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The more the merrier? The effect of group size on welfare, production results and carcass traits in fattening pigs

Oda Braar Wæge
Animal science – Breeding and genetics

Forord

Det er mange momenter i livet som symboliserer personlig utvikling. For meg var det når mamma gikk fra å sende videoer av hester til å sende videoer av griser. Dette ble videre solidifisert når en tilfeldig mann kalte meg en «svinehvisker» mens jeg klødde en ullgrisråne på hodet. Denne oppgaven er dermed et forsøk på å teste denne mannens teori.

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Oda Braar Wæge

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Abstract

Pigs in a commercial setting find themselves in group sizes that deviate from what is observed in the wild. Production pigs also lack the ability to regulate group size in accordance to available resources as they would do in the wild. Consequently, exploring the effect of group size on the quality of life of pigs has an inherent importance to achieve and maintain good animal welfare. The aim of this study was to examine the difference in welfare indicators, production results and carcass traits for pigs held in groups of 9 or 18 pigs with equal stocking density. The welfare data was collected from Felleskjøpets experimental farm in Øyer (n = 16 pens; n = 216 pigs) the day after arrival, after six weeks and after 9 weeks using the NMBU welfare protocol. The experiment was a two-by-two factorial design with group size (9 vs. 18 pigs) and feeding strategy (restrictive vs. *ad libitum*) as independent variables. The protocol included measurements for pig- and pen cleanliness, human-fear, tail position, health, and lesions. The production results, and carcass traits were collected from the abattoir. All data was collected and analysed on a pen level. The results show that small groups had more lesions on the body, ears, and tail, but had regardless more curly tails and showed more heterospecific contact seeking compared to pigs in large groups. Heterospecific contact seeking, number of curly tails, ear lesions and pig filthiness increased over time for both group sizes. Tail lesions however, increased for small groups and decreased for large groups over time suggesting a difference in their experience of stress and available space. For the production results only an increased number of feeding days for large groups was observed as an effect of group size. *Ad libitum* feeding had however a significant positive effect on both slaughter weight and daily weight gain compared to restrictively fed pigs. The results suggest that increasing group size, given the pigs get ample resources, may be an effective tool for decreasing aggression and frustration in fattening pigs without drastically hampering production results.

Sammendrag

Griser i et konvensjonelt system befinner seg ofte i grupper som avviker i størrelse fra hva som er observert i naturen. Disse produksjonsgrisene har heller ikke mulighet til å selv regulere gruppestørrelsen etter hva som passer ressursgrunnlaget. Å analysere effekten av gruppestørrelse på grisers livskvalitet har derfor en høy egenverdi, og kan være viktig for å oppnå og opprettholde god dyrevelferd. Målet med denne studien var å undersøke forskjellen mellom griser i grupper på ni mot 18 gris med lik dyretetthet ved å sammenligne velferdsindikatorer, produksjonsresultater og kjøttprosent. Velferdsdataene var samlet hos Felleskjøpets feltvert i Øyer (n = 16 binger; n = 216 griser) dagen etter innsett, etter seks uker og etter ni uker ved hjelp av NMBU sin velferdsprotokoll. Det eksperimentelle designet var en to-ganger-to latinsk kvadrat med gruppestørrelse (9 vs. 18)) og fôringsstrategi (*ad libiutm* vs. restriktiv) som uavhengige variabler. Protokollen inkluderte mål på grise- og binge renhet, menneskefrykt, haleposisjon, helse og sår. Produksjonsdataene var hentet fra slakteriet. All data ble samlet og analysert på bingenivå. Resultatene viste at små grupper hadde mer sår på kroppen, ørene og halen, men viste fortsatt mer krøllete haler og var mer menneskesøkende. Hvor menneskesøkende grisene var, antall krøllete haler, øresår og hvor skitne grisene var økte over tid for begge gruppestørrelsene. På en annen side økte antall halesår for små grupper, og falt for store grupper over tid. Dette kan bety at grisene hadde en forskjellig opplevelse av stress og tilgjengelig plass. Store grupper hadde flere fôringsdager enn små grupper, og dette var den eneste effekten gruppestørrelse hadde på produksjonsresultater. *Ad libitum* fôring påvirket både slaktevekt og daglig tilvekst positivt sett opp mot restriktiv fôring. Resultatene antyder at gruppestørrelse kan være et verktøy for å redusere aggresjon og frustrasjon hos slaktegris uten å drastisk påvirke produksjonsresultater.

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1. Introduction

The five freedoms were proposed by '*The Brambell report*' (1965), and are the first attempt at developing a definition animal welfare. However in recent years it has been suggested that relying on the five freedoms alone does not incentivise the accommodation of rewarding behaviours (FAWC, 2009; Mellor, 2016). In 2001 the paper '*A concept of welfare based on reward evaluating mechanisms in the brain: anticipatory behaviour as an indicator for the state of reward systems'* (Spruijt et al., 2001) proposed welfare to be a balance between rewarding and aversive events and their effect on an animal's experience of their situation. Further the value of positive welfare was set into focus in *'Farm Animal Welfare in Great Britain: Past, Present and Future'* (FAWC, 2009), where they presented the concept of including Quality of Life with using the three levels: 'A life not wort living', 'a life worth living' and 'a good life'. Having Quality of Life as a part of evaluating animal welfare might be essential for the future, as members of the public's perception of belief in animal mind (BAM) solidify. BAM is a term for how we attribute animals mental capabilities such as intellect, the ability to reason and the feelings of emotion. Vigors et al. (2021) found in their study that members of public with a higher BAM score had a higher likelihood of putting a larger importance on the ability to perform natural behaviour when compared to the importance of health. This can make it more correct to use a standardized measurement of welfare that both include health and natural behaviour.

The Welfare Quality project is an European project with the goal of standardizing the assessment of animal welfare (Welfare Quality®, 2009). The welfare protocols developed in this project set them self apart from older assessment protocols by focusing on animal-based measurements. This means that criteria such as correct temperature should be measured not only with a thermometer but also alongside behaviour such as huddling or panting. Welfare Quality's protocols base themselves on the four principles: good feeding, good housing, good health, and appropriate behaviour. This creates a foundation for comparing the quality of life between different management systems. It is therefore important to include a holistic, and species-specific set of measurements when evaluating the effect of different social environments on animal welfare. The welfare quality protocol is estimated to take 5.5 hours to perform, this can make the protocol unrealistic to apply outside of an academic setting (Welfare Quality®, 2009). Evaluating shorter protocols can for this reason be important to achieve a realistic implementation of welfare assessments in a farm's day to day care routine.

All species of farm animals used today are social animals who in nature form social groups. Social groups create both costs and benefits for the individual, making groups sizes in the wild naturally regulated (Estevez et al., 2007). Some of the benefits of living in a social group are anti-predation from dilution, higher likelihood of observing the predator and less energy per animal spent on vigilance. Many social species are also found to benefit from the effect of social support or social buffering were one or more social partners can lower the stress response of an individual experiencing negative stimuli (Reimert et al., 2014). As reviewed by Kikusui et al. (2006) social buffering can be the presence of other individuals decreasing the stress level of an individual during an adverse situation, sooth stressed animals after a negative experience and the secretion of soothing chemical cues. Examples of this are Rhesus monkeys that encountered a novel environment in pairs had a lower cortisol response compared to the monkeys alone, stressed rats sought out conspecific animals to potentially improve their situation or gain neurochemical rewards, and in pigs the pheromone androstenone, secreted from the peripheral region of lactating nipples, is shown to reduce agnostic behaviour within groups of unfamiliar pigs (McGlone et al., 1986). This makes the social environment a potential factor for regulating behaviour in production animals.

While food distribution and predation pressure are the elements most thoroughly examined it has also been hypothesized that cognitive ability is a limiting factor for group size (Lehmann et al., 2007). In larger groups, a high cognitive ability is important for monitoring social behaviour, coordination of foraging strategies, as well as for recognition of individuals and their place in the hierarchy, or others' reproductive status. (reviewed by Croney & Newberry, 2007). The need for a high cognitive ability for social interactions is also supported by Pérez-Barbería and Gordon (2005), who found that brain size, adjusted for body mass, was most affected by gestation length and gregariousness (living in groups larger than six animals) across ungulate species. It is especially the size of the neocortex that has been observed to correlate with group size in primates, carnivores, bats, and dolphins. Having a strong cognitive ability might both be a result of, and consequently a important trait to thrive in larger social groups and can therefore be an important tool for establishing stable hierarchies to reduce injurious aggression.

As reviewed by Camerlink et al. (2020), in situations with competition an aggressor has an evolutionary benefit from gaining or reclaiming resources necessary for survival. For wild boars and domestic pigs these disputes are often solved with threats and withdrawals, but can escalate to physical altercations resulting in skin lesions and death (Rushen & Pajor, 1987). Physical aggression and fights are rare and is mainly seen between boars during the mating season. The cost of aggressive interactions puts the individual in a position where depending on the abundance and distribution of resources, in relation to the group size, different foraging and social strategy are optimal (Estevez et al., 2007).

What an animal deems an optimal strategy can be exploited to reduce the risk for aggression in a herd. An environment with deficient resources with a low distribution will reward individuals able to partake in intense competition to achieve monopolization (Estevez et al., 2007). This being an optimal strategy is mainly dependent on group size, were too many animals competing for the same resource will increase the cost of monopolizing. This leads to the tolerance hypothesis were individuals in larger groups will show less aggressive behaviour and not develop a linear hierarchy due to the cost of maintaining it (Estevez et al., 2007). This has been observed in chickens where multiple studies have shown that smaller groups create more instances of aggression (Croney & Newberry, 2007). With larger group sizes, given that there is adequate accessibility to the resources, a form of scramble competition should be a more optimal strategy as observed in hens (Estevez et al., 2002).

In the wild, the social structure for pigs (*sus scrofa*) consists of stable matrilineal groups with several generations of related sows and their offspring, while the adult boars live in solitary (Gabor et al., 1999; Graves, 1984; Kaminski et al., 2005). In Texas the average observed group size was 3.9 ± 0.5 pigs, with the largest observed groups consisting of 28 pigs (Gabor et al., 1999). Another study carried out in the Italian national park "Cilento e Vallo de Diano" found an average of 4.14 ± 0.21 pigs per group, and the largest group observed being 12 animals (Maselli et al., 2014). The same study also found that group size varied throughout the year, with the smallest groups in the winter and the largest in the summer. This shows that the pigs can adjust group sizes when the resources are limited. In juxtaposition with its wild counterparts fattening pigs do not have the freedom to adjust their groups sizes according to what is ideal in their current environment. Internationally the number of pig per pen varies from 6 to more than 100, but there is a preference for 10 to 40 individuals per pen (Street & Gonyou, 2008). When the group dynamics in captivity varies from what is observed in the wild to this degree it is of interest to examine the effect group size has on animal welfare.

The main bodies of work exploring the effect of group size in pigs have generally focused on aggression and production traits. These traits are both important for economic sustainability and can be relatively simple to register compared to behaviours like play, which happen sporadically. For aggression the consensus is that larger groups, where the ratio of resources to pigs is the same, have a lower frequency of aggressive interactions (Andersen et al., 2004; Misra et al., 2021; Nielsen et al., 1995; Samarakone & Gonyou, 2009; Street & Gonyou, 2008; Turner et al., 2001). It should be noted that the definition of what is a large group varies in these studies from 24 to 108 individuals. Andersen et al. (2004) observed in their study that going from 6 or 12 pigs to 24 pigs had the most significant drop in aggression. The largest group was also observed after three hours to have a lesser proportion of pigs participating in aggression compared to the smaller groups. The increase in group size seems to force pigs to adapt to a different social strategy as the cost of dominance and monopoly rises. The reduction in fights is of economic importance due to lesions decreasing carcass quality and the relation between decline in weight gain and increased need for immune response (Driessen et al., 2020).

The effect different environments have on production traits is always of interest due to its financial consequences. What group sizes a producer chooses to design and build their facilities for can for this reason come down to what is most economically efficient. Turner et al. (2000) compared group sizes of 20 and 80 and found that larger groups had 0.048kg lower average daily weight gain (ADG). A similar result was found by Street and Gonyou (2008) that compared 18 vs 108 pigs, and found larger groups to have 0.035kg lower ADG. Misra et al. (2021) found the same effect when comparing groups of 12, 24, and 48 pigs, but also found larger groups to also have a lower average daily feed intake (ADFI), but no differences in feed conversion ratio (FCR). In contrast Nielsen et al. (1995) found no evidence for difference in ADFI, ADG or FCR between groups of 5,10,15, or 20 pigs. They argued that there should not be an adverse effect on performance if the animals are given enough space and ad libitum feeding. They observed under these conditions that pigs in larger groups adjusted their forage strategy to have fewer but longer visits at a single space feeder. This change in foraging strategy is also observed in the study from Boumans et al. (2018). How group size affects performance can be dependent on other aspects such as stocking density, feeder space and an increase in locomotion due to increased pen size.

Modern pig production is a comparatively barren and restrictive environment compared to what pigs would experience in the wild. This has caused some stereotypic and agnostic behaviours such as bar biting, tail biting, ear biting and vulva biting (Cox & Cooper, 2001; Lyons et al., 1995). Tail biting has been a high focus issue due to its ability to cause serious infections and pain to the animal (Schrøder-Petersen & Simonsen, 2001). Tail biting has traditionally been solved with tail docking as a part of the management routine in the rest of Europe, whereas this is banned in Norway, Sweden, and Switzerland. In the EU legislation it has been stipulated since 1994 that tail cropping should not be preformed routinely unless all other measures have first been taken to prevent tail biting (De Briyne et al., 2018). However as tail biting is a complex issue making it nearly impossible to prevent most piggeries perform tail docking on piglets. The European Union is still trying to phase out tail docking, making the knowledge of how to treat the causation of tail biting, rather than the symptoms highly relevant (Nalon & De Briyne, 2019).

In relation to how group size affect tail biting both Moinard et al. (2003) and Schmolke et al. (2003) found that there was no effect of group size on the prevalence of tail biting. These two are some of the only examples to our knowledge of studies exploring the effect of group size, and as reviewed by Valros (2021) there is not much more done on the subject of frustration.

In a semi-natural environment pigs are found to split their time in daylight into 21% rooting, 31% grazing and 23% exploring their enclosure (Reviewed by Zwicker et al., 2013). However, in a conventional system each feed intake bout is reduced to 10 minutes in restrictive system, drastically opening time for exploration. Expanding possible feed-time by implementing *ad libitum* feeding has been shown to reduce exploratory behaviour towards both enrichment and the pen. The reduced need for exploratory behaviour can be calming for the pigs and reduce the development of into abnormal oral behaviour such as ear- tail and bar biting (Reviewed by Zwicker et al., 2013).

Ad libitum feeding has also been shown to potentially reduce the amount of aggression at mixing (Arey & Edwards, 1998; Kelley et al., 1980). Quiniou et al. (2012) also found more skin lesions in restrictive fed immunocastrated boars. They also found restrictive feeding to reduce average daily weight gain, but it gave no difference in feed conversion ratio. The *Ad libitum* fed pigs had more backfat that the restrictively fed pigs, there was however no difference in lean meat content. Stahly and Wahlstrom (1973) found that pig fed ad libitum had a higher end weight, higher daily weight gain but had a worse feed conversion ratio. Pig genetics and body composition have most likely changed since 1973, and the production result may differ if the experiment was repeated with modern pig genetics. Arguing that the *ad libitum* feeding strategy should be the preferable setup may therefor not be applicable for all breeds of pig.

Positive welfare behaviours and its relation to group size is another aspect of pig production where little is done. One example is Camerlink et al. (2022) where they observed that the frequency of allogrooming went up with age and group size for weaner pigs. When looking at other production animals the lack of data is equally present. A study by Færevik et al. (2007) observed in calves that larger groups (16 calves) resulted in less aggression, animals lying closer together and showing more social behaviour toward acquainted calves. The results may indicate that calves in larger groups will spend more time maintaining established relationships. Abdelfattah et al. (2013) observed on the other hand no difference in play, social contact, and aggression between different group sizes of 2, 4 and 8 calves per pen. For goats, groups of 24 showed both less positive and negative social behaviour compared to groups of 12 animals (Andersen et al., 2011). The same study argued the lack of change in group size may indicate a dynamic nature of the social interactions. There is with other words conflicting data so far and a need for more exploration of the effect of group size on positive behaviours.

The aim of this study was to examine the effect of group size on welfare indicators, production results and carcass traits in pigs throughout the fattening period. Based on previous studies I predict that the frequency of body and ear lesions will be lower for the larger groups due to the increasing cost of aggression, there will be observed equal levels of tail lesions due to being a multifactorial problem and no significant difference in daily weight gain, slaughter weight and meat percentage.

2. Material and Method

2.1. Pigs, housing, and management

This study was a part of a larger project, Griseløftet, which is an industry-owned project. Nortura is the project owner and Norsvin, Felleskjøpet, and Norwegian University of life sciences (NMBU) are project partners. The experiment was conducted at Felleskjøpets experimental farm in Øyer, Norway. A total of 216 DDZL (Duroc x TN70) grower-finisher pigs were housed in pens with partially slatted floors. Each pen consisted of 50% sows and 50% castrated boars. The pigs were divided into 16 pens of two group sizes and two feeding systems giving 4 different treatments. The group sizes were 9 (n = 8 pens) and 18 pigs (n = 8 pens). They were fed with dry feed in either an *ad libitum* automatic feeder (n = 8 pens) or restricted feeding in a trough (n = 8 pens), equally distributed between both group sizes. Feed was formulated to contain 9,68 MJ/kg and 0,87 g SID lysine/kg. In the pens with restricted feeding the pigs had 34cm feeder space per pig and got an average of 3 kg feed a day distributed across three feedings. The pig to drinking nipple ratio was 9 to 1 in all groups.

The pens were 3.05m by 6.80m for the groups of 18 pigs (1.15m^2/pig, Figure 1, A). The pen had an anti-slip epoxy coated concrete solid floor, and a 2m wide slatted section in the middle. For groups of 9 pigs the pen was split in two by a diagonal gate across the slats giving a 3.1m by 3.4m area (1.15m^2/pig, Figure 1 B). They were weighed at arrival and at the abattoir. This gives 1.6 kg/m^2 at the start of the experiment, and an estimated 6.7 kg/ m^2 by the end of the experiment. The temperature was 20-22 C° at arrival and decreased to 16-17C° by the end of the finishing period. The pigs had access to natural light through windows along the south facing wall, and only got additional artificial lighting during the management routine.

The pigs were given sawdust as bedding material in the resting area, followed by provision of rooting material twice a day. In the morning the pigs got a fistful of hay, and in the evening, they got either hay, newspapers, bark, or large high fibre pellets with 80% beet pulp (Felleskjøpet Format Trivsel). The pigs had access to a small rubber tire hanging from a chain as additional enrichment. During the daily care routine, some pigs were let out into the walking area between pens to facilitate both easier handling in the future and give the pigs an opportunity for extra activity and to move more freely on a weekly basis.

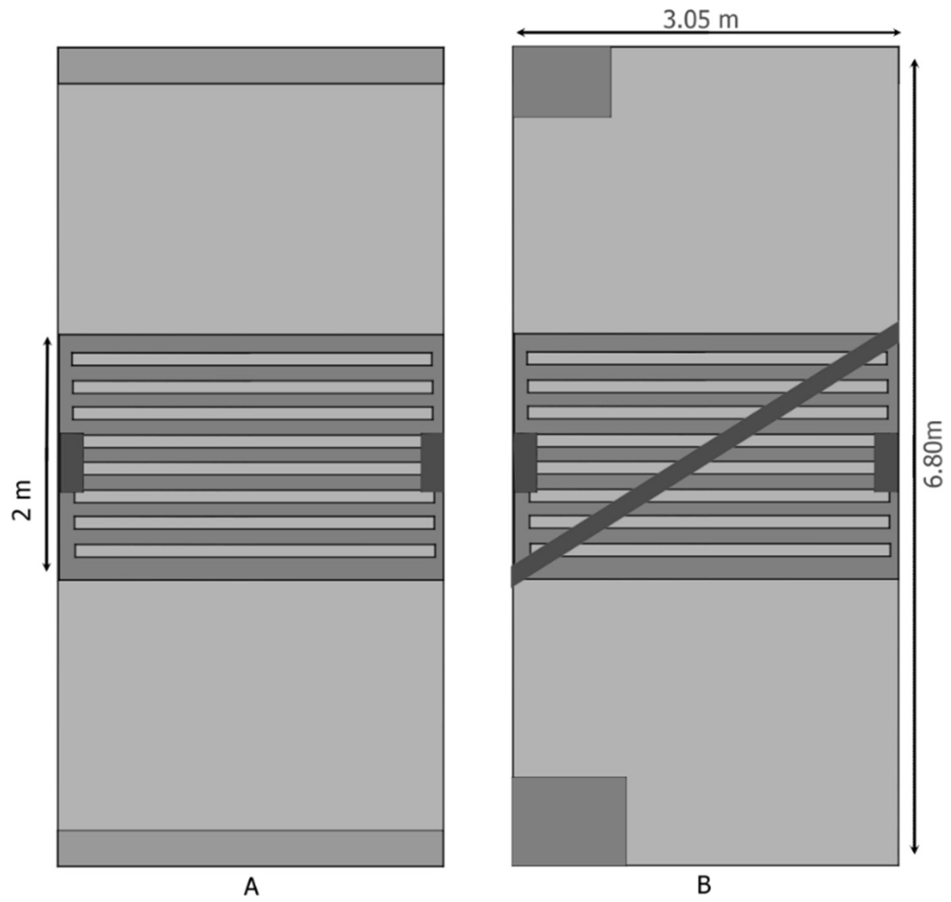

Figure 1 : Example of two out of four pen setups. A) Large pen with the restricted feeding trough; B) Small pens with automatic feeders. The two last pen setups are large pen with automatic feeder, and small pens with troughs

Figure 2. Picture of a large pen with restricted feeding.

2.2.Protocol for welfare indicators

The welfare of the pigs was registered according to the NMBU welfare protocol at the day after arrival, six weeks after arrival, and days before first group was sent to the abattoir (Table 1). The protocol was design with the goal of spending less than 90 minutes per herd for a complete welfare assessment, meaning that while it would be relevant to include more measurements, they were dropped to fit the assessment within the mentioned timeframe. This experiment was performed between October and December. During the data collection the observer entered the pen by opening the gate inward while holding a fistful of hay. After 5 seconds the hay was dropped and the number of pigs belonging to the different confidence levels were counted. While the pigs were standing, we counted the pig tails according to the position (straight down, curled, wagging). The pigs have to be standing since straight tails on lying pigs is not necessarily correlated to mental state (reviwed by Camerlink & Ursinus, 2020). Using the last eight points in the protocol the state of the pen and the pigs were registered before repeating the procedure in the next pens.

Oral manipulation and tail biting, and their relation to frustration, negatively affects welfare, thus making the threshold for what classifies as tail biting low in our protocol. Based on figure 3 all tails with small bites were deemed mild tail biting, and all tails shortened and/or covered in one or more wounds were classified as severe.

Table 1: Welfare protocol used to evaluate the animal welfare of a pig herd within 90 minutes.

Welfare criteria	score	Description
Fear-test	1	Flees immediately away with its whole body, and wants a large distance to the observer
	2	Moves head/ front half and/or takes a few steps away from the observer
	3	Shows no visible response/ remains standing or continues their behaviour
	4	Shows no visible response / remains standing but tries interacts with observer after some hesitation
	5	Tries to interact with observer immediately
Tail position	1	Straight tail – Tail hangs down along the hind legs while the pig is standing
	2	Curly tail – The tail is curled outwards and/or upwards on a standing pig
	3	Wagging - The tail is moving rapidly from side to side while the pig is standing
Amount of bedding material	1	Nothing
	2	Small amounts – little bedding material on the solid floor, with visible flooring through the litter
	3	Moderate amounts – bedding material distributed across the solid floor, with smaller part of the floor visible through the litter
	4	Large amounts – bedding material distributed over the entire solid floor, no visible floor
Cleanliness pens	1	0 ≥ 10% of the area with solid floor is wet and/or covered with manure
	2	> 10 ≥ 40% of the area with solid floor is wet and/or covered with manure
	3	> 40% of the area with solid floor is wet and/or covered with manure
Cleanliness pigs	1	0 ≥ 10 % of the body is covered with manure
	2	> 10 ≤ 40% of the body is covered with manure
	3	> 40 % of the body is covered with manure
Movement disorders	1	Some loss of mobility, slight stiffness
	2	Severe loss of mobility, severe lameness, or problems with walking or standing
Hernia	0	The pig does not have a hernia
	1	The pig has a hernia
Body lesions	1	A few lacerations/lesions
	2	Lacerations/lesions on multiple locations
	3	Lacerations/lesions covering most of the body
Tail lesions	1	Red bite/puncture marks, but the tail is not damaged
	2	Bleeding wound, short tail, or damaged tail
Ear lesions	1	Some red lesions after being bitten
	2	Red lesions covering the ears with red marks or healed over marks after bites

Figure 3 : Examples of tail biting. in: B. Forkman and L. Keeling (eds), Assessment of Animal *Welfare Measures for Sows, Piglets and Fattening Pigs*, Welfare Quality Reports No. 10, Cardiff University, 2009

2.3.Data collected

Human fear test

29.5 % of the pigs had no response when a human observer entered the pen (score 3). 18.7% pigs initially showed no interest but came over to the observer after some time (score 4), and 51.9% of the pigs showed immediate interest and interacted with the human observer (score 5). Since both score 3 and 4 represent some neutrality towards the human observer they were combined for the statistical analysis. Fleeing (score 1) and avoidance (score 2) were not observed and excluded from the study.

Tail positions

95.5% of the pigs had curly tails (score 2) throughout the experiment, while 2% had straight tails, and 2.5 had wagging tails. Wagging and straight tails had 15 and 12 total observations; thus, we excluded the data from statistical analysis.

Cleanliness

The amount of bedding material was held constant throughout the experiment making it irrelevant to analyse. The pigs were mainly clean with score 1 getting on average 92%. Moderately dirty pigs (score 2) had 7% of the observations and severely dirty pigs (score 3) had 1%. Severely dirty pigs were excluded from analysis.

The pens were clean (score 1) 55.3% of the time, moderately dirty (score 2) 44.7% of the time, and never observed to be severely dirty (score 3).

Health

Movement disorders were observed a total of 12 times throughout the experiment and was not included in further analyses. Hernias were observed in 1.6% of all observations.

Lesions

Out of all the observations 38.9% of ears had moderate lesions (score 1) and 14.9% of ears had severe lesions (score 2). 14.3% of tails had mild lesions (score 1) and 3% of tails had severe lesions (score 2). 15.9% had mild body lesions (score 1), 21.8% had moderate body lesions (score 2) and 7.15% had severe body lesions (score 3).

Production results

The pigs were sent to the abattoir on four different days due to multiple random variables such as price, pen space and what time was convenient, thus creating an unfortunate situation where half the small groups were slaughtered after on average ca.85 days, while the other half after ca.88 days. For the large groups it was split between half of the pens being slaughtered after an average of 88 days and the other half after 90 days. There was no opportunity to weigh the final live weight at a standardized timepoint before slaughter. In Norway the slaughter weight represents the weight of the carcass after the head, legs and innards are removed and is estimated to be approximately 68% of the live weight (Fatland, 2020), this constant was used for estimating the final live weight. All slaughter data was registered on a pen level.

2.4. Unforeseen events

Due to the location of the slats, and lack of adequate ventilation above the slats the larger pens had problems with cleanliness and needed more regular cleanings compared to the smaller pens. Three pigs were taken out of the study.

2.5.Data analysis

Statistical analyses were conducted using R version 4.1.2 (2021-11-01) in RStudio version 2021.09.1+372. The effect of group size on the welfare variables was estimated using a general linear model with a weighted binomial distribution:

i. $$l(P(Y = y_{jkm})) = \beta_0 + \beta_1 G_j + \beta_2 W_k + \beta_3 F_m + \beta_4 G_j W_k$$

$$l = \log\left(\frac{p}{1-p}\right))$$

Where Y_{jkm} is the proportion of pigs classified as the relevant welfare indicator, β_0 in the intercept estimator for all pens, β_1 is the general regression for group size (G) j, β_2 represents the general regression for Week (W) k, β_3 is the regression for feeding strategy (F) m, and β_4 is the regression for the interaction between group size j and week k. To compare the group means, Tukey's honest significance test was used.

The effect of groups size and feeding strategy on production and carcass traits were estimated using general linear model with gaussian distribution:

ii.
$$y_{jm} = \beta_0 + \beta_1 G_j + \beta_2 F_m + \varepsilon_{jk}$$
$$\varepsilon_{jk} \sim N(0, \sigma)$$

Here y_{jk} is the predicted value for a pen with group size j and feeding strategy k. β_0 is the intercept estimator for all pens, β_1 is the general regression for group size (G) j, β_2 represents the general regression for feeding strategy (F) m. Tukey's honest significance test was also applied here to compare group means.

2.6.Ethical considerations

The experimental situation was comparable to normal commercial routines and the strain from being included was low enough not to need permission from the Norwegian Food Safety Authority (*Forskrift om bruk av dyr i forsøk*, 2015).

3. Results

3.1. Welfare indicators

There was no effect of restrictive vs. *ad libitum* feeding, and no interactions between feeding strategy and group size for any of the welfare indicators.

3.1.1. Effect of group size – model i

Group size affected some of the welfare indicators (Table 2, Figure 4). Pigs in larger groups showed less contact seeking behaviour towards a novel, human observer, and had fewer observed curly tails compared to the smaller group. The total number of observed ear and tail lesions were significantly more frequent in the smaller groups (Table 2). The subgroups of the lesion classifications were only significant for moderate ears lesions, severe mild tail lesions and moderate body lesions (Table 2), showing groups of 18 pigs to have less observed lesions.

Table 2: The effect of group size on proportion of pigs registered for the different indicators

	Small groups	**Large groups**		
	Mean% (SE)	Mean% (SE)	F (1, 43)	P
Contact seeking	68.0 (2.3	44.4 (3.7)	29.9	<0.001 ***
Curly tails	91.7 (1.5)	88.3 (2.8)	0.8	<0.001 ***
Clean pigs	86.1 (3.0)	91.5 (1.4)	1.9	0.216
Moderately dirty pigs	9.7 (1.9)	5.6 (0.9)	3.3	0.093
Moderate ear lesions	44.9 (2.9)	35.8 (3.1)	4.9	0.043 *
Severe ear lesions	17.6 (3.4)	13.5 (2.8)	2.1	0.184
Total nr. of ear lesions	62.5 (4.4)	49.3 (5.4)	18.4	<0.001 ***
Mild tail lesions	25.5 (2.5)	8.7 (1.4)	21.3	<0.001 ***
Severe tail lesions	4.6 (1.1)	2.1 (0.5)	2.8	0.120
Total nr. of tail lesions	30.1 (2.4)	10.8 (1.4)	26.4	<0.001 ***
Mild body lesions	13.8 (3.1)	19.1 (2.8)	1.5	0.222
Moderate body lesions	30.6 (4.7)	17.3 (3.6)	9.5	0.003 *
Severe body lesions	6.0 (1.6)	7.7 (1.8)	0.7	0.389
Total nr. of body lesions	48.6 (6.2)	42.8 (6.2)	3.8	0.072

Signif. code: '***' $p < 0.001$, '**' $P < 0.01$, '*' $P < 0.05$, SE = standard error

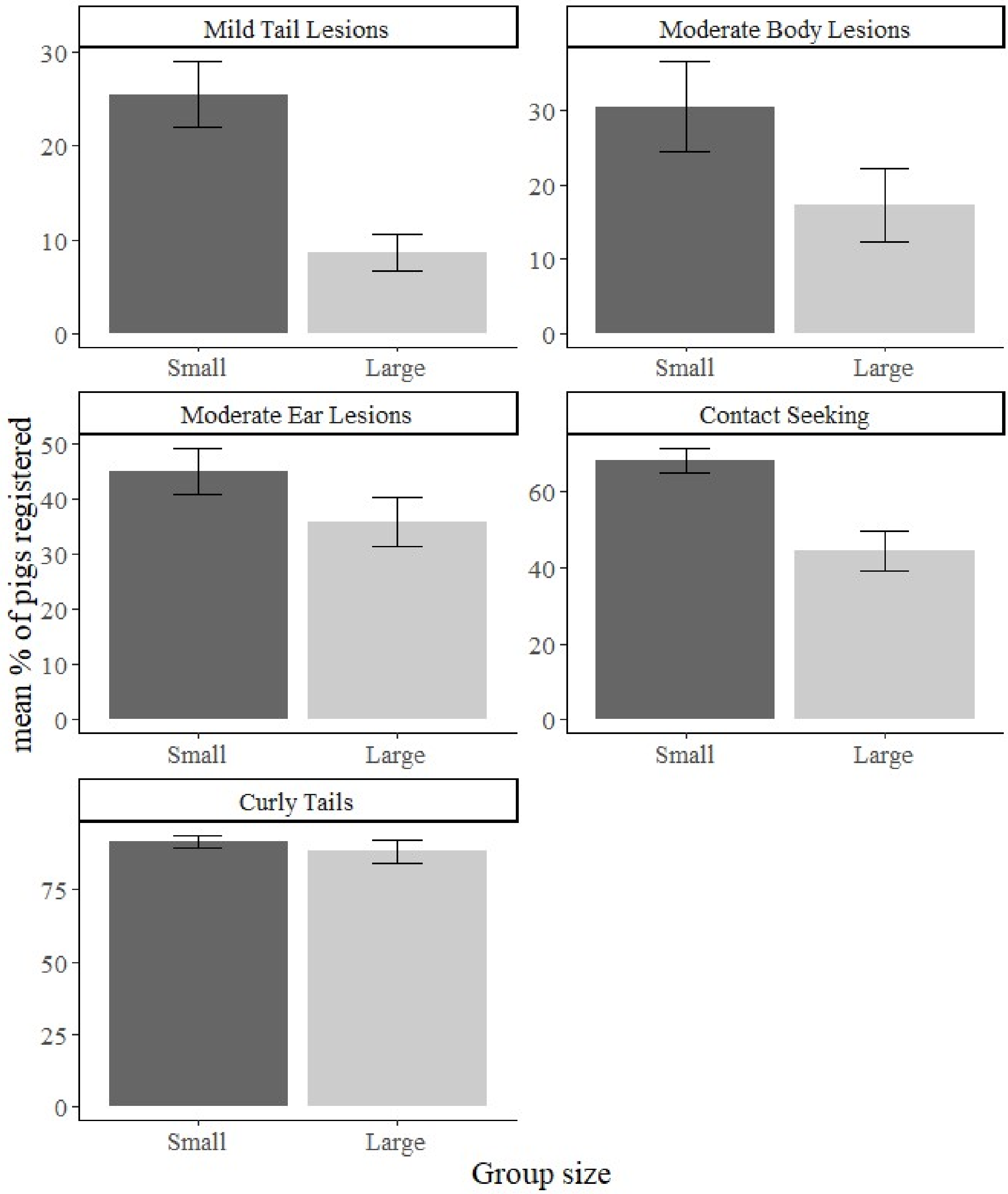

Figure 4 Mean percentage of pigs within the different welfare indicators significantly affected by group size (9 vs 18 pigs) in pens with constant stocking across all timepoints.

3.1.2. Effect of time – model i

The proportion of pigs observed in the different categories changed over time (Table 3, Figure 5). The changes were significant for most of the categories beside hernias, total tail lesions and severe tail lesions (Table 3).

Table 3 : The effect of week of observation on the percentage of pigs in observed in the different welfare indicators.

	Week 1	Week 6	Week 9			
	Mean%(SE)	Mean%(SE)	Mean%(SE)	F	P	
Contact seeking	34.7 (6.3)	61.2 (4.0)	72.7 (3.3)	29.9	< 0.001	***
Curly tails	75.5 (4.7)	95.8 (1.7)	98.6 (0.9)	19.6	< 0.001	***
Clean pigs	98.3 (1.4)	82.9 (2.5)	85.3 (5.8)	5.5	0.007	**
Moderately dirty pigs	1.7 (1.4)	15.4 (2.4)	5.9 (2.4)	11.1	< 0.001	***
Moderate ear lesions	55.5 (3.3)	45.1 (4.5)	20.5 (3.6)	34.1	< 0.001	***
Severe ear lesions	42.1 (3.4)	4.5 (2.8)	0.0 (0.0)	105.6	< 0.001	***
Total nr. of ear lesions	97.6 (1.5)	49.6 (3.8)	20.5 (3.6)	262.5	< 0.001	***
Mild tail lesions	16.7 (3.3)	10.1 (2.5)	24.4 (5.2)	4.0	0.026	*
Severe tail lesions	2.5 (1.0)	5.9 (2.0)	1.8 (0.8)	1.5	0.237	
Total nr. of tail lesions	19.1 (3.4)	16.1 (3.7)	26.1 (5.0)	2.1	0.137	
Mild body lesions	24.2 (6.0)	24.4 (4.1)	0.7 (0.7)	12.3	< 0.001	***
Moderate body lesions	55.0 (5.4)	16.7 (3.9)	0.0 (0.0)	60.0	< 0.001	***
Severe body lesions	20.6 (3.0)	0.0 (0.0)	0.0 (0.0)	54.7	< 0.001	***
Total nr. of body lesions	99.7 (0.3)	36.7 (4.7)	0.7 (0.7)	438.3	< 0.001	***

Signif. code: '***' p < 0.001, '**' P < 0.01, '*' P < 0.05, SE = Standard Error

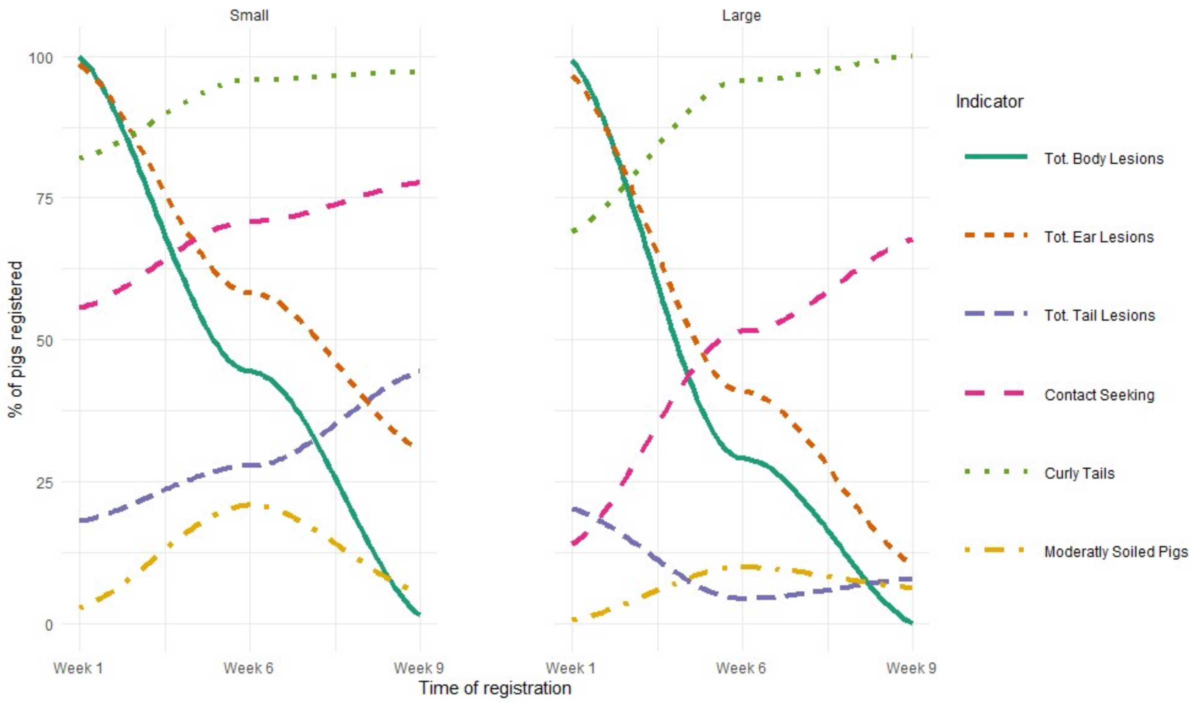

Figure 5 Percentage of pigs registered in the distinct categories for large (n = 18) and small (n = 9) groups across the three different days of observation. Body, ear, and tail bites show the summed number of mild, moderate, and severe occurrences.

3.1.3. Effect of interaction between group size and time – model i

Significant interactions between group size and day of observation were observed for contact seeking, total nr. of ear lesion, and mild, severe, and total nr. of tail lesions (Table 4). Frequency of total nr. of ear lesions went down for both group sizes over time (Figure 6). Both total and mild tail lesions were most frequent in larger groups for the first week but changed to the smaller groups showing more lesions on the sixth and ninth observation week. Severe tail lesions were most frequent in large groups on the first and especially second day of observation. On the final day of observation, the moderate tail lesions were more frequent in the larger groups. Contact seeking went up for both group sizes over time, but the difference between the two treatments grew smaller by the end of the experiment.

Table 4: The effect of interaction between group size and time. Mean percentage of pigs registered in the various categories for large (n = 18) and small (n = 9) groups across the three different days of observation

	Small groups			**Large groups**			**Group size x Time**		
	Week 1	**Week 6**	**Week 9**	**Week 1**	**Week 6**	**Week 9**			
	Mean% (SE)	Mean% (SE)	Mean% (SE)	Mean% (SE)	Mean %(SE)	Mean% (SE)	F	P	
Contact seeking	55.6 (5.6)	70.9 (5.5)	77.8 (3.0)	13.9 (3.8)	51.5 (3.5)	67.7 (5.5)	5.6	0.007	**
Curly tail	81.9 (3.6)	95.8 (2.9)	97.2 (1.8)	69.1 (8.4)	95.7 (1.8)	100.0 (0.0)	1.6	0.219	
Clean pigs	97.2 (2.8)	77.8 (4.2)	83.3 (11.1)	99.3 (0.7)	88.0 (1.3)	87.2 (4.7)	0.4	0.695	
Moderately dirty pigs	2.8 (2.8)	20.8 (3.9)	5.6 (4.2)	0.7 (0.7)	9.9 (1.0)	6.3 (2.7)	2.7	0.082	
Moderate ear lesions	54.2 (5.7)	50.0 (8.4)	30.6 (4.6)	56.7 (3.8)	40.2 (3.4)	10.5 (2.2)	2.7	0.081	
Severe ear lesions	44.4 (6.3)	8.3 (5.5)	0.0 (0.0)	39.8 (3.1)	0.7 (0.7)	0.0 (0.0)	0.6	0.531	
Total nr. of ear lesions	98.6 (1.4)	58.3 (5.5)	30.6 (4.6)	96.5 (2.8)	40.9 (3.2)	10.5 (2.2)	3.8	0.031	*
Mild tail lesions	15.3 (5.9)	18.1 (2.9)	43.1 (3.3)	18.1 (3.4)	2.2 (1.1)	5.7 (1.9)	18.6	< 0.001	***
Severe tail lesions	2.8 (1.8)	9.7 (3.3)	1.4 (1.4)	2.1 (1.0)	2.2 (1.5)	2.1 (1.0)	3.2	0.050	
Total nr. of tail lesions	18.1 (6.3)	27.8 (3.6)	44.4 (3.0)	20.2 (3.3)	4.3 (2.2)	7.8 (1.9)	15.5	< 0.001	***
Mild body lesions	18.1 (9.4)	22.0 (7.0)	1.4 (1.4)	30.4 (7.5)	26.7 (4.7)	0.0 (0.0)	0.7	0.515	
Moderate body lesions	63.9 (6.6)	27.8 (4.7)	0.0 (0.0)	46.0 (7.8)	5.7 (2.7)	0.0 (0.0)	2.7	0.080	
Severe body lesions	18.1 (4.7)	0.0 (0.0)	0.0 (0.0)	23.1 (3.9)	0.0 (0.0)	0.0 (0.0)	0.7	0.523	
All body lesions	100.0 (0.0)	44.4 (7.9)	1.4 (1.4)	99.3 (0.7)	29.0 (3.8)	0.0 (0.0)	3.0	0.063	

Signif. code: '***' p < 0.001, '**' P < 0.01, '*' P < 0.05, SE = Standard Error

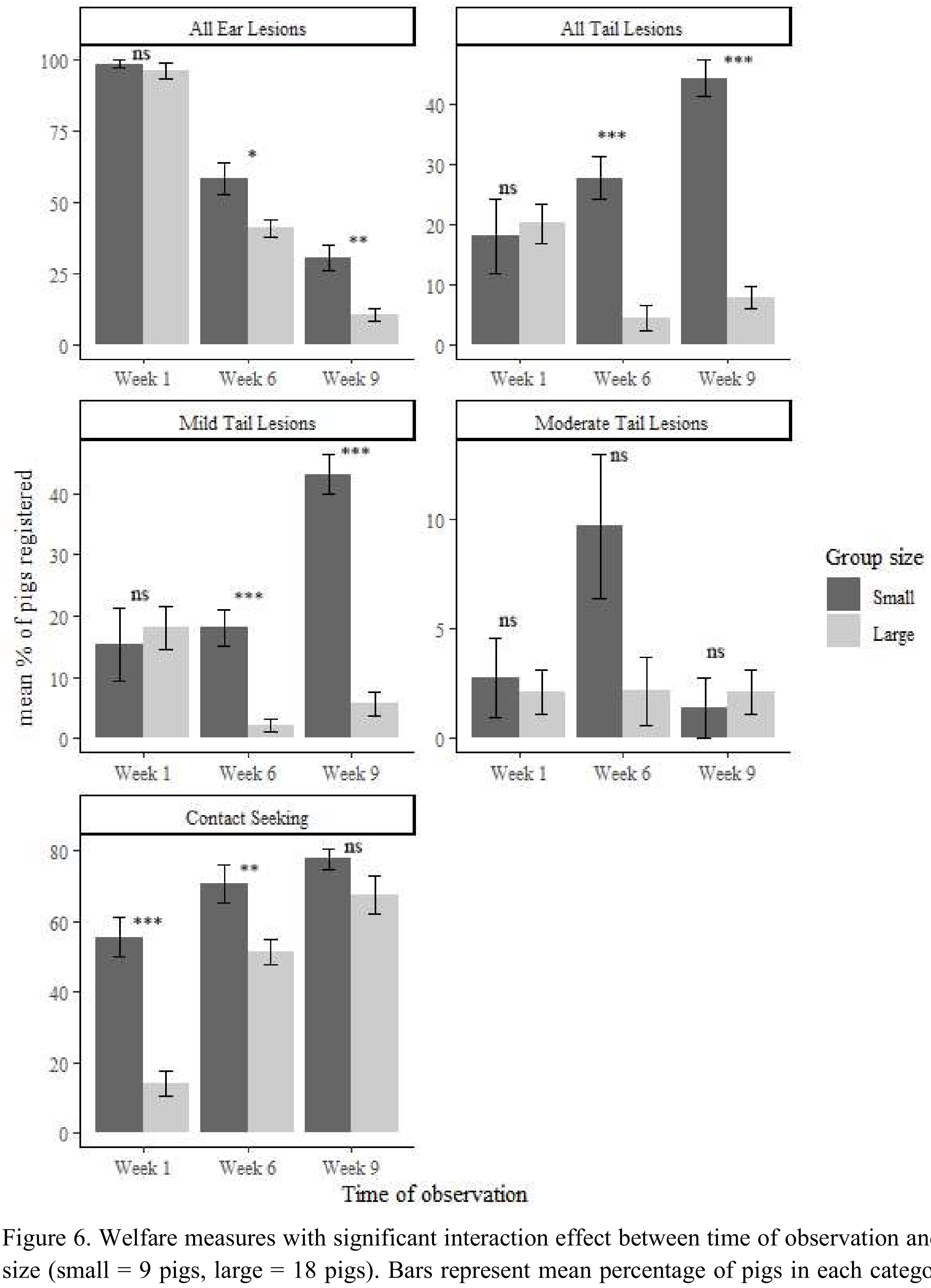

Figure 6. Welfare measures with significant interaction effect between time of observation and group size (small = 9 pigs, large = 18 pigs). Bars represent mean percentage of pigs in each category with Standard Error indicated. Significant difference between large and small group shown with ‘ns’ P > 0.05, ‘*’P < 0.05, ‘**’ P < 0.01, ‘***’ P < 0.001

3.2.Production and carcass traits

There was no interaction between group size and feeding strategy.

3.2.1. Effect of group size – model ii

There were significantly more feedings days in the large groups compared to the small groups (Figure 7 A), however group size did not significantly affect the other production results or carcass traits (Table 4, Figure 7).

Table 4: The effect of group size (9 vs 18 pigs) with a stocking density of 1.15m^2/pig on production traits

	Small groups	Large groups	Group size		
	Mean (SE)	Mean (SE)	T	P	
Meat Percentage (%)	59.1 (0.2)	59.7 (0.3)	1.0	0.322	
Slaughter weight(kg)	93.5 (0.7)	95.5 (0.7)	1.9	0.087	
Nr. Of feeding days	85.6 (0.8)	88.8 (0.2)	2.9	0.011	*
Est. final live Weight(kg)	137.5 (1.0)	140.4 (1.0)	1.9	0.087	
Daily weight gain(g)	1222.0 (12.0)	1210.7 (11.7)	-0.8	0.432	
FCR	2.4 (0.0)	2.4 (0.0)	0.0	0.994	

Signif. code: '***' P < 0.001, '**' P < 0.01, '*' P < 0.05, SE = Standard Error, FCR = Feed conversion ratio

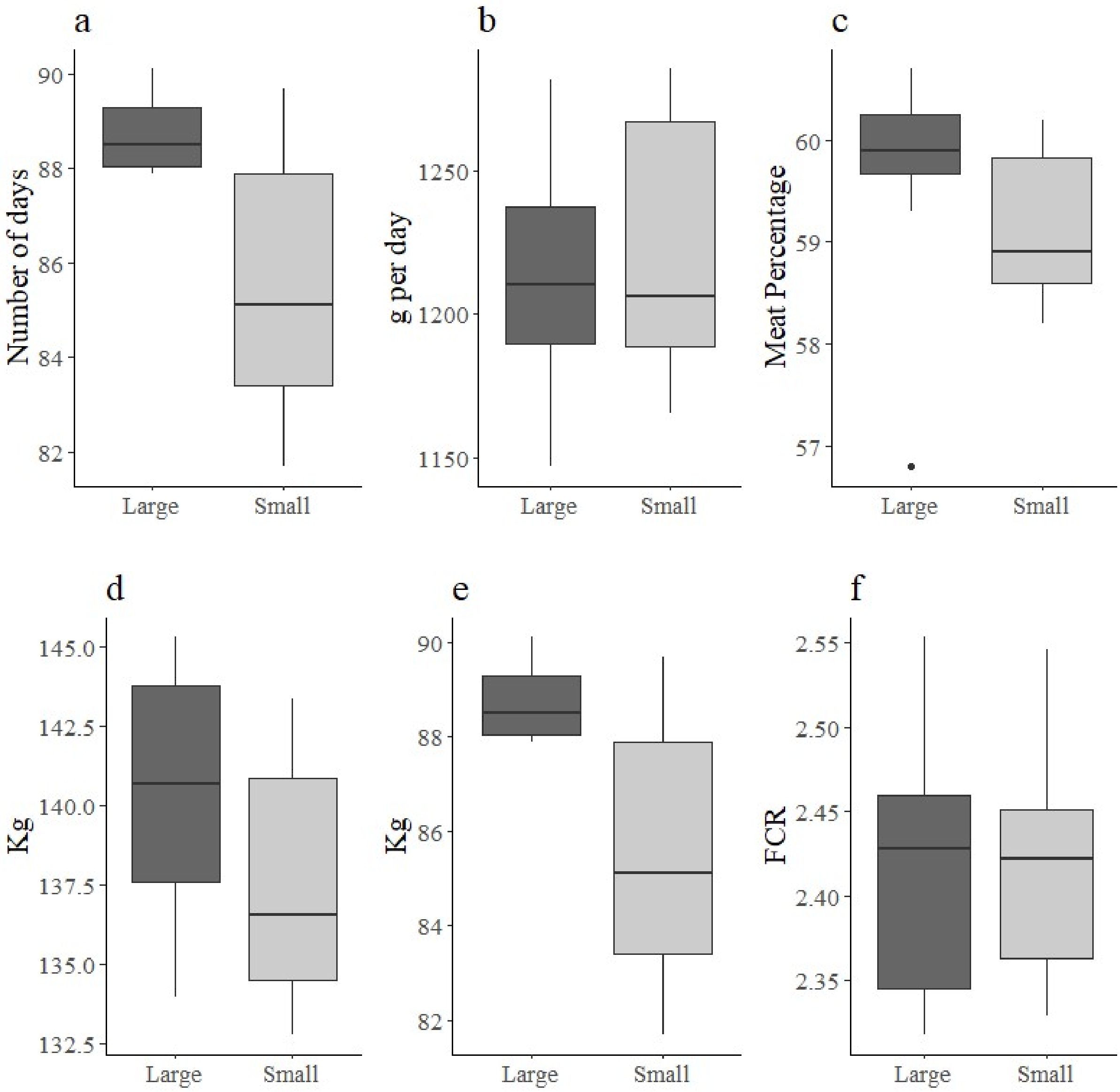

Figure 7. Performance variables for large (n = 18) and small (n = 9) groups of pigs. a) Nr. Of feeding days, b) Daily weight gain, c) Meat percentage, d) Estimated final live-weight, e) Slaughter weight f) feed conversion ratio (FCR)

3.2.2. Effect of feeding strategy – model ii

Feeding strategy significantly affected slaughter weight, estimated final live weight and daily weight gain (Table 5, Figure 8). *Ad libitum* feeding resulted in heavier pigs and a higher daily weight gain compared to pigs fed restrictively.

Table 5: The effect of ad libitum vs. restrictive feeding on production traits

	Ad libitum	Restricted	Effect	
	Mean (SE)	Mean (SE)	T	P
Meat Percentage (%)	59.6(0.2)	59.3(0.3)	-0.8	0.417
Slaughter weight(kg)	96.2(0.7)	92.8(0.5)	-3.2	0.007**
Fattening period(days)	86.3(0.8)	88.1(0.5)	1.7	0.109
Est. final live Weight(kg)	141.5(1.0)	136.4(0.7)	-3.2	0.007**
Daily weight gain(g)	1252.8(7.5)	1179.9(6.2)	-5.2	<0.001***
FCR	2.4(0.0)	2.4(0.0)	0.5	0.637

Signif. code: '***' P < 0.001, '**' P < 0.01, '*' P < 0.05, SE = Standard Error, FCR = Feed Conversion Ratio

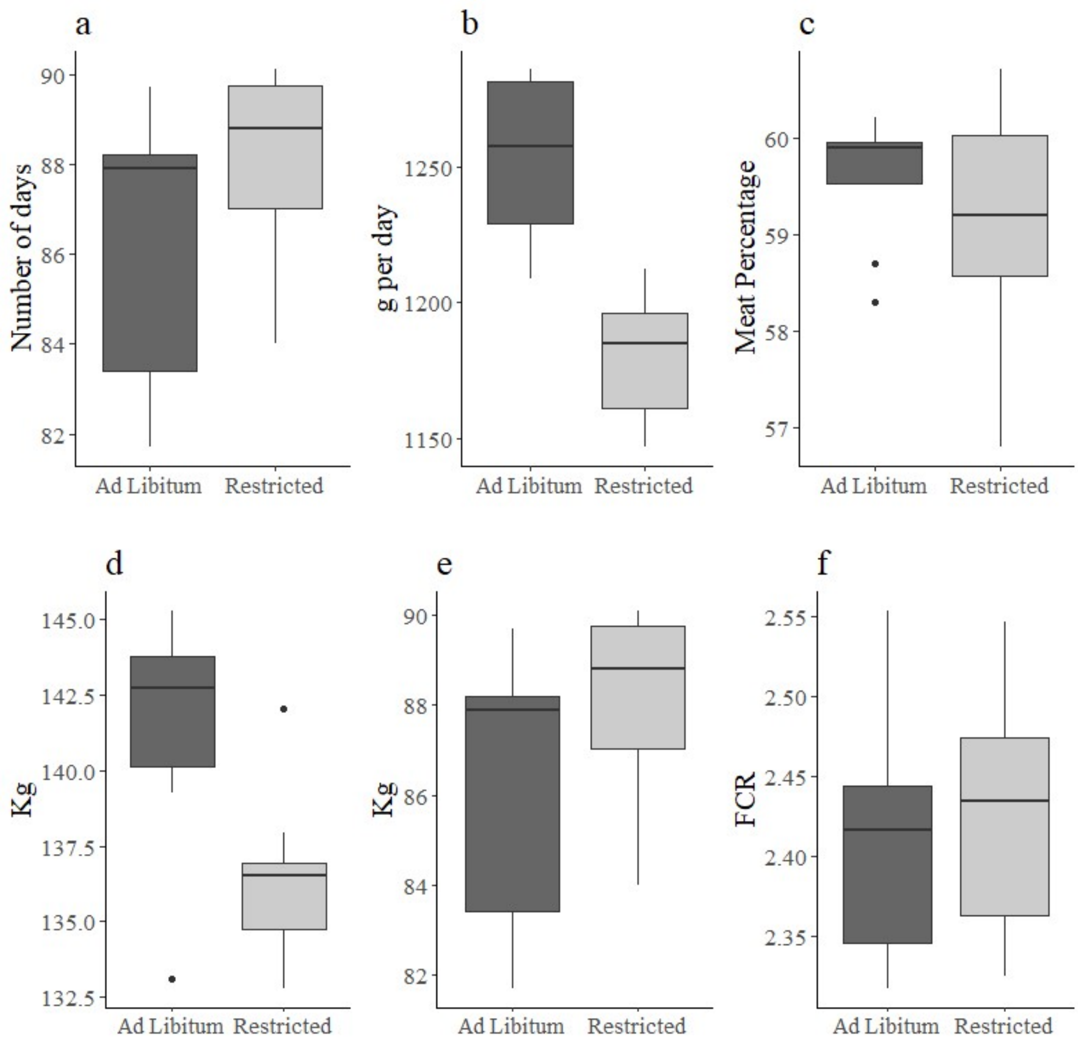

Figure 8. Performance variables for *Ad libitum* (9 pigs per feeder) and restrictive feeding (34cm feeder space per pig). a) Length of finishing period, b) Daily weight gain, c) Meat percentage, d) Estimated final live-weight, e) Slaughter weight, f) Feed conversion ratio (FCR)

4. Discussion

The aim of this study was to examine the effect of groups size on welfare indicators in grower-fattening pigs throughout the fattening period. The experiment demonstrates that group size may have the ability to affect the stability of a social group and the nature of their interactions, without inhibiting production results, given the pigs have access to ample resources. The method was based on pen level welfare assessment as well as slaughter data. The results show that group size affects welfare indicators, with smaller groups having more interest in the human observer and more frequent curly tails, but also have more tail, ear, and body lesions. For the production results the smaller group have slightly fewer feeding days. Beside this group size does not affect the slaughter weight, final live weight, daily weight gain, feed conversion ratio or meat percentage. This suggest that increasing groups size for grower-fattening pigs might be an efficient tool for reducing aggression if the pigs are given adequate resources.

Pigs in smaller groups interact more with the novel human observer compared to pigs from larger groups. As the weeks progress, both groups have an increased interest in the observer with the larger groups having a more drastic change in interest. An animal being reluctant to interact with a stimulus can both indicate fear or indifference. For this experiment there is a case to be made for the reluctance to interact originating in indifference and not fear, as fleeing or showing avoidance behaviour was not observed. The larger group having more disinterested pigs might stem from the increased social stimuli caused by having more pen mates and subsequently decreasing the social motivation.

While pen cleanliness is constant for both groups in the present study, pig cleanliness is however affected by time and is the lowest at week three and gets a slight increase by the final week. The effect of time and the unfortunate situation of larger groups defecating in one of the two lying areas can all be a result of suboptimal pen design. Over time as the pigs become larger the lying area may become insufficient in size for the pigs to feel comfortable to rest at the same time. Both wild and domestic pigs are shown to trend towards rest synchronization (Robert et al., 1987), which can suggest that the reason one of the lying areas became a designated area for defecation is that the pigs preferred to lie together as one group. This may make one larger lying area more ideal reducing the possibility of pigs lying on the slats compared to the current split.

Curly tails are correlated to with positive stimuli, and is argued to represent a pleasant state of mind (Camerlink & Ursinus, 2020). For this study smaller groups show a higher frequency of curly tails than in larger groups. For both group sizes the percentage of curly tails increase over time. The results suggest that pigs in smaller group sizes have a more positive experience of their situation when compared to their counterparts in the larger groups. A secondary explanation may be the observer, as a form of novel stimuli, might cause a stronger response in small groups as an effect of less social enrichment compared to the large group. The increase over time can be explained by both the pigs being more comfortable in their environment transport and mixing are high stress events with increased aggression (Peden et al., 2018). Positive reinforcement where human presence is associated with provision of enrichment might also explain the higher level of curly tails during the assessment period.

Multiple studies have found larger groups sizes to either not affect the prevalence of tail biting (Moinard et al., 2003; Schmolke et al., 2003; Valros, 2021) or significantly increase it (Valros, 2021). This does not coincide with the present experiment as the results show larger groups to have lower levels of lesions to the tail. Aggressive interactions are primarily directed towards the head, neck, and shoulders of pigs (Turner et al., 2006), making it natural to associate tail lesions with tail biting. Tail biting is a multifactorial problem where different elements in the environment can affect to what degree the problem is observed. Valros (2021) did however not deem lack of social stimuli a risk factor for tail biting. As pig per pen is the only difference between the two groups the results may indicate that social stimuli is also a relevant factor for understanding tail biting. In dairy calves' social deprivation is shown to enhance oral behaviour towards objects, themselves and other calves (Abdelfattah et al., 2013). This may indicate a need for a greater understanding of the effect of social stimuli.

An unexpected result is larger groups getting fewer tail lesions the ninth week compared to the first week, and smaller groups having an increasing prevalence of lesions over the same period. Walker and Bilkei (2006) argued that the lack of a stable hierarchy may affect the incidence of tai biting due to the increase in social stress. This might show that the larger groups experience less social stress. Further support is found in the review by Schrøder-Petersen and Simonsen (2001), who write that tail biting should be discouraged by stable hierarchies as elements disturbing the peace may increase the experienced frustration. In the present study this may explain the decrease in tail biting over time for the larger group as less aggression is also observed for this treatment.

Having an increasing frequency of tail biting is expected as the relative stocking density increases as the pigs gain more weight (Valros, 2021).Beside stocking density, the total available space is larger for big groups, this increased possibility for movement may affect the odds of observing tail biting, and as McGlone and Newby (1994) argued, the amount of total free space might also increase for larger groups as pigs prefer synchronized resting. An additional positive element of the larger pens is two separated feeders and lying spaces. As reviewed by Valros (2021) tail biting often occurs around the feeder, and having two at opposite ends of the pen might give the pigs the ability to separate from the group when eating, and reducing the pressure around one resource. The pigs subjective experience of group density and ability to disperse at feeding may hence be factors explaining the increased frustration for small groups compared to larger groups.

As predicted the frequency of body and ear lesions is lower for the larger groups and decreases for both groups over time. Lesions to the body correlates to bouts of aggression (Peden et al., 2018), making the results coincide with previous studies where larger groups sizes reduces the frequency and length of aggressive bouts, and further supports the tolerance theory (Andersen et al., 2004; Estevez et al., 2007). A reduction in aggression over the fattening period can be explained by hierarchies stabilizing after mixing, removing the need for aggressive behaviours around limited resources. The reduction in aggression is important for pig welfare as signs of stress is observed to significantly increase after intra-group aggression (Norscia et al., 2021).

Group size does not have a significant effect on any production results beside the number of feeding days. The pigs were sent to the abattoir at different days, with all the smaller groups leaving before the larger groups. The slaughter weight and final live weight might therefor not represent the true effect of group size. However, if this is the case a significant difference in daily weight gain should be present, this is however not observed. The lack of effect of group size might also be a result of the pigs getting a sufficient access to resources and space regardless of group size (Nielsen et al., 1995). In the future it would be relevant to have a pre slaughter weighing to ensure final live weight is estimated under equal circumstances.

The effect of group size on production results and carcass traits can be difficult to compare due to the differences in pen layout and distribution of recourses. With keeping a constant stocking density, the length an individual in a group of 100 pigs must move to access resources such as feed and water, and how these are distributed in the pen might drastically increase amount locomotion and energy spent compared to pigs in much smaller pens. Examining the effect of pen design and how the pigs access their resources may thus be relevant to explore in the future.

Feeding strategy affects daily weight gain, slaughter weight and with this also the final live weight estimated from the slaughter weight. The results coincide with previous studies with *ad* *libitum* reaching a higher weight and higher daily weight gain (Quiniou et al., 2012; Stahly & Wahlstrom, 1973). The two strategies had no difference in feed efficiency, suggesting that pigs have a natural ability for efficiently regulating feed intake. This can be important for reducing the number of feeding days, creating a shorter and potentially more economically efficient production cycle

The protocol is not an ideal way to measure pig welfare and has several limitations. The protocol is not reliant on neutral measurements such a score for no lesions on the ears, tail, and body. This together with the study not being blind can have resulted in biased scoring. Knowing the inherent predisposition for bias measurements not having completed an analysis of observer reliability may have affected on the results. Further, the partly ambiguous causation of lesions can reduce the data quality. Aggressive behaviour does not always explain wounds and necrosis on ears, the frustration from an limiting environment is also a motivation for ear biting (Jericho & Church, 1972). There is a connection between pigs who bite tails and those who bite ears, but also a difference in pen-culture were some pens only tail bite, and others only ear bite (Blackshaw, 1981; Jericho & Church, 1972). It could for this reason be interesting to explore the difference in ear wounds caused by aggressive bouts compared to those from frustrated chewing. This could show the importance of observing the behaviour of biting or fighting instead extrapolating the cause of lesions. The different causes of lesions and problems with human neutrality can show the need for automating the data collection process with technology such as machine vision.

5. Conclusion

In summary, smaller groups have more lesions on the body, ears, and tail, yet maintain more curly tails and are more contact seeking towards humans compared to pigs in the large groups. Contrary to previous studies large groups experience fewer tail lesions, that further decrease over time. Additionally, group size seems to not affect production results and carcass traits, beside some extra feeding days for large groups. Feeding strategy had a significant effect on production results with *Ad libitum* fed pigs being both heavier and achieving a higher daily weight gain compared to pigs fed restrictively. This might suggest that given ample resources, increasing group size can be an effective tool for reducing aggression and tail biting in a conventional system without affecting the economic results.

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Norges miljø- og biovitenskapelige universitet
Noregs miljø- og biovitskapelege universitet
Norwegian University of Life Sciences

Postboks 5003
NO-1432 Ås
Norway