UNIVERSITY OF COPENHAGEN

Det Natur- og Biovidenskabelige Fakultet

Are Restricted Gilts and Sows More Stressed Compared to Free-Ranging Gilts and Sows? A Comparative Study of Cortisol Levels in Restricted and Free-Ranging Gilts and Sows

Project outside course scope in Husdyrvidenskab

Cecilie Ravn Skovlund wqg189
& Helene Lina Åhman Welden htb186

Main supervisor: Annette Bruun Jensen
Co-supervisor: Christopher Harold Knight

Date of admission: 24th of October 2014

Contents

Division of labour
Division of labour has been equally divided and we both vouch for the full context of this project.

Abstract

As Denmark is one of the leading countries in pig production in the world, the demands of production are continuously expanding, and this can can have detrimental effects on the gilts and sows. Due to the the high piglet mortality resulting from this, the gestating and lactating gilts and sows are being restricted, in order to refrain them from laying on the piglets and hereby crushing them.

Using a non-invasive media circumvents the induced stress by invasive sampling, which is especially prominent in the pig, as these have no superficial veins. The main media used for non-invasive stress assessments today is saliva, and to some extent urine. Both media offer advantages and disadvantages, however saliva seems most applicable in a production context. As the stress response in pigs in different production stages is generally the same but with individual differences, non-invasive sampling seem to make it possible to use this method on all pigs as long as these differences are taking into account.

The different production systems give rise to various factors which are contributing to elevations in cortisol levels, and especially prominent is the inability to perform natural behaviours, such as nest-building and also the imposed group structures, which differ largely from the naturally occurring groups. This give rise to different factors affecting the gilts and sows in the systems.

The behavioural needs of gilts and sows have large effects on piglet mortality. If the gilt or sow is unable to perform nesting-behaviour, it will highly affect the passivity and duration of farrowing. Thus, accompanying the behavioural needs of the gilts and sows may be an economical benefit for the farmer. However, the restructuring of the housing conditions may be a hindrance, as it requires a financial surplus which may not be present.

In general, we found evidence pointing towards restricted gilts and sows being more stressed than free-ranging gilts and sows, and that the lack of opportunity to perform nesting-behaviour, is a factor that highly affect piglet mortality. These findings could prove beneficial as a gateway to improve conditions for gilts and sows in the conventional production, for both the economical aspects of meat production and for the welfare of piglets, gilts and sows.

1. Introduction

Denmark is one of the leading countries in the world in production of pigs (*Sus scrofa domesticus)* (Landbrug & Fødevarer 2014a) with 29.1 million produced in 2013 (Landbrug & fødevarer 2014b), and this number excludes the high number of piglet mortality. In 2009, the number of piglets dead either before, during or short after parturition, was estimated to approximately 24 %, where about 11.8 % were dead at birth and 12.4 % were alive at birth but dead before weaning (Århus Universitet 2010).

The pressure to achieve a more efficient production is expanding with the continuous demand, and thus each sow must produce more, i.e. give birth to a still larger number of piglets; the higher amount of piglets bred, is a result of breeding objectives, but at the same time the gilts and sows are not bred towards having evolved the accompanied maternal skills. This intensive production is resulting in a demanding and stressful environment, which in turn may affect quality and quantity of production. Therefore, from both an economical and a welfare point of view, it is of interest to reach a low mortality among piglets. It is thus common practice in the conventional production, to restrict the gilts and sows in five days prior to expected farrowing until the piglets are weaned, which is typically around four weeks of age, in order to keep the them from laying on, and crushing, the piglets (Landbrug & fødevarer 2014a). There is, however, a general agreement that farrowing crates contribute to increased stress and frustration and thereby reduce welfare for the gilts and sows. Thus, it is necessary to explore alternatives to the current housing conditions even though this might require a restructuring of the industry.

This paper focusses on restricted versus free-ranging gilts and sows, where the restricted are housed in farrowing crates, which is the most common way of housing during farrowing and lactation, due to the advantages in production efficiency. Organic and free-ranging gilts and sows are housed in enclosures where they are either fully free to roam in that pen or outside and can turn around unhindered, none of these are housed in crates during farrowing or lactation.

Organic farmed and free-ranging gilts and sows are not permitted to be restricted during farrowing and lactation, and the mortality among piglets is higher here, yet we see a generally shorter and more passive farrowing due to less frustration. These result in lower piglet mortality and in stronger piglets (Videncenter for Svineproduktion 2009).

As chronic elevated cortisol levels can have harmful effects on the organism (Koeppen & Stanton 2010), it is regarded as a contributing factor to reduced welfare. Therefore, cortisol has been widely used as a physiological indicator of welfare in various studies. When assessing welfare by measuring cortisol, it is important to note that stress arises due to both physical and emotional causes, where physical causes are such as pain and emotional causes are such as fear. It can therefore be difficult to isolate these, as the physical stress can influence emotional stress (Blache *et al.* w.y.). This strongly indicates that stress and welfare is highly negatively correlated and that the assumption of high levels of stress equals bad welfare.

This paper is relevant in order to establish whether farrowing crates is a factor in reducing welfare for gestating and lactating gilts and sows. By examining the different factors influencing the gilts and sows in the conventional production systems, it may be possible to establish which implementations can acquire the most optimal environment for reducing stress, in order to obtain a satisfying compromise between production efficiency and welfare.

Hypothesis

Our hypothesis is that restricted gilts and sows are experiencing more distress than free-ranging gilts and sows which affects welfare, production and piglet mortality.

Objective

In this project we wish to account for the stress response of pigs and to examine if all pigs react the same, in order to establish whether the non-invasive techniques for stress-assessment are applicable on all pigs.

We will account for the practice of measuring stress non-invasively as done today and the advantages and disadvantages hereof.

We wish to examine what factors could potentially influence cortisol levels and thus welfare, in the different housing systems.

Finally, we will examine whether restricted gilts and sows are more stressed compared to free-ranging gilts and sows, and draw perspectives to the economical aspect of implementing welfare-inducing factors - is there an economical benefit in housing gilts and sows in the least stressful environments?

2. How pigs react to stress - endocrinology of the pig

When the hypothalamus-pituitary-adrenal (HPA) axis is activated in response to a stressor, it results in a series of neural and endocrine adaptations, also known as 'the stress response'. The stress response makes it possible for the organism to carry out the physiological and metabolic changes, necessary to cope with the demands related to a given threat to homeostasis (Miller & O'Callaghan 2002).

When a threat is perceived by the central nervous system (CNS), a biological defense starts. This defense is consisting of different combinations of the four general biological defense responses: the behavioural response, the autonomic nervous system (ANS) response, the neuroendocrine response and the immune response (Moberg 2000).

The HPA axis is activated by the neuroendocrine response and starts a pathway which begins when the anterior hypothalamus is releasing corticotropin-releasing hormone (CRH). This hormone then activates the pituitary gland to release adrenocorticotropic hormone (ACTH) into the general circulation. ACTH travels to the adrenal cortex through the bloodstream and activates it to secrete cortisol from the adrenal gland, which is the primary glucocorticoid (GC) in pigs. The hormonal response from the adrenal cortex is prolonged, as GCs effects on the stress response ranges from minutes to hours. The half-life of cortisol varies from one to two hours depending on the hormone levels, with longer half-life during large steroid loads (ncbi 2003), which makes its effects on stress prolonged. This also makes cortisol a suitable hormone for measuring stress non-invasively, as it can be tracked within the body for a longer period of time, compared to stress hormones with immediate and intermediate effects on the stress response.

The hypothalamus, the anterior pituitary and the adrenal glands combined, act as a negative feedback system in the regulation of cortisol secretion. Cortisol, functioning as the negative feedback signal, inhibits the secretion of CRH and hence also of ACTH (Sjaastad *et al.* 2010). In the stress response, the role of cortisol is to prepare the organism to respond to a given stressor and does so by increasing blood glucose, thus providing the organism with the energy needed for this reaction (Koeppen & Stanton 2010). It is noteworthy, that the continuously elevated cortisol concentrations, as a result of chronic stress, can have negative impacts on the organism (Koeppen & Stanton 2010). This may influence production yield and thereby economics in the pig industry, which could act as an incentive to improve welfare for gilts and sows.

2.1 Inter-individual variations in stress responses

Even though the endocrinology of stress is similar in most mammals, individual differences may exist depending on differences in genetics, stage of reproduction, social rank, early experiences etc. The different life stages of pigs are so distinct, that in order to establish whether non-invasive techniques are valid tools for measuring stress, it is necessary to establish an understanding of how different pigs react to stress.

Stress responses may vary due to differences in genetics, and these variations are therefore important to include when analyzing data in stress studies. Findings show that there is an inter-individual difference in cortisol responses in pigs and that these are heritable (Kadarmideen & Janss 2007). Also, in a study by Bergeron *et al. (*1996), data suggested an influence of genetic differences of stress responses in different breeds and in adaptive abilities or strategies. Therefore, not only may the stress response itself vary within different species, but also behaviours that can influence the response due to capabilities and inabilities to perform these.

Stage of reproduction has also proven to be a factor which can influence the cortisol response. This have been demonstrated in a study, where the responses of lactating sows were lower, compared to those of non-lactating whom also elicited a higher cortisol:ACTH ratio in response to CRH challenge (Jarvis *et al.* 2006). In addition, in a study by Lawrence *et al.* (1994), findings demonstrated that cortisol levels rose in early post-partum, indicating parturition is mediating a stress response, which may be due to physiological factors.

It is generally assumed that pigs in social groups with low social status experience higher stress levels. This could be related to the fact that lower ranking individuals receive more lesions and scratches, are not allowed to access the drinking and feeding stations as often as the higher ranking individuals and that they spend more time laying in the dunging areas (Riggenberg *et al.* 2012). Yet, there is some controversy as studies have found inconclusive results to the relationship between social status and cortisol concentrations (Kadarmideen & Janss 2006; O'Conell *et al.* 2003). This inconclusiveness shows the significance of taking the individualities into account when measuring and assessing stress and welfare.

The stress experienced by the gilts and sows during gestation can have significant effects on the piglets' behavioural and hormonal responsiveness to stress and their immune systems (Jarvis *et al.* 2006; Otten *et al.* 2007). Jarvis *et al.* (2006) found that piglets that had been subject to prenatal stress displayed more nosing and less play behaviour at weaning (Jarvis et al. 2006; Kranendonk *et al.* 2006).
These inter-individualities underline the importance of taking the circumstances of the pigs in different life stages into account when assessing stress.

3. The practice of measuring non-invasively in pigs- advantages and disadvantages

The benefits of measuring cortisol levels non-invasively are many. Non-invasive sampling offers the ability to assess cortisol levels without altering these by stressing the animal, and to avoid biased results caused by handling-induced stress. Plasma cortisol levels can be assessed in pigs invasively by venipuncture, but this has proven to be especially problematic as pigs lack superficial blood vessels, thus intensifying the level of invasiveness of this method (Bushong *et al.* 1999).
Several non-invasive techniques exists, including faeces, urine, hair and saliva. Mainly saliva, and to some extent urine, are most commonly used in pigs. The different media offer different time frames of cortisol fluctuations. Saliva offer a more immediate display of stress levels, well-reflecting plasma cortisol fluctuations (Sheriff *et al.* 2011), urine and faecal samples offer insight of stress levels during several hours as they accumulate cortisol between excretions (Touma & Palme 2005), and cortisol in hair is accumulating over weeks and months (Sheriff *et al.* 2011).
Non-invasive sampling is widely used today and studies have found that these methods seem valid and practical for stress-assessment. Yet, is it important to consider several factors some of which will be examined in the following.

3.1 Urine sampling

Due to the disadvantages of sampling plasma mentioned previously, it is interesting to examine the benefits of the non-invasive techniques, but also which problems might occur in this fairly new way of assessing stress in pigs. Because the literature on sampling urine in pigs is still scarce, the general advantages and disadvantages of this sampling media are also described.
The few articles that use urine as sampling media, describe the opportunity to collect urine when it is either spontaneously voided (Pol *et al.* 2002) or by a permanent catheter (Palme *et al.* 1996). When collecting as pigs are spontaneously voiding, operators need to observe the pigs and collect the urine as soon as it is excreted. Pol *et al.* (2002) collected the urine in a flask, exactly how it was done, is not clear. This sampling technique seems impractical when performed outside experimental settings. In a production stall with sometimes thousands of pigs, it is unlikely that there is enough staff to observe each individual along with the fact that it will be difficult to reach the urine before it is contaminated or spread out

by other pigs. In a gestation and farrowing crate, it will be easier to observe the individual animals, yet it will still be logistically difficult to maintain a focus on every individual. Furthermore, pigs are housed on slatted floors, which is of advantage in extensive productions, but disadvantageous when collecting voided urine.

If urine is collected as done in Palme *et al.* (1996), the same difficulties might not occur as urine is collected directly from the bladder. This makes it easy to determine which pig is linked to the individual samples, yet might offer the difficulties of inserting them into hundreds of individuals, along with the economical factor that might influence as this would require extensive resources.

The limited and older literature on urine as a sampling media may be a sign of too many disadvantages, associated with this technique, to perform this in practice.

It is generally possible to collect urine samples when excreted and thus it can be conducted on many different species. This will also allow it to be used on not only gilts and sows, but all pigs in the production system.

A huge advantage of measuring cortisol in urine, is that urinary GCs accumulate over several hours and is thus a picture of the fluctuations since the last voiding. In addition, GCs are protein-bound corticosteroids from the kidney filtrate, and are therefore a direct reflection of the free hormones in plasma, during the time between voidings (Cook 2012). Because of this, urine concentrations can be considered as more integrative than plasmatic concentrations, and that small variations of HPA activity can be more easily detectable from urinary excretions compared to both plasma and saliva (Hay & Morméde 1998).

As urinary GCs is a product of adrenocortical output and hydration, there is a possibility that two individuals with the same plasma levels of cortisol can excrete different urinary cortisol concentrations, because of the differences in the total urine output, throughout the sampling period. A common way to correct for the effects of dilution is by expressing urinary GCs as a ratio to urinary creatinine, because it is produced at a relatively constant rate, with almost no reabsorption by the kidneys and is thus relatively unaffected by urine volume (Cook 2012). Hay & Morméde (1998) found that the Chinese Meishan pig showed plasma cortisol concentrations that are about two times as high as the concentrations of the European Large White pig and Yorkshire and thus it is necessary to know the baselines of each race of pigs, to ensure the urinary excretion is a true reflection of the plasma concentrations in that specific race.

When collecting urine, there are no specific requirements for collecting and storing the samples. However, urine should be frozen as soon as possible after sampling to avoid bacterial decay. This could make it a suitable media for domestic animals, as sampling is done in locations with storage opportunities available. Hormones in urine are measurable in most immunoassays, with assay sensitivity rarely being a problem when sample volumes are not too small. However, assay specificity is a cause of concern, due to the presence of cross-reacting and structurally similar conjugated compounds is the major contributor of the variation in cortisol measurements between assays (Cook 2012).

3.2 Saliva sampling

Saliva sampling offers a non-invasive technique to assess cortisol levels in pigs, and due to the many benefits, it is one of the most widely used techniques of stress assessment in farm animals today.

Cortisol levels can be assessed in saliva because lipid-soluble steroids like GCs, pass freely from blood to saliva through the lipophilic layers and diffuses into the saliva being produced. Only the free hormone is able to pass from blood to saliva, as the GCs in blood are largely protein-bound, and GC levels are unaffected by salivary flow (Sheriff *et al.* 2011).

The collection of saliva can be obtained either with or without handling the animal, with the latter technique providing the most valid results, as the cortisol concentrations will not be biased by additional stress that may be induced by handling. Thus, many of the problems arising from invasive sampling can be avoided with measuring cortisol from saliva (Bushong *et al.* 1999). In humans and various animals, salivary cortisol has proven to reflect plasma cortisol levels, although salivary cortisol are at lower concentrations than plasma cortisol, yet salivary cortisol follows the fluctuations of plasma cortisol (Bushong *et al.* 1999). Studies in pigs have investigated the relationship of salivary and plasma cortisol, and although few inconsistencies has been found, this technique is accepted as a valid approach in pigs today. In comparison to sampling of other media, saliva provides an insight in a specific moment, displaying recent stress responses, whereas urine, faeces and hair samples provide broader timeframes and a more general picture of the cortisol levels (Sheriff *et al.* 2011).

There are several ways to sample saliva, with some requiring more handling than others.

Saliva can simply be sampled by swabbing the interior of the mouth and this approach involves some interaction with the animal, either voluntary or involuntary, and may elicit a stress response itself. The resulting increase in cortisol levels do not occur until 20 – 30 minutes later in saliva (in contrast to plasma), and thus it is not interfering with the current sampling (Sheriff *et al.* 2011). However, in this project, the focus is on stress of longer duration and chronic stress, which arise due to factors that are constant in the environment, and continuous sampling is therefore needed to account for both internal and external factors that may cause fluctuations in cortisol concentrations. A single sample will usually reflect a stress response only in a given moment and not the steady state of the animal, and singular sampling is therefore less relevant in this project. These handling-induced fluctuations in cortisol may be overcome by adapting the pigs to the sampling technique (if possible) and hence they may show a reduced or lacking response to sampling (Schönreiter & Zanella 2000).

Obtaining saliva from objects is another useful technique. This can especially be an applicable technique in the production systems, which offer relatively controlled settings, where workers patrol on a regular basis, which in turn allows the objects to be continuously collected. In addition, as GCs in saliva are relatively stable and can be stored in room temperature for a couple of days (Sheriff *et al.* 2011), this method also allows a more casual sampling approach where the samples are not necessarily to be assembled immediately, which can be beneficial whenever resources are not abundant. In group-housed systems, it may be difficult to determine which specific animal has deposited saliva on the object, and this approach may therefore be more appropriate for animals housed in solitary or for restricted animals.

Another approach is the use of devices which can be inserted into the mouth of the animal for a given period, where it throughout time gathers information about the cortisol levels by assembling samples. An example of such device is tested in the study by Schönreiter & Zanella (2000), which was found to provide a valid technique to assess cortisol levels in saliva, compared to the use of cotton bud swatches. The device, 'Oral Diffusion Sink' (ODS), is secured with an elastic band in the animal's upper jaw and it allows the accumulation of steroids from saliva during approximately eight hours, with a defined flow rate through the ODS (Schönreiter & Zanella 2000). The device, which is developed by WADE (1992), consists of a column that measures 2 mm x 13 mm and is coated with the polymer ß-cyclodextrin, which has high affinity for steroid hormones and is originally used to sample GCs in human saliva. In addition, it improves saliva collection as it inhibits the conversion of harvested cortisol into cortisone and excludes plasma contamination (Schönreiter & Zanella 2000). This is beneficial as the salivary glands contains an enzyme (11β-hydroxysteroid dehydrogenase type II), that converts active GCs into their inactive form (cortisone) (Sheriff *et al.* 2011).

Applying devices for assembling information about the cortisol levels in saliva, allows continuous sampling throughout the day and it circumvents the conflicts arising from handling the animal. However, some handling is required in order to insert the device, yet this can be accounted for when interpreting the results, by knowing the time of insertion. Discomfort resulting from the attachment of the device may be a factor to integrate when designing the device, as this may contribute to additional rises in cortisol levels. It is also noteworthy that dirt particles may enter the device, blocking the membrane, and this needs to be taken into account if the device is present in the animal for longer durations (Schönreiter & Zanella 2000).

A planted device may also account for the reduced excretion of saliva found in pigs compared to other species. Unlike other animals (e.g. cattle), the excretion of saliva in pigs is discontinuous and mostly restricted to feeding activity, with the exception of the boar when eliciting sexual behaviour, and excretion rates generally are rather slow (Blackshaw & Blackshaw 1989). As the device is present for longer durations, the problems with swabbing scarce amounts of saliva are evaded.

4. Factors influencing cortisol levels in gilts and sows in different housing systems (restricted and free-ranging)

In production systems today, animals are housed in manners which are refraining them from performing natural behaviours, and the different housing systems result in different stressors. In the following, we are examining some of the main stressors specific to restricted and free-ranging gilts and sows.

4.1 Restricted gilts and sows

According to Danish legislation, gestating gilts and sows in the conventional production are moved to the farrowing crate five days prior to farrowing until the piglets are weaned. During this time, the gilt or sow is fixated to prevent crushing of the piglets (Landbrug & fødevarer 2014a). There are no specific requirements for the amount of space provided for the animals, although the interior needs to make sure that every gilt or sow can lie down and stand up without inconvenience, yet small enough for the gilt or sow to be unable to turn around (Videncenter for Svineproduktion 2013a).

The most prominent differences between free-ranging and restricted gilts and sows, are the fixation and the reduced locomotive freedom restricted animals are experiencing. All sows are free-ranging from weaning until close to farrowing, and this alteration in housing is a big contrast which can increase cortisol levels (Pedersen *et al.* 2010).

In this section, it is assumed that the lack of opportunity to perform behavioural needs, leads to stress and reduced welfare. Thus, the behavioural needs that are specific to gestating and lactating gilts and sows are examined.

Several studies have been conducted on the natural behaviour of gilts and sows, all of which show little variation between peri-parturient behaviour in extensively kept individuals. Especially nest-building behaviour pre-partum seems to be an innate behavioural need, as the failure for domestication to significantly alter this behavioural pattern provides evidence that it is biologically significant (Jensen 2002; Baxter *et al.* 2010). It is stubbornly being attempted by the gilts and sows, despite the extremely limited opportunity to successfully build a satisfying nest that will reduce activity prior to farrowing. As the motivation for this behaviour persist even though it appears unnecessary in a production environment (e.g. as there is no predatory threats and temperature is stable), it appears of biological significance to the gilts and sows and is thus assumed to be a reason of frustration and stress if the they are not allowed to perform this.

Nest-building behaviour is a very fixed pattern (Jensen 2002). Two to three days prior to parturition the gilt or sow will increase its locomotive activity. If possible, she will seek isolation and wander from the group in order to find a suitable site for the nest. During this time she will travel several kilometres, another behaviour observed in domestic pigs with limited opportunity (Baxter *et al.* 2010).

In addition the chosen nest-site, locations are in consideration to excretory and feeding locations. Dung is often found metres away from the nest, which is believed to be due to disease control (Baxter *et al.* 2010). Because of the crates, this is obviously not an option for restricted gilts and sows, as they only have the opportunity to dung where they are stabled. Because of the very fixed pattern of nest-building; this being the preparation of locating the nest-site along with the building of the nest itself, it is clear that every step is a behavioural need and the lack of opportunity to performing these leads to stress and frustration.

Damm *et al.* (2003) found that by removing nest material every fourth hour until parturition, the plasma cortisol levels in gilts increased (compared to sham removal). Whether the gilts were exposed to nest removal or sham removal, it did not affect the quantity or duration of nest-building. It did however, significantly altere plasma cortisol levels, as parturition approached in the gilts that were exposed to nest removal but remained constant for gilts exposed to sham removal. This suggests that the lack of opportunity of nest-building is a cause of stress for restricted gilts and sows.

According to Damm *et al.* (2003), it has been found that confinement may increase cortisol levels further, and they believe that it might be associated with the physical tension of attempting to built a nest, combined with the physiological frustration of the hindrance of performing the behaviour and reaching and end point. This is supported by Jarvis *et al.* (2002), who suggest that plasma ACTH and cortisol was significantly higher in pre-parturient gilts expressing redirecting nest-building behaviour, than gilts housed in larger environments provided with straw. The studies referred to by Damm *et al.* (2003) and Jarvis *et al.* (2002) could not, however, distinguish the chronic stress or chronic sporadic stress from the confinement itself from the stress associated with not having materials for nest-building. This could possibly suggest that both the confinement as well as the lack of opportunity to nest-build, is causes of stress in restricted gilts and sows.

Damm *et al.* (2003) further suggest that the gilts in their study generally had been frustrated because of the lack of materials and surroundings, that enabled them to reach a satisfying nest and environment for farrowing. They found that completely removing the nest caused an additional stress factor, expressed by an increase in cortisol levels and heart rate. Yet, they did not see behavioural changes as they were already reflected by the general frustration of the insufficient materials; which is in accordance to Jarvis *et al.* (2002) who suggest that restriction of space along with absence of substrates, which could possibly interfere with nest-building, can result in increased activation of the HPA axis.

Jarvis *et al.* (2002) also suggest that space restriction itself increases HPA activity, and that if sows are given a choice of the width of farrowing crates, they will choose the widest and especially so if there is room enough for them to turn around. Although increased activation of the HPA axis is often associated to parturition itself, Jarvis *et al.* (2002) found that HPA activation was additionally environmentally induced, as space-restricted gilts had higher ACTH and cortisol levels, especially during the peak of nest-building behaviour. Furthermore, even though exercise is known to activate the HPA axis (Jarvis *et al.* 2002), the same study found that space-restricted gilts had a higher activation of the HPA axis even though they were less active during the pre-parturition phase.

In a production context, the gilts and sows are continuously exposed to new individuals, there is a high replacement rate and as the they are moved from the farrowing and lactation crates and back to the gestation pen (i.e. where they are group-housed), they may very well be introduced to new individuals of which they need to establish a relationship with. When pigs are mixed with strangers in the production, they usually fight intensely for a period, until a dominance order has emerged (Jensen 2002). Furthermore, the most important sense for social interactions in pigs is the olfactory sense; this means that even though the gilts and sows are isolated in the crates, they are still able to smell their previous group mates. This can possibly create a sense of frustration, as they are not able to reach the others. This also apply to the auditory and visual senses. As pigs has a repertoire of vocal signals, they have different calls, amongst others a warning call that is emitted as a response to frightening stimuli. When emitted, other pigs respond by repeating the call and then either freeze or run away (Jensen 2002). When restricted, a gilt or sow cannot react naturally to such a call. If one individual is frightened and emits the warning call, each of the remaining gilts and sows will react to the danger yet are not able to escape, and thus remove themselves from the potential danger, which can potentially be a cause of stress.

Although conventional systems house gilts and sows individually during farrowing and lactation, which keep them from having direct social interactions, antagonistic behaviours between neighboring gilts and sows may still be a reality and thus increases in cortisol levels due to social aggression, may still be a factor in individually housed gilts and sows. Several studies have reported this high aggression between crates. This high intensity of aggression may be due to the nature of social conflicts amongst pigs, as they respond with retaliation after an initial attack, which in turn leads to withdrawal. This results in cease of aggression, as would be the case in group-housed systems. As there is no consequence in the attacks and the conflict is unresolved, the intensity of aggression escalates (Marchant-Ford 2009). Thus, the aggression levels in individually housed gilts and sows may be quite high as these encounters are unsettled, and it have been postulated that the unresolvable aggressive interactions may stand as a stress factor, and even a factor of chronic stress (Marchant-Ford 2009).

4.2 Free-ranging gilts and sows

Due to welfare reasons, it is common today to see pigs housed in systems which allow social interactions and offer more space for the animals to roam, most often during gestation. This is endorsed in order to circumvent possible complications arising from individual housing, such as behavioural and social deprivation. Although it eliminates these possible stress factors, the occurrence of other factors which increases stress may be an issue, and these are often due to group related aggressions, for example aggressions due to hierarki establishments and mixing of gilts and sows between groups introducing unfamiliar individuals (Tsuma *et al.* 1996). Social aggression is therefore one of the most prominent risks of reducing welfare in group housed pigs, due to the possible induced stress and injuries hereof (Chapinal *et al.* 2010).

Looking into the natural group dynamics of the domestic pig, the reasons behind the social aggressions in group-housed systems become quite clear, as the imposed group structures here differ largely from the natural formed group structures. The natural core group of pigs consists of two to four related females with their litters. The group size remain small, there is no mixing with unrelated animals, the environment is complex and offers plenty of space to roam and food is scattered and available ad libitum (Marchant-Ford 2009). These natural groups avoid each other and under circumstances where contact does come about, agonistic interactions may occur.

Intra-group aggressions are rare as the social hierarchy is well-established and stable. However, when these happen to befall, they are most likely provoked by conflict over resources (e.g. food) (Marchant-Ford 2009). The groups imposed in the production systems often consist of a large number of unrelated females housed together, often in a rather confined area and non-complex environment, where avoidance is impossible, mixing of individuals happens frequently and the gilts and sows will usually be fed a restricted diet (Marchant-Ford 2009). Considering the above, it is evident why social aggressions happen more recurrently under unnatural conditions.

Free-ranging and organic farmed sows during farrowing, lactation and weaning, are normally kept in large areas with few animals in each enclosure, with an average of 7.5 sows per hectare, 10.4 sows per hectare and 11.5 sows per hectare, respectively, in Denmark (Videncenter for Svineproduktion w.y.). As limitations of space is one of the main initiating factors of social aggression between gilts and sows (Marchant-Ford 2009), it is plausible that antagonistic behaviours between free-ranging individuals are remarkably reduced, due reduced stocking density and increased space available. However, limited literature, concerning farrowing and lactating sows housed outside, is available in this area. Examining the dynamics of space and aggression in the general life stages of pigs, studies have shown that with decreased space allowance, an increase in aggressive interactions follows (Marchant-Ford 2009).

Feed may be another contributing factor to cause elevations in cortisol levels, due to either restricted feed or competition for feed amongst individuals. Under natural conditions, pigs will spend many hours during the day, foraging with synchronized feeding with others, yet the performance of these behaviours are often unattainable in commercial systems, as the diet may be restricted, which leave the gilts and sows unoccupied for many hours, time otherwise spent on foraging. Aggression due to competition for feed is also more frequent, as feed and space, or both, is limited (Marchant-Ford 2009).

It is plausible that the absence of possible foraging behaviour and an impoverished environment, may cause elevations in cortisol. This can be due to the phenomenon 'contrafreeloading', in which the animal will perform work to obtain feed, even when already available, as foraging is an innately rewarding act for which animals may have a need to perform (Morgan & Tromborg 2007). Applying the above to the gilts and sows in the free-ranging and organic farmed systems, continuous foraging behaviour is possible as is under natural conditions, and therefore this will not pose a factor contributing to stress. Also, social aggression due to competition for food and other resources, may very well be reduced as the resources and space is more abundant here. However, in group-housed stalls, the environment is less enriched and thus this may very well be a factor contributing to stress..

At last, when distinguishing between factors that may cause stress in free-ranging gilts and sows kept outside, that are not as likely to be present in restricted gilts and sows, factors like disease, abiotic factors such as temperature and human contact is worth emphasizing. In free-ranging systems, where gilts and sows are kept outside, the animals are often more susceptible to disease as the environment is less controllable. Disease originating from different sources (e.g. parasite infections) may cause elevations in cortisol levels, which studies have described in different species (Young *et al.* 2004). Also, temperatures outside the comfort range of the animal is known to cause increased cortisol levels. In the domestic pig, salivary cortisol have been reported to increase with temperatures above 17 °C, and high-

frequency vocalization along with huddling behaviour, during exposure to lower temperatures, is more prominent (Morgan & Tromborg 2007).
Human contact is less frequent in free-ranging gilts and sows kept outside, although when handling of the animals is required, the handling is likely to induce a stress response, as the animals are not adapted to this activity (Marchant-Ford 2009).

5. Are restricted gilts and sows more stressed?

In the following section, the cortisol concentrations in restricted, partly free-ranging and free-ranging gilts and sows are examined. The present literature is commonly based on gestating gilts and sows, where comparisons are drawn between different housing systems and the accessible space in these, and to a lesser extent on farrowing and lactating sows. Thus, a broader sense of 'free-ranging' has been applied here.
It is generally accepted that restriction causes acute cortisol elevations, and that this response declines after a period of 24 hours. Yet, it is of interest to examine the long-term effects restriction has on cortisol levels, as the animals are restrained for a longer period, leaving the preliminary response less significant (Marchant-Ford 2009). Several studies have observed and analyzed the relationship between space allowance and close confinement and the corresponding stress levels of domestic pigs, and some of these findings are mentioned in the following.
A study by Lawrence *et al.* (1994) is one of these studies, where they examined the plasma cortisol concentrations and behaviour in gilts kept in conventional farrowing crates without bedding, and in gilts in kept in farrowing crates allowing movement with bedding. They found a general increase in cortisol levels post-partum, as parturition itself may induce a stress response, and higher cortisol levels in the gilts in confined crates, suggesting the interference with maternal behaviour prompts physiological stress (Lawrence *et al.* 1994).
Another study by van der Staay *et al.* (2010), examined the blood cortisol after slaughter in sows that had been tethered for 1.5 and 4.5 years and in age-matched sows kept in a social housing system. The findings showed that the tethered sows had higher concentrations of cortisol and they suggested, in accordance with other measures, that chronically stressed sows develop depression-like symptoms.
An establishment of the relationship of chronic stress and cortisol levels in individually housed sows kept in smaller crates and in pens with different sizes, has been conducted in the study by Jarvis *et al. (*2006). Here it was found that cortisol responses to CRH injections are higher in the sows in the more confining crates, compared to sows kept in larger pens, suggesting that these sows are suffering from chronic stress. The same relationship between salivary cortisol and sizing of individual enclosures was also found in another study by Oliviero *et al.* (2008).
Several additional studies by Barnett *et al.* (1985; 1987a; 1987b), found a general pattern of sows housed either tethered or in gestation stalls, had increased cortisol levels compared to group-housed sows (Marchant-Ford 2009), with only gestating sows responding with chronic stress and reduced immunological reactivity to tethering as opposed to non-

gestating sows (Barnett *et al.* (1985; 1987b). In their studies (Barnett *et al.* 1987b), they suggested that the increased cortisol levels imposed by tethering was due to the unresolved conflict that occurs amongst neighboring sows, which they had examined in a previous study (Barnett *et al.* 1987a). They concluded this to be a contributing stress factor, as the incorporation of modified stalls, which inhibits antagonistic behaviours between stalls, reduced the quantity of aggressive interactions and reduced cortisol levels. Estienne *et al.* (2006) also examined this relationship, and found that serum cortisol concentrations were higher in stall-housed gilts, in comparison to group-housed gilts. Bergeron *et al.* (1996) compared two systems, in which one of conventional gestation stalls and one of turn-around gestation stalls, in gilts of three different genotypes; Meishan, Yorkshire and Meishan x Yorkshire/Yorkshire x Meishan. The study concluded, that with the implementation of the ability to turn around in the stalls, the activity level increased and cortisol concentrations dropped accordingly, accentuating the negative correlation of space available and cortisol levels.

A few other studies have also examined this relationship and confirmed the above, but also investigated the more protruding response to other stressors during tethering (Marchant-Ford 2009). This may be due to facilitation (Romero 2004), where confined sows and gilts elicits a more prominent cortisol response to stressors due to chronic stress, which is induced by the tether which is galvanizing the stress response.

There is, however, a few other studies which have found either no changes in HPA activity due to housing conditions, or increased HPA activity with increased space (Marchant-Ford 2009), indicating quite the opposite as found in the other studies mentioned earlier.

In a study by Anil *et al.* (2005), where the salivary cortisol levels was assessed of sows in group-pens and in conventional individual stalls, cortisol levels, along with total injury scores, were higher in the group-housed animals. It is proposed that the increased stress levels found in the groups, were due to the aggressions resulting from imposed introduction and mixing. Jansen *et al. (*2007) and Karlen *et al. (*2007) found the same pattern, where the group-housed sows had higher salivary cortisol levels compared to the individually stall-housed sows, with the same positive relationship of higher frequencies in aggressive behaviours and social housing.

No difference of stress levels were found in sows that were tethered and housed in individual pens in the study by Soede *et al.* (1997). In addition, the study by Von Borell *et al.* (1992) examined the cortisol responses in various group-housed systems and gestation stalls by ACTH challenge, and found no differences in the responses between sows. There is an overall agreement in the present literature, implying that elevations in cortisol concentrations follow confinement in gilts and sows, and we have found only few studies which is presenting conflicting results on the matter. Additional literature could be beneficial in order to clarify some of these relationships and the influencing factors hereof, and also to assess further data of the cortisol levels during gestation, parturition and lactation in free-ranging and organic-farmed sows, housed outside.

6. Is there an economic incitement in accommodating the behavioural needs of gilts and sows?

The primary reason for fixating gilts and sows during the last stages of gestation and during lactation, is to prevent the sow from crushing the piglets laying down (Landbrug & fødevarer 2014a). The piglet mortality in conventional housed pigs in Denmark is approximately 12 % (Sørensen & Pedersen 2013) for piglets alive at birth yet dead before weaning. In contrast, the mortality for piglets in the free-range production is 21,7 % (Sørensen & Pedersen 2013). Whether crushing is the reason for the mortality or how high a percentage is caused by crushing, is not clear.

As the reason for keeping gilts and sows is highly economic, the main interest for farmers is to find the perfect balance between the most economically beneficial housing arrangement and having the highest amount of piglets survive until they reach slaughter weight. Yet a high rate of survival is not the only means to a higher economic outreach; the average consumer is becoming increasingly concerned with animal welfare and insists of purchasing meat from "happy" animals, this also includes the abolishment of the farrowing crates (Baxter *et al.* 2009). Thus, aside from the physical properties which may be affected by housing conditions, there is certainly also the image of the producer, which might serve as incitement for increasing the welfare of gilts and sows.

By identifying the biological needs, it is possible to create the proper design criteria for farrowing and lactation systems, that in turn will optimise both welfare and animal production (Baxter *et al.* 2010).

According to Baxter *et al.* (2010), if the behavioural needs of the pig is not recognised, it might act counter-productive when trying to maximise animal productivity, as it is generally accepted that carrying out behavioural needs is fitness-inducing.

Sows will not lay on their piglets in nature. Jarvis *et al.* (2002) describe that sows in semi-natural environments will stand up during parturition to inspect their offspring, making nose-to-nose contact and then rooting the nest to move piglets away before resuming to lateral lying. Providing the gilts and sows with the opportunity to perform behavioural needs (e.g. nest-building behaviour), can release a feedback by affecting neuro-endocrine regulation of maternal behaviour during farrowing (Baxter *et al.* 2010). For example, authors have proposed a link between high nest-building activity and reduced risk of crushing, where nest-building in this context is included in other maternal behaviours such as nosing the piglets and quick response to distress calls. They found that sows that spend more time laying laterally before parturition had higher rate of piglet crushing. When other possible explanations were ruled out, it is suggested that it is because of generally more passivity, including low nest-building behaviour pre-partum (Andersen *et al.* 2005; Pedersen *et al.* 2006).

If gilts and sows are not allowed to properly express nesting-behaviour, it may compromise later maternal behaviour and piglet survival. According to Jarvis *et al.* (2002), the availability of nesting materials can alternate maternal behaviour, reduce crushing of piglets and increase responsiveness to piglet distress calls. Jarvis *et al.* (2002) mentions a study in which sows in crates that savage their piglets have been exposed to greater disturbance

during nesting-behaviour phase, and previous work by Jarvis *et al*. suggest that appropriate maternal behaviour during farrowing (i.e. lying passively during delivery) may be related to disturbance to the physiological changes necessary to result in a passive parturient sow.
Baxter *et al*. (2010) suggest that the more complete and functional the nest is, the quicker the gilt or sow stops nest-building and enters the more inactive phase of farrowing. Furthermore, they suggest that gilts and sows that continued nest-building during farrowing were more likely to crush their piglets and to have prolonged farrowing, which increased risk of piglet mortality.
The above suggest that by accompanying the consumers wish of "happy animals", not only will it be profitable to eliminate the farrowing crate because of the image it will portrait to the public; it may possibly reduce piglet mortality by allowing the gilts or sows to roam more freely and give them the most optimal opportunity to perform nesting-behaviour, in a way that will let them create a satisfying nest, and thereby reducing piglet mortality. A lower piglet mortality will not only result in better welfare for the piglets and the gilts and sows, but it will also result in more piglets reaching slaughter weight, which is an economical benefit for the farmer.
Although certain behavioural aspects point to an increase in income when allowing the gilts and sows to perform behavioural needs, several factors are influencing the economical side of the production industry. The gilts and sows are bred to a standard with a risk of giving birth to more piglets than they can actually nurture (Pedersen *et al*. 2010). Thus, it is a general assumption that a piglet mortality of a certain extent will happen, and this is carefully calculated into the financial statement. Furthermore, if the farmers were to change the environments to suit the behavioural needs of the gilts and sows, this too would be an extensive economical cost that might not be profitable enough to make it attractive for the individual farmers.

7. Discussion

Throughout this project, we have reviewed how pigs react to stress by looking at the stress response in general and on the responses to stress by pigs in different stages of life. This is of importance in order to establish whether non-invasive measurements are viable for pigs in given situations. This is followed by a quick review of the advantages and disadvantages of using non-invasive techniques, compared to invasive plasma cortisol measurements. Next, we specifically review the advantages and disadvantages of two sampling media; urine and saliva, as these two are most commonly used in the literature available.
In order to establish whether restricted gilts and sows are more stressed than free-ranging, we examine the factors affecting each group respectively. This then leads to the analysis on whether restricted gilts and sows are more stressed than free-ranging gilts and sows. Finally, a quick examination on the economical aspect of keeping gilts and sows restricted is looked upon, in order to establish if there may be an economical benefit from accommodating the behavioural needs of the animals, as this could serve as a further incitement for restructuring the housing conditions of gestating and lactating gilts and sows.

By examining the different life stages in the production, we acquire a clearer understanding on which factors are of significance, during the different stages of life and a given role in a production context. If non-invasive methods will be gaining ground, it is important that the techniques can be used on each pig in the production, as this is most economic appropriate. There is no evidence that these methods are inapplicable on all types of pigs, as long as the factors relating to a given production context is considered. This is a general precaution that needs to be considered every time stress-assessment is conducted, as not only do the different life stages influence the results but every individual react differently to stress due to genetics, previous experience and other factors previously mentioned in section 2.1.

The main media used in the literature available is saliva, and fewer studies have focused on sampling urine. Urine has many advantages and seems possible to use in an experimental context, although it may be more troublesome to apply in a production context. Saliva seems as the better media, due to the many benefits described in section 3.2, and because it might be difficult to obtain proper sample sizes when collecting hair, and because that faeces, as well as urine, is generally excreted through the slatted floors and therefore is difficult to distinguish between individuals due to high stocking densities (i.e. primarily in slaughter pigs).

As this project focuses on gestating and lactating gilts and sows, the factors affecting the restricted and free-ranging, respectively, are of significance as these are factors in determining whether restricted gilts and sows experience more stress than free-ranging, and whether these are stressors that can be accommodated in a financially beneficial manner for the farmer.

The literature points towards one major issue arising when fixating gilts and sows during the last stage of gestation and during lactation; several studies have found that gilts and sows experience significant rise in cortisol levels when they are not allowed to perform nesting behaviour. This fixed pattern of nesting ranges from the gilts or sow isolating herself from the group to search a proper location to the very specific building of the nest. When she is not able to perform these steps, it will affect the act of farrowing and the frequency of piglet crushing. This indicates that piglet crushing can be avoided when the behavioural needs of the gilt or sow are met. Whether this is financially doable may be questionable, as the production systems today focuses on the solution of restriction.

Besides the welfare of the gilts and sows, it is clear that the mortality of piglets are higher in the free-ranging productions and that there is a general acknowledgement of more piglets being crushed in the free-ranging production systems (Sørensen & Pedersen 2013). This issue is not to be taken lightly as the welfare of the sows should not overshadow the welfare and viability of piglets, along with the fact that it is a financial cost for the farmers. Yet, there are still financial incitements for improving the environment for the gilts and sows. Several studies suggest that farrowing is less complicated and less hazardous for piglets, when the gilt or sow is allowed to perform the necessary behaviours leading up to farrowing (Videncenter for Svineproduktion 2009; Baxter *et al.* 2010; Damm *et al.* 2003). Thus, it might be worth examining the opportunity of moving the gilts and sows out of the farrowing crates and still maintain a low piglet mortality. The welfare issues cannot be solved by

eliminating the farrowing crates alone. As we have seen in section 4.2 on free-ranging gilts and sows, aggression is often extensive when they are housed in groups, which increase cortisol and thus reduce the welfare of these. The welfare of gilts and sows is a complex matter and the farrowing crates are only a small part of the issue. If the gilts and sows were to move out of the farrowing crates, a whole restructuring of the production is required, as enough space and enrichment is necessary in order to accommodate the needs of the gilts and sows. This is a larger issue and the financial surplus is not necessarily present at the moment. Housing pigs outside requires significantly more space than traditional housing systems, yet the financial investments in buildings etc. are much lower (Videncenter for Svineproduktion w.y.).
This project has focussed on the welfare of restricted gilts and sows and whether they experience more stress than free-ranging gilts and sows. We believe that we have presented evidence that points towards restricted gilts and sows having higher levels of stress compared to free-ranging gilts and sows, and this may serve as a gateway to improve conditions for these in the conventional production.

From section 5 it is evident that there is an overall tendency of higher levels of stress in restricted gilts and sows found in the literature, which in general is consistent in both the older and newer studies. However, we have found a few newer studies finding contrasting results, with higher levels in 'free-ranging' social arrangements in comparison to restricted gilts and sows.
The study by Anil *et al. (*2005) compared well-being, performance and longevity of 382 gestating gilts and sows in stalls and in pens with electronic sow feeders (ESF). They found higher occurrences of injuries and higher levels of cortisol in the groups housed in pens compared to those housed in stalls. In the pens, it was especially the smaller animals that were susceptible to injuries, whereas it was the larger animals in the stalls, which stressed the problems arising with restriction of space. Also, the problems arising in group-housed animals contributed to higher cortisol levels, due to social aggression resulting from e.g. mixing of animals.
Karlen *et al. (*2007) found a similar relationship. They examined the welfare of 640 sows housed in stalls and in large groups on deep litter. The welfare was measured by different physical, immunological and endocrinological factors. They found higher levels of cortisol in the group-housed sows in early gestation, which is likely a result of social aggression imposed by group-housing. In the stall-housed sows, they found a worsened physical and immunological state. However, the study concluded that there are welfare advantages and disadvantages in each housing arrangement, which vary depending on reproductive stage.
The third study mentioned which found the same pattern, is by Jansen *et al. (*2007), who examined the effects of stall-housing and group-housing of sows on behaviour and fertility, on 96 sows. They found that group-housed sows were involved in aggressive encounters more frequently than stall-housed sows, and that salivary cortisol concentrations was higher in these as well, yet no effects was found on fertility.

Soede *et al.* (1997) found no differences in cortisol levels according to housing conditions. This study, however, was only conducted on 21 sows and each sow had been tethered during lactation and hereafter placed into the given housing condition. The same accounts for Von Borell *et al.* (1992), who examined the effects of housing systems on performance (132 gilts used), endocrinological functions (35 gilts used) and immunological functions (28 gilts used). Although assessing cortisol levels was not the main target for the research, it was examined, and they found no difference in the two housing conditions, which was gilts housed in stall and gilts housed in smaller groups.
By examining these studies further, it is clear that the higher levels of cortisol that was found in the more recent studies, are likely to result from social aggression which arose due to the imposed groups, involving conflict arising from mixing and feeding among others, as described in section 4.2. Therefore, for future studies, it may be interesting to conduct more studies exclusively on the available space aspect, where there is either no contact with other animals, or where the animals are in groups that are more alike their natural group structures, resulting in the antagonistic social interactions are at a minimum.
As we have mentioned previously, the piglet mortality in organic farmed gilts and sows is higher than in conventional systems. This is possibly due to the fact that all gilts come from the same breeding programs and thus is bred to the same objectives. The sows can give birth to more piglets than they have teats and maternal instinct are generally not part of the breeding objectives (Baxter *et al.* 2013; Videncenter for svineproduktion 2013b). A breeding program targeting maternal instincts might reduce piglet mortality by crushing, while allowing sows to roam freely during farrowing and lactation. Andersen *et al.* (2005) found that crushing sometimes seemed intentional as the sow had had nose-to-nose contact (in 33 % of the times) with the piglet before fatal overlying (i.e. she is aware of its presence), which could suggest that this is a way of reducing the number of piglets in order to increase survival rates of the remaining piglets. As a financial goal of the farmers is to have as many piglets as possible to reach slaughter weight, it might be financially beneficial to target breeding towards fewer piglets, increased maternal instincts and thus a higher survival rate for piglets to reach slaughter weight.

It is plausible, that through intensive housing and breeding, the pigs in question may have adapted to their environment, both behaviourally coping and genetically adapted, therefore eliciting stress responses reflecting this. This may be important if one is to assess welfare from cortisol levels, as these then may not be well-reflecting indicators of welfare, if the animals are still psychologically experiencing the stressors as being detrimental. This is thus emphasising the point of assessments of welfare by including not only physiological measures, but also behavioural measures.
This natural evolution may prove to be beneficial if incorporated into breeding objectives. As mentioned earlier in section 2.1, cortisol responses have proven to be heritable in pigs, as well as in other animals and humans. These findings can therefore prove important in a welfare aspect, as stress responses then can be incorporated into selective breeding, in order to lower these (Kadarmideen & Janss 2006). Not only may this be a valuable tool to increase

the welfare of pigs, but also be valuable for the economics behind pig production, as the quality of meat produced will decline with higher levels of cortisol present in the animal. Thus, higher cortisol levels are unwanted for various reasons regarding several aspects. We believe that such a consideration of the heritability of stress responses when planning breeding programmes is thus beneficial, not only to the animal, but also to the producer as well as to the consumer who is conscious of animal welfare. However, we believe it is of importance to stress that the potential out-breeding of certain traits that selects for increased stress-responsiveness, should not be followed by a general accepted idea of pigs not having reduced welfare if they are not highly responsive to their surroundings, when accounting for cortisol. Even if a given response to a stressor is not detectable in fluctuations of cortisol, it is not a guarantee that the pig is not experiencing distress in other ways, and thus other measures may be incorporated into data and therefore may account for this uncertainty.

8. Conclusion

The use of non-invasive methods seem applicable for domestic pigs in all production stages as long as the factors relating to a given stage is considered as stress responses may vary between individuals.

Housing systems of both restricted and free-ranging gilts and sows as seen today, each come with inevitable factors which contribute to elevated cortisol levels. In restricted gilts and sows, one of the main contributing factors to stress is the inability to perform nest-building behaviour, whereas one of the main contributor to stress in free-ranging housed gilts and sows is social aggression, arising from various reasons specific to this.

The literature indicates that restricted gilts and sows are more stressed than free-ranging gilts and sows. This is especially so in areas affecting piglet mortality, such as the inability to perform nest-building behaviours resulting in increased frequency of crushing of piglets, and prolonged farrowing which affects the number of stillborn piglets. This could prove beneficial as a gateway to improve conditions for gilts and sows in the conventional production for both the economical aspects of meat production and for the welfare of piglets, gilts and sows.

References

Andersen, I.L., Berg, S. & Bøe, K.E. (2005): Crushing of piglets by the mother sow (Sus scrofa)—purely accidental or a poor mother? *Applied Animal Behaviour Science*. Vol 93. pp. 229–243.

Anil, L., Anil, S. S., Deen, J., Baidoo, S. K.and Wheaton, J. E. (2005): Evaluation of Well-being, Productivity, and Longevity of Pregnant Sows Housed in Groups in Pens with an Electronic Sow Feeder or Separately in Gestation Stalls. *American Journal of Veterinary Research*. Vol. 66. pp. 1630 – 1638.

Barnett, J. L., Winfield, C. G., Cronin, G. M., Hemsworth, P. H. and Dewar, A. M. (1985): The Effect of Individual and Group Housing on Behavioural and Physiological Responses Related to the Welfare of Pregnant Pigs. *Applied Animal Behaviour Science*. Vol. 14. pp. 149 – 161.

Barnett, J. L., Hemsworth, P. H. and Winfield, C. G. (1987a): The Effects of Design of Individual Stalls on the Social Behaviour and Physiological Responses Related to the Welfare of Pregnant Pigs. *Applied Animal Behaviour Science*. Vol. 18. pp. 133 – 142.

Barnett, J. L., Hemsworth, P. H., Winfield C. G. and Fahy, V. A. (1987b): The Effects of Pregnancy and Parity Number on Behavioural and Physiological Responses Related to the Welfare Status of Individual and Group-housed Pigs. *Applied Animal Behaviour Science*. Vol. 17. pp. 229 – 243.

Baxter, E.M., Jarvis, S., Sherwood, L., Robson, S.K., Ormandy, E., Farish, M., Smurthwaite, K.M., Roehe, R., Lawrence, A.B. & Edwards, S.A. (2009): Indicators of piglet survival in an outdoor farrowing system. *Livestock Science*. Vol 124. pp. 266–276 124

Baxter, E.M., Lawrence, A.B. & Edwards, S.A. (2010): Alternative farrowing systems: design criteria for farrowing systems based on the biological needs of sows and piglets. *Animal*. Vol. 5. no. 4. pp. 580–600

Baxter, E.M., Rutherford, K.M.D., D'Eath, R.B., Arnott, G., Turner, S.P., Sandøe, P. Moustsen, V.A., Thorup, F., Edwards, S.A. & Lawrence, A.B. (2013): The welfare implications of large litter size in the domestic pig II: management factors. *Animal Welfare*. Vol. 22. pp. 219-238.

Bergeron, R., Gonyou, H. W. and Eurell, T. E. (1996): Behavioural and Pysiological Responses of Meishan, Yorkshire and Crossbred Gilts to Conventional and Turn-around Gestation Stalls. *Canadian Journal of Animal Science*. Vol. 76. pp. 289 – 297.

Blache, D., Terlouw, C. & Maloney, S. K. (w.y.): Physiology. In: M.C. Appleby, J. A. Mench, I. A. S. Olsson & B. O. Hughes (eds) (2011). *Animal Welfare*, 2nd Edition. CABI, UK. pp. 155 - 182

Blackshaw, J. K. & Blackshaw A. W. (1989): Limitations of Salivary and Blood Cortisol. *Veterinary Research Communications*. Vol. 13. pp. 265 – 271.

von Borell, E., Morris, J. R., Hurnik, J. F., Mallard, B. A. and Buhr, M. M. (1992): The Performance of Gilts in a New Group Housing System: Endocrinologic and Immunological Functions. *Journal of Animal Science*. Vol. 70. pp. 2714 – 2721.

Bushong, D. M., Friend, T. H. & Knabe, D. A. (1999): Salivary and Plasma Cortisol Response to Adrenocorticotropin Administration in Pigs. *Laboratory Animals*. Vol. 34. pp. 171-181.

Chapinal, N., Ruiz de la Torre, J . L., Cerisuelo, A., Gasa, J., Baucells, M. D., Coma, J., Vidal, A., Mantesa, X., (2010): Evaluation of Welfare and Productivity in Pregnant Sows Kept in Stalls or in 2 Different Housing Systems, *Journal of Veterinary Behavior*. Vol. 5. pp. 82 – 93.

Cook, N.J. (2012): Review: Minimally Invasive Sampling Media and the Measurement of Corticosteroids as Biomarkers of Stress in Animals. *Canadian Journal of Animal Science*. Vol. 92. pp. 227-259.

Damm, B.I., Pedersen, L.J., Marchnant-Forde, J.N. & Gilbert, C.L. (2003): Does feed-back from a nest affect periparturient behaviour, heart rate and circulatory and oxytocin in gilts?. *Applied Animal Behaviour Science*. Vol 83. pp. 55-76.

Estienne, M. J., Harper, A. E. and Knight, J. W. (2006): Reproductive Traits in Gilts Housed Individually or in Groups During the First 30 Days of Gestation. *Journal of Swine Health and Production*. Vol. 14. pp. 241 – 246.

Fisker, B.N. & Hansen, L.U. (2009): *Moder-afkom adfærd,* [online]. vsp.dk, Denmark, oktober 2009. [Citeret oktober 2014]. Tilgængelighed på internet: http://vsp.lf.dk/viden/grisens%20adfaerd/normal%20adfaerd/moder-afkom%20adfaerd.aspx

Frandsen, C.K., (2014a): *Svineproduktion i Danmark,* [online]. lf.dk, Denmark, marts 2014. [Citeret oktober 2014]. Tilgængelig på internet: http://www.lf.dk/Viden_om/Landbrugsproduktion/Husdyr/Svin.aspx

Hay, M. & Morméde, P., 1998: Urinary excretion of cathecolamines, cortisol and their metabolites in Meishan and Large White sows: validation as a non-invasive and integrative assessment of adrenocortical and sympathoadrenal axis activity. *Veterinary Research.* pp. 119-128.

Jansen, J., Kirkwood, R. N., Zanella, A. J. and Templeman, R. J. (2007): Influence of Gestation Housing on Sow Behavior and Fertility. *Journal of Swine Health and Production.* Vol. 15. Pp. 132 – 136.

Jarvis, S., Calvert, S.K., Stevenson, J., vanLeeuwen, N. & Lawrence, A.B. (2002): Pituitary-adrenal activation in pre-parturient pigs (*Sus scrofa*) is associated with behavioural restriction due to lack of space rather tham mesting substrate. *Abstract Animal Welfare.* Vol. 11. pp. 371-384.

Jarvis, S., D'Eath, R. B., Robson, S. K. and Lawrence, A. B. (2006): The Effect of Confinement during Lactation on the Hipothalamic-pituitary-adrenal Axis and Behaviour of Primiparous Sows. *Physiology & Behavior.* Vol. 87. pp. 345 – 352.

Jarvis, S. Moinard, C. Robson, S.K. Baxter, E. Ormandy, E. Douglas, A.J., Seckl, J.R., Russell, J.A. & Lawrence; A.B. (2006): Programming the offspring of the pig by prenatal social stress: Neuroendocrine activity and behavior. Hormones and Behavior. Vol. 49. pp. 68 – 80.

Jensen, P. (2002): *Behaviour of pigs. In The ethology of domestic animals* (ed. P Jensen), pp. 159–172. CABI Publishing, Wallingford, UK.

Kadarmideen, H.N. & Janss, L.L.G (2006): Population and systems genetics analyses of cortisol in pigs divergently selected for stress. *Physiological genomics.* Vol. 29. pp. 57-65

Kadarmideen, H. N. & Janss, L. L. G. (2007): Population and Systems Genetics Analyses of Cortisol in Pigs Divergently Selected for Stress. *Physiol. Genomics.* Vol. 29. pp. 57 – 65.

Karlen, G. A. M., Hemsworth, P. H., Gonyou, H. W., Fabrega, E., Strom, A. D. and Smits, R. J. (2007): The Welfare of Gestating Sows in Conventional Stalls and Large Groups on Deep Litter. *Applied Animal Behaviour Science.* Vol. 105. pp. 87 – 101.

Koeppen, B. M. & Stanton, B. A. (2010): Berne & Levy Physiology. Sixth Edition. Mosby Elsevier. Philadelphia.

Kranendonk, G., Hopster, H., Fillerup, M. Ekkelm E.D., Mulder, E.J.H. & Taverne, M.A.M. (2006): Cortisol administration to pregnant sows affects novelty-induced locomotion, aggressive behaviour, and blunts gender differences in their offspring. *Hormones and Behavior*. Vol. 49. pp. 663–672.

Landbrug & fødevarer (2014b): *Statistik 2013. Svinekød*. Rapport, juni 2014. [Citeret oktober 2014).

Lawrence, A. B., Petherick, J. C., McLean, K. A., Deans, L. A., Chirnside, J., Vaughan, A., Clutton, E. and Terlouw, E. M. C. (1994) The Effect of Environment on Behaviour, Plasma Cortisol and Prolactin in Parturient Sows. *Applied Animal Behavior Science*. Vol. 39. pp. 313 – 330.

Marchant-Ford, J. N. (2009): Welfare of Dry Sows. In: Marchant-Ford, J. N. (2009) *The Welfare of Pigs*. Vol. 7. Springer, USA. pp. 95 – 139.

McKay, L. I. & Cidlowski, J.A. (2003): *Pharmacokinetics of Corticosteroids* [online]. www.ncbi.nlm.nih.gov, USA, 2003, [Citeret oktober 2014]. Tilgængelig på internet: http://www.ncbi.nlm.nih.gov/books/NBK13300/

Miller, D.B. & O'Callaghan, J.P. (2002): Neuroendocrine Aspects of the Response to Stress. *Metabolism*. Vol. 51, No 6. pp. 5-10.

Moberg, G.P. (2000): Biological Response to Stress: Implications for Animal Welfare. *International*. pp. 1-2. Moberg, G., 2000. In: Moberg, G., Mench, J. (Eds.), *The Biology of Animal Stress: Basic Principles and Implications for Animal Welfare*. CAB International, Wallingford, UK, pp. 1–21.

Morgan, K. N. & Tromborg, C. T. (2007): Sources of Stress in Captivity. *Applied Animal Behaviour Sciences*. Vol. 102. pp. 262 – 302.

Mousten, V.A. & Petersen, L.B. (2013a): *Farestier med so i boks – generelle forhold,* [online]. vsp.dk, Denmark, november 2013. [Citeret oktober 2014]. Tilgængelig på internet: http://vsp.lf.dk/Viden/Stalde/Staldindretning/Farestald/Farestald_generelle_forhold_so_i_boks.aspx?full=1

O'Conell, N.E., Beattie, V.E. & Moss, B.W. (2003): INFLUENCE OF SOCIAL STATUS ON THE WELFARE OF SOWS IN STATIC AND DYNAMIC GROUPS. *Animal Welfare*. Vol. 12. pp. 239-249

Oliviero, C., Heinonen, M., Valros, A., Hälli, O. and Peltoniemi, O. A. T. (2008): Effect of the Environment on the Physiology of the Sow during Late Pregnancy, Farrowing and Early Lactation. *Animal Reproduction Science*. Vol. 105. pp. 365 – 377.

Otten, W., Kanitz, E. Tuchscherer, M., Puppe, B. & Nürnberg, G. (2007): Repeated administrations of adrenocorticotropic hormone during gestation in gilts: Effects on growth, behaviour and immune responses of their piglets. Livestock Science. Vol. 106. pp. 261–270

Palme, R., Fischer, P., Schildorfer, H. & Ismail, M. N. (1996): Excretion of infused 14C-steroid hormones faeces and urine in domestic livestock. *Animal Reproduction Science.* Vol. 43. pp. 43-63

Pedersen, L.J., Jørgensen, E., Heiskanen, T. & Damm, B.I. (2006): Early piglet mortality in loose-housed sows related to sow and piglet behaviour and to the progress of parturition. *Applied Animal Behaviour Science*. Vol. 96. pp. 215–232

Pedersen, L.J., Berg, P-, Jørgensen, E., Bonde, M.K., Herskin, M.S., Knage-Rasmussen, K.M., Kongsted, A.G., Lauridsen, C., Oksbjerg, N., Poulsen, H.D., Sorensen, D.A., Theil, P.K., Thodberg, K. & Jensen, K.H. (2010): *Pattegrisedødelighed i DK. Muligheder for reduktion af pattegrisedødeligheden i Danmark,* [online]. Århus Universitet, Tjele, oktober 2010. [Citeret oktober 2014]. Tilgængelig på internet: http://www.foedevarestyrelsen.dk/SiteCollectionDocuments/25_PDF_word_filer%20til%20download/06kontor/DJF_rapport_Pattegrisdødelighed.PDF

Pol, F., Courboulay, V., Cotte, J-P., Martrenchar, A., Hay, M. & Morméde, P. (2002): Urinary cortisol as an additional tool to assess the welfare of pregnant sows kept in two types of housing. *Veterinary Research*. pp. 13-22.

Riggenberg, N., Bergeronc, R. Meunier-Salaünd, M-C. & Devillersa, N. (2012): Impact of social stress during gestation and environmental enrichment during lactation on the maternal behavior of sows. *Applied Animal Behaviour Science*. Vol. 136. pp. 126– 135.

Romero, L.M. (2004): Physiological Stress in Ecology: Lessons from Biomedical Research. *Trends in Ecology and Evolution*. Vol. 19 No. 5. pp. 249 - 255.

Sheriff, M. J., Dantzer, B., Delehanty, B., Palme, R. & Boonstra, R. (2011): Measuring Stress in Wildlife: Techniques for Quantifying Glucocorticoids. *Oecologia*. 166. pp. 869–887

Schönreiter, S. & Zanella, A. J. (2000): Assessment of cortisol in swine by saliva: new methodological approaches. *Dummerstorf.* Vol. 43. pp. 165 – 170.

Sjaastad, Ø.V., Sand, O. & Hove, K. (2010): Physiology of Domestic Animals. Second edition. Scandinavian Veterinary Press. Oslo, Norway

Soede, N. M., Helmond, F. A., Schouten, W. G. P. and Kemp, B. (1997): Oestrus, Ovulation and Peri-ovulatory Hormone Profiles in Tethered and Loose-housed Sows. *Animal Reproduction Science*. Vol. 46. pp. 133 – 148.

van der Staay, F. J., Schuurman, T., Hulst, M., Smits, M., Prickaerts, J., Kenis, G. and Mechiel Korte, S. (2010): Effects of Chronic Stress: A Comparison between Tethered and Loose Sows. *Physiology & Behavior*. Vol. 100. pp. 154 – 16.

Sørensen, J.T. & Pedersen, L.J. (2013): *Status, årsager og udfordringer i forhold til løsning af forhøjet dødelighed hos økologiske pattegrise*, [online]. Århus universitet, Århus DCA rapport no. 021, juni 2013. [Citeret oktober 2014]. Tilgængelig på internet: http://dca.au.dk/fileadmin/DJF/DCA/Pattegrisedoedelighed.pdf

Touma, C. & Palme, R. (2005): Measuring Fecal Glucocorticoid Metabolites in Mammals and Birds: The Importance of Validation. Annals of the New York Academy of Sciences. 1046. pp 54- 74.

Tsuma, V. T., Einarsson, S., Madej, A., Kindahl, K., Lundeheim, N., & Rojkittikhun, T. (1996): Endocrine Changes During Group Housing of Primiparous Sows in Early Pregnancy. *Atca vet. Scand*. Vol. 37. pp. 481 – 490.

Vernersen, A. (2013b): *Avlsmål*, [online]. Videncenter for Svineproduktion, Denmark. [Citeret oktober 2014]. Tilgængelig på internet: http://vsp.lf.dk/viden/avl/drift/avlsmaal.aspx

Videncenter for Svineproduktion (w.y.): *Friland/Økologi*, [online]. Videncenter for Svineproduktion, Denmark. [Citeret oktober 2014]. Tilgængelig på internet: http://vsp.lf.dk/Viden/Friland_Oekologi.aspx.

Wade, S.E. (1992): An Oral-Diffusion-Sink Device for Extended Sampling of Multiple Steroid Hormone from saliva. *Clin Chem*. Vol 38/9. pp. 1878 – 1882.

Young, K. M., Walker, S. L., Lanthier, C., Waddel, W. T., Monfort, S. L., Brown, J. L. (2004): Noninvasive Monitoring of Adrenocortical Activity in Carnivores by Fecal Glucocorticoid Analyses. *General and Comparative Endocrinology*. Vol. 137. pp. 148 – 165.