Wageningen UR Livestock Research

Partner in livestock innovations

Report 708

On farm development of bedded pack dairy barns in The Netherlands

Animal welfare and milk quality

March 2014

LIVESTOCK RESEARCH
WAGENINGEN UR

Colophon

Publisher
Wageningen UR Livestock Research
P.O. Box 65, 8200 AB Lelystad
Telephone +31 320 - 238238
Fax +31 320 - 238050
E-mail info.livestockresearch@wur.nl
Internet http://www.livestockresearch.wur.nl

Editing
Communication Services

Wageningen UR Livestock Research and Central Veterinary Institute of Wageningen UR, both part of Stichting Dienst Landbouwkundig Onderzoek (DLO Foundation), together with the Department of Animal Sciences of Wageningen University comprises the Animal Sciences Group of Wageningen UR (University & Research centre).

Single numbers can be obtained from the website.

ISO 9001 certification by DNV emphasizes our quality level. All our research projects are subject to the General Conditions of the Animal Sciences Group, which have been filed with the District Court Zwolle.

Abstract
This report describes figures on animal health and welfare on three Dutch commercial dairy farms that house their cows in bedded pack barns. Moreover, some milk quality parameters and culling and replacement figures are reported.

Keywords
heat stress, lying comfort, culling, replacement

Reference
ISSN 1570 - 8616

Authors
Wijbrand Ouweltjes
Gidi Smolders

Title
On farm development of bedded pack dairy barns in The Netherlands

Report 708

LIVESTOCK RESEARCH
WAGENINGEN UR

Report 708

On farm development of bedded pack dairy barns in The Netherlands

Wijbrand Ouweltjes
Gidi Smolders

March 2014

This project is funded by the Ministry of Economic Affairs, from the policy support research, BO-22.02-012-005.

Ministry of Economic Affairs

Preface

This report is the second of a series of five reports on the development of bedded pack barns on three commercial dairy farms in the period 2010 till mid-2013 (table 1).

Table 1 Five reports about research on three commercial bedded pack barns

Rapport	Titel	Auteurs
707	Introduction and first experiences on three farms	Galama
708	Animal welfare and milk quality	Ouweltjes
709	Nutrient balances and fertilizer value of bedding material	Boer, de
710	Gaseous emissions from housing	Dooren, van
711	Overall sustainability: status and outlook	Galama et al

This research is a continuation of a tentative study on the feasibility of bedded pack barns and experiments on experimental farms and is funded by the Dutch Dairy Board and Ministry of Economic Affairs. The research and the communication concerning the three commercial farms have much impact in the Netherlands and abroad. The way of thinking about sustainable housing systems has changed. During the development of the free stall barn system from the late 60's in the last century the focus was on increasing labour efficiency. The increasing interest in bedded pack barns has drawn attention to especially improving animal welfare and manure quality. The financiers also asked, in addition to these aspects, to study any negative effects on environment and milk quality. This report focuses on the animal welfare, animal health and the risk of milk contamination. The research about milk contamination is done by NIZO, Frank Driehuis.

I want to thank the three dairy farmers Meindert Wiersma, Jeroen Groenewegen and Marc Havermans sincerely for sharing their experiences and for providing their farms and data for research. As pioneers in the dairy industry they are an example to many who are interested in a bedded pack barn and especially for those who have actually built one, in the Netherlands as well as abroad.

I also want to thank my colleagues Klaas Blanken for collecting data of these three farms and Hendrik Jan van Dooren, Herman de Boer and Judith Poelarends for their critical remarks.

Paul Galama
Project manager bedded pack barns

Samenvatting

Op de meeste Nederlandse melkveebedrijven worden de koeien gehuisvest in ligboxenstallen. Er wordt voortdurend gezocht naar verbetering van de duurzaamheid van de huisvesting, waarbij dierenwelzijn een van de aspecten is. Vrijloopstallen zijn een alternatief huisvestingssysteem voor melkvee wat vooral positief lijkt te zijn voor het welzijn. Uit onderzoek in de USA blijkt dat op bedrijven die een vrijloopstal zijn gaan gebruiken de klauwgezondheid en het ligcomfort verbeterden. Het afwezig zijn van obstakels die het gaan liggen beperken en het zachte ligbed zorgen ervoor dat de dieren gemakkelijk kunnen gaan liggen en opstaan, en lage incidenties van hakbeschadigingen. Het schoon houden van de dieren vergde wel meer aandacht dan in ligbxenstallen. In dit rapport worden resultaten wat betreft gezondheid en welzijn alsmede melkkwaliteit beschreven van drie Nederlandse praktijkbedrijven die hun melkvee de laatste jaren huisvesten in nieuw gebouwde vrijloopstallen.

De drie bedrijven hebben gemeen dat de koeien kunnen liggen in een vrijloop-ruimte, maar het soort bodem en de stalopzet zijn verschillend. Twee bedrijven gebruiken compost als bodemmateriaal, het derde bedrijf gebruikt houtsnippers die in de stal composteren. Bij het composteringsproces komt een aanzienlijke hoeveelheid warmte vrij, de temperatuur in de bodem kan oplopen tot circa 5 °C. Verondersteld werd dat deze warmteontwikkeling de thermoregulatie van de koeien nadelig zou beïnvloeden. Daarom zijn het stalklimaat en ook de ademhalingssnelheid, huidtemperaturen en liggedrag van de koeien in deze stal onderzocht. Geen van deze parameters leverde aanwijzingen op dat er een verhoogd risico was op hitte stress in een vrijloopstal met composterende bodem. Luchttemperatuur en luchtvochtigheid 3 m boven het ligbed waren vrijwel gelijk aan dezelfde parameters in de buitenlucht en ademhalingssnelheid en huidtemperatuur waren niet verhoogd. Ook lagen de koeien vrijwel evenveel als in ligboxenstallen.

Vrijloopstallen zijn in zekere zin vergelijkbaar met traditionele potstellen, en deze hebben een slechte reputatie wat betreft uiergezondheid. De melkcelgetallen waren niet wezenlijk veranderd nadat de koeien in de vrijloopstallen werden gehuisvest, ondanks dat twee veehouders eveneens hun management rond afkalven drastisch hebben aangepast. Op één bedrijf worden de koeien doorgemolken, op het tweede bedrijf is gestopt met standaard preventief gebruik van antibiotica bij droogzetten en worden droogzetpreparaten alleen nog selectief gebruikt. De kiemgetallen in de tankmelk waren incidenteel sterk verhoogd, maar slechts in een incidenteel geval leidde dit tot een korting op de uitbetaling. De grote variatie geeft aan dat handhaven van een goede melkkwaliteit op deze bedrijven aandacht vraagt, ondanks dat er geen duidelijke veranderingen waren sinds de in gebruik name van de vrijloopstallen. Daarnaast zijn verhoogde thermoresistente en mesofiele aerobe sporen vormende bacteriën een potentieel risico bij bewaring van zuivelproducten.

Beoordeling van het welzijn met Welfare Quality® parameters laat zien dat het ligcomfort in de vrijloopstallen beter was dan in ligboxenstallen. De koeien hadden minder tijd nodig om te gaan liggen en hadden zeer weinig huidbeschadigingen. Ook bij vrijloopstallen kan bijvoorbeeld een verkeerd afgesteld voerhek echter tot beschadigingen leiden. Gebleken is dat koeien in een vrijloopstal redelijk schoon gehouden kunnen worden. Vergeleken met koeien in ligboxenstallen hadden relatief veel koeien in de vrijloopstallen op twee bedrijven een matige klauwvorm, maar ernstige kreupelheid kwam op alle drie de bedrijven nauwelijks voor. Ten slotte bleek dat bij de koppels in de vrijloopstallen weinig negatief sociaal gedrag (zoals verjagen) voorkwam maar relatief veel positief sociaal gedrag (met name sociaal likken).

Uit de analyse van gegevens van afvoer en vervanging bleek dat relatief veel afgevoerde dieren 30 dagen na afvoer nog in leven was. De omvang en samenstelling van de veestapels op de drie bedrijven in de periode dat de nieuwe vrijloopstallen in gebruik zijn genomen was niet stabiel, en de jaarlijkse afvoerpercentages waren in deze periode sterk variabel. De dieren die voor de dood werden afgevoerd hadden een iets lagere productieve levensduur en levensproductie dan de landelijke gemiddelden. Op twee bedrijven werden regelmatig koeien met een verhoogd celgetal afgevoerd, maar dat was ook al het geval voordat de vrijloopstallen in gebruik werden genomen. Slechte vruchtbaarheid was een reden voor afvoer op alle 3 de bedrijven.

Summary

The majority of Dutch dairy farms currently uses cubicle barns to house their cows, but there is an on-going search to improve sustainability of housing systems. Animal welfare is one of the aspects of sustainability of animal production. Bedded pack barns are an alternative housing system for dairy cows that particularly has potential benefits for animal welfare. Research from the USA reports improved claw health and lying comfort for cows housed in such barns. The absence of obstacles that restrict the lying down movements and the soft bedding result in more ease to lie down and get up and low incidences of hock lesions. Maintenance of hygiene seems more difficult compared with cubicle housing. This report describes animal health and welfare and milk quality parameters observed on three commercial Dutch dairy farms where the cows are kept in newly built bedded pack barns.

The three farms have in common that a bedded pack lying area is provided for the cows, but the type of bedding and barn layout differ. Two of the farms use compost as bedding material, whereas the third uses wood chips that are composting in the barn. The composting process is characterised by substantial heat production in the bedding layer with temperatures that can go up to 55 °C. It was hypothesized that this heat production could impair the thermoregulation of the cows. Therefore we studied barn climate in the composting barn and respiration rates, skin temperatures and lying behaviour of the cows in this barn. None of the parameters studied provided evidence for an increased risk of heat stress for cows in a barn with a composting bedded pack lying area. Air temperature and humidity air 3 m above the bedding were very similar to outside temperatures and respiration rates and skin temperatures were not increased. Moreover, lying bout lengths and time budgets for lying were similar to those of cows in cubicle barns.

Bedded pack barns to some extent are comparable to deep litter straw yards, but these have a poor reputation with regard to udder health. According to the scc information udder health on the three farms was not systematically altered after housing the cows in the bedded pack barns, even though two farmers also drastically altered their transition cow management. One started to omit drying off and milk continuously, the other farmer stopped with routine use of dry cow antibiotic therapy and now only uses antibiotics selectively. The obligatory registration showed that all three farms had low average usage of antibiotics. The total bacterial counts in bulk milk samples peaked incidentally, but the threshold for milk payment penalties was only occasionally exceeded. Although there was no clear trend since the transition, the variation indicates that maintaining good milk quality can indeed be a concern on farms with bedded pack barns. Increased levels of thermophilic aerobic spore formers (TAS) and mesophylic aerobic spore formers (MAS) in bulk milk are a potential major milk quality concern.

Animal welfare assessment with Welfare Quality® parameters indicates that lying comfort was better in bedded pack barns than in cubicle barns because the cows can lie down more quickly and had very low prevalence of integument alterations. However, also in these barns wrongly placed equipment such as a feeding rack can cause lesions. It was also shown that it is possible to keep the animals sufficiently clean in bedded pack barns. Compared to herds kept in cubicle barns claws with poor conformation were recorded relatively often for two of the bedded pack herds. Despite this, the incidence of severe lameness was low in all three bedded pack barns compared to the cubicle barns, but contrary to straw yard barns imperfect locomotion (locomotion score 1) occurred to the same extent as in cubicle barns (16 vs. 14%). The herds housed in bedded pack barns had low prevalence of agonistic behaviours and relatively frequent social licking compared to the other herds.

The analysis of culling and replacement data showed that a large proportion of the animals that were culled from the bedded pack herds was still alive 30 days after culling. The herd compositions were not stable in the years just before and after the introduction in the new bedded pack barns, therefore the yearly culling figures were quite variable. The animals that were culled for slaughter had a herd life and lifetime milk yield a little below the national average. In two of the farms a considerable part of the culled cows had high scc, but this was already the case before the introduction of the bedded pack barns. Poor fertility contributed to culling on all three farms.

Table of contents

1 Introduction

Animal health and welfare are two aspects of the overall assessment of sustainability of housing systems in dairy farming. This report starts with a literature review of these aspects in bedded pack barns, and also reports the results of exploratory measurements carried out by students. The remainder of this report focuses on results obtained on three participating commercial farms that have built a bedded pack barn recently (see Galama, 2013). Because one of these bedded pack barns had a heat producing (composting) bedding layer, and it was speculated that this might increase the risk of occurrence of heat stress, this was investigated in detail. To obtain inferences on udder health the bulk milk somatic cell counts of milk deliveries between January 1st 2009 and November 1st 2012 from the three participating farms were analysed. During this period each of the three farms introduced their dairy cows in a new bedded pack barn. Somatic cell count (**scc**) is a widely accepted udder health indicator and udder health is one of the concerns with regard to housing and also relevant for the milk processors. Risks of microbial contaminants in the milk are also important for the dairy producers. These are investigated by Driehuis et al. (2012) and some main conclusions are presented in this report. Standardised figures on the usage of antibiotics, that have become available recently in the Netherlands, were also obtained for the three farms and integrated in this report. In order to obtain inferences on the welfare of the dairy cows each herd was scored twice according to animal based parameters of the Welfare Quality® assessment protocol (Welfare Quality®,2009). The results were compared with those obtained on a number of farms with either cubicle barns or straw based deep litter barns. Finally figures regarding culling and replacement from January 2009 onwards were investigated, because culling can affect animal health and welfare figures and vice versa, and the dairy sector aims to improve longevity of dairy cows. Improved health and longevity is also one of the key motivations of farmers to build a bedded pack barn (Barberg et al., 2007).

2 Literature review

Currently the majority of Dutch dairy cows are housed in cubicle barns with concrete slatted flooring in the alleys. Compared with the tie stalls that were common until the 1970's the freedom of movement that such barns provide to the animals is an important advantage for their welfare. However, many of the existing cubicle barns also have some disadvantages with regard to animal welfare (Ouweltjes et al., 2003). The main disadvantages are: slippery alley floors, insufficient lying comfort, suboptimal barn climate and limited space. Some of these disadvantages can be overcome when new barns are built with wider alleys, lager cubicle dimensions etc., but restrictions regarding lying areas are particularly intrinsic to the concept of cubicle barns. Bedded pack barns do not have these restrictions and therefore can provide better lying comfort.

Barberg et al. (2007) have investigated practical experiences with bedded pack barns on 12 commercial farms in the USA and attempted to describe changes in cow health and performance after the transition. The housing situation before the transitions however is not described, and the interval between the transition and when the farm observations took place was quite variable (between six months and nearly four years). Therefore it is difficult to generalise those results. Nevertheless, it was concluded that an improvement of udder health after transition was possible: 3 out of 7 herds recorded a reduction of the bulk milk scc while one recorded an increase, 6 out of 9 recorded a reduction of mastitis incidence of on average 12% whereas only one recorded an increase of on average 4%. Milk production per cow increased on 8 out of 9 farms with DHIA data and decreased on 1 farm. Although it is acknowledged that other factors could have contributed to changes in production, it is suggested that improved cow comfort in the bedded pack barns enabled higher milk production. Moreover, some improvements in fertility and culling after transition were reported. The farmers were also asked for their motivations to choose for a bedded pack barn. Important arguments were: an expected improvement of cow comfort, increased longevity of the cows and more attractive labour. It was reported that these expectations were largely achieved in practice, and that these farmers were satisfied with their new barns. For many aspects of daily management the same techniques could be used as on farms with conventional housing. However, udder preparation and teat cleaning before milking required more attention for cows kept in bedded pack barns.

A study of Rutherford et al. (2009) in the UK indicated that herds kept in straw yards had significantly lower incidence of lameness compared to herds kept in cubicle barns. This corresponds with results of Somers (2004) who compared straw yards and cubicle barns in the Netherlands. Because of the resemblance for many aspects of straw yard barns with bedded pack barns it is expected that also the latter type of barns will show relatively low lameness incidence. In line with this, Barberg et al. (2007) reported substantially lower lameness incidence in the bedded pack herds (8%) than found for cows kept in tie stalls (20%) or cubicle stalls (25 – 28%) in other studies in the USA (Cook, 2003; Espejo et al., 2006).

Endres and Barberg (2007) conducted behavioural research on the same 12 farms mentioned above after the transition. Information on lying and standing behaviour was recorded with IceTag® sensors. The average lying time for cows in the 10 herds with no access to pasture was 9.99 ± 2.02 hours per day, compared to 6.45 ± 1.57 hours for 2 grazing herds. The figures for the herds with no access to pasture were in line with lying times reported for other studies on cows kept indoors. The number of daily lying bouts for these cows (11.0 ± 3.2) also corresponded well with figures obtained for cows in straw yards and cubicle barns. In contrast, a study of Fregonesi et al. (2009) showed that cows in a straw yard had longer lying times than cows in cubicle barns. Cows that were given a choice where they would lie down (either in an unrestricted area or in cubicles) lay down more in the unrestricted area, but the difference was small. Other work of Fregonesi et al. (2007) showed that cows lay down significantly longer when the surface of the lying area was dry (13.8 ± 0.8 h/d) than when it was wet (8.8 ± 0.8 h/d). This shows that humidity of the bedding can also affect lying behaviour and results of comparisons of different barn types. The figures of Endres and Barberg (2007) for the grazing herds indicate that reduced overall lying time is not necessarily indicative for poor lying comfort. Average bout length in their study was 50.8 ± 35.6 minutes (bouts <2 minutes were ignored) and diurnal patterns were similar to those observed in other barn types. It was reported that an increase of the barn temperature and the Temperature Humidity Index (THI) in the bedded pack barns coincided with reduced lying times of the dairy cows, shorter lying bout lengths and more steps per hour. It is not clear to what extent the variation of THI coincided with diurnal patterns, therefore these findings have to be interpreted with caution. In the same study, the lying postures were scored according to the method of Krohn and Munksgaard (1993). “Head up” was the most frequently occurring lying posture (84.6%), but also the postures “head back” (8.8%) and “head on the ground” (5.4%) occurred regularly. Incidentally cows lay flat on the side (0.8%). Observation of social interactions in the bedding area revealed that social licking occurred more frequently than agonistic interactions (chasing away, pushing, head butting). It was concluded that social interactions of cows in the bedded pack barns did not differ substantially from those in other housing systems.

Another study in Minnesota (Lobeck et al., 2011) showed that the prevalence of lameness was lower in bedded pack barns with compost as bedding material than in 2 new types of sand bedded cubicle barns: 4.4 vs. 15.9/13.1%. The authors hypothesized that this was due to both less standing on concrete and an absence of restrictions when lying down or rising. Regardless of barn type lameness incidence was highest in winter and early spring. The farmers involved in this study significantly underestimated the prevalence of lameness. Prevalence of severe lameness was not significantly different between the different barn types (0.8, 1.0 and 1.4%). However, in the bedded pack barns the prevalence of hock lesions was significantly lower (3.8 vs. 31.2 and 23.9% for the two cubicle barns). It was suggested earlier (Barberg et al., 2007) that the hock lesions of cows in the bedded pack barns originated from before the introduction of the animals into these barns, this might explain the lower prevalence found in this study compared to the earlier work. It could also imply that the prevalence for bedded pack barns is still overestimated. Lobeck et al. (2011) also reported that the animals in the bedded pack barns had higher hygiene scores (3.18 vs. 2.83/2.77), which indicates that they were dirtier than the animals from the cubicle barns. The differences between barn types were only significant during winter. However, also in other seasons the average figures were unfavourable for bedded pack barns. Different seasonal circumstances could perhaps explain the discrepancy with results of Barberg et al. (2007) with regard to hygiene (they reported better hygiene for bedded pack barns compared with cubicle barns in summer). Lobeck et al. (2011) found no differences between barn types with regard to BCS, respiration rates, mastitis prevalence, culling or mortality. Therefore, it was concluded that the better feet and leg health of cows in bedded pack barns did not result in significantly improved longevity.

The exploratory work of students Van Middendorp and Cornelissen (2009) on lying postures of cows in two experimental bedded pack barns on research farms and comparable observations in one cubicle barn indicated that the frequencies of postures observed corresponded well with those reported by Endres and Barberg (2007). Moreover, these students did not observe significant differences in lying postures between the cubicle barn and the bedded pack barns. This corresponded with results of Fisher (2011), who compared lying postures of cows in one of the bedded pack barns monitored for this study (farm A) with those of cows in a cubicle barn on a research farm. Hoekstra and Lekkerkerker (2011) reported that cows on this farm relatively often lay down in positions “flat on the side” and “head on the ground” and that cows relatively often had one or two legs stretched in front of the body. According to Fisher (2011) the occurrences of cows lying flat on the side on this farm nearly always had a short duration (<10 seconds). He also reported that unloading of the claws by weight shifting, which is presumed to be an indicator for tissue irritation in the claws, occurred more often in the cubicle barn than in the bedded pack. Hoekstra and Lekkerkerker (2011) reported that getting up and down again on the other side shortly afterwards did occur regularly in the bedded pack barn of farm A.

It can be concluded that bedded pack barns and straw yards have shown to be beneficial for animal welfare, particularly claw health and lying comfort. The absence of obstacles that restrict the lying down movements and soft bedding result in more ease to lie down and to stand up and low incidences of hock lesions. The lying postures in bedded pack areas do not differ substantially from those in modern cubicle barns. Maintenance of hygiene seems more difficult compared with cubicle housing. So far, there is no evidence that bedded pack barns coincide with improved cow longevity.

3 Barn climate, bedding temperature and heat stress in a barn with composting bedding

One of the three farms (farm A) uses composting bedding material that is replaced once a year when the composting process slows down. Due to the on-going composting process the temperature in the bedding material can be around 50 °C or even up to 55 °C (Galama et al., 2012), although the top layer has a lower temperature. Moreover, due to the composting process water is evaporated. When the composting process comes to an end the temperature inside the bedding layer decreases, less water is evaporated and therefore the top layer becomes more wet. A specific concern for this barn was whether the heat production in the bedding material could negatively affect animal welfare due to impaired heat exchange of the cows (heat stress) during lying bouts or through effects on barn climate. Therefore barn climate, bedding temperature and lying behaviour were studied in more detail in this barn. Because heat exchange is determined by air temperature, air humidity and air flow (Kadzere et al., 2002), it is common to express the climatic circumstances in a so called Temperature Humidity Index (THI) that combines these separate factors. Several definitions of THI are reported in scientific literature (e.g. Berman, 2005; Kadzere et al., 2002; Ravagnolo et al., 2000), the first and second study use dry and wet bulb temperatures to account for air flow whereas the third ignores effects of air flow. Because we did not have information on air flow, and assumed that this was relatively constant in the barn with mechanical ventilators above the bedding, we used the definition of Ravagnolo et al. (2000): THI = (9/5*T+32)-(11/20-RH*0.11/20)*(9/5*T-26) where T = Temperature (°C) and RH = Relative Humidity (%).

For two periods (between 15/7 and 9/9 2010 and between 8/12 and 16/12 2011) the climate in the barn was monitored and recorded on an hourly basis with Escort RH iLog sensors (Escort Data Loggers Inc., Buchanan, VA, USA) and additional observations (described below) were carried out to detect possible behavioural changes that could indicate heat stess. During the first measurement period 5 sensors were evenly distributed ± 3 m above the lying area, and it was concluded that air temperature and humidity were uniform in the area above the bedded pack, i.e. did not depend on the location of measurement (Galama et al., 2012). Moreover, the differences between sensor readings were very small. The data obtained were compared with those from the nearest official measurement station of the Royal Dutch Meteorological Institute (KNMI) in Eelde, and it was concluded that both temperature and relative humidity in the barn showed the same patterns (both diurnal and on a day to day basis) as those from the weather station. We therefore concluded that air temperature and relative humidity above the bedding were not affected by the composting process in the bedding, so apparently the barn ventilation was adequate. The data from the nearest official weather station could have been used equally instead of the figures obtained with the Escort loggers to calculate the Temperature Humidity Index in the barn.

Despite the absence of effects composting on air temperature and relative humidity at 3 m above the bedding area, the heat production in the bedding could affect the animals heat exchange with the environment, particularly during lying bouts. **Figure 1** shows infrared images of cows in the composting bedded pack near their lying spot, just after they got up. These pictures visualise that both bedding and skin temperature are high in the area where the skin touches the bedding (explanation of the colours is given below the figure).

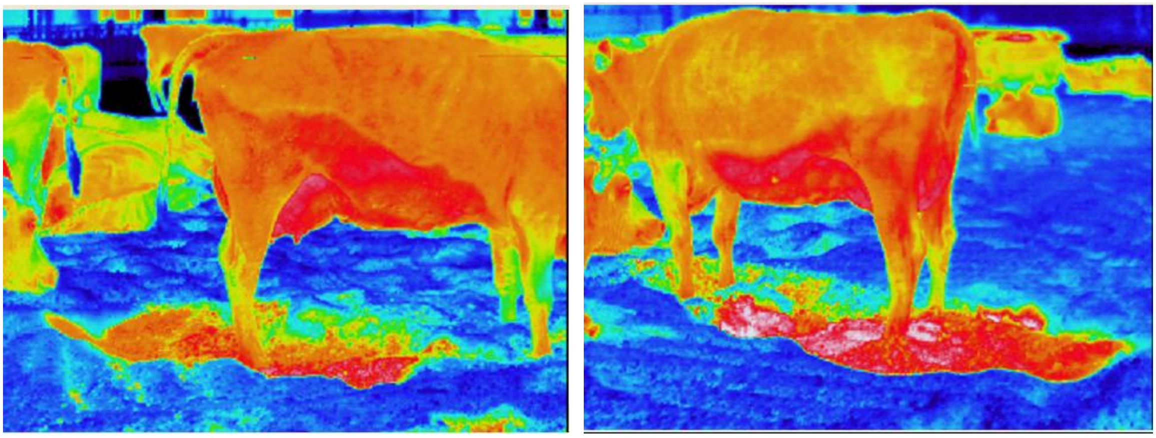

Figure 1 Infra-red images of two cows near their lying spot after getting up from a composting bedding

In this figure, the intense red to pink colour represents the highest temperature and the intense blue colour represents the lowest temperature. Both the spot where the animals laid down and the part of the skin that has touched the bedding show an increased temperature relative to the surrounding bedding and skin respectively. This could be caused by heat production of the animals, but could also be caused by heat accumulated from the bedding. Particularly in the latter case this could affect the animals' heat exchange, and the animals could have difficulty to maintain body temperature while lying down even while climatic circumstances do not cause an above threshold THI in the barn environment.

Endres and Barberg (2007) reported reduced lying times for higher THI values in bedded pack barns and assumed the relationship between THI and lying time was similar for bedded pack barns and cubicle barns. However, heat production in the bedding could lower the threshold for heat stress. One of the possible effects of heat accumulation in the bedding on the lying spot and a potential indicator of heat stress is an increased standing time, because standing better enables the animals to dissipate their body heat than lying (Berman, 2005; Brown-Brandl et al., 2006; Kadzere et al., 2002). Alternatively, cows could maintain lying time but decrease lying bout lengths. Therefore, during the nearly 2 month climate monitoring period in the barn of farm A 20 animals were equipped with an IceTag® sensor and the data were captured afterwards. The animals were chosen randomly, only animals that were to be culled or dried off within the data collection period were excluded. The data showed that the animals had an average %standing of 55.3 ± 1.2, 85.6 ± 5.7 steps/hour and average lying bout length was 65.1 ± 3.0 minutes. These results are similar to those obtained for cows in experimental bedded pack barns with sand, reed and pet soil or compost in the bedding on research farms (unpublished results). Lying times of the cows of farm A were also comparable to those reported by Barberg et al. (2007) for bedded pack barns in the USA, while bout lengths in their study were shorter (50.8 minutes). This implies that the cows in this barn did not spend more time standing nor had reduced lying bout lengths and suggests they did not experience heat stress. The relationship between THI (calculated with the formula of Ravagnolo et al., 2000) and %standing, number of steps/hour and length of the lying bouts was analysed with ASReml statistical package (Gilmour et al., 2006) on an hourly basis. Figures were corrected for diurnal patterns. The estimates for THI-classes were significantly different for all three trait analysed, and are presented in **Figure 2**.

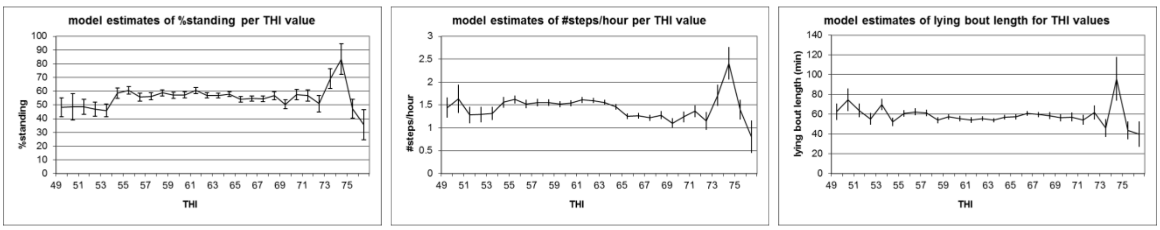

Figure 2 Estimates of relationships of THI with behavioural parameters derived from Icetag® sensor data

It must be mentioned that the number of observations in the lowest and highest THI classes was low, therefore the estimates for these classes have higher standard errors. Although the measurements were carried out during the summer, THI values above 70 did not occur frequently and if so only for short periods. It can be concluded that there was no clear trend of increased standing above a certain threshold THI value (**Figure 2**), certainly not for values that are below the THI threshold of 72 mentioned by Ravagnolo et al. (2000). We therefore conclude that the Icetag data provide no evidence of occurrence of heat stress at moderate THI values.

Another potential indicator for heat stress is an increased respiration rate (Berman, 2005; Brown-Brandl et al., 2003; Gaughan et al., 2008; Kadzere et al., 2002), since respiration is a pathway for heat loss. An advantage of this indicator is that it responds quickly to changes in environmental temperatures and is relatively easy to observe visually. We have filmed a number of lying and standing animals from the side on three occasions and analysed the film fragments afterwards. Respiration rates per minute were calculated by counting the number of rises of the flank for 30 s and conversion to breaths/min as was reported by Schütz et al. (2010). The values obtained (average 38, range 24 – 58) were below the threshold value of 60 that could indicate heat stress according to Brown-Brandl et al. (2006) and Schütz et al. (2010). Thus the observed respiration rates also did not indicate that the cows in this barn experienced heat stress.

To obtain further evidence for the absence of heat stress we measured skin temperatures during lying bouts. This also enabled us to investigate to what extent it occurred that animals stood up after a lying bout and shortly afterwards lay down on their other side. It was hypothesized that this could occur in order to prevent heat stress and was reported to occur occasionally during the investigations by students on this farm. For these measurements five animals in the herd were equipped with two Ibutton® temperature sensors (www.maxim-ic.com) on their body, such that one of the two sensors was in direct contact with the lying surface when the animal is lying in a normal position and the other was not (**Figure 3**). The loggers recorded temperature every 5 minutes. The same animals were also equipped with Icetag® activity sensors to record lying behaviour. To obtain a set of reference data, similar measurements were carried out on the Waiboerhoeve research farm (Lelystad, the Netherlands) with cows in a cubicle barn and cows in a traditional straw yard.

Figure 3 Cows with Ibutton® temperature sensor and Icetag® accellerometer

Results (described in more detail in Galama et al, 2012) indicated that during lying bouts the temperature of the skin that is in contact with the bedding gradually increased to body temperature regardless of bedding material. As soon as the animal got up the skin temperature returned to pre-lying values within a couple of minutes. Contrary to our hypothesis, the behavioural patterns of getting up followed by lying down on the other side within 10 minutes occurred more often in the cubicle barn and straw yard of the research farm than on this bedded pack farm.

In summary, none of the parameters studied provided evidence for an increased risk of heat stress for cows in a barn with a composting bedded pack lying area. This also implies that it is not useful to obtain accurate figures of air flow in the barn and air temperature just above the bedding material to get better figures for the thermal load of the animals.

4 Bulk milk somatic cell count, total bacterial count and antibiotics usage

As reported in the literature review some of the bedded pack barns in the USA achieved an improvement of udder health after housing the cows in the new barn. This was indicated by a reduction in bulk milk cell counts and a lower mastitis incidence. We have not recorded mastitis incidence, but obtained data on geometric cell counts from deliveries to the milk processing plant and percentages of cows with scc >500.000 cells/ml during milk recording herd tests from 1-1-2009 onwards for the three farms. These are presented in **Figure 4**.

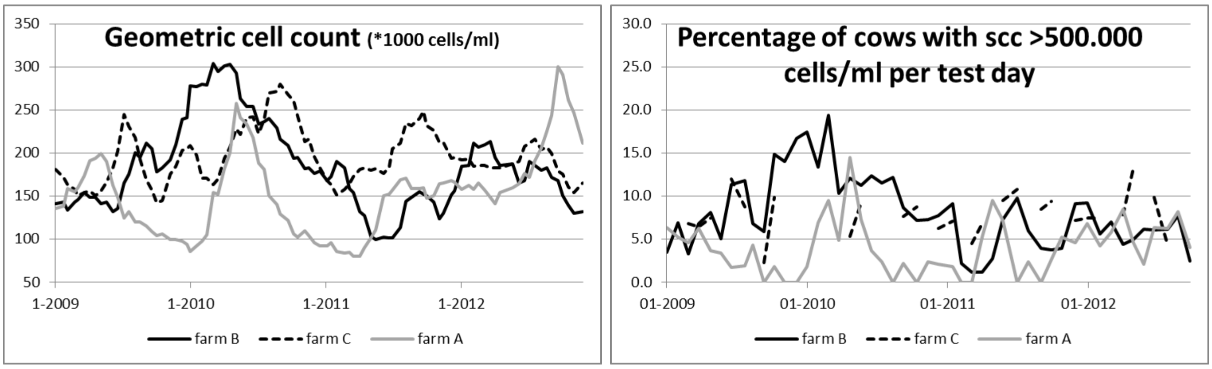

Figure 4 Geometric cell count and percentage of cows with scc >500.000 cells/ml per test day

Geometric cell counts were used in **Figure 4** because these suppress short term fluctuations in cell counts of individual samples and provide better insight in potential trends. The bulk tank cell counts for farm B were high in the period before the cows were housed in the bedded pack barn (December 2010), but had already decreased by then. **Figure 4** shows that there is no clear trend in geometric cell counts after introducing the cows in the new barn on this farm. However, it must be mentioned that the dry off therapy on this farm has drastically changed in 2011 and that the bulk milk cell counts have remained at an acceptable level. Before spring 2011 the cows were routinely dried off with antibiotics, but during the rest of 2011 no antibiotics were used at drying off. From January 2012 onwards antibiotics are used selectively on quarters that have a positive CMT. This farm has realised a usage of 0.4 animal day doses of antibiotics in 2012. For farm C there also is no clear difference in bulk milk scc before and after July 2010 (introduction of bedded pack barn). However, on this farm the usage of antibiotics at drying off is stopped in October 2010 and many cows are continuously milked (without a dry period before calving or a shortened dry period). According to the Dutch system for registration of usage of antibiotics this farm has realised a usage of only 0.02 animal day doses in the first 9 months of 2012, which is presumably far below the national average (because the registration only started recently there are no reliable figures yet, but a usage of 4.6 animal day doses per cow per year or lower is considered acceptable). For farm A the cell counts increased considerably in the first half of 2010 (after the start with the new barn in December 2009) and have returned to a lower level later on. The increase in 2012 shows that udder health still requires attention on this farm. On this farm the dry cow therapy was not altered after 1/1/2009, and antibiotics are used routinely at drying off. This farm has realised a usage of 2.44 animal day doses of antibiotics on annual basis, which is also considerably below the maximum usage that is considered acceptable.

The pattern for bulk milk scc resembles that for percentages of cows with scc >500.000 cells/ml during milk recording herd tests. Farms A and B had 4-weekly test day intervals. Farm C had longer and more irregular test day intervals than the other two farms, and therefore had some missing information. According to the scc information udder health was not systematically altered after housing the cows in the bedded pack barns. All three farms had low usage of antibiotics, particularly farm C and to a lesser extent farm B who both drastically altered their dry cow management.

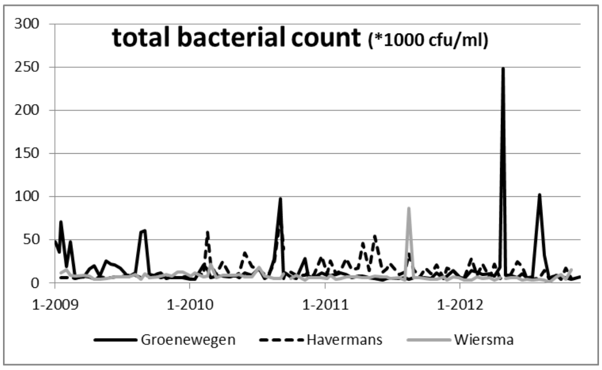

Figure 5 Total bacterial count in bulk milk samples

The total bacterial counts (**Figure 5**) peaked incidentally, the national average is around 10.000 cfu/ml (Productschap Zuivel, 2012). Although there was no clear trend since the transition, this indicates that maintaining good milk quality can indeed be a concern on farms with bedded pack barns. Barberg et al. (2007) conclude that good milk quality from bedded pack herds can be achieved with proper sanitation efficiency and milk handling.

5 Milk contamination from bedding material

The study of Driehuis et al. (2012) was carried out on farms with different kinds of bedding material. Both samples of bedding material and bulk milk samples were analysed bacteriologically. The reference farms in this research were 5 farms where sawdust was used in the cubicles, and besides these farms and the three bedded pack farms also farms that used straw or compost as bedding material in the cubicles were included, The average spore concentrations of two categories of bacteria (thermophilic aerobic spore formers or **TAS** and mesophylic aerobic spore formers or **MAS**) in bulk milk and bedding material are presented in **Figure 6**.

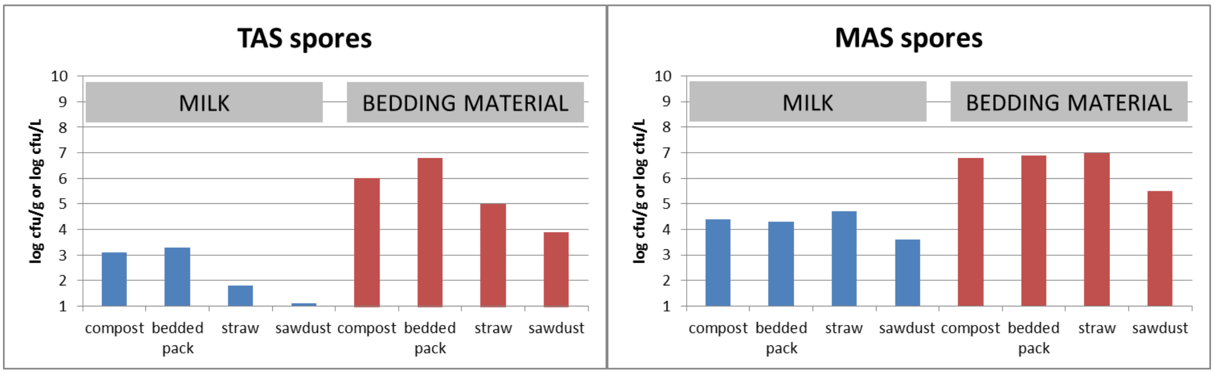

Figure 6 Average spore concentration of TAS and MAS in bedding material (log cfu/g) and bulk milk (log cfu/L) for farms with different bedding materials. Data copied from Driehuis et al. (2012), where more information can be found.

The levels of both TAS and MAS spores in milk are higher for both barns that use compost in cubicles and bedded pack barns. Although it was estimated that the transmission of compost bedding material to bulk milk is low (about 1 mg/l), the relatively high bulk milk levels of particularly TAS for the bedded pack barns (and barns with compost bedding in cubicles) presumably are caused by the bedding material. The possibilities to reduce the transmission by improved teat cleaning are assumed to be insufficient to substantially reduce the TAS spore levels (Driehuis et al, 2012). It is concluded that the increased levels of thermophilic aerobic spore formers (TAS) and mesophylic aerobic spore formers (MAS) in bulk milk are a potential major milk quality concern, but the impact of these bacteria on specific dairy products is currently unknown and should further be studied.

6 Welfare assessment

On each of the three farms animal welfare of the herd was assessed with Welfare Quality® parameters in the fall of 2011 and April/May 2012. As a reference, similar observations carried out on 68 other Dutch dairy farms (particularly organic farms with horned cattle, farms using different kinds of bedding material and farms participating in studies on grazing) were used. Of these farms 54 had a cubicle barn and 14 had a traditional straw yard barn. The following animal based parameters were assessed and used for this study:

- time needed to lie down
- cleanliness of the udder, flank and legs
- body condition score
- integument alterations
- claw conformation
- locomotion score
- social behaviours

All observations were done by the same observer. The number of observations per parameter was determined according to the WQ protocol (Welfare Quality, 2009). The results for each parameter are outlined below.

6.1 Time needed to lie down

The time recording for this variable starts when one of the carpal joints of the front legs is bent and lowered (before touching the ground). The movement ends when the hind quarter of the animal has touched the ground and the animal has pulled out the front leg from underneath the body. A short duration of this movement indicated the animal is able to lie down easily, whereas long duration indicates difficulty to lie down. The results for the three bedded pack farms are in **Table 1**.

Table 1 Average time needed to lie down in seconds for three bedded pack farms

	farm A		farm B		farm C	
	2011	2012	2011	2012	2011	2012
Time (s)	4.53	4.93	4.96	4.93	4.85	4.88

The distribution of the averages for all farms assessed is presented in **Figure 7**.

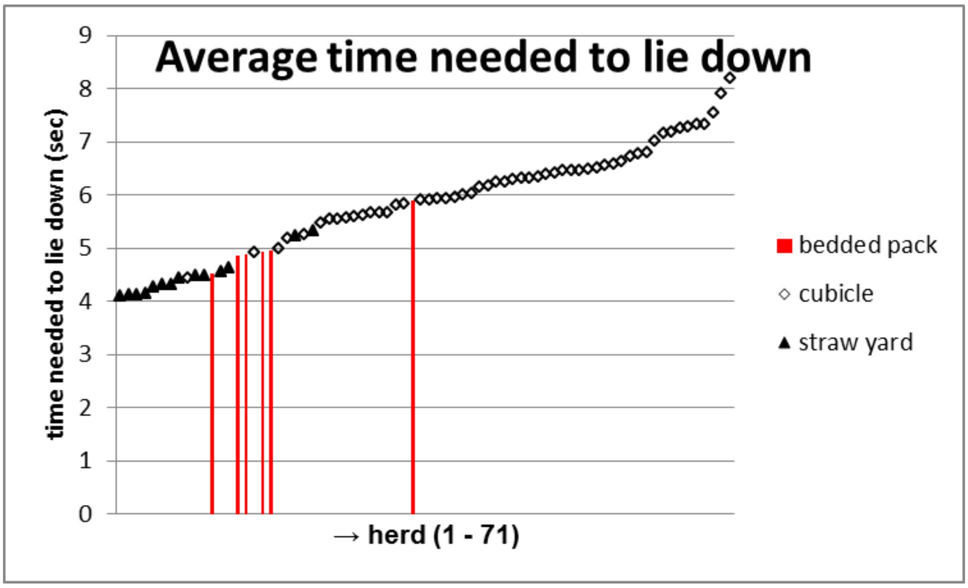

Figure 7 Average time needed to lie down (71 farms, bedded pack farms assessed twice each)

Figure 7 shows that for the majority of cubicle barns the time needed to lie down was between 5.5 and 9 seconds. The average duration for these barns was 6.3 seconds. This is more than the 5.2 seconds considered as the maximum average duration for undisturbed lying down movements (Welfare Quality®, 2009). This indicates that in many existing cubicle barns the cows have difficulties to lie down. It can be caused by claw disorders that make them hesitant to load painful claws, but also can be caused by lack of manoeuvring space in the cubicle area due to either too small cubicle dimensions or wrong placement of construction elements, lack of head space, uncomfortable hard bedding or insufficient foothold on the surface. Nevertheless, **Figure 7** also shows that in some cubicle barns the cows are able to lie down quickly, although not as quick as in traditional straw yards. So it is possible to achieve sufficient lying down circumstances in cubicle barns. In both straw yards and bedded pack barns there are no constructions to guide the animals where they can lie down, so that they have similar space to lie down as on pasture. **Figure 7** indeed shows that in these barn types the animals lie down quicker on average, in less than 5 seconds. It is not clear why these movements were carried out even quicker in the straw yards than in the bedded pack barns, but it might be caused by the daily cultivation of the bedded pack that made it very soft. The repeated measures on the three bedded pack farms showed that time needed to lie down can vary in time. During the assessment in May 2012 the bedding for one of the farms (farm B) was very soft and the animals had to pull out their legs from the bedding before they could lie down. As a result, time needed to lie down was around 1 second longer than during the previous assessment on this farm. This indicates that for uncomplicated lying down the bedding should provide sufficient bearing capacity.

The figures for time needed to lie down do not visualise all aspects of restricted lying comfort. In cubicle barns it occurred regularly that animals apparently wanted to lie down, but hesitated to do it and sometimes also performed several failed attempts. For these events no time is recorded and so they are not included in the average time. In traditional straw yards and bedded pack barns no failed attempts were observed. In summary, the observations indicate that lying comfort is better in bedded pack barns than in cubicle barns.

6.2 Cleanliness of the udder and teats, flank and legs

Cleanliness of the cows was assessed for four body regions: the lower part of the hind legs, the hind quarter and upper part of the hind legs and udder and teats (Welfare Quality®, 2009). When an area bigger than the size of a hand of the udder, hind quarter or legs was covered with dirt or manure the animal was given a score of 1, otherwise it was given a score of 0 for these body parts. Teats were given a score of 1 when there was only a small splash of dirt, a score of 2 if they were dirtier and a score of 0 if they were clean. Lower scores indicate cleaner animals, therefore low scores are favourable. The results for the three farms are in **Table 2**.

Table 2 Average cleanliness scores for udder, teats, flank and legs on three bedded pack farms

	farm A		farm B		farm C	
	2011	2012	2011	2012	2011	2012
Udder	0.40	0.29	0.39	0.55	0.56	0.23
Teats	0.50	0.36	0.52	0.63	0.76	0.20
Hind quarter	0.60	0.25	0.58	0.83	0.65	0.40
Hind legs	0.45	0.46	0.71	0.75	0.65	0.94

Table 2 shows that the cows of farm A on average were somewhat cleaner than those at the other two farms, but also indicate that the scores per farm differed between the two observations. We had the impression that the cleanliness scores were related to the condition of the bedding material, and this is more variable on bedded pack and traditional straw yard farms than on cubicle farms. On farm A for instance the welfare assessment in 2011 took place shortly before the bedding material was replaced, while the bedding was not in optimal condition. This may have contributed to the higher (unfavourable!) cleanliness scores in 2011 on this farm. The hind legs on average had the highest scores on the three bedded pack farms. The scores of these three farms were compared with those obtained on the other farms. The scores for teats were excluded from the comparison, because on some of the farms the assessments were performed shortly after milking. A total score is added to obtain overall impressions of cleanliness of the body parts that were scored. Averages for the three barn types are in

Table 3 Average cleanliness score per barn type and body region

	Cubicle (54 farms)			Straw yard (14 farms)			Bedded pack (3 farms)		
	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max
Hind legs	0.86	0.33	1.00	0.80	0.51	0.97	0.66	0.45	0.94
Hind quarter	0.54	0.08	0.92	0.74	0.47	0.94	0.55	0.25	0.83
Udder	0.30	0.04	0.67	0.49	0.24	0.73	0.40	0.22	0.56
Total	1.70	0.46	2.58	2.04	1.22	2.59	1.61	1.00	2.12

The overall average scores for all assessments were 0.82 for hind legs, 0.58 for hind quarter and 0.34 for udder. This implies that more than 50% of the cows had dirty hind legs and a dirty hind quarter and one third of the animals had a dirty udder. Cows in the traditional straw yards were dirtier than those in the other two barn types, but contrary to the observations of Lobeck et al. (2011) the cows in the cubicle barns were not cleaner than those in the bedded pack barns. The variation between herds for cubicle barns and straw yards was large, and also the hygiene of the bedded pack herds varied considerably. This shows that in each barn type the animals can be kept clean, but it also indicates that other factors than the type of barn are important for cleanliness of the animals. Clean bedding is a prerequisite for clean animals, but barn type has implications for bedding management. For traditional straw yards the cleanliness of the bedding is mainly determined by the amount of straw that is used in the bedding area and its distribution in time and place. In bedded pack barns the bedding is primarily kept clean and dry by cultivation of the top layer and either evaporation or absorption of water. It depends on the type of bedding material which management practices should be applied. In cubicle barns clean cubicles can be achieved by proper dimensioning of the cubicles, sufficient cleaning of the cubicles and removal of manure from the alleys behind the cubicles. In conclusion, the cleanliness observations indicate that it is possible to keep the animals sufficiently clean in bedded pack barns.

6.3 Body condition score (BCS)

This parameter was scored on a scale from 1 – 5, where 1 is very thin and 5 is very fat. This is different from the scale used in the Welfare Quality® protocol, but is a scale used regularly for ration evaluation and other purposes other than welfare assessment. For most dairy breeds the optimal BCS is between 2.5 and 3.5 and depends on lactation stage. Animals around peak lactation (2 months after calving) generally have a lower BCS than those in late lactation or shortly after calving. The scores obtained on the three bedded pack farms are in **Table 4**.

Table 4 Average BCS for cows in three bedded pack barns

	farm A		farm B		farm C	
	2011	2012	2011	2012	2011	2012
BCS	3.1	3.0	2.9	2.9	3.1	3.5

The cows of farm C on average had a slightly higher BCS than those at the other two farms in 2012, those of farm B had the lowest BCS. The assessments on farms with cubicle barns or traditional straw yard barns revealed an overall average BCS of 3.0 with a range from 2.6 to 3.4. There was no difference between these two barn types. The scores obtained on the bedded pack barn farms were in the same range as those from the other farms. BCS is primarily determined by feeding: ration composition and feed provision. The higher BCS of the cows of farm C can also partly be a result of a more dual purpose type of cows with around 50% Montbeliarde genes compared to the Holstein herds on the other two bedded pack farms. We have no explanation for the difference in average BCS between the two measurements for farm C. In summary, the observations indicate that the cows in the three bedded pack barns had normal BCS.

6.4 Integument alterations

The integument alterations (hairless patches, lesions and swellings) were assessed for different body parts separately: hock, carpus, hind quarter, neck/shoulder/back and body flank according to the Welfare Quality® protocol. For each area the number of alterations was counted per category. The animals were assessed from one side (chosen randomly). To obtain an impression of the occurrence of alterations the scores for hairless patches, lesions and swellings were summed for each body area. The averages for each assessment on the three farms are presented in **Table 5**.

Table 5 Average score for integument alterations per body region on three bedded pack farms

	farm A		farm B		farm C	
	2011	2012	2011	2012	2011	2012
Hock	0.10	0.21	0.03	0.03	0.14	0.21
Carpus	0.00	0.11	0.00	0.00	0.00	0.03
Hind quarter	0.00	0.08	0.06	0.05	0.14	0.15
Neck/shoulder/back	0.10	0.25	1.81	0.63	0.00	0.15
Body flank	0.00	0.00	0.13	0.00	0.00	0.00

Table 5 indicates that the animals in the three bedded pack barns had low prevalence's of integument alterations, particularly for hock, carpus, hind quarter and body flank. The alterations recorded were mainly hairless patches, lesions hardly occurred. During the 2011 assessment at farm B relatively many animals had hairless patches and/or swellings in the neck, presumably due to the feeding rack that was too low. During the assessment in 2012, after adjustment of the feeding rack, a substantial improvement was achieved. The scores for the bedded pack farms are compared with those from the other groups of farms (**Table 6**).

Table 6 Average integument alteration scores per body region and barn type

	Cubicle	Straw yard	Bedded pack
Hock	0.75	0.11	0.12
Carpus	0.52	0.02	0.02
Hind quarter	1.44	1.52	0.08
Neck/shoulder/back	1.26	1.53	0.48
Body flank	1.40	2.85	0.02

The cows in both barns with traditional straw yards and bedded pack lying areas had low scores for hock and carpus alterations compared with those in cubicle barns (**Table 6**). This corresponds with the results of Lobeck et al. (2011), and is probably due to the softer and less abrasive bedding in these barns. The scores for the other body areas were influenced by the fact that a number of the farms that were assessed (both with straw yard and cubicle barns) had horned cattle. These farms had considerably higher scores for integument alterations on the hind quarter, neck/shoulder/back and body flank. The higher prevalence's of alterations in cubicle barns for these body regions compared to the bedded pack barns probably are partly caused by collisions with housing equipment such as cubicle dividers, but this is not likely for the straw yard barns. The proportion of horned herds was highest in these barns, and it is assumed that this influenced the figures in **Table 6**. In summary, the results show that bedded pack barns had clear advantages over cubicle barns with regard to minimization of the prevalence of integument alterations However, also in these barns wrongly placed equipment such as a feeding rack can cause lesions.

6.5 Claw conformation

This part of the assessment focused on the comparison of the length of the inner and outer claws, the claw angle, the claw - floor contact, smoothness of the wall and the width of the interdigital space between the inner and outer claw. Both a hind and a front leg of the same cow were assessed. If two or more of the criteria were not fulfilled the animal was given a score of 1, otherwise a score of 0 was given. This implies that a low score for a herd coincides with good claw conformation and vice versa. The average scores recorded for the three bedded pack farms are in

Table 7.

Table 7 Average scores for claw conformation in three bedded pack barns

	farm A		farm B		farm C	
	2011	2012	2011	2012	2011	2012
Average score	0.06	0.21	0.39	0.31	0.30	0.63

The most remarkable figure in

Table 7 is the relatively high score for farm C in 2012. The cows on this farm hardly walked on hard flooring, in contrast to those on the other two farms where the alley behind the feeding rack is equipped with slatted concrete flooring. It was noticed that long toes, particularly of the front claws, occurred relatively often on this farm. Claw conformation scores were most favourable on farm A, where the concrete slatted area is relatively large. It must be mentioned that suboptimal claw conformation has less negative effect on locomotion when the animals walk and stand on a soft surface, as is the case in bedded packs. Despite this, overgrown claws should be trimmed to restore claw conformation. In barns with concrete flooring it is less likely that wear of the horn is low and not in balance with growth than in bedded packs and straw yards. The average claw conformation score for the cubicle barns was 0.22 and for straw yards it was 0.26, thus claw conformation was below these averages for farm C and to a lesser extent also for farm C. The scores are influenced by the trimming policy applied on the farms. In summary, the results show that claws with poor conformation were recorded relatively often for two of the bedded pack herds.

6.6 Locomotion score

Locomotion of the cows was scored on a scale from 0 to 2: 0 = not lame, 1 = slightly lame and 2 = severely lame (Welfare Quality®, 2009). Low average scores indicate good locomotion and high scores indicate impaired locomotion. The cows were assessed on the spot where they were seen standing or walking. In cubicle barns this was usually on concrete flooring (either slatted or solid), in the other barn types it could also be in the bedding area. The different floorings affected the gait of the animals. On the slippery concrete floor in the barn of farm A the cows did not walk lame, but walked hesitantly to prevent slipping. In very loose and soft bedded areas (such as the bedded pack in farm A after cultivation) the animals had to pull out their legs and thus moving was difficult, but the animals again did not walk lame. The average locomotion scores are presented in **Table 8**.

Table 8 Average locomotion scores for three bedded pack barns

	farm A		farm B		farm C	
	2011	2012	2011	2012	2011	2012
Average score	0.14	0.15	0.35	0.08	0.18	0.19

For farm B the two scores were rather different, it is not known what could have caused this. Occurrences of claw disorders were not recorded. For the other two farms the results of both assessments were very similar. The higher claw conformation score for farm C in 2012 compared to 2011 did thus not have a negative effect on locomotion score in the bedding area. The assessments in traditional straw yard barns revealed that 91% of the cows were not lame whereas 3% were severely lame. For the bedded pack barns the figures were 83% and 1% respectively and for cubicle barns 79% and 7%. The average locomotion scores for straw yard, bedded pack and cubicle barns were 0.11, 0.18 and 0.27 respectively. This implies that the locomotion scores for the bedded pack barns on average were better than those for average cubicle barns, but less favourable than those for the straw yards. However, severe lameness occurred less frequently in the bedded pack barns compared with the other types of barns. Better locomotion scores for cows in straw yards compared with cubicle barns are in line with results of other studies (Rutherford et al., 2009; Somers, 2004), but the locomotion scores for bedded pack barns in our study were less favourable than those of Lobeck et al. (2011). This can be influenced by the fact that all three bedded pack farms had only recently housed their cows in the new barn, but it can also be affected by the considerable area with concrete flooring on two of the farms. In summary, the results show that the incidence of severe lameness was low in the bedded pack barns compared to the other barns, but contrary to straw yard barns imperfect locomotion (locomotion score 1) occurred to the same extent as in cubicle barns (16 vs. 14%).

6.7 Social behaviour

Behavioural observations were performed during 2 periods of 20 minutes per barn section for each assessment according to the Welfare Quality® protocol. The following agonistic behaviours were assessed: head butting, displacing, fighting, chasing and chasing up. Also, events of social licking and coughing were recorded. To obtain comparable figures the scores (event counts) were expressed as average number of events per animal per hour. The results are presented in **Table 9**.

Table 9 Average number of social behaviours per animal per hour in three bedded pack barns

	farm A		farm B		farm C	
Behaviour	2011	2012	2011	2012	2011	2012
Head butt	0.16	0.38	0.04	0.72	0.11	0.25
Displacement	0.03	0.38	0.19	0.17	0.09	0.32
Fighting	0.00	0.00	0.00	0.05	0.02	0.04
Chasing	0.00	0.00	0.08	0.00	0.02	0.01
Chasing up	0.00	0.00	0.00	0.02	0.04	0.03
Social licking	0.32	0.12	0.42	0.02	0.24	0.20
Coughing	0.32	0.15	0.04	0.12	0.18	0.33

It was noticed that the number of agonistic behaviours generally was higher during the 2012 assessments on all three farms than during the 2011 assessments. The majority of the agonistic interactions occurred in the feeding area, therefore it is assumed that somehow the cows were less satisfied with their feed and did more attempts to try elsewhere along the feeding lane. For better interpretation the results were compared with those obtained on the other farms. Since there were no clear behavioural differences between herds in cubicle barns and herds in straw yards barn type was ignored while calculating the averages. However, prevalence's of agonistic behaviours were different for horned and dehorned herds. Therefore, the figures for the reference herds were averaged for horned and dehorned herds separately. The results are presented in **Table 10**.

Table 10 Average number of social behaviours per animal per hour for three categories of herds

	Horned herds	Dehorned herds	Bedded pack herds
Heat butt	0.26	0.60	0.28
Displacement	0.37	0.55	0.20
Fighting	0.02	0.04	0.02
Chasing	0.08	0.02	0.02
Chasing up	0.23	0.03	0.02
Social licking	0.09	0.11	0.22
Coughing	0.37	0.27	0.19

Chasing and chasing up occurred more frequently in horned herds, but head butting and displacement occurred more frequently in dehorned herds. In the bedded pack barns, with dehorned cattle, the latter two behaviours did not occur more frequently than in horned herds. This could be a result of the large area per animal that better enables the animals to avoid confrontations. Social licking did occur relatively often in the bedded pack barns. In conclusion, the results indicate that the herds housed in bedded pack barns had low prevalence of agonistic behaviours and relatively frequent social licking compared to the other herds.

7 Culling and replacement

Between January 1st 2009 and November 1st 2012 all three farms introduced their herds in the new bedded pack barns. The development of the number of milking animals and the herd average standardised daily milk yield at each milk recording test day (see Wilmink, 1987) during this timeframe are presented in **Figure 8**.

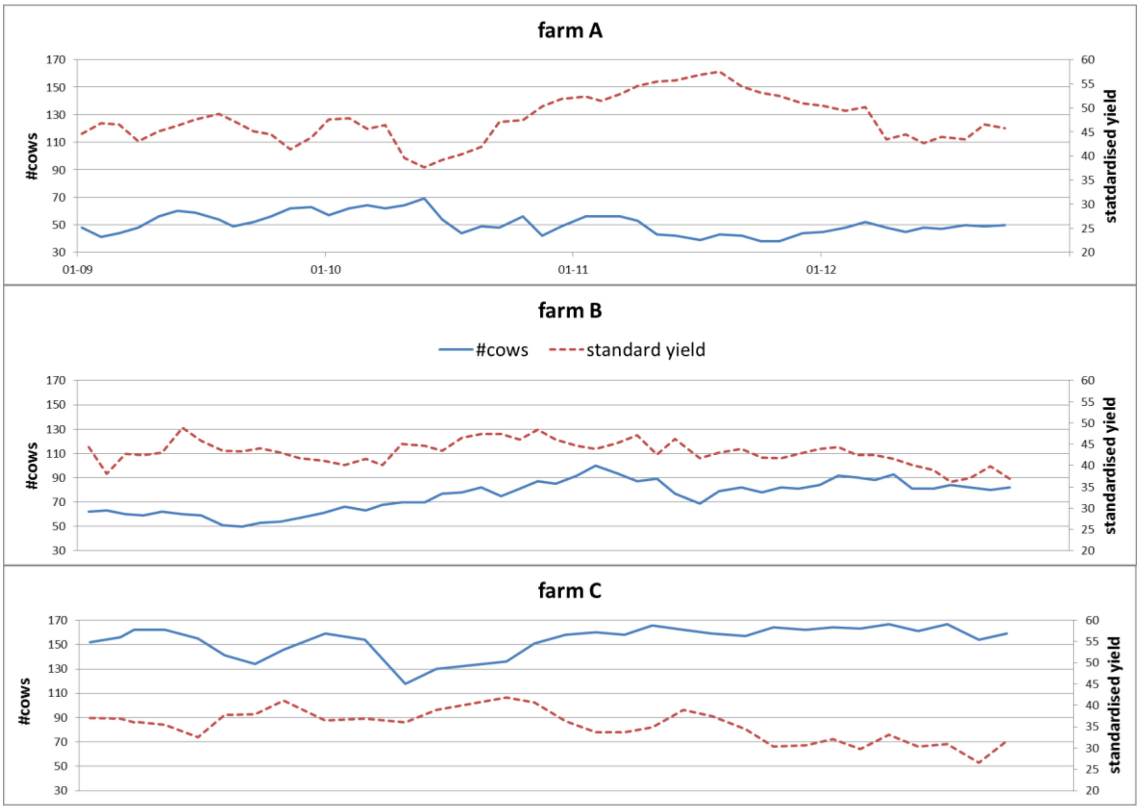

Figure 8 Development of number of milking cows and standardised milk yield from 2009 onwards

For farm B the herd size was increasing when the bedded pack barn was first used (in December 2010). For farm C the herd size was temporarily lower during 2010, while the bedded pack barn was first used in July 2010. For farm A the herd size has decreased since June 2010, while it was increasing at the time of introduction of the bedded pack barn in December 2009. On this farm the production per animal has increased considerably from June 2010 onwards. Because of the quota system this can at least partly explain the decrease in herd size. It can be seen in **Figure 8** that the average herd size and production level differ substantially between the three farms. The changes in herd size that have occurred on each of the farms have had considerable influence on the culling and replacement figures in the milking herds. The numbers of newly introduced milking animals per farm per year are presented in **Table 11**.

Table 11 Number of newly introduced animals in the milking herd per farm per year*

Herd	2009	2010	2011	2012**
farm A	41 (65)	32 (48)	12 (22)	16 (28)
farm B	15 (23)	59 (68)	37 (39)	9 (10)
farm C	59 (35)	69 (44)	55 (33)	68 (39)

*percentages of average herd size on a yearly basis between brackets, **data until November 1st

Table 11 suggests that the percentages of heifers in the herds were not stable in the years considered. However, 10 of the animals introduced on farm A in 2009 had already calved elsewhere before they entered the milking herd on that farm. The rest of the animals introduced were first calving heifers. Particularly on the farm A and B the differences between years in numbers of animals introduced in the milking herd were large. The temporary decrease in herd size on farm C in 2010 was due to a number of animals that was stalled elsewhere. The majority of these animals returned to the herd after the new barn was taken into use. On the other farms it did not occur that animals left the herd after their first calving and returned later on, but for young stock it did occur. All three farms had animals in the milking herd that had been born on other farms, with highest percentages for farm A from 2010 onwards (35 to 43%). Many of the animals that were born elsewhere were bought as calf and raised on the farm, but also pregnant heifers and milking cows were occasionally bought.

Both herd size and percentages of newly introduced animals in the milking herds in the years 2009 until 2012 have fluctuated considerably. It is therefore doubtful if the culling policies and culling figures for this period are predictive for the years to come. Moreover, it is hard to predict to what extent they are affected by the bedded pack barns, although it is assumed that these barns can contribute to improved longevity. Percentages of culled animals per year are presented in **Table 12**. For each culled animal it was determined whether the animals were kept elsewhere for at least 30 days and thus still alive 30 days after culling, were slaughtered within 30 days after being culled or were culled because of natural death on the farms. This last category is not presented in **Table 12** but is the difference between overall culling and the other two categories.

Table 12 Culling figures per year for bedded pack farms (percentages of average herd size)

	farm A			farm B			farm C		
	All	P	S	All*	P*	S*	All	P	S
2009	52.2	26.9	20.6	19.9	1.5	13.8	40.4	17.8	19.6
2010	46.8	42.3	4.5	32.1	6.9	17.2	46.7	21.1	21.1
2011	31.4	22.1	7.4	37.8	25.2	10.5	21.8	10.9	9.1
2012**	20.8	3.5	17.4	10.5	2.1	7.3	19.6	0.0	17.3
average	37.8	23.7	12.5	25.1	8.9	12.2	32.1	12.4	16.8

*All = all culling, P = still alive 30 days after culling, S = slaughtered within 30 days, **data until November 1st

As was the case for the introduction of heifers, the culling figures were quite variable over the years. The culling rates for the herd of farm A were high, but relatively often the animals were not sent to a slaughterhouse. This did also occur on both other farms, but to a lesser extent. Because the animals still alive 30 days after culling probably were not at the end of their productive life and could continue to produce milk elsewhere, the production figures of the culled animals were calculated for animals that died on the farm or were sold for slaughter within 30 days only and are presented in **Table 13**.

Table 13 Age and production figures of animals culled for slaughter within 30 days or death on the farm

	farm A			farm B			farm C		
	age*	laclen**	kg milk	age	laclen	kg milk	age	laclen	kg milk
2009	2004	266	32161	2054	310	32512	1955	203	22957
2010	1991	347	31632	1694	304	24380	1825	261	20194
2011	1835	191	23665	1718	221	27948	2170	334	29383
2012***	2039	359	33611	1791	298	22309	2177	280	28048
average	1967	291	30267	1814	283	26787	2032	269	25146

*age at culling in days, **days in lactation at the culling date, ***data until November 1st

Average age at culling and milk production of the culled animals varied from year to year (**Table 13**). Currently the age at culling for the bedded pack herds is somewhat below the national average for herdbook cows (CRV, 2012). If the bedded pack barns are beneficial for longevity this might become visible in future figures if the herds become more stable. As already suggested by the average days in lactation at culling, the majority of the animals were culled in late lactation. However, on the farms B and C also around 25% of the animals were culled within 90 days after calving whereas this was only 12% for farm A.

Because impaired udder health is regarded as one of the major reasons for involuntary culling on dairy farms, the average last test day scc of the culled cows were investigated for all culled animals and for the animals slaughtered within 30 days after culling. Moreover, the numbers of animals culled with scc >500.000 cells/ml were counted (**Table 14**).

Table 14 Average scc (cells/ml) *1000 at last test day for culled animals per herd per year

	farm A			farm B			farm C		
	all	S*	>500**	all	S*	>500**	all	S*	>500**
2009	163	101	2	310	314	3	363	517	12
2010	90	106	-	514	389	8	363	452	7
2011	102	144	-	516	717	7	242	314	2
2012***	437	493	1	254	289	1	285	285	3
average	166	227		447	420		332	406	

* average for animals culled for slaughter only, **number of animals culled with last scc >500.000 cells/ml, ***data until November 1st

The high scc of the animals culled on farms B and C in 2009 and 2010 could mean that impaired udder health was an important reason for culling in the period before the bedded pack barns were introduced. The scc at culling for these two farms remained high in 2011 and 2012. For farm A the figures for 2012 correspond with the increased bulk milk scc, but the increase was mainly due to one animal with mastitis and an scc of 2973. For this farm elevated scc was not a main reason for culling. Some of the animals with very high scc at culling were still alive 30 days after culling. It must be mentioned that the animals that were culled shortly after calving often did not have test day productions after their last calving. The figures in **Table 14** indicate that the introduction of the bedded pack barns did not substantially influence the culling policy with regard to somatic cell counts. This is in line with the information obtained from bulk milk cell counts.

Another possible cause of involuntary culling is poor fertility. The animals that calved between 1-1-2009 and 31-10-2012 on average had 1.71 recorded inseminations per pregnancy. Of the animals that were culled 48% had been inseminated after the last calving, the average number of recorded inseminations until culling for these animals was 2.06. Averages per farm are given in **Table 15**.

Table 15 Average number of inseminations of animals that calved and animals that were culled

	farm A	farm B	farm C
Number of inseminations:			
Cows inseminated and calved	1.80	1.65	1.70
Cows inseminated and culled	2.34	1.81	2.02
% of culled cows inseminated	43	54	43

The figures in **Table 15** show that for a considerable proportion of the cows that were culled it was tried to get them in calf again, and that these cows on average were inseminated more often than the cows that conceived. On average the animals that had been inseminated before culling were culled 320 days after the last calving date. The animals that were not inseminated were culled 123 days after the last calving. Together this suggests that poor fertility has contributed to the culling decision on all three farms, but most on farm A.

The analysis of culling and replacement data showed that a large proportion of the animals that were culled from the bedded pack herds was still alive 30 days after culling. The herd compositions were not stable in the years just before and after the introduction in the new bedded pack barns, therefore the yearly culling figures were quite variable. The animals that were culled for slaughter had a herd life and lifetime milk yield a little below the national average. In two of the farms a considerable part of the culled cows had high scc, but this was already the case before the introduction of the bedded pack barns. Poor fertility was a factor on all three farms.

8 Conclusions

- Heat production due to the composting process in the bedding does not increase the risk of heat stress in a well-ventilated barn.
- Scientific literature on housing systems for dairy cattle indicates that bedded pack barns can have positive effects on animal welfare. Most of the expectations have been realised on the three farms monitored for this study. Particularly the ease to lie down, the low prevalence of integument alterations and the lower prevalence of severe lameness are favourable compared with cubicle barns. Moreover, the herds kept in the bedded pack barns were characterised by low prevalence of agonistic behaviour and relatively frequent occurrence positive social behaviour (social licking).
- Trimming may be required to prevent the development of overgrown claws.
- Cleanliness scores of herds kept in bedded pack barns were comparable with those of cows in cubicle barns. However, several occasions of elevated bacterial counts in bulk milk have occurred, which indicates that teats should be cleaned carefully.
- Bulk milk from bedded pack barns has increased levels of TAS and MAS, comparable to bulk milk from cubicle barns that use compost as bedding material. Potentially these bacteria have negative effects on quality of dairy products.

References

Barberg, A.E., M.I. Endres, J.A. Salfer, and J.K. Reneau. 2007. Performance and welfare of dairy cows in an alternative housing system in Minnesota. J. Dairy Sci. 90:1575-1583.
Berman, A. 2005. Estimates of heat stress relief needs for Holstein dairy cows. J. Anim Sci. 83:1377-1384.
Brown-Brandl, T. M., J. A. Nienaber, R. A. Eigenberg, G. L. Hahn, and H. Freetly. 2003. Thermoregulatory responses of feeder cattle. Journal of Thermal Biology 28:149-157.
Brown-Brandl, T. M., J. A. Nienaber, R. A. Eigenberg, T. L. Mader, J. L. Morrow, and J. W. Dailey. 2006. Comparison of heat tolerance of feedlot heifers of different breeds. Livest. Science 105:19-26.
Cook, N. B. 2003. Prevalence of lameness among dairy cattle in Wisconsin as a function of housing type and stall surface. J. Am. Vet. Med. Assoc. 223:1324–1328.
CRV, 2012. CRV Annual statistics 2011 Nederland, CRV, Arnhem, the Netherlands.
Driehuis, F, E. Lucas-van den Bos and M.H.J. Wells-Bennik. 2012. Risks of microbial contaminants of bedding materials: compost, cattle manure solids, horse dung and bedded pack barns. NIZO-report 2012/119, NIZO, Ede, the Netherlands.
Endres, M.I., and A.E. Barberg. 2007. Behavior of dairy cows in an alternative bedded-pack housing system. J. Dairy Sci. 90:4192-4200.
Espejo, L. A., M. I. Endres, and J. A. Salfer. 2006. Prevalence of lameness in high-producing Holstein cows housed in freestall barns in Minnesota. J. Dairy Sci. 89:3052–3058.
Fisher, W. 2011. Gedrag van melkkoeien in de compoststal en ligboxenstal. Een studie naar verschillen in liggedragingen. Report student reseach project Van Hall Larenstein, Leeuwarden.
Fregonesi, J.A., D.M. Veira, M.A.G. von Keyserlingk, and D.M. Weary. 2007. Effects of Bedding Quality on Lying Behavior of Dairy Cows. J. Dairy Sci. 90:5468–5472.
Fregonesi, J.A., M.A.G. von Keyserlingk, and D.M. Weary. 2009. Cow preference and usage of free stalls compared with an open pack area. J. Dairy Sci. 92:5497–5502.
Galama, P. 2013. On farm development of bedded pack dairy barns in The Netherlands: Introduction and first experiences on three farms. Report 707 (in preparation), WUR Livestock Research, Lelystad.
Galama, P., H.J.C. van Dooren, H. de Boer, W. Ouweltjes, G. Smolders, K. Blanken en J. Poelarends. 2012. Vrijloopstal Wiersma. Rapport 740, WUR Livestock Research, Lelystad. (in Dutch)
Gaughan, J. B., T. L. Mader, S. M. Holt, and A. Lisle. 2008. A new heat load index for feedlot cattle. J. Anim Sci. 86:226-234.
Gilmour, A. R., B. J. Gogel, B. R. Cullis, and R. Thompson. 2006. ASREML User Guide Release 2.0. VSN International Ltd., Hemel Hempstead, UK.
Hoekstra, N. en A. Lekkerkerker. 2011. Eindverslag HLB200 “onderzoek naar vrijloopstallen”. Report student reseach project Van Hall Larenstein, Leeuwarden.
Kadzere, C. T., M. R. Murphy, N. Silanikove, and E. Maltz. 2002. Heat stress in lactating dairy cows: a review. Livestock Production Science 77:59-91.
Krohn, C.C. and L. Munksgaard. 1993. Behaviour of dairy cows kept in extensive (loose housing/pasture) or intensive (tie stall) environments II. Lying and lying-down behaviour. Appl. An. Behav. Sci. 37:1–16.
Lobeck, K.M., M.I. Endres, E.M. Shane, S.M. Godden, and J. Fetrow. 2011. Animal welfare in cross-ventilated, compost-bedded pack, and naturally ventilated dairy barns in the upper Midwest. J. Dairy Sci. 94:5469–5479.
Middendorp, B.J. van en M. Cornelissen. 2009. Gedrag van koeien in een vrijloopstal. Report student reseach project CAH, Dronten.
Ouweltjes, W., H.J.C. van Dooren, L.F.M. Ruis-Heutinck, G.J. Dijk en A. Meijering. 2003. Huisvesting van melkvee: knelpunten uit oogpunt van welzijn. PraktijkRapport Rundvee 21, Praktijkonderzoek Veehouderij, Lelystad. Dutch with English summary.
Productschap Zuivel, 2012. Zuivel in cijfers 2011 Melkveehouderij, update 27 juni 2012. www.prodzuivel.nl/pz/productschap/publicaties/zic/zicmvh2011.pdf
Ravagnolo, O., I. Misztal, and G. Hoogenboom. 2000. Genetic Component of Heat Stress in Dairy Cattle, Development of Heat Index Function. Journal of Dairy Science 83:2120-2125.
Rutherford, K.M.D., F.M. Langford, M.C. Jack, L. Sherwood, A.B. Lawrence, and M.J. Haskell. 2009. Lameness prevalence and risk factors in organic and non-organic dairy herds in the United Kingdom. The Veterinary Journal 180:95–105.
Schütz, K. E., A. R. Rogers, Y. A. Poulouin, N. R. Cox, and C. B. Tucker. 2010. The amount of shade influences the behavior and physiology of dairy cattle. Journal of Dairy Science 93:125-133.

Somers, J. 2004. Claw disorders and disturbed locomotion in dairy cows: the effect of floor systems and implications for animal welfare. PhD thesis, Universiteit Utrecht, Faculteit Diergeneeskunde.
Welfare Quality®. 2009. Welfare Quality® assessment protocol for cattle. Welfare Quality® Consortium, Lelystad, Netherlands.
Wilmink, J.B.M. 1987. Adjustment of test-day milk, fat and protein yield for age, season and stage of lactation. Livest. Prod. Sci. 16:335–348.



Wageningen UR Livestock Research

Edelhertweg 15, 8219 PH Lelystad T 0320 238238 F 0320 238050

E info.livestockresearch@wur.nl I www.livestockresearch.wur.nl