion of defecating in new land decreases and is lowest in week 4.The proportion of urinating in new land and alfalfa increases with decreasing proportion of new land. In grass the proportion of urinating in new land is increasing between the first and second week and then decreasing from week 3 on again (Table 5).

Table 5 Proportions of expected and observed defecating and urinating frequency on new and old land per observation week.

Observation week	Expected[1] proportion of urinating/defecating (%)		Observed proportion of defecating (%)				Observed proportion of urinating (%)			
			alfalfa		grass		alfalfa		grass	
	New land	Old land	New land	Old land	New land	Old land	New land	Old land	New land	Old land
1	32	68	21	79	21	79	0	100	7	93
2	24	76	8	92	18	82	4	96	16	84
3	19	81	3	97	17	83	3	97	11	89
4	16	84	11	89	7	93	12	88	8	92

[1]Equal to relative area of new and old land respectively

3.2.4 Development across weeks

Foraging activity

When the proportions of old and new land are compared to the proportions of rooting and grazing, differences between the observation weeks have been shown. To get an insight on the development of the behaviours per week, the observation per m² was calculated per observation week and land status. Grazing behaviour per m² in new land remaind relatively constant, but was a bit higher in week 4 whereas rooting behaviour in new land increased over the four weeks and decreased in old land at the same time (Fig.4).

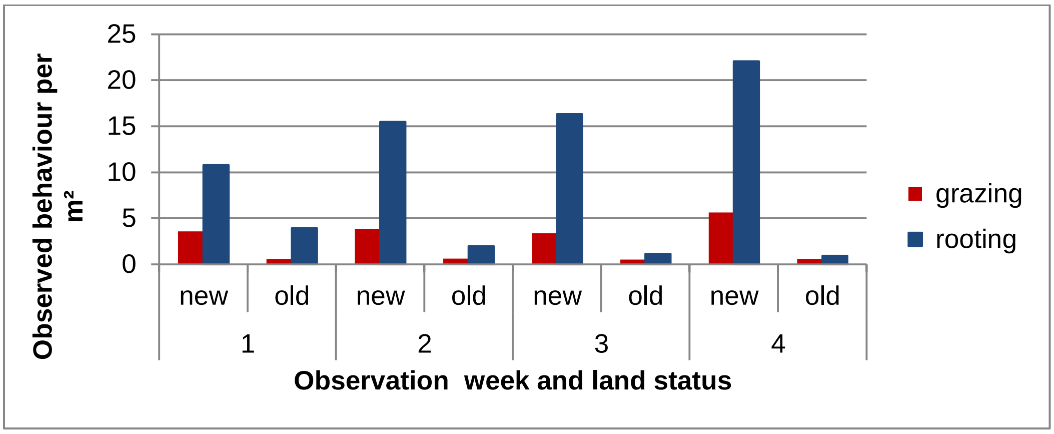

Fig. 4 Observed behaviour per m² for rooting and grazing over the four observation weeks (1-4) and land status (new vs. old land)

Excretory behaviour

Urinating was shown to be much lower in new land compared to old land, but in week 4 urinating in old and new land were very similar. Defecating was highest in new land in week 1 and decreased over time in new land and old land (Fig.5).

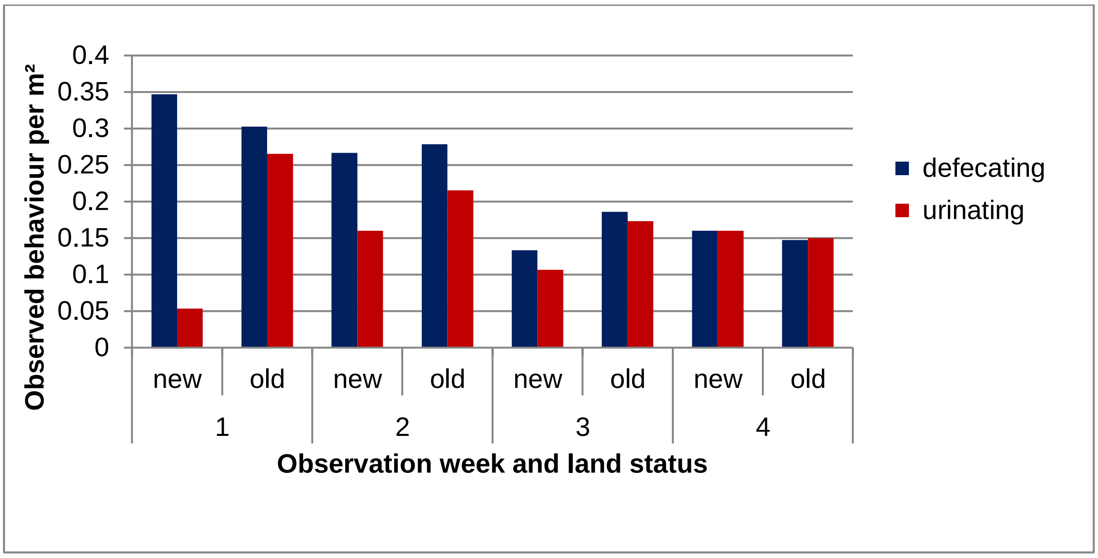

Fig. 5 Observed behaviour per m² for defecating and urinating per observation week (1-4) and land status (new vs. old land).

4. Discussion

In this study the foraging behaviour was 36.42% of total behaviour observed. This is in line with observations of Andresen and Redbo (1999), who observed foraging in growing pigs and found that they foraged 39.3% of the day. However the foraging behaviour observed in this study is higher compared to Buckner et al. (1997) who observed foraging in pregnant sows and found a mean foraging proportion of 25.9 %.

4.1 Land status

Foraging activity

From the literature review it became clear that foraging activity in pigs does have nutritional as well as explorative purposes (Andresen 2003). Thus, novelty of new land is a major factor for increasing pasture intake (Andresen, 2003). Within the current study it was confirmed that growing pigs were grazing and rooting significantly more often in new land compared to old land. Even when the proportion of new land was much smaller than old land, rooting and grazing in new land remained high in alfalfa. However, grazing in new land was lower than expected in week 2 and 3 as pigs clearly preferred rooting in new land with grass and were grazing more in the old land with grass. Thus, grazing frequency was higher in new land with alfalfa compared to new land with grass. This result is also in line with former studies, e.g., Rachuonyo et al. (2005) found a preference for alfalfa over grass in gilts and assumed that the reason for this might be the succulent nature in combination with the ease of grazing on legumes. Their results also showed that pigs consume and damage alfalfa faster and more severe than buffalograss and tall fescue. Thus, they consume a higher amount of alfalfa. Furthermore, the highest rooting frequency in the present study was shown in new land in combination with low protein in the supplemental feed. This finding is in agreement with Jensen et al. (1993) who suggested that pigs in the low protein group performed more appetitive foraging to meet their nutritional needs. Therefore, the first hypothesis in this experiment could be confirmed: **Foraging activity of pigs will be performed more often in 'new' land compared to 'old' land as pigs expect to find novelty and visit the new area more often compared to old.** For the present study more results on cropping and feeding strategy will be published by Jakobsen et al. (2014).

Excretory behaviour

Literature on the excretory behaviour of pigs regarding land status is very scarce. In the available literature it was stated that excretory behaviour is performed to a higher extent in new land (Andresen and Stern, 2003). Additionally, pigs may excrete more in new land as it was observed that pigs excreted close to fences when they had visual contact to other groups of pigs, thus they probably mark their territory also in new land (Hacker et al., 1994). Therefore the hypothesis in the present study was: **Pigs will defecate and urinate more in**

new land as they will mark their territory in unknown land. However, this hypothesis could not be confirmed. There was no significant effect of land status on defecating behaviour, but urinating was performed to a significantly lower extent in new land. When the proportion of old and new land were taken into account defecating and urinating were low in new land compared to the proportion of new land. This finding is not in line with results of Stern and Andresen (2003) who found that the successive allocation of new land stimulated pigs to defecate and urinate on newly allotted land. However, in their study pigs were fed twice a day in newly allotted area and thus, they might have spent more time in the new area. Whereas pigs in the present study were fed close to the hut and therefore had to go back to the old land to get their supplemental feed. Quintern (2005) also states that distribution of faeces is in relation with the time pigs spend on a certain area, thus, the longer they stay the more faeces are excreted. For urine it was shown that pigs prefer to urinate close to the hut (Quintern, 2005) and as the hut was located in the old land it explains why pigs did urinate significantly less in the new land. Additionally pigs are very social animals and their excretory behaviour is also influenced by group members as well as other groups of pigs (Mollet and Wechsler, 1991). That means pigs like to excrete at the same time at the same place as their group members and also prefer to excrete at places where they already excreted before (Meynhardt, 1982). Furthermore, pigs do not like to smell or to get in contact with their excreta (Pfeiler et al., n.d.).

4.2 Land allocation strategy

Foraging activity

As pigs become more passive when they spent a longer time period on the same area (Andresen, 2003) it can be concluded that regular allocation of new land is the key to make pigs forage more. Thus, two different strategies of land allocation were compared within this study. In land allocation strategy 1 pigs got access to 1x12.5 m on three days in a row whereas they got 3x12.5 m right away on one day in allocation strategy 3. The hypothesis was: **In the 'new' land there will be a higher frequency of foraging activity when pigs get access to 1x12.5 m of land on three days in a row compared to 3x12.5 m right away.** However, in the present study no significant effect of land allocation strategy on foraging behaviour was found when the three observation days per land allocation strategy were averaged. Rivero et al. (2013) who investigated European wild boars did also not find a difference between the foraging behaviour on new and old land. In their study pigs did enter the pasture of the continuous system for 5 days and in the rotational system they got access to new land every day for 5 days. A reason for that might be that the land on the continuous system was still new enough to forage on it. The present study showed no significant different effect of land allocation strategy on rooting and grazing behaviour either when it was calculated as a mean over the three observation days of the four weeks. The reason might be the same as in the study by Rivero et al. (2013). As in the present study the new land in allocation strategy 3 was just three days old on the last observation days, the land was probably still new enough to be interesting for the pigs. This might be a reason why no significant difference could be observed when the mean foraging frequencies of both allocation strategies were compared. Thus, a more pronounced difference would probably be reached when the daily allocation of land is compared to e.g. weekly allocation of land as pigs become more passive over time.

However, when the three observation days were regarded separately, differences could be observed. Grazing was in general higher in alfalfa which is due to the fact that pigs prefer grazing on alfalfa over grass as it was mentioned before (Rachuonyo et al., 2005). Grazing frequency remained relatively constant over the three observation days when pigs got access to new land on each of the three observation days, whereas grazing frequency was decreasing after the first day when pigs got access to land allocation strategy 3 (3x12 m right away). One reason for these results is probably that pigs prefer to forage on newly allotted land which has not been grazed before (Andresen and Stern, 2003) thus, the grazing behaviour in allocation strategy 3 decreased on day 2 and 3 as the land was already grazed on day 1. Another factor for the more constant grazing on land allocation strategy 1 could be the grazing habit of pigs on alfalfa. It was shown that pigs foraged the leaves of alfalfa first and left the fibrous part of the stem (Rachuonyo et al., 2005). In land allocation strategy 3, where pigs just got access to new land on observation day 1 they probably started to forage on the leaves and thus, there were less leaves left for day 2 and 3. Subsequently, grazing was more constant in land allocation strategy 1 as they got access to new alfalfa leaves every day.

In the present study grass was rooted more compared to alfalfa. In land allocation strategy 1 rooting activity increased on every observation day whereas in land allocation strategy 3 it decreased every day. This is probably again due to the fact that pigs prefer to forage in land that has not been grazed before (Andresen and Stern, 2003). However, in a former study by Rose and Williams (1983) it has been shown that a large population of earthworms was the reason for an intense rooting activity in village pigs. It has been shown that earthworms contain a considerable high amount of crude protein and lysine which can contribute to the pigs nutritional needs. If pigs consume 720 earthworms per day they have a daily crude protein intake of 29.3 g with 1.76 g of lysine (Rose and Williams, 1983). Thus, it might be that rooting in allocation strategy 1 increased every day as pigs found earthworms in the new area while in allocation strategy 3 pigs rooted the most on day 1 as earthworms on the area became less it decreased on day 2 and 3. As the memory of pigs is very good, pigs in land allocation strategy 1 probably associated new land with a high number of earthworms. The good ability of memorizing feeding places was shown by Mendl et al. (1997), who found that pigs which are used to feed in a certain location will even come back to that area after a retention time. Thus, pigs are using their memory to find feed and avoid revisiting empty areas. As they experienced rooting in new area was successful in the current experiment pigs in allocation strategy 1 were probably rooting more on day 2 and 3 as they remembered their successful rooting experience. In addition to the higher explorative activities of pigs in new land the motivation to forage is also dependent on the time budget of pigs as the expression of one behaviour limits the amount of time to perform other behaviours (Young and Lawrence, 1996). Young and Lawrence (1996) offered pigs a low or a high rate of feed reinforcement from a foraging device ('the Edinburgh Foodball') and found that a decrease in the rate of reinforcement lead to an increase in pushing and feeding frequency. Thus, pigs do have the ability to adapt to different foraging conditions and to adapt the time they spend on certain behaviours (Andresen and Redbo, 1999). This might be an explanation why pigs where grazing more constantly on alfalfa over the three observation days in land allocation type 1. As they had a lower feed allowance per observation day they spend more time on feeding compared to land allocation type 3 where pigs had access to more land. The second hypothesis of this study could not be confirmed when the three observation days were averaged. However, when the three days were regarded separately a positive effect of land allocation strategy 1 on foraging activity was found.

Excretory behaviour

There was no significant effect of land allocation strategy shown on excretory behaviour when a mean of the three observation days was analyzed. However, when the three observation days were regarded separately differences could be observed. In alfalfa pigs did not urinate at all in new land when allocation strategy 1 was used. A reason for this could be that pigs were grazing intensively during the three days and as they try to avoid getting in contact with their excretions (Pfeiler et al., n.d.). Pigs probably avoided urinating as urine might be spread on the plant leaves easily. In allocation strategy 3 they did urinate which was probably due to the larger area, thus enough alfalfa was available to take the risk to contaminate a part with urine. In grass pigs urinated in allocation type 1 as well as in type 3, this was probably because they just grazed to a low extent and therefore the risk to feed on contaminated grass was low. Explaining rooting behaviour with this approach is more difficult as rooting frequency remained high although pigs urinated in the same area. Maybe urine does have a stronger smell when excreted on plants compared to on soil and as pigs were searching for food in the soil it might be that they left over contaminated feed. However, as literature on the reason behind the excretory behaviour of pigs is lacking, this cannot be fully explained.

Defecating decreased over time in all treatments, except for land allocation type 1 in combination with grass, were pigs did not defecate on the first day. The decrease in defecating behaviour over time was probably because pigs spent more time in the new area in the beginning and thus, defecated more in the area. The relationship of time spent on a certain area and defecating behaviour was approved by Quintern (2005).

4.3 Development across weeks

Foraging activity

The increase in rooting behaviour over the four weeks is probably the result of the very good memory of pigs as it was shown in Mendl et al. (1997). As the pigs remember that more feed can be found in the new land compared to old they increased rooting in new land over the four observation weeks. Grazing remaind relatively contant, because pigs mainly grazed on alfalfa leaves and these were limited, thus, pigs could not increase grazing further.

Excretory behaviour

A reason for the lower defecating in the new area in the end of the experiment could be that pigs do not like to excrete their dung in busy areas (Baxter, 1982). As foraging behaviour was more pronounced in the last week it is possible that pigs spent more time on the new area and thus, pigs reduced defecating in the new area as it was too busy. In general pigs reduced their urinating and defecating frequency between the first and the last week of the experiment.

4.4 Conclusion

According to the EU regulations pigs have to have access to an outdoor area. However, organic growing pigs are usually kept indoors with access to concrete yards. As organic farming aims to establish sustainable farming systems with high animal welfare standards, proper pasture management strategies for pigs are urgently needed. Thus, the aim of the present study was to find suitable paddock management systems for organic growing pigs. From this study and the literature review suitable knowledge for designing paddock management systems for organic growing pigs could be obtained. It became clear that allocation of new land is a major factor to increase pasture intake as pigs clearly prefer to forage in new land which has not been grazed before. Alfalfa as forage crop and a low protein content in the supplemental feed strengthened this effect of new land. When pigs got access to new land more often a more constant grazing activity in alfalfa and an increased rooting activity in grass was observed. Thus, a more frequent allocation of new land leads to a higher pasture intake over time and should be the basis for paddock management systems. Moreover, it has been shown that pigs did not excrete more in new land although some studies found a higher excretory frequency in new land. Within the current study pigs urinated significantly less in new land. Nevertheless, from the literature review it became clear that pigs like to excrete in certain areas of the paddock, e.g. close to hut areas and avoid excreting in other areas like the feeding area. Thus, mobile equipment such as huts and feeding troughs should be used to get a more equal distribution on the free range area. To make mobile systems for growing pigs more common research on mobile fence systems is necessary. These fence systems should be easy implementable in practice to enable farmers to use mobile systems without high efforts.

5. Perspectives

The daily allocation of new land can contribute to an increased pasture intake in growing pigs. As it was shown in the present study strip grazing is a possible strategy to ensure regular access to new land. However, to achieve high pasture intakes from the free range several strategies need to be combined. As the literature review show also the forage crop and the supplemental feed need to be adapted. Moreover, defecating and urinating was also affected by allocation of new land, but pigs excreted to a much higher extent in old land. In addition, it has been shown that pigs prefer to excrete in willow zones which take up high amounts of nutrients and thus, can help to avoid nutrient leaching (Horstedt et al., 2012). Therefore, a combination of land allocation with willow zone could also be a suitable paddock management system. For getting a more equal distribution of excretory behaviour it is important that feeders, drinkers and huts are mobile as it has been shown from the literature review. It would be a good strategy to offer pigs a complete new area regularly to avoid nutrient hot-spots in the old area. Systems were pigs get access to a complete new area of land would help to increase pasture intake and get a better distribution of feaces and urine. A way to ensure that pigs get access to new land regularly is a mobile system without electric fences. Salomon et al., 2008 developed a mobile organic piggery (MOP) which is a rectangular pen consisting of 10 guardrails of steel tubing. These guardrails rest on steel runners to make a forward movement possible. The hut does have wheels to be moveable. As there are no electric fences included this MOP can be moved easily every day (Salomon et al., 2008). During the experimental period of 87 days the MOP was moved 65 times and pigs spent half of the day on grazing (Salomon et al., 2008). With this system pigs could also be cooperated easily in crop rotations as the MOP can be removed easily from the fields. At the moment there is not more literature available on similar systems. However to make outdoor systems for growing pigs more common and to reach a better distribution of nutrients on the field this is an interesting approach, although more research in the field of paddock management systems for growing pigs is required.

Acknowledgments

In particular I would like to thank my supervisor senior scientist Anne Grete Kongsted for answering all my questions and for discussions on the behaviour of pigs in personal or via Email. I am also very grateful for Anne Grete’s help and support with the programme SAS and with data preparation. I really appreciated her supervision.

Moreover, I thank Malene Jakobsen very much for conducting the main experiment, for collecting the behavioural data and also for sharing her knowledge on pig’s behaviour. I am very grateful for her remarks and helpful comments as well as for the pictures she provided.

I would also like to extend my thanks to Alina Eschkötter, Vanessa Schulz and Jonas Brauer for reading and giving helpful comments and suggestions on this thesis.

Last but not least, I thank my parents for their encouragement and support throughout my studies.

References

Andresen, N. (2000). The foraging pig. Doctoral thesis. Schwedish University of Agricultural Sciences Uppsala. *Acta Universitatis Agriculturae Sueciae. Agraria* 227.

Andresen, N.; Björklund, J.; Rydberg, T. (2000). Ecological and conventional pig production-an analysis of resource flows and environmental dependency on farm scale level. IIn: the foraging pig. Ed. Andresen, N. Doctoral thesis. Schwedish University of Agricultural Sciences Uppsala. *Acta Universitatis Agriculturae Sueciae. Agraria* 227.

Andersen, N.; Ciszuk, P.; Ohlander, L. (2001). Pigs on grassland-animal growth rate, tillage work and effects in the following winter wheat crop. *Biological Agriculture and Horticulture.* 18:327-343.

Andresen, N.; Stern. S. (2000). Performance, site preferences and foraging behavior of growing pigs on pasture in relation to feed concentrate level. In: the foraging pig. Ed. Andresen, N. Doctoral thesis. Schwedish University of Agricultural Sciences Uppsala. *Acta Universitatis Agriculturae Sueciae. Agraria* 227.

Andresen, N.; Redbo, I. (1999). Foraging behaviour of growing pigs on grassland in relation to stocking rate and feed crude protein level. *Applied Animal Behaviour Science*, *62*(2-3):183–197.

Anonymous (2008): *Håndbog i svinehold.* Landbrugsforlaget. Skejby, Aarhus. pp. 76.

Baxter, M.R. (1982). Environmental determinants of excretory and lying areas in domestic pigs. *Applied Animal Ethology* 9:195.

Benfalk, C., Lindgren, K., Lindahl, C., Rundgren, M. (2006). Mobile and stationary systems for organic pigs-animal behaviour in outdoor pens. http://orgprints.org/4313/ (last accessed 20/06/2014).

Carlson, D.; Lærke, H.N.; Poulsen, H.D.; Jørgensen, H. (1999). Roughages for Growing Pigs, with Emphasis on Chemical Composition, Ingestion and Faecal Digestibility. *Acta Agric. Scand., Sect. A, Animal Sci*. 49:129-136.

Day, J. E. L.; Kyriazakis, I.; 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.

Dierick, N.A.; Vervaeke, I.J.; Demeyer, D.I.; Decurypere, J.A. (1989). Approach to the energetic importance of fibre digestion in pigs. I.Importance of fermentation in the overall energy supply. *Anim. Feed Sci. Technol.* 23:141-167.

Edwards, P. J.; Hollis, S. (1982). The Distribution of Excreta on New Forest Grassland Used by Cattle , Ponies and Deer. *Journal of Applied Ecology 19*:953–964.

Edwards, S. A. (2003). Intake of nutrients from pasture by pigs. *Proceedings of the Nutrition Society 62*:257–265.

Eriksen, J. (2001). Implications of grazing by sows for nitrate leaching from grassland and the succeeding cereal crop. *Grass and Forage Science* 56:317-322.

Eriksen, J.; Hermansen, J. E.; Strudsholm, K.; Kristensen, K. (2006). Potential loss of nutrients from different rearing strategies for fattening pigs on pasture. *Soil Use and Management*, *22*: 256–266.

Eriksen, J.; Kristensen, K. (2001). Nutrient excretion by outdoor pigs: a case study of distribution, utilization and potential for environmental impact. *Soil Use and Management*, *17*:21–29.

European Comission (2008). European Comission Regulations (EC) No 889/2008.

European Comission (2010). An analysis of the organic sector. Directorate-General Agriculture and Rural Development.

European Comission (2013). Facts and figures on organic agriculture in the European Union. Agriculture and Rural Development.

Ferm, M. (1998). Atmospheric ammonia and ammonium transport in Europe and critical loads : a review. *Nutrient Cycling in Agroecosystems*.51:5–17.

Graves, H.B. (1984). Behavior and Ecology of Wild and feral Swine (Sus Scrofa). *Journal of Animal Sci*ence 8:482-492.

Gustafson, G.M.; Stern, S. (2003). Two strategies for meeting energy demands of growing pigs at pasture. *Livestock Production Science* 80;167-174.

Hacker, R. R.; Ogilvie, J. R.; Morrison, W. D.; Kains, F. (1994). Factors affecting excretory behavior of pigs. *Journal of Animal Science*, *72*:1455–60.

Halberg, N.; Hermansen, J.E.; Kristensen, I.S.; Eriksen, J., Tvedegaars, N. (2004). Comparative environmental assessment of three systems for organic pig production in Denmark. http://orgprints.org/15585 (last accessed 20/06/2014).

Harper, G.; Henson, S. (2001). Consumer Concerns about Animal Welfare and the Impact on Food Choice. Final Report. CeFER. EU Fair CT98-3678.

Hermansen, J.E. (2005). Integration of organic pig production into land use. In: *Organic pig production in free range systems. Eds:* Sundrum, A., Weißmann, F. Landbauforschung Völkerode, Special Issue 281.

Hermansen, J.E., Strundsholm, K., Horsted, K. (2004). Integration of organic animal production into land use with special reference to swine and poultry. *Livestock Production Science* 90:11-26.

Hodgkinson, S.M.; Cárcamo, A.; López, L. (2011). Selective grazing of *Lolium perenne* and *Plantago lanceolata* by growing European wild boar (*Sus scrofa L.*) in a semi-extensive system. *Livestock Science* 140:268-274.

Horsted, K.; Kongsted, A. G.; Jørgensen, U.; Sørensen, J. (2012). Combined production of free-range pigs and energy crops - animal behaviour and crop damages. *Livestock Science* 150:200-208.

Hovi, M., Sundrum, A., Thamsborg, S. M. (2003). Animal health and welfare in organic livestock production in Europe: current state and future challenges. *Livestock Production Science* 80:41–53.

Høøk Presto, M.; Andersson, H.K.; Wallgren, P.; Lindberg, J.E. (2007). Influence of dietary amino acid on performance, carcass quality and health of organic pigs reared indoors and outdoors. *Acta Agriculturae Scan. Section A* 57:61-72.

IFOAM (2002). IFOAM Norms. II. IFOAM Basic Standards for organic production and processing. International Federation of Organic Movements. Tholey-Theley, Germany.

Jakobsen, M.; Kongsted, A.G.; Hermansen, J.E. (2014). Organic growing pigs in pasture systems-effect of feeding strategy and cropping system on foraging activity, nutrient intake from the range area and pig performance. Not published yet.

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

Jensen, M.B.; Kyriazakis, I.; Lawrence, A.B. (1993). The activity and straw directed behaviour of pigs offered foods with different crude protein content. *Applied Animal Behaviour Science* 37:211-221.

Kanga, J.S.; Kanengoni, A.T. (2012). Estimating pasture intake and nutrient digestibility of growing pigs fed a concentrate-forage diet by n-alkane and acid-insoluble ash markers. *Trop. Animal. Health Prod.* 44:1797-1802.

Kongsted, A.G.; Hermansen , J.E. (n.d.). Organic pig production-with particular reference to Danish production conditions. http://orgprints.org/6457/ (last accesses 23/06/2014).

Kongsted, A.G.; Horsted, K.; Hermansen, J. E. (2013). Free-range pigs foraging on Jerusalem artichokes (*Helianthus tuberosus L.*) – Effect of feeding strategy on growth, feed conversion and animal behaviour. *Acta Agriculturae Scan. Anima. Sci.* 63(2): 76-83.

Kosaric, N.; Cosentino, G. P.; Wieczorek, A.; Duvnjak, Z. (1984). The Jerusalem Artichoke as an Agricultural Crop. *Biomass*, *5*:1-36

Laister, S.; Konrad, S. (2005). Behaviour, performance and carcass quality of three genotypes of growing-finishing pigs in outdoor pig production in Austria: A pilot study. In: *Organic pig production in free range systems. Eds:* Sundrum, A., Weißmann, F. Landbauforschung Völkerode, Special Issue 281.

Lund, V. (2006). Natural living — a precondition for animal welfare in organic farming. *Livestock Science* 100: 71–83. doi:10.1016/j.livsci.2005.08.005.

Martin, P; Bateson, P. (2007). Measuring Behaviour. An introductory guide. Cambridge University Press. Cambridge, UK. pp.176.

Mendl, M.; Laughlin, K.; Hitchcock, D. (1997). Pigs in space: spatial memory and its susceptibility to interference. *Animal Behaviour* 54:1491-1508.

Meynhardt, H. (1982), Schwarzwildreport. Mein Leben mit Wildschweinen. Radebeul. 169.

Mollet, Wechsler (1991), Auslösende Reize für das Koten und Harnen bei Hausschweinen. KTBL-Schrift 344 1990/9.1

Mowat, D.; Watson, C.A.; Mayes, R.W., Kelly, H.; Browning, H.; Edwards, S.A. (2001). Herbage intake of growing pigs in an outdoor production system. Proceesings of the British Society of Animal Science. Annual Meeting 169, York, UK.

Novak, S. M.; Fiorelli, J. L. (2010). Review article Greenhouse gases and ammonia emissions from organic mixed crop-dairy systems : a critical review of mitigation options. *Agron. Sustain. Dev.* 30:215–236.

Olsen, A.W.; Dybkjær, L.; Simonsen, H.B. (2001). Behaviour of growing pigs kept in pens with outdoor runs II.Temperature regulatory behaviour, comfort behaviour and dunging preferences. *Livestock Production Science* 69:265-278.

Petherick, J.C. (1982). A note on the space use for excretory behaviour of suckling piglets. *Applied Animal Ethology* 9 (1982/83): 367-371.

Pfeiler, U. (n.d.). Ergebnisse zur Untersuchung zur Bodenbelastung bei der Freilandhaltung von Schweinen. Dissertation, Humboldt-Universität, Berlin.

Quintern, M. (2005). Integration of organic pig production within crop rotation: Implications on nutrient losses In: *Organic pig production in free range systems.* Eds.: Sudrum, A.; Weißmann, F., Special Issue 281.

Quintern, M.; Sundrum, A. (2006). Ecological risks of outdoor pig fattening in organic farming and strategies for their reduction—Results of a field experiment in the centre of Germany. *Agriculture, Ecosystems and Environment*, 117: 238–250.

Rachuonyo, H. A.; Allen, V. G.; McGlone, J. J. (2005). Behavior, preference for, and use of alfalfa, tall fescue, white clover, and buffalograss by pregnant gilts in an outdoor production system. *Journal of Animal Science* 83:2225-2234.

Rivera Ferre, M.G.; Edwards, S.A.; Mayes, R.W.; Riddoch, I.; DeB. Hovel, F.D. (1999). Grass utilization by outdoor sows in different seasons measured by the n-alkane technique. In: *Ecological Animal Husbandry in the Nordic Countries.* DARCOF. Eds.: Hermansen, J.E.; Lund, V.; Thuen, E.

Rivero, J.; López, I.; Hodgkinson, S. (2013). Pasture consumption and grazing behaviour of European wild boar (*Sus scrofa L*.) under continuous and rotational grazing systems. *Livestock Science 154*:175–183.

Rose, C.J.; Williams, W.T. (1983). Ingestion of earthworms, *Ponoscolex Corethrurus* by village pigs, *Sus Scrofa Papuensis*, in the Highlands of Papua New Guinea. *Applied Animal Ethology* 11:131-139.

Rotz, C.A. (2004). Management to reduce nitrogen losses in animal production. *Journal of Animal Science* 82:E119-E137.

SAS institute (2013). SAS/STAT © 9.3 User's Guide. Institute Inc. http://support.sas.com/documentation/cdl/en/statug/63962/HTML/default/viewer.htm#titlepage.htm (last accessed 23/06/2014).

Salomon, E.; Åkerhielm, H.; Lindahl, C.; Lindgren, K. (2007). Outdoor pig fattening at two Swedish organic farms—Spatial and temporal load of nutrients and potential environmental impact. *Agriculture, Ecosystems & Environment*, 121:407–418.

Salomon, E.; Andresen, N.; Gustafsson, M.; Nyman, M.; Ringmar, A.; Tersmeden, M. (2008). Development of a mobile organic piggery for outdoor pork production- function, productivity, animal behaviour and environmental risk assessments. 16th IFOAM Organic World Congress, Modena, Italy, June 16-20, 2008.

Sehested, J.; Søegaard, K.; Danielsen, V.; Kristensen, V.F. (1999). Mixed grazing with sows and heifers: effects on animal performance and pasture. In: *Ecological Animal Husbandry in the Nordic Countries*. DARCOF. Eds.: Hermansen, J.E.; Lund, V.; Thuen, E.

Sommer, S.G.; Søgaard, H.T.; Møller, H.B.; Morsing, S. (2001). Ammonia volatilization from sows on grassland. *Atmospheric Environment* 35:2023-2032.

Stern, S.; Andresen, N. (2003). Perdormance, site preferences, foraging and excretory behaviour in relation to feed allowance of growing pigs on pasture. *Livestock Production Science* 79:257-265.

Stolba, A.; Wood-Gush, D. G. M. (1989). The behaviour of pigs in a semi-natural environment. *Animal Production*, *48*(02): 419–425.

Studnitz, M.; Jensen, M. B.; 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.

Wiegand, R. M.; Gonyou, H. W.; Curtis, S. E. (1994). Pen shape and size: effects on pig behavior and performance. *Applied Animal Behaviour Science*, *39*:49–61.

Williams, J. R., Chambers, B. J., Hartley, a. R., Ellis, S., & Guise, H. J. (2000). Nitrogen losses from outdoor pig farming systems. *Soil Use and Management*, *16*(4): 237–243.

Worthington, T.R.; Danks, P. W. (1992). Nitzrate leaching and intensive outdoor pig production. *Soil Use and Management*, *8*(2):56–60.

Young, R.J.; Lawrence, A.B. (1996). The effects of high and low rates of food reinforcement on the behaviour of pigs. *Applied Animal Behaviour Science* 49:365-374.

Zihlmann, U.; Weisskopf, P.; Menzi, H.; Ingold, U. (1997). Bodenbelastung durch Freilandschweine. *Agrarforschung* 4:459-462.

Pictures on the front page were provided by Malene Jakobsen.

Statutory Declaration

I herewith declare that I composed my thesis submitted independently without having used any other sources or means than stated therein.

Aarhus, 1st of July 2014

Juliane Helmerichs

Appendix I

Rooting, grazing, defecating and urinating frequency as a mean of two observation days per m² per paddock and block with allocation strategy 1= 1x12.5 m on three days in a row vs. 3=3x12.5 m right away (1 vs. 3), land status (old vs. new land) and cropping system alfalfa vs. grass (alf vs. gr).

Paddock	Block	Allocation strategy	Land status	Feed	Crop	Rooting (m^2)	Grazing (m^2)	Defecating (m^2)	Urinating (m^2)	Foraging (m^2)
1	1	1	new	LP	alf	1.13	0.41	0.01	0.00	1.55
1	1	3	new	LP	alf	1.69	0.51	0.03	0.01	2.20
2	1	1	new	HP	alf	0.77	0.73	0.01	0.00	1.51
2	1	3	new	HP	alf	0.89	0.73	0.03	0.01	1.63
3	1	1	new	HP	gr	1.05	0.04	0.01	0.01	1.09
3	1	3	new	HP	gr	1.19	0.12	0.07	0.01	1.31
4	1	1	new	LP	gr	1.60	0.07	0.03	0.01	1.67
4	1	3	new	LP	gr	2.63	0.11	0.00	0.01	2.73
5	2	1	new	LP	gr	2.56	0.33	0.00	0.00	2.89
5	2	3	new	LP	gr	1.12	0.13	0.07	0.00	1.25
6	2	1	new	HP	gr	1.03	0.15	0.01	0.03	1.17
6	2	3	new	HP	gr	0.51	0.03	0.03	0.03	0.53
7	2	1	new	HP	alf	0.41	0.59	0.01	0.00	1.00
7	2	3	new	HP	alf	0.87	0.33	0.01	0.01	1.20
8	2	1	new	LP	alf	2.39	0.81	0.00	0.00	3.20
8	2	3	new	LP	alf	1.47	0.40	0.00	0.00	1.87
9	3	1	new	HP	alf	0.89	0.49	0.03	0.00	1.39
9	3	3	new	HP	alf	0.76	0.67	0.00	0.01	1.43
10	3	1	new	HP	gr	0.73	0.03	0.00	0.04	0.76
10	3	3	new	HP	gr	0.65	0.01	0.01	0.01	0.67
11	3	1	new	LP	gr	2.52	0.15	0.04	0.01	2.67
11	3	3	new	LP	gr	2.16	0.09	0.01	0.00	2.25
12	3	1	new	LP	alf	1.33	0.72	0.01	0.00	2.05
12	3	3	new	LP	alf	1.99	0.56	0.03	0.01	2.55

1	1	1	old	LP	alf	0.20	0.07	0.02	0.00	0.28
1	1	3	old	LP	alf	0.07	0.08	0.01	0.01	0.16
2	1	1	old	HP	alf	0.08	0.03	0.02	0.02	0.11
2	1	3	old	HP	alf	0.11	0.07	0.01	0.01	0.19
3	1	1	old	HP	gr	0.12	0.06	0.02	0.01	0.18
3	1	3	old	HP	gr	0.08	0.06	0.02	0.01	0.14
4	1	1	old	LP	gr	0.35	0.03	0.02	0.01	0.38
4	1	3	old	LP	gr	0.28	0.04	0.01	0.02	0.32
5	2	1	old	LP	gr	0.21	0.07	0.01	0.01	0.28
5	2	3	old	LP	gr	0.45	0.04	0.02	0.02	0.49
6	2	1	old	HP	gr	0.07	0.03	0.02	0.02	0.10
6	2	3	old	HP	gr	0.22	0.05	0.03	0.02	0.26
7	2	1	old	HP	alf	0.09	0.05	0.01	0.02	0.14
7	2	3	old	HP	alf	0.07	0.02	0.02	0.02	0.10
8	2	1	old	LP	alf	0.09	0.02	0.02	0.02	0.10
8	2	3	old	LP	alf	0.09	0.02	0.02	0.02	0.11
9	3	1	old	HP	alf	0.15	0.07	0.02	0.03	0.22
9	3	3	old	HP	alf	0.09	0.06	0.03	0.03	0.15
10	3	1	old	HP	gr	0.08	0.04	0.02	0.02	0.12
10	3	3	old	HP	gr	0.28	0.03	0.00	0.02	0.31
11	3	1	old	LP	gr	0.15	0.04	0.02	0.02	0.19
11	3	3	old	LP	gr	0.27	0.09	0.03	0.04	0.35
12	3	1	old	LP	alf	0.24	0.04	0.03	0.01	0.29
12	3	3	old	LP	alf	0.11	0.06	0.03	0.00	0.18