Sveriges lantbruksuniversitet
Swedish University of Agricultural Sciences

Fakulteten för landskapsarkitektur,
trädgårds- och växtproduktionsvetenskap

How does rubber flooring in farrowing pens affect the lying time and lying behaviour of the sow and her time to lie down?

Hur påverkar gummigolv i grisningsboxen suggans liggtider, liggbeteende och hennes tid för att lägga sig?

Nina Winter

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FÖRORD

Studien har genomförts på uppdrag av Institutionen för biosystem och teknologi och Svenska Djurhälsovården AB som en del av projektet ”Gummimattor i grisningsboxar: hållbarhet och effekter på sugga och smågrisar”. Studien genomfördes med hjälp av projektbidrag från Partnerskap Alnarp.

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Alnarp juli 2014

Nina Winter

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SUMMARY

In the farrowing pens the amount of bedding material and the quality of the concrete floor has a huge impact on both the sow and the piglets. In this study imbedding of rubber flooring on the solid area in the farrowing pen was used to see if it had any effects on the sows lying behaviour when compared to concrete. Another important aspect was to evaluate if the rubber floorings had a high enough durability to resist the normal wear in a farrowing pen. Concrete flooring is assumed to have a higher thermally conductive effect then rubber which can affect the sow's chance to cool down. Therefore the temperature in the farrowing compartment was measured to see if there was a correlation between the sows lying behaviour and the temperature.

In total, the study was performed during five farrowing batches, in total about 30 weeks observation period. In each batch, two "rubber" pens and two "concrete" pens were included in the behavioural observations. Three different rubber floorings were included in the study; ProCoat[1] rubber compound, Porca relax[2], and KKM Porca prototype[2]. Continuous video recordings for the behavioural observations were made twice during the suckling period of five weeks. The video recordings were 24 hours each and took place at about one and three weeks after farrowing. The different behaviours that were noted were standing/walking, lying on the side, lying on the abdomen and sitting. The floor in the farrowing pen was divided into three different zones: solid flooring, slatted flooring and transition zone between solid and slatted flooring.

In the behavioural study there was a significant difference one week after farrowing and a trend three weeks after farrowing, that the sows in the rubber pens lay down less than the sows in the concrete pens. This difference was not due to less lying on the solid floor area in the "rubber" pens, but was due to significantly less lying in the transition zone. In contrary, when only looking at the behaviour lying and recalculating the figures for this there was a weak, but not significant, trend that the sows chose to lie more on the solid rubber area than on the solid concrete area in the pen.

The highest mean temperature was 21.9 ˚C and the lowest mean temperature was 15.1 °C. The assumption that sows could be more sensitive to higher temperatures when on the rubber floor, due to less thermal conductivity, could not be confirmed nor disregarded because the temperature during the observation period did not exceed the sows' thermo neutral zone (15-20 ˚C) by much. The relation between temperature and lying percent on the slatted area showed a large variation between individual sows. The time it took for the sows to lie down showed no significant difference between the treatments, but a great variation between individual sows could be noted.

The good durability of the Porca relax and of the KKM Porca prototype rubber mats were convincing during the whole study. In contrast ProCoat rubber flooring did not sustain the tough rooting behaviour of a sow in a farrowing pen and broke down.

[1]Henry Allt i Allt AB [2]Kraiburg Elastik GmbH

In conclusion there were large individual variations in sow behaviour in the study and the sows, in the farrowing pens, choose between different surfaces with different thermal and comfort properties. The use of rubber flooring instead of concrete on the solid area in the farrowing pen did not seem to be a great advantage in this herd. But the study showed that there are now rubber mats on the market, which can sustain the weight and behavioral activity of sows.

SAMMANFATTNING

I grisningsboxar påverkar mängden och kvaliteten strö samt golvets typ och kvalitet både suggan och smågrisarna. I denna studie lades gummimattor alternativt en gummimassa in på grisningsboxens betonggolv för att se om det hade någon inverkan på suggornas liggbeteende jämfört med de suggor som hölls på betong. En annan aspekt som också var viktig att utvärdera var om gummimattorna och gummimassan hade en så pass hög hållbarhet att de kunde motstå påfrestningarna som uppstår i en grisningsbox. Betonggolv har en viss värmeledande effekt som antas vara högre än den hos gummigolv. För att se om det fanns ett samband mellan liggbeteende och temperatur mättes därför också temperaturen i grisningsavdelningen.

Studien utfördes under totalt fem grisningsomgångar under sammanlagt ca 30 veckor. I varje omgång av beteendeobservationer ingick två boxar med gummigolv och två med betonggolv. Tre olika sorters gummigolv användes: ProCoat[1] gummimassa, Porca relax[2] och KKM Porca prototyp[2]. Dygnsvisa videoinspelningar gjordes en och tre veckor efter grisning. Dessa inspelningar användes för att observera suggans beteende. De beteende som noterades var står/går, ligger, sidoligger/sidobukligger och sitter. En indelning av golvet i grisningsboxen gjordes också och de olika zonerna var: helt golv, spaltgolv och övergång mellan helt golv och spaltgolv.

I beteendestudierna av suggorna var det en signifikant skillnad en vecka efter grisning, och tre veckor efter grisning sågs en trend att suggor i boxar med gummigolv låg mindre än de med betonggolv. Denna skillnad berodde dock inte på att suggorna låg mindre på det hela golvet utan på att de låg signifikant mindre på övergången mellan helt golv och spaltgolv. Då en omräkning av siffrorna gjordes och endast beteendet Ligger studerades fanns en svag, men ej signifikant, trend att suggor valde att ligga mer på det hela gummiområdet än på det hela betongområdet. Den högsta medeltemperaturen var 21.9 ˚C och den lägsta temperaturen var 15.1˚ C. Hypotesen att suggor kan vara mer känsliga för högre temperaturer på gummigolv, på grund av sämre värmeledningsförmåga, kunde varken bekräftas eller förkastas eftersom medeltemperaturen inte mer än marginellt översteg den termiska komfort zonen (15-20˚C) under observationsperioden. Förhållandet mellan temperatur och liggtiden i procent på spalten visade en stor variation mellan suggorna. Tiden det tog för suggorna att lägga sig ner visade också på en stor variation mellan suggorna, men ingen signifikant skillnad mellan behandlingarna kunde ses.

[1]Henry Allt i Allt AB [2]Kraiburg Elastik GmbH

Porca relax och KKM Porca prototyp visade god hållbarhet under hela studien. Däremot kunde inte ProCoat gummimassa stå emot suggans bökande i grisningsboxen utan gick sönder.

Slutsatserna av studien var att det fanns en stor variation mellan suggor och att icke fixerade suggor själva kan bestämma vilken yta i boxen med olika komfort och termiska egenskaper som de vill uppehålla sig på. Gummigolv istället för betong på den fasta ytan i grisningsboxen verkade inte vara någon fördel i den här studien. Undersökningen visade att det finns gummimattor på marknaden som kan motstå suggors vikt och bökande beteende i grisningsboxen.

INTRODUCTION

Background

The floor in modern pig production has a great influence on the pigs' welfare (Kilbride et al., 2009). The use of bedding material has been decreasing as the development of the intensive production in modern days has been established (Arey, 1993). In the farrowing pens the amount of bedding material and the quality of the concrete floor has a huge impact on both the sow and the piglets (Kilbride et al., 2009). Concrete floors are most often used but are hard and the structure can cause injuries such as shoulder lesions and lameness in the sows and knee injuries in the piglets (Jais & Knoop, 2010).

Different types of flooring are used in pig production; for example solid concrete, slatted concrete, slatted plastic, slatted metal, deep straw litter and the combinations of the above. They all have their pros and cons and vary between production steps. Keeping sows on deep straw litter during gestation will decrease the problems with shoulder lesions but other problems may occur, such as too long and deformed claws (Jais & Knoop, 2010). Growing and breeding pigs are affected by the floors in different ways then piglets are. The skin and the claws will get tougher with age but the pressure on the parts in close contact with the floor will increase as the animal gets heavier (Kilbride et al., 2009).

In a study by Arey (1993) bedding material in the pens improved the comfort for the pigs and also reduced injuries, but if straw was used as a bedding material it usually got pushed to the sides of the pen and in that way lost its function (Kilbride et al., 2009). The straw is also be expensive and could cause problems in the manure removal depending on which system is used in the production (Durrell et al., 1997). According to Tuyttens (2005) another problem with the use of straw was that it could be a good source for pathogens and bacterial growth, which of course is unwanted in the pig production. These above mentioned examples explain why rubber flooring could be an alternative. Rubber flooring not only improves the sow comfort in farrowing pens (Boyle et al., 2000; Gravås 1979), but could also help already existing wounds to heal more rapidly (Jais & Knoop, 2010). Actually in Denmark rubber flooring was used as a part of the treatment of sows with shoulder lesions (Kaiser et al., 2013).

When introducing rubber flooring in the farrowing pen it might be more difficult for the sows to cool down by using the heat conductivity of the concrete floor. Concrete floor has a higher U-value than rubber flooring and this means that the thermal conductivity, the cooling effect, is higher (Jeppson, 2011). Lactating sows have a thermic comfort zone between 15-20˚C provided that the relative air humidity is between 50-70%. Temperatures and air humidity outside this range will affect the performance and behaviour of the sow (Christiansen, 2010).

Aim

The aim of the current study was to see how an attempt to improve the floor quality affected the sows lying behaviour. But, also to find an alternative to concrete that is resistant enough to the normal wear in the farrowing pen.

Purpose

The purpose with the study was to compare the sows' behaviour on the different flooring types, concrete versus rubber flooring. Lying time, lying behaviour of the sow and position in the pen was in focus but also the time it took for the sows to lie down.

Hypothesis

The sows in pens with rubber flooring on the solid area will use this area different compared to sows in pens with concrete floor.

The differences in the thermal conduction of the rubber flooring versus the concrete floor will affect the sows lying behaviour when temperatures are increasing.

Limitations

This study was made as a part of a larger study. In the other part of the study the piglets' leg health was observed (injury study). That is why only the sows' behaviour is included in this thesis (behaviour study). Results from the injury study are presented by Ehlorsson et al. (2013).

LITTERATURE REVIEW

Flooring quality

In Sweden fully slatted flooring in pig production is not allowed (Jordbruksverket, 2013) and the most commonly used flooring in farrowing pens is partly slatted floors with a solid concrete area made of concrete provided with bedding material. In Sweden bedding materials for pigs should be given in such quantities that the pigs comfort and activity needs are met (Riksdagen, 2013). The slatted floors can be made of concrete, plastic or cast iron and also have very different profiles. The width of the slats also varies a lot. The fact that the sow is crated during different lengths of periods in the farrowing pen and thus receive different exposure time, makes it difficult comparing influence of floors between different studies in different countries.

The characteristics of the floor in the pen are important since it can cause injuries on the animals. Slipperiness, hardness, abrasiveness, hygiene, surface profile and void ratio of the floor are critical parameters to take into consideration when searching for the cause of lameness in sows (Pluym et al., 2013).

Today there are several different tools available to measure the physical properties of the floor (Pluym et al., 2013). In the farrowing pen the floor should meet the needs of both the sow and the piglets and provide high friction but should, on the other hand, not be too abrasive (Persson, 2006). Friction can be defined as resistance of sliding between two bodies in contact (Nationalencyklopedin, 2013a) for example claw and floor. A softer floor usually has a higher friction than a harder and the benefit of a high friction in the farrowing pen is to reduce the sow from slipping and to ease for the piglets to suckle. The theoretical friction in the farrowing pen should be at least 80 British Pendulum Number (BPN) according to the Skid Resistance Tester (SRT) (Persson, 2006). Abrasion can be defined as loss of material from the surface under the influence of friction forces. One way to measure floor abrasion is to draw a piece of rubber or gypsum across the surface and then measuring the weight loss of it. In addition to the loss of material, surface changes can also occur (Nationalencyklopedin, 2013b). Abrasion causes wear damage of the piglets' legs. That is why the abrasion effect in the farrowing pen needs to be as small as possible. Theoretically the abrasion should not exceed 5 gram when using the so called plaster block method (Nilsson C., 1988).

In a study by Munsterhjelm et al. (2006) welfare and reproductive performances in sows were defined with the help of different parameters/categories. Floor quality included parameters which could be perceived as part of the management; the amount and quality of bedding material, cleanliness of the lying area, but also the risk of slipping and the width of the slats. When a good floor quality was achieved the sow's reproductive performance improved by a shorter (average) reproduction cycle. Furthermore, good quality flooring resulted in less feet and teat injuries, fewer cases of lameness and shoulder lesions. This meant that the characteristics of the floor also had an impact on the economy of the farm.

Lameness, shoulder lesions and leg injuries

Lameness in cows is defined by Phillips (2010) as a change from normal gait caused by injury, disease, pain or discomfort in a part of the limb or trunk. Lameness in sows could be displayed in a few different ways: alteration in stride length and walking speed, reduced time spent standing and prolonged lying-to-standing transition (Grégoire et al., 2013). The causes of lameness are many and include both genetics and management and can be divided in infectious or non-infectious problems (Heinonen et al., 2013).

Heinonen et al. (2013) described that an increase in culling rate was highly associated with lameness. Therefore lameness is not only a welfare question but also an economic issue. Treating lameness is expensive because of the extra working time and medicine but also because of reduced income and losses from premature culling of lame sows.

Lameness and poor body condition can lead to shoulder lesions because of increased lying time and more pressure on the shoulder bone without cushioning flesh, respectively (Bonde et al., 2004). Since the sows have longer lying bouts when in the farrowing pen they are more exposed to the risk of developing shoulder lesions (Persson, 2006). Ivarsson et al. (2009) found the risk of developing shoulder lesions twice as high when the slatted area in the pen was large and the solid lying area was small (<1.5 m^2). They explained that slatted floors distribute the weight of the sow on a smaller pressure area of the shoulder than solid floors. On the other hand Holmgren et al. (2007) showed that a larger solid concrete area increased the risk for piglets to develop sole abscesses and knee injuries due to friction damages. Yet again the conflict between the welfare of the sow and the welfare of the piglets arises.

One way to prevent shoulder lesions in sows could be to have some restriction in their lying bouts after farrowing, by for example increasing the feeding times per day Rolandsdotter et al. (2009). In Denmark Kaiser et al. (2013) showed that rubber flooring in the farrowing crates helped already developed shoulder lesions to heal faster than on fully slatted plastic floor.

Leg injuries in piglets often develop due to repeated rubbing against the floor when suckling (Phillips et al., 1992). These lesions are often related to the abrasive properties of the floor, but the relationship between floor characteristics and number of lesions of the piglets seems to be more complicated than this. Gravås (1979) found that piglets in pens with concrete on the solid area did not have more knee wounds than piglets in pens with rubber (5mm rubber lining). Therefore both higher abrasions on the concrete and higher friction on the rubber were suggested to have an effect on skin tissue. Friction heat can build up and damage the tissue in a short time and also floor surface temperature has been shown as another parameter to be aware of. In a simulation study with concrete, rubber or metal slatted floors leg damage was evaluated in an artificial way at two different temperatures (21 and 34˚ C). No significant interaction between floor and temperature was seen but tissue damage on piglets' legs was in general greater on the warmer floor (34˚ C) than on the cooler one (21˚ C) for all three tested floor types. The total weighted lesion score was worst on the concrete floor, least on the metals slats and the rubber floor took a place in the middle (Phillips et al., 1992)

Lying down behaviour

The sequence of lying down in sows was described by Baxter and Schwaller (1983) and divided into five different stages. First step was lifting of one forefoot and dropping it into a half-kneeling position and then lifting the other forefoot to bring the sow into a fully kneeling position. Second step usually is a pause. In step three the sow slides one knee frontward and at the same time rotates the upper part of her body to rest the shoulder and head on the floor. In step four another pause may take place. In step five the hindquarter of the sow is lowered and the body is rotated a bit, the rear legs slides sideways, and the hindquarters is dropped to the floor.

Four different techniques of how the sow lies down were described by Schmid and Hirt (1993):

1. The sow lies down on the belly
2. The sow lies down on the side
3. The sow lies down by falling on the side
4. The sow lies down by leaning on a wall

The time it takes from standing to lying down was measured and it seemed to be quite individual (Bonde et al., 2004). A longer lying down sequence might reflect an increased body control and an increased attention towards the piglets which implies that the sow has good mother qualities. But, it can also have a negative explanation such as an uncomfortable flooring for the sow or poor claw or leg health. If the sequence is prolonged because of poor claw and leg health it is however a negative situation (Damm et al., 2004). Therefore the reason why the sow is lying down slowly must be evaluated in each case.

Thermal comfort zone and thermal properties of the floor

The term thermal comfort zone (thermo neutral zone) is the temperature interval which the animal prefers and means that the animal’s heat loss equals the heat produced. Outside the thermal comfort zone the animal requires energy to be in temperature balance, keep warm or cool down. The animal experiences heat stress if the temperature is above the temperature range and cold stress if the temperature is below. The thermal comfort zone depends on the age of the animal, the housing system (type of flooring) and the climate in the stable such as humidity and draught (Persson, 2006). Lactating sows have a thermal comfort zone between 15-20˚C, and temperatures outside this range will affect the performance and behaviour of the sow (Christiansen, 2010).

Thermoregulation is the system that keeps the warm-blooded animals' body temperature constant. This is controlled through heat emission from the body and heat production (Nationalencyklopedin, 2013c). The temperature that the animal experience is the effective environmental temperature and will increase or decrease due to different factors in the environment it is measured by a thermometer (Baker, 2004). Heat loss is caused by thermal convection, thermal conduction, thermal radiation and thermal evaporation. In a stable the thermal conduction of excessive heat from the body is transferred from the animal to the floor in an amount affected by the materials of the floor, the construction and the use of litter (Persson, 2006). According to Mount (1975) the contribution of thermal conduction to the change in effective environmental temperature of the sow was + 4ºC in a pen with straw, -5ºC in a pen with concrete floor and -5 – -10ºC in a pen with a wet surface.

In pig production the animal can cool down by increasing the contact with cold surfaces; this is usually made by the concrete floors in the pen. The cooling effect of slatted flooring might differ due to the width of the slats and the material; metal, concrete and plastic. Another natural way for pigs to cool themselves is through evaporation, i.e. conduction of heat by humidity. In confined conditions sows could defecate on the solid floor and roll in the dirt (Persson, 2006). In a study by Bull et al. (1997) gilts were given three choices of cooling down during heat stress. It was concluded that gilts preferred lying on a cold surface, a conductive cool pad, instead of using snout coolers or drop coolers.

The overall heat transfer coefficient or the U-value is expressed in Watts per m^2 Kelvin. The U-value expresses the ability to transfer heat from one medium to another (Nationalencyklopedin, 2013d) and is decided by the temperature and other properties of the media (Nationalencyklopedin, 2013e). In a study by Jeppsson (personal communication, December 2013) heat transfer through different floors in milking pits was measured. The heat transfer coefficient was determined by placing a heat vessel on the floor and measuring how fast the vessels were cooled down. The result showed that the U-value for solid concrete floor was 0.66 Watts per m^2 K and that a 25mm thick solid rubber mat lowered the U-value to 0.35W/ m^2 K (Jeppson, 2011). From this study it was concluded that it was easier for the milkers to keep their feet warm during milking when standing on a rubber mat compared to a concrete floor. In a farrowing pen, with a temperature in the upper border of the thermal comfort zone (heat stress), the sow will prefer to lie on a surface, like concrete, that conduct excessive heat better (Bull et al. 1997).

Rubber flooring

Soft flooring materials can help the pig to adapt the gait on a dirty floor and ensure a safer walk with fewer slips (von Wachenfelt et al., 2010). Too increase the lying comfort for the sow a soft bedding/flooring can be used. Gravås (1979) showed that the proportional lying time of the sows in percentage over 24 hours was significantly higher on rubber flooring (86.1) than on concrete floors (74.6) and epoxy painted floor (81.1) which indicates that the lying comfort on rubber flooring is higher. He also showed that piglets in pens with rubber flooring moved around easier compared to those on concrete floors or epoxy painted flooring.

When comparing concrete and rubber flooring, both the crated sows and the piglets had benefit from the rubber flooring (Vermeer & Binnendijk, 1997). The sows had fewer udder injuries and the litters where less treated for arthritis. Westin (2013) showed that even if rubber flooring in farrowing pens prevented claw injuries on piglets it did not prevent all of them. Therefore she recommended rubber flooring on the solid floor area together with a generous amount of straw. The latter recommendation was based on another study on strategic giving straw (Westin et al., 2008).

MATERIALS AND METHODS

Animals and housing

The study took place in a 15 years old farrowing compartment in a conventional piglet producing herd in the south of Sweden. All the farrowing pens within this compartment were 2.2 meters wide and 3.0 meters deep (6.6m^2) and made of a solid lying area approximately 4m^2 and a plastic slatted flooring as dunging area (figure 1). On the slatted flooring area there was a hatch where the dung was disposed. The concrete flooring held a creep area for the piglets and a feeding trough for the sow. In half of the pens the solid flooring was covered with rubber (rubber mats or rubber compound) and the remaining was made of solid concrete (control pens). There was a floor heating system in the pens, which was currently disconnected. The interior used in the pens was about 15 years old.

The sows had free access to water through water nipples and were fed liquid feed twice a day, at 06.45 and 13.45. The diet to lactating sows was a full feed with distillers grain and water. Management, amount of straw etc. was the same in all pens and only healthy sows that had their second or third litter were used in the study.

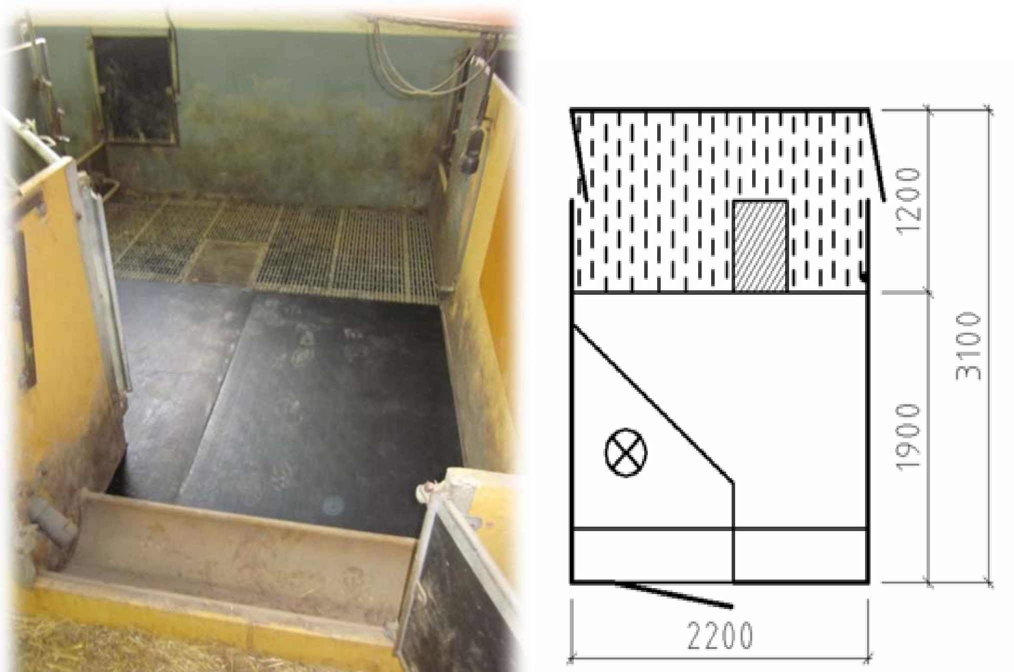

Figure 1. Picture and design of the farrowing pen.

Experimental design

To test the two hypothesizes, parallel controlled studies were performed during five farrowing batches (~30 week period). In each batch ten pens were included: five "rubber" pens and five "concrete" (control) pens (figure 2). Four pens (two "rubber" pens and two "concrete" (control) pens) were equipped with video cameras for behavioural studies.

Rubber flooring

The ProCoat[1] rubber compound (figure 3) was casted in four farrowing pens. The Porca relax[2], rubber mat, (figure 4) with a thickness of 20mm was cut to fit in to the fifth pen. Instead of bolting the mat to the floor, as recommended, the mat was glued because of the disconnected heating coils in the floor of the pens. Due to problems with the durability of the Procoat rubber, the initial experimental set up was changed. The Procoat rubber flooring was replaced with KKM Porca prototype[2] from batch number 3 (table 1). The KKM Porca prototype, (figure 5) was 30 mm thick.

Table 1. Number of concrete and rubber equipped pens with video cameras in the five different batches

	Concrete	Rubber (Porca relax)	Rubber (KKM Porca prototype)	Rubber (ProCoat)
Batch 1	2	1	0	1
Batch 2	1	1	0	1
Batch 3	2	0	1	1
Batch 4	2	1	1	0
Batch 5	2	1	1	0
In total	9	4	3	3

[1]Henry Allt i Allt AB [2] Kraiburg Elastik GmbH

Figure 2. Concrete flooring in a farrowing pen.

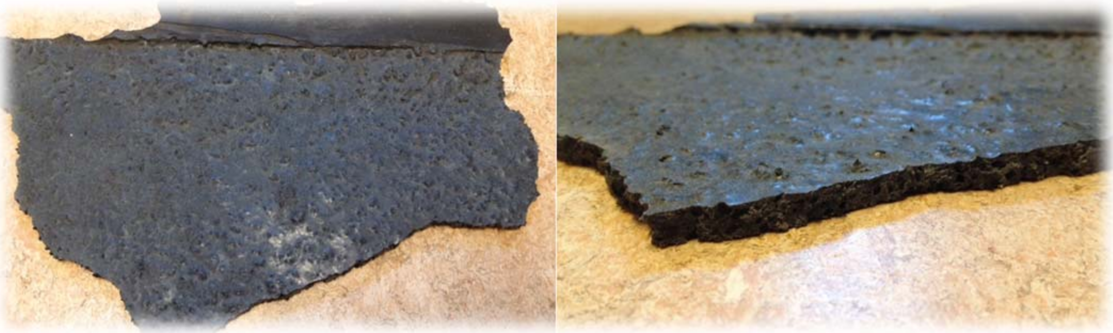

Figure 3. ProCoat rubber.

Figure 4. Porca relax, Kraiburg Elastik GmbH, rubber mat.

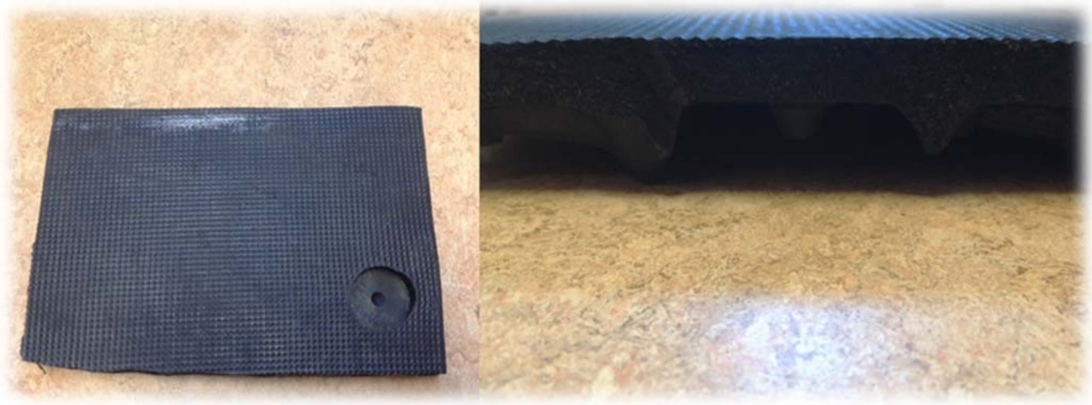

Figure 5. KKM Porca prototype, Kraiburg Elastik GmbH.

Behavioural observations

The sow lying and standing behaviour was recorded[3] and then studied from the video recordings. The recordings were stored digitally with the software MSH-Video client[4]. All four pens were recorded simultaneously. The first recordings in each batch took place when the piglets were about one week old and the second when they were about three weeks. During the 24hours the lights in the farrowing compartment was turned on. The cameras where switched on approximately one day before the recording day and the files where collected the following day.

At video decoding of behavioural observations, time (hour, minute, second) for all the observations was noted continuously on the tape as they occurred. This was made blinded, ie. without knowing the treatment. The spatial positioning of the sow in the farrowing pen was defined as lying on solid or slatted floor if >2/3 of the body was in either zone. It was recorded as lying in the transition zone if only ½ was placed in either zone (table 2). Four positions were recorded: lying on the side, lying on the abdomen, sitting and standing/walking (table 2). The difference between lying on the side and lying on the abdomen is illustrated in figure 6. The time it took for the sows from standing to lying was also measured. The protocol used to decode the video recordings is shown in the appendix.

[3] TVCCD-182HCOL, Monacor UK Ltd [4] M. Shafro & Co

Table 2. Definitions of the position of the sow in the pen and body position

Position in the pen	
Solid floor	>2/3 of the sow's body is on the solid floor
Slatted floor	>2/3 of the sow's body is on the slatted floor
Transition zone, between solid & slatted floor	½ of the sow's body is on the solid floor and ½ is on the slatted floor
Body position	
Lying on the side	All four legs are visible and stretched out from the sow's body and the teats/abdomen are also visible
Lying on the abdomen	The sow lies on the chest and abdomen or on the side of the abdomen and all legs are not visible
Sitting	The hindquarter is in contact with the floor, the front legs are extended and the claws are in contact with the floor
Standing or walking	Upright body position on extended legs

During the study data for one sow in a pen with concrete flooring were excluded due to camera problems and the data for one sow in a pen with rubber could not be measured since the sow was slipping.

Figure 6. Sow lying on the side (left) and lying on the abdomen (right).

Temperature

The temperature was measured twice every hour at each recording session with two Tinytag Plus 2 data loggers[5]. One logger was collected from the farm approximately one day after the video recordings were made and the other logger was always left in the farrowing compartment. The data in the temperature logger was emptied using the software EasyView[6] and a temperature diagram for the 24hour period was made.

Statistical analysis

All decoded data was transferred to Microsoft Office Excel and then further processing took place in SAS statistical software (SAS, version 9.3). A two sided t-test in SAS, PROC GLM, was performed.

[5] Gemini Data Loggers [6] MKS Instruments UK Ltd

RESULTS

Durability of the rubber flooring

The ProCoat rubber had to be replaced several times during the first three batches. In an attempt to make the compound to attach better, the concrete was pre-treated with screed and a primer was added before the rubber compound was spackled out again. Despite these efforts, the problems remained which caused changes in the experimental set up. At the end of the study it was noticed that the glue had detached from the KKM Porca prototype and it was wet and dirty underneath.

Behavioural observations

The results from the 24hour behaviour studies of the sows one and three weeks after farrowing are presented in table 3 and 4, respectively. One and three weeks after farrowing the sows were lying on the side or on the abdomen, on both floor types, on average 87% and 82% during the 24hour period, respectively.

One week after farrowing the sows in the pens with concrete were lying down significantly longer than those on rubber. Although not significant, the lying time differed more on the slatted area where sows in the concrete pen spent about 21% of their time compared to about 13% in the rubber pen. The shorter lying time of the sows in the rubber pens meant a tendency to a longer time standing and walking in these pens, 12.4% in the rubber pen compared to 9.0% in the concrete pen.

Table 3. 24hours behaviour of sows ($\bar{x} \pm$ s d) **1 week** after farrowing, batch 1-5

	Concrete	Rubber	p-value
No. sows	9[1)]	10	
Lying	89.7± 3.1	84.9± 6.0	0.05
Solid floor	59.1±25.2	64.2±15.7	0.60
Slatted floor	20.6±23.2	12.6±11.7	0.35
Transition zone	10.0± 7.4	8.1± 7.1	0.58
Sitting	1.3± 1.3	2.7± 2.2	0.13
Standing/walking	9.0± 2.9	12.4± 4.5	0.07

1) One sow excluded due to camera problems.

Table 4. 24hours behaviour of sows ($\bar{x}$ ± s d) **3 weeks** after farrowing, batch 1-5

	Concrete	Rubber	p-value
No. sows	9[1)]	10	
Lying	84.4± 4.1	80.5± 6.6	0.15
Solid floor	53.1±17.5	60.1± 9.3	0.28
Slatted floor	18.2±16.9	15.1±10.2	0.63
Transition zone	13.0± 7.6	5.2± 4.6	0.01
Sitting	1.8± 1.2	2.4± 2.3	0.53
Standing/walking	13.8± 3.6	17.1± 5.3	0.13

[1)] One sow excluded due to camera problems.

Also three weeks after farrowing, there was a trend that the sows in the rubber pens were lying less and the sows in the concrete pens were lying significant more in the transition zone.

In tables 5 and 6 the differences in lying % on the three different rubber floorings are shown for 1 and 3 weeks after farrowing, respectively.

Table 5. 24hours lying on three different types of rubber flooring ($\bar{x}$ ± s d), **1 week** after farrowing, batch 1-5

1week	No. sows	%
Lying in total on rubber	10	84.9± 6.0
Lying- Porca relax	4	89.5± 2.8
Lying-Porca prototyp	3	81.9± 0.5
Lying-ProCoat	3	81.9± 9.1
Standing/walking in total on rubber	10	12.4± 4.5
Standing/walking-Porca relax	4	9.3± 3.7
Standing/walking-Porca prototype	3	15.2± 1.4
Standing/walking-ProCoat	3	13.9± 6.0

Table 6. 24hours lying on three different types of rubber flooring ($\bar{x} \pm$ s d), **3 weeks** after farrowing, batch 1-5

3 weeks	No. sows	%
Lying in total on rubber	10	80.5± 5.7
Lying-Porca relax	4	87.0± 4.4
Lying-Porca prototype	3	76.4± 2.7
Lying-ProCoat	3	76.0± 4.1
Standing/walking in total on rubber	10	17.1± 5.3
Standing/walking-Porca relax	4	12.5± 4.7
Standing/walking-Porca prototype	3	20.5± 4.1
Standing/walking-ProCoat	3	19.9± 2.9

Both one and three weeks after farrowing the Porca Relax rubber mat had the largest proportion of lying.

In tables 7 and 8 only the total lying time data is shown, recalculated to 100%. With this recalculation it is easier to see in which zone sows chose to lie. The sows in the rubber pens were lying less in the transition zone than the sows in the concrete pens, three weeks after farrowing. No significant differences were found.

Table 7. 24hours position of lying in the pen by different body position ($\bar{x} \pm$ s d), **1 week** after farrowing, batch 1-5

	Concrete	Rubber	p-value
No. sows	9[1)]	10	
Lying- solid floor	65.6±27.6	75.7±18.0	0.35
Lying on the side	45.4±23.8	51.8±18.7	0.52
Lying on the abdomen	20.2± 8.0	23.9±10.0	0.39
Lying-slatted floor	23.3±26.4	14.8±13.8	0.38
Lying- transition zone	11.1± 8.3	9.5± 8.0	0.67

[1)] One sow excluded due to camera problems.

Table 8. 24hours position of lying in the pen by different body position ($\bar{x} \pm$ s d), **3 weeks** after farrowing, batch 1-5

	Concrete	Rubber	p-value
No. sows	9[1)]	10	
Lying- solid floor	63.0±21.4	74.7±10.0	0.14
Lying on the side	38.1±20.4	50.3± 9.9	0.13
Lying on the abdomen	24.9±16.0	24.4± 8.7	0.93
Lying-slatted floor	21.8±20.8	18.9±12.7	0.71
Lying- transition zone	15.2± 8.7	6.4± 5.5	0.02

[1)] One sow excluded due to camera problems.

The average number of lying down occasions per 24hour period, average time to lie down (seconds) and the total lying time per occasion (minutes) one and three weeks after farrowing is shown in table 9 and 10. No significant differences were found.

Table 9. Lying down behaviour (No. occasions, time to lie down per occasion and total lying time per lying occasion ($\bar{x} \pm$ s d)), 24hours **1 week** after farrowing, batch 1-5

	Concrete	Rubber	p-value
No. sows	9[1)]	9[2)]	
No. occasions	25.7±10.1	24.0±10.6	0.74
Time to lie down, sec	12.0± 5.8	12.2± 3.1	0.92
Time per lying occasion, min	55.7±24.3	57.3±25.7	0.90

[1)] One sow excluded due to camera problems.

[2)] One sow (Porca Relax) could not be evaluated due to slipping.

Table 10. Lying down behaviour (No. occasions, time to lie down per occasion and total lying time per lying occasion ($\bar{x}$ ± s d)), 24hours **3 weeks** after farrowing, batch 1-5

	Concrete	Rubber	p-value
No. sows	9[1)]	9[2)]	
No. occasions	33.3±12.9	30.6±12.0	0.64
Time to lie down, sec	13.7± 5.5	14.1± 3.6	0.84
Time per lying occasion, min	41.1±17.5	41.2±15.6	0.99

[1)] One sow excluded due to camera problems.

[2)] One sow (Porca Relax) could not be evaluated due to slipping.

Temperature

The results of the temperature measurements one and three weeks after farrowing are presented in tables 11 and 12. The lowest temperatures were measured in batch one with about the same minimum and maximum temperature (about 15.0 °C) in the 24hour periods both one and three weeks after farrowing. The highest temperatures were measured in batch four, one week after farrowing (26.8 °C). In appendix 2, line charts of all temperatures during batch 1-5, two times 24hours, are presented.

Table 11. Temperatures in ˚Celsius during the 24hour video recordings, **1 week** after farrowing, batch 1-5

1 week	Date	Mean value	Min	Max
Batch 1	2013-03-05	15.2 °C	15.0 °C	15.4 °C
Batch 2	2013-04-23	17.0 °C	16.7 °C	17.3 °C
Batch 3	2013-06-19	19.5 °C	18.0 °C	22.2 °C
Batch 4	2013-08-07	21.9 °C	19.2 °C	26.8 °C
Batch 5	2013-10-16	18.0 °C	17.8 °C	18.2 °C

Table 12. Temperatures in ˚Celsius during the 24hour video recordings, **3 weeks** after farrowing, batch 1-5

3 weeks	Date	Meanvalue	Min	Max
Batch 1	2013-03-19	15.1 °C	14.8 °C	15.3°C
Batch 2	2013-05-08	19.0 °C	17.5 °C	21.4°C
Batch 3	2013-07-02	19.0 °C	17.9 °C	21.6 °C
Batch 4	2013-08-21	19.7 °C	17.9 °C	22.1 °C
Batch 5	2013-10-31	17.3 °C	17.1 °C	17.5 °C

Temperature and choice of lying zone in the pen

The relation between the mean temperature and the mean % lying on the slatted area, three weeks after farrowing, in the pens with concrete or rubber on the solid area, respectively, are presented in figure 6 and 7. There was a large individual variation and the regression coefficient was 2.3 in pens with concrete compared to 2.9 in the pens with rubber. For the pens with concrete the coefficient of determination R^2 was very low (0.06), which means that very little of the variation is explained by the regression, while the coefficient of determination R^2 for the pens with rubber was a little higher (0.26).

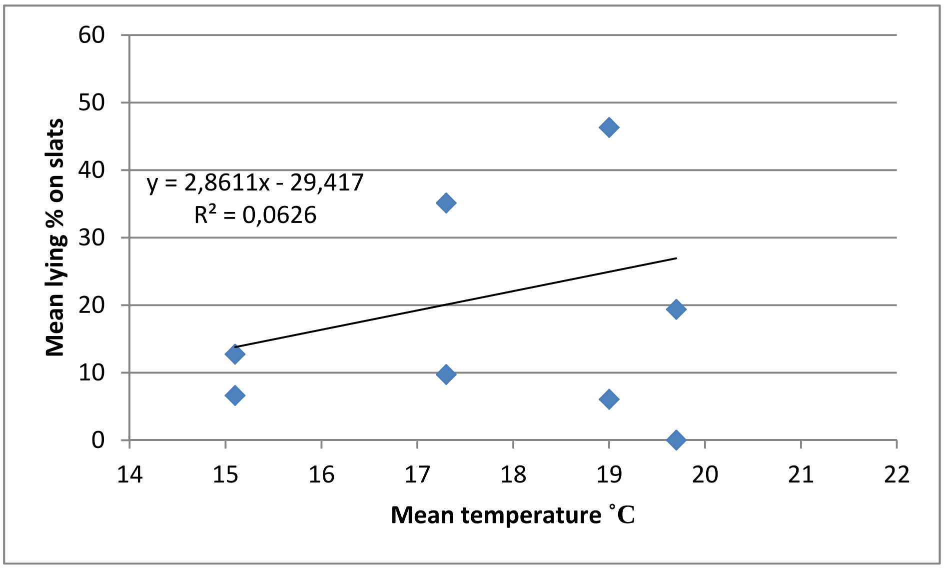

Figure 6. The relation between mean temperature ˚C and % lying on the slatted area in the pens with concrete on the solid area, **3 weeks** after farrowing, batch 1-5.

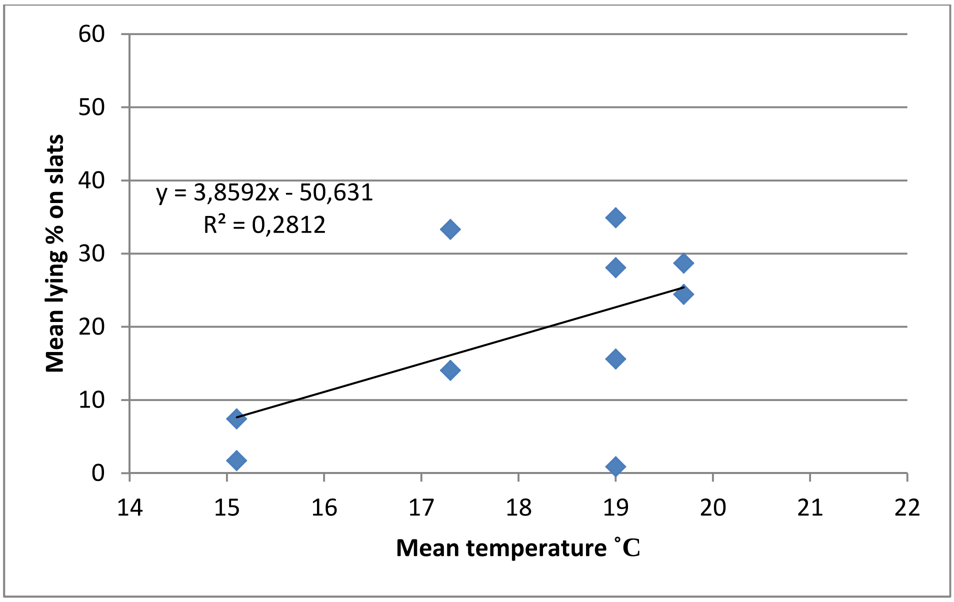

Figure 7. The relation between mean temperature ˚C and mean lying % on the slatted area in the pens with rubber on the solid area, **3 weeks** after farrowing, batch 1-5.

DISCUSSION AND CONCLUSIONS

The durability of the Porca relax and of the KKM Porca prototype rubber mats were good during the whole study period. The attachment of the Porca relax mat to the concrete was satisfactory while half the KKM Porca prototype detached from the concrete. Thus it was not enough to glue this rubber mat and the recommendation from the producer (Kraiburg Elastik GmbH & Co), is to bolt the mat to the concrete floor. It was coincidentally noticed on the video recordings from the last batch that a sow in the pen with the KKM Porca prototype was manipulating the mat. However, no observations of sows manipulating the rubber flooring in the pens with ProCoat, was noticed although the sows managed to tear off the rubber compound from the floor in each batch until batch three. ProCoat rubber was then replaced with the KKM Porca prototype rubber mat. The conclusion is that any rubber compound has to sustain the tough rooting behaviour of a sow in a farrowing pen before it can be used in a practical context.

Another aspect considered in this study was different thermal properties of rubber and concrete floors. The possible benefits of the rubber flooring are lost if the utilization is limited due to difficulty to lead away heat at high environmental temperatures (Elmore et al., 2010). The regression diagrams were done three weeks after farrowing because the sows get more active with time. The regression diagrams, however, showed no correlation ($R^2 < 0.6$) probably because the mean temperature did not really exceed the thermal comfort zone of the sows. This meant that the hypothesis that the sows could be more sensitive to higher temperatures, due to the lower U-value of the rubber flooring couldn’t be rejected nor confirmed. The coefficient of determination R^2 for linear regression line between temperature and time for lying on the slatted area in the pens was a little higher (0.26) with rubber compared to for the pens with concrete (0.06). This could confirm the hypothesis, but still both these figures are low. The reason for looking at the slatted area instead of the solid floor was simply to see if the sows preferred the slatted area instead of the rubber flooring when the temperature was higher. This was also supported by the unpublished material from Jeppsson (personal communication, December 2013), where a rubber mat lowered the U-value. In a farrowing pen, with a temperature in the upper border of the thermal comfort zone of the sow, this can be a disadvantage for the rubber. This means that if the sow is too warm, she will try to find another way to thermo regulate than using the insulated solid (rubber) floor in the pen. If given a choice the sow might prefer to lie on the slatted floor instead (as possibly in this case), but if crated this is impossible. Also the thermal conduction of the slatted floor, to cool the sow down, might differ with the material in the slats and the slat width of the floor.

Sows in pens with rubber on the solid area lie down less than the sows in the pens with concrete on the solid area, both one and three weeks after farrowing. But, the total lying time was not consequently shorter in all the pens with rubber flooring and the time lying on the solid area in the pen was not shorter in the pens with rubber compared to pens with solid concrete. The mean total lying time was only less for the pens with KKM Porca prototype and ProCoat rubber, but not for the pens with the Porca relax mats. This shows that the sows in the pens with Porca relax mats where more active. It is common in dairy cows with rubber mats on the walking alleys that the activity is higher than on concrete (Benz, 2002). Less lying could also result from being more active because of trying to manipulate the rubber flooring instead of lying down. In the study by Elmore et al. (2010) sows provided with rubber mats stood up and lied down more frequently than the sows on concrete, which also is seen in cattle on rubber slatted flooring (Graunke et al., 2011). On the other hand Gravås (1979) showed that sows´ total lying time was longer when provided with a rubber mat.

It is difficult to interpret the small difference in total lying time between the different pens. The difference was not due to more lying on the solid concrete area in the concrete pen but because of more lying on the plastic slats and the transition zone. This is why the results could not be interpreted as the concrete floor being more favourable for the sows. Instead when recalculating the lying observation to 100%, there were no significant difference, but a trend that the sows in the pens with rubber on the solid area chose to lie more, especially on the side. These results are in line with the results by Elmore et al. (2010), where the sows spent more time lying on the side in the stall area with rubber flooring than on concrete.

Another result that is worth discussing is that the sows in the pens with the Porca relax, and KKM Porca prototype, lay down surprisingly much in the transition zone compared to the sows in pens with ProCoat rubber. Since both these mats are so thick (20 and 30mm each) and formed an edge in the transition between solid and slatted floor, it could be expected to be very uncomfortable to lie on this edge. This result might be explained by the difference in temperature in the farrowing compartment during the different batches, the ProCoat rubber was only in use during springtime, when temperatures were lower. The Porca relax and KKM Porca prototype rubber mat was used during summer and autumn, when temperatures were higher. The sows might have preferred to use the slatted floor for cooling down but still wanted the comfort of the rubber mat and were therefore overseeing the rubber mat edge in the transition zone. Also the thickness of the rubber flooring played a role for the piglets access to the creep area, this since the gap between floor and wall became smaller when placing a rubber mat over the concrete.

The time to lie down showed no significant difference between the treatments but great individual differences between the sows were noted. For one sow in batch two (three weeks after farrowing), in a pen with the Porca relax rubber mat, it was impossible to clock and observe the time for every lying down sequence since the sow slipped a lot. This sow was excluded from the calculations of the time to lie down both one and three weeks after farrowing. The Porca relax mat was also perceived as very slippery by the staff. Slip-resistance is very important for the sow's wellbeing in the farrowing pen, and it has to be taken into account in the development of future pen flooring (Persson, 2006, Pluym et al., 2013).

Damm et al. (2004) described that the frequency of standing up and laying down increased from farrowing and onwards. In present study the number of lying down sequences also increased from week one to week three, which is in agreement with (Rolandsdotter et al. 2009).

It is hard to decide by the data in this study and the information from the literature if a slow or fast lying down sequence is positive or negative. No reports are found about the exact time it takes for an uncrated sow to lie down. For crated sows the lying down sequence takes 7 – 20 seconds according to Damm et al. (2004). In this study the variation in lying down time (mean value) per sow varied between 6 and 26 seconds. In studies performed close after the farrowing, remarks about the positive effect of the sow being careful and taking time to lie down can be found. It is important for the sow to have control of her behaviour to protect the piglets from trauma (Damm et al., 2004). However, an unusually long lying down sequence could also be explained by problems to lie down due to for example lameness.

The idea was to also measure the time it took for the sow from lying to standing. However the sows transition from lying to standing was too complex to measure due to different lengths of sitting within the rising procedure.

Parallel to present study claw and leg injuries of the piglets in the farrowing pens were recorded in another study and rubber floorings did not differ from concrete regarding the piglets' claw and leg injuries (Ehlorsson et al., 2013). This was in contrast to the results by Westin (2013), who showed a positive effect on the piglets claws and knees. The conclusion from these two studies was that rubber flooring in the farrowing pen only was a better choice if the current concrete flooring was of a very poor quality. Rubber flooring can have both advantages and disadvantages for the animals. In the farrowing pen rubber flooring can be a good alternative when trying to prevent shoulder lesions in sows. However skin and claw get more resistant to wear with age (Kilbride et al., 2009). This gives rise to a problem since the piglets then are sensitive to other properties of the floor than the sow is e.g. the abrasion which, depending on the structure, might increase with rubber flooring, (Persson, 2006).

The results in this study showed a higher activity on rubber floors compared to concrete. Moreover it showed a weak trend towards a somewhat greater use of the rubber flooring when lying three weeks after farrowing. However, a higher temperature sensitivity in the pens with rubber floorings cannot be ruled as a disadvantage of lying on solid rubber compared to concrete although it was not confirmed in this study. The highest mean temperature three weeks after farrowing was within the thermal comfort zone. Therefore, if the sows had been observed in more extreme temperatures a larger discrepancy towards rubber flooring might have been able to show.

It was concluded that there was large individual variation in sow behaviour and that sows, when housed loose in farrowing pens, could choose between different surfaces with different thermal properties. Rubber flooring instead of concrete on the solid area in the farrowing pen did not seem to be a great advantage in this herd. But the study showed that there are durable rubber mats on the market, which can sustain the weight and behavioral activity of sows.

The overall results in this study were unexpected and a satisfactory explanation for all of them cannot be found. More studies on sows housed on rubber flooring in farrowing pens seem to be needed before any definitive elimination or confirmation of the hypotheses in this study can be made.

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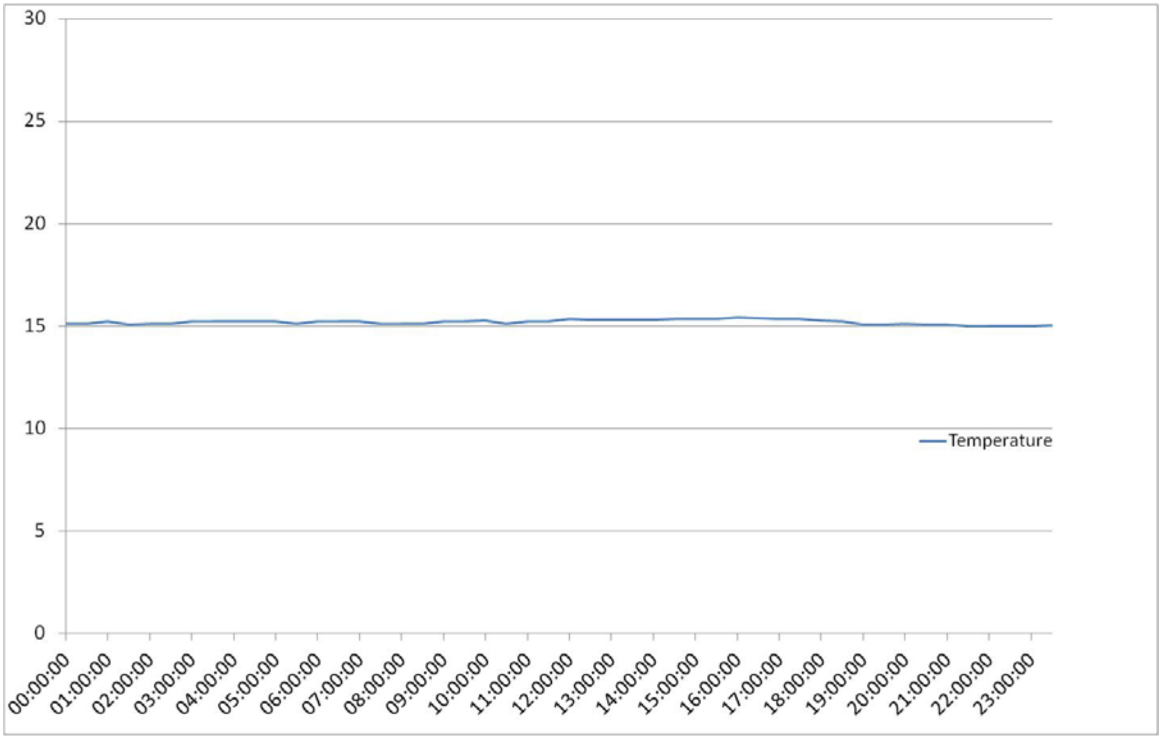
APPENDIX

Date

Camera

Zone			Activity				Start				
Solid floor (≥ 2/3)	Slatted floor (≥ 2/3)	Transition zone	Lying on the side	Lying on the abdomen	Sitting	Standing or walking	Hour	Min	Sec	Hour; Min; Sec	L=Lying down (Start time- Stop time)
So	Sl	T	1	2	3	4					

2013-03-05

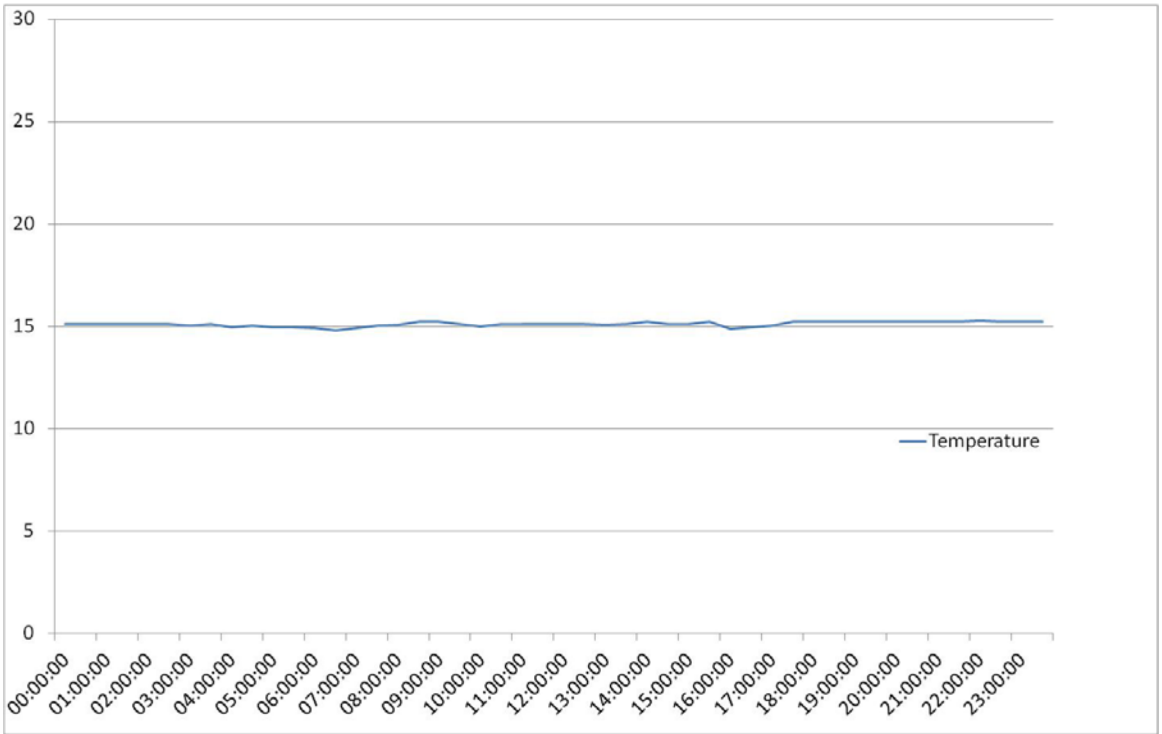


Mean: 15.2 °C

Min: 15.0 °C

Max: 15.4 °C

2013-03-19

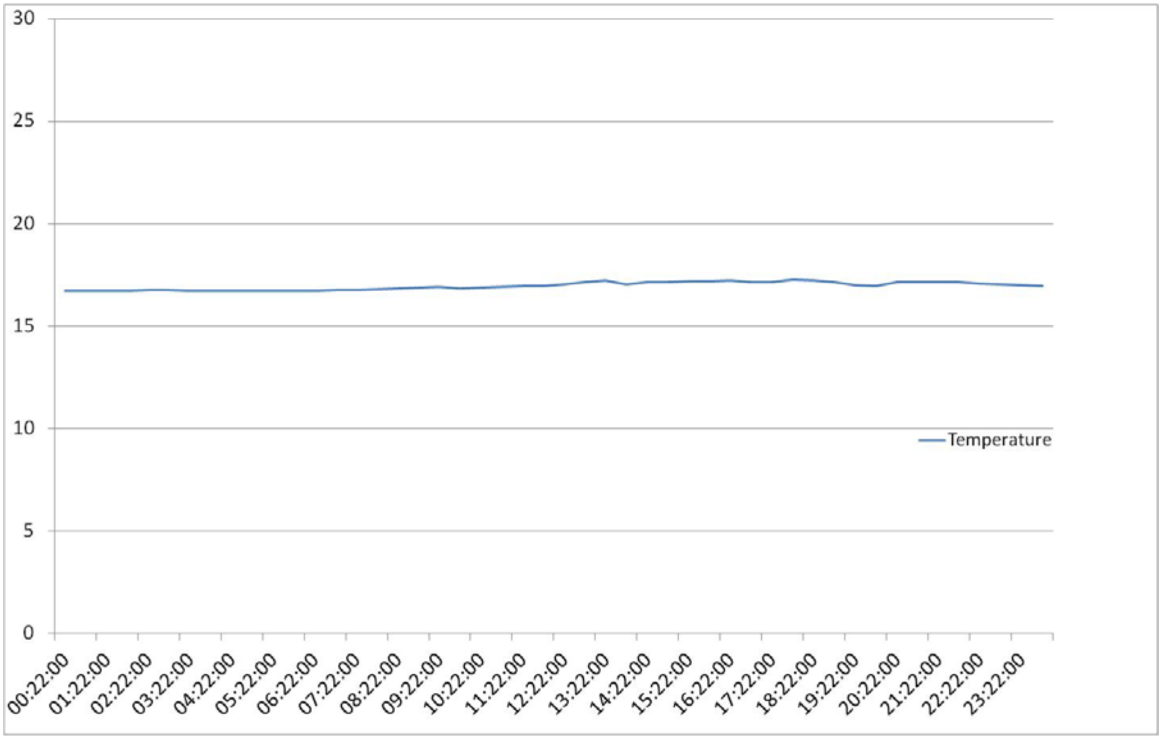


Mean: 15.1 °C

Min: 14.8 °C

Max: 15.3 °C

2013-04-23

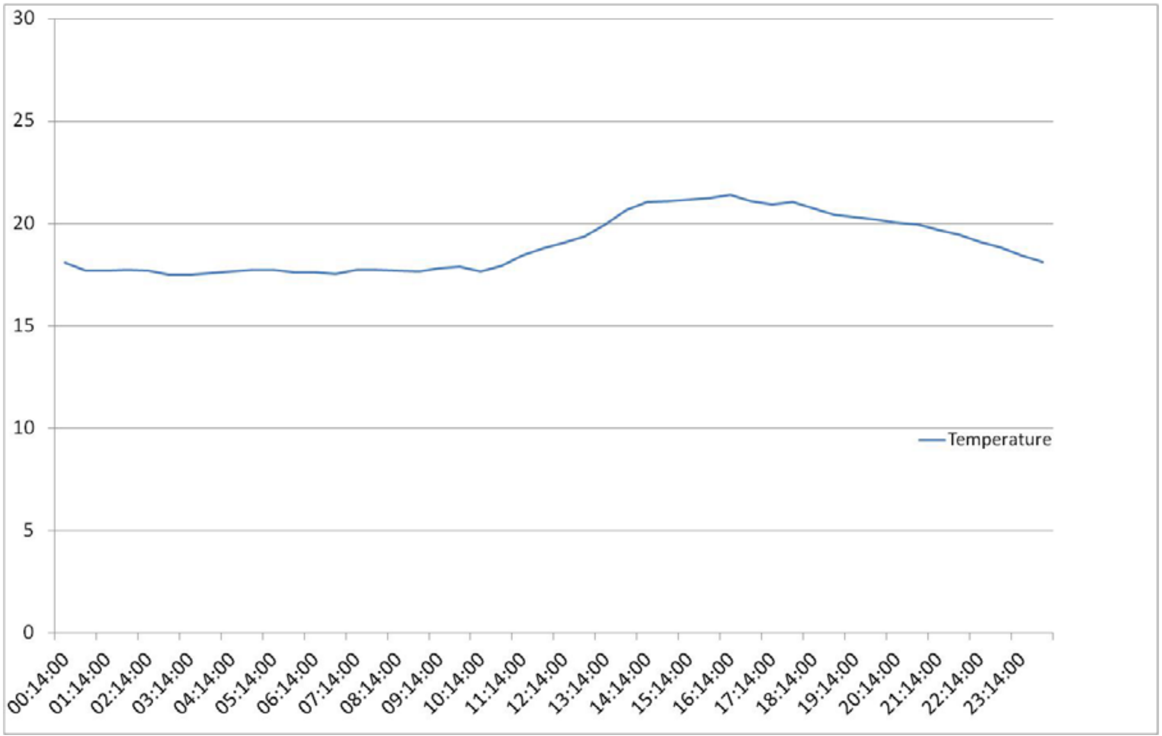


Mean: 17.0 °C

Min: 16.7 °C

Max: 17.3 °C

2013-05-08

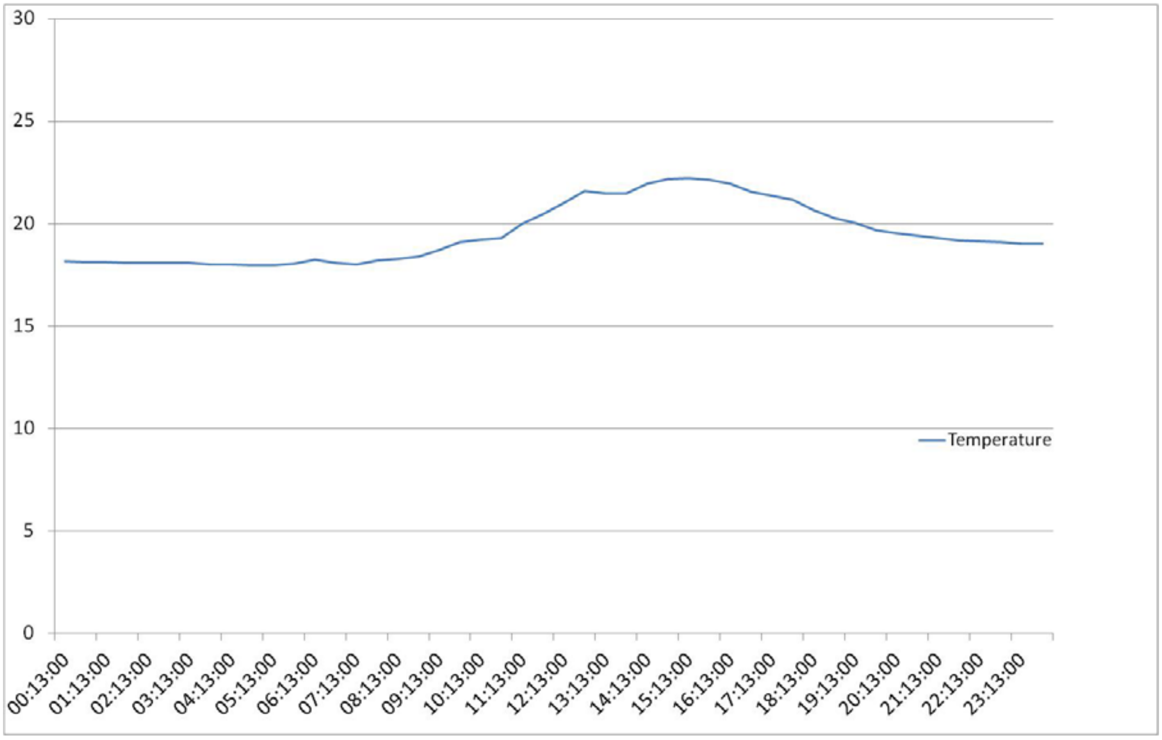


Mean: 19.0 °C

Min: 17.5 °C

Max: 21.4 °C

2013-06-19

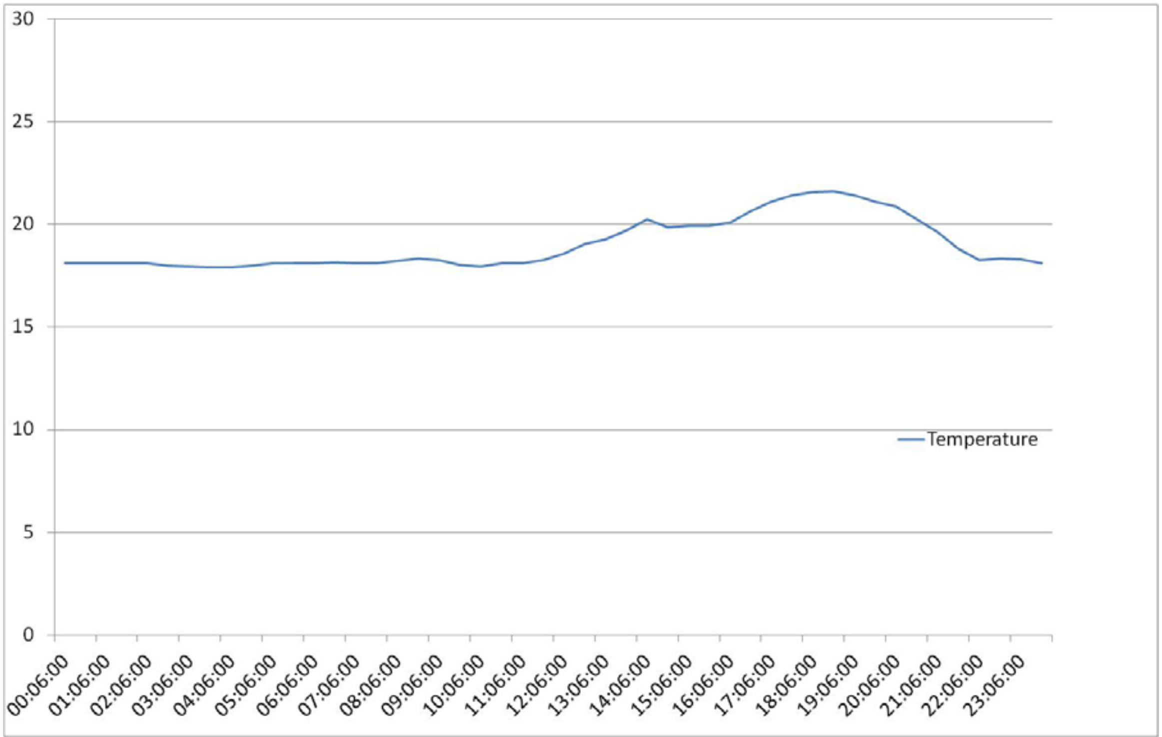


Mean: 19.5 °C

Min: 18.0 °C

Max: 22.2 °C

2013-07-02

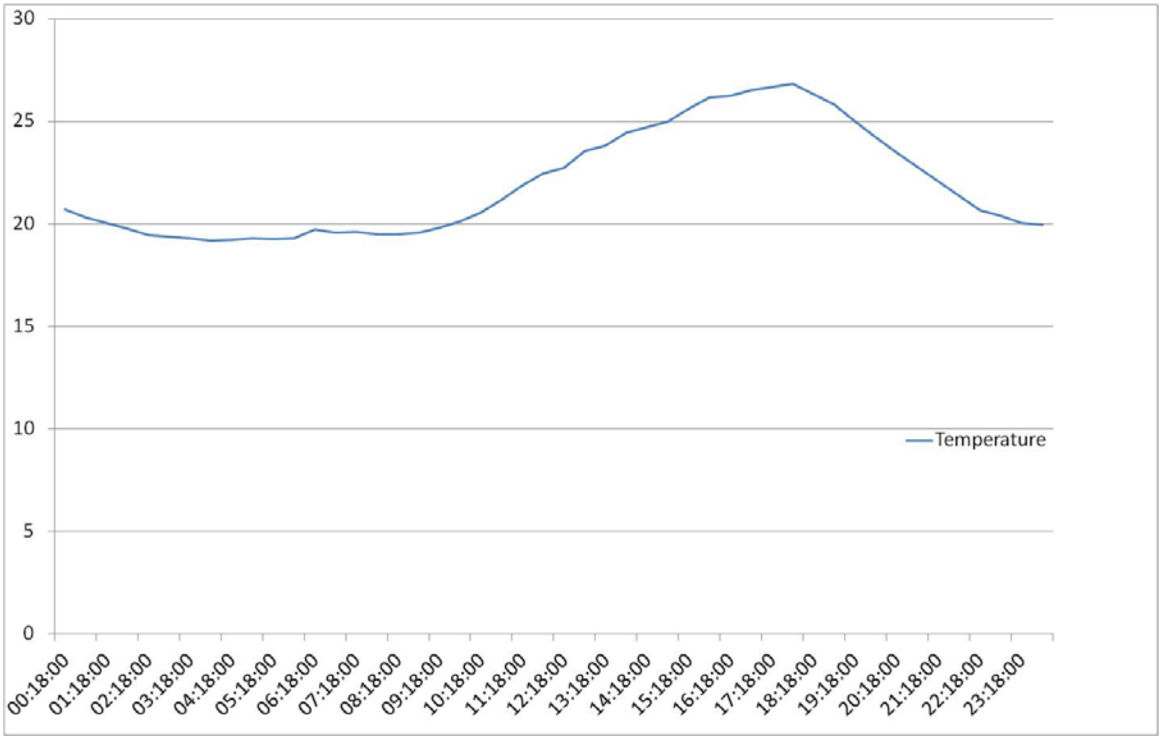


Mean: 19.0 °C

Min: 17.9 °C

Max: 21.6 °C

2013-08-07

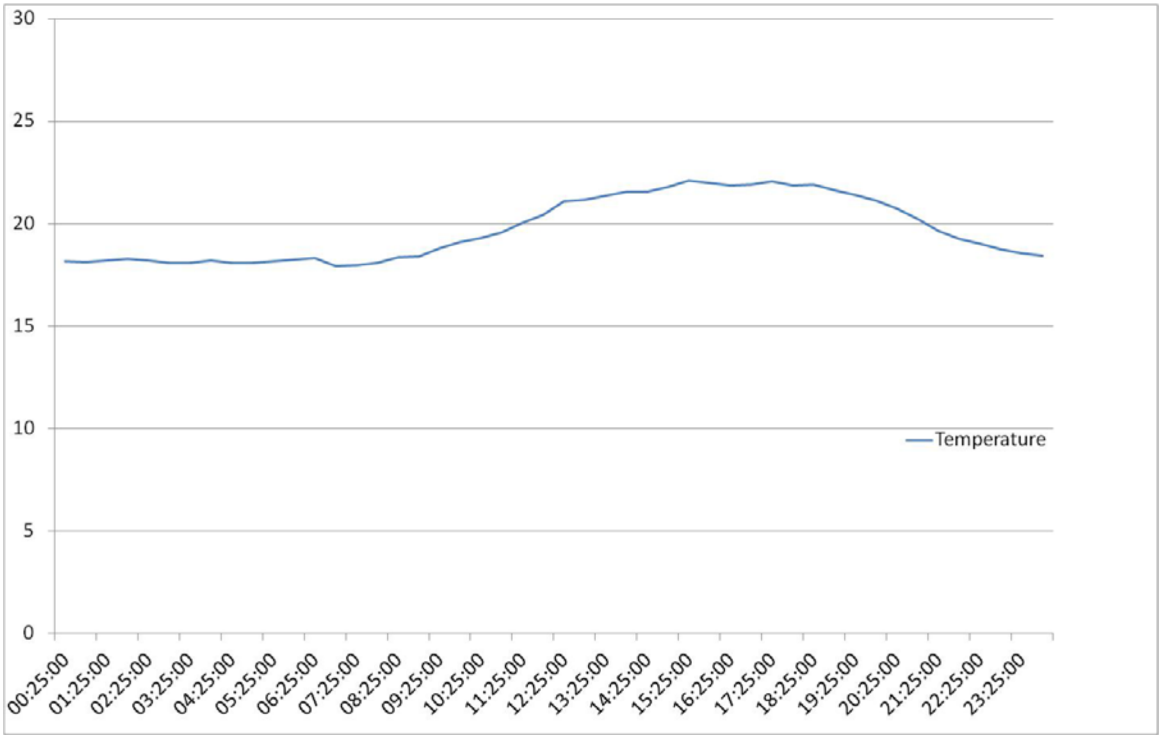


Mean: 21.9 °C

Min: 19.2 °C

Max: 26.8 °C

2013-08-21

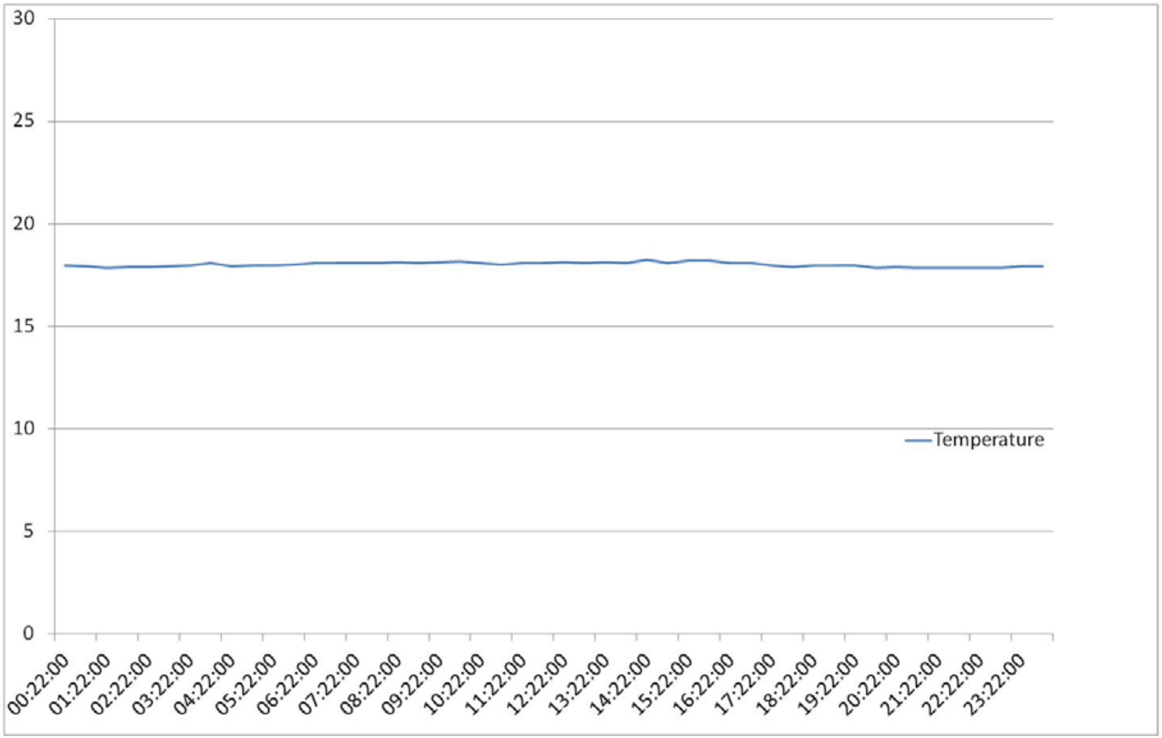


Mean: 19.7 °C

Min: 17.9 °C

Max: 22.1 °C

2013-10-16

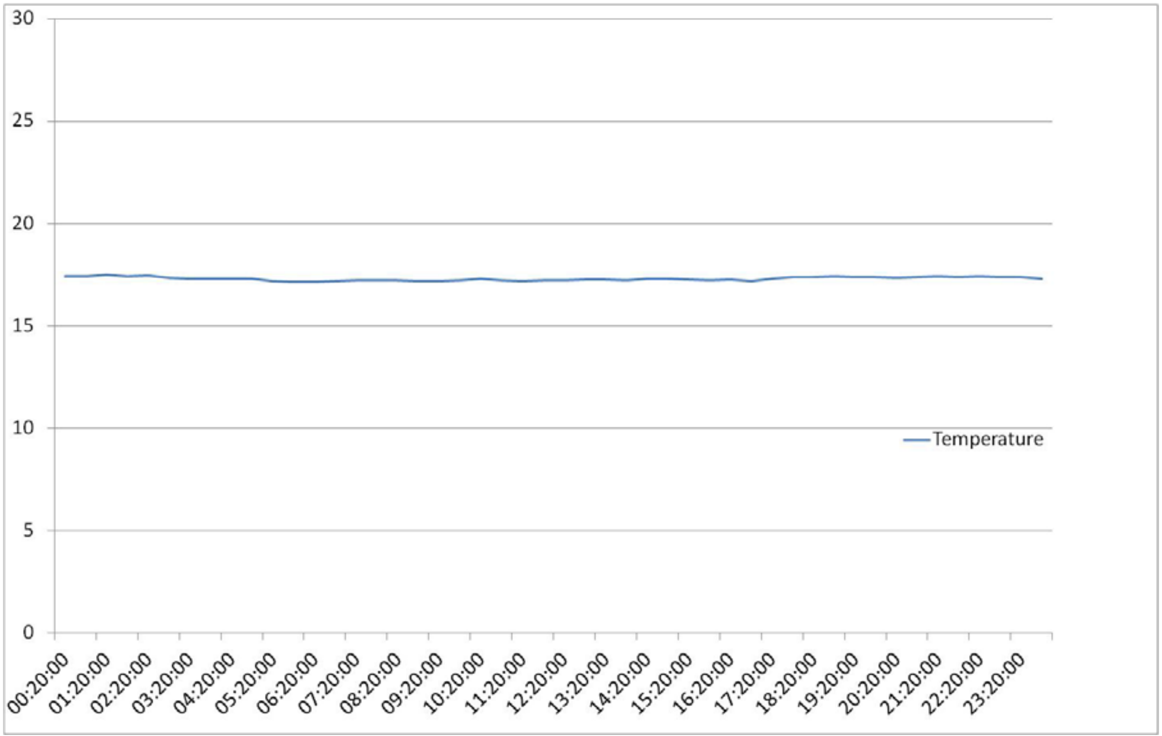


Mean: 18.0 °C

Min: 17.8 °C

Max: 18.2 °C

2013-10-31



Mean: 17.3 °C

Min: 17.1 °C

Max: 17.5 °