Effects of Implementing a Compost Bedded Pack System on Somatic Cell Count Compared to a Free Stall System within the Same Farm

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ABSTRACT

The objective of this study was to evaluate the effects of implementing a compost bedded pack (CBP) barn on somatic cell count (SCC) compared to a free stall (FS) barn with sand bedded cubicles within the same farm.

A randomized longitudinal trial was carried out in an organic Danish dairy farm with Danish Holstein breed. 461 multiparous cows were included in the study. From December 2012 to May 2013 cows were randomly assigned to the CBP barn and FS barn according to ear tag numbers. Monthly SCC from milk recordings were analyzed during 17 months, five months after the CBP barn was implemented and 12 months before.

A random coefficient (mixed) model showed a significant difference in SCC between the two housing systems. Cows in the CBP barn had approximately 60,000 to 80,000 cells/mL higher level of SCC in comparison to cows in the FS barn. The difference between the groups became visible when implementing the CBP barn and was detectable throughout the five months of the study. The level of SCC in the cows housed in the CBP barn was, contrary to the SCC level of cows in the FS barn, above 200,000 cells/mL throughout the five months. Focusing on udder health is suggested in implementing of a CBP barn.

Key words: compost bedded pack, somatic cell count, dairy cow, udder health

INTRODUCTION

The compost bedded pack (**CBP**) barns are loose housing systems characterized by a deep bedded pack as resting area. The pack is usually bedded with dry wood shavings and sawdust or both (Barberg et al., 2007), but other organic materials has been used (Shane et al., 2010b). CBP barns are evaluated as an alternative to free stall (**FS**) housing systems and straw yards (**SY**) (Janni et al., 2007; Barberg et al., 2007; Klaas and Bjerg, 2011). The first CBP barn was built in Minnesota in 2001 (Janni et al., 2007; Barberg et al., 2007), and the system is subsequently reported from Israel (Klaas et al., 2010), and the Netherlands (Galama, 2011). CBP barns are typically built for improved cow comfort. Prevalence of lameness and hock lesions in CBP barns is reduced or within the range of the prevalence in SY and FS with sand bedded cubicles, and much lower than in FS with mattresses (Klaas and Bjerg, 2011; Lobeck et al., 2011). There may also be an advantage in relation to reduced ammonia emission from the CBP compared to emission from slatted floors (Klaas et al., 2010; Galama, 2011). Furthermore the CBP barn could be cheaper to build as an FS barn (Galama, 2011).

Because lameness is a major economic and welfare problem in many countries, including Denmark (Enting et al., 1997; Ettema and Ostergaard, 2006), and because of increasing focus on sustainability and the environment, CBP barns may be a relevant alternative housing system in Denmark. Furthermore, non-organic straw must be phased out from Danish organic farming before 2022, and a priority in strategy for phasing out is alternative bedding materials (Organic Association & Danish Organic, 2011). This, together with the prospect of improved cow comfort and reduced lameness, is why a Danish organic farmer was interested in implementing a CBP barn for his dairy cows.

Cleanliness of udder and legs can be a challenge in CBP barns (Lobeck et al., 2011). The pack surface needs to stay dry to keep the cows clean (Shane et al., 2010a). To keep the pack surface dry, the pack must be aerated to enhance the microbiological activity, which generates heat and enhance the evaporation from the pack (Barberg et al., 2007; Klaas and Bjerg, 2011). In a humid and cold climate, like we have in Denmark, sufficient evaporation and keeping the pack dry can be a problem (Klaas et al., 2010; Galama, 2011).

Organic bedding material enhances bacterial growth resulting in higher bacterial counts than inorganic beddings like sand (Hogan et al., 1989). Udder hygiene has been associated with SCC (Schreiner and Ruegg, 2003; Reneau et al., 2005), and bacterial count in bedding is positively correlated with bacteria on teat ends which is correlated with increasing SCC and incidence of

clinical mastitis (Hogan et al., 1989; Peeler et al., 2000). It is expected, therefore, that a disadvantage of the CBP barns can be an increasing SCC. However two studies from Minnesota suggested that there was no problem with udder health in CBP barns (Barberg et al., 2007; Lobeck et al., 2011).

This study was conducted as part of a larger project with the purpose to develop a CBP system that is able to work under Danish climatic conditions and tight Danish environmental regulations (Oakman, 2012). The objective of this study was to evaluate monthly SCC from milk recording in dairy cows housed in a Danish CBP barn, compared to dairy cows housed in a sand bedded FS barn within the same organic farm.

MATERIALS AND METHODS

Study Design and Study Population

This study was a longitudinal randomized experiment. The target population was dairy cows in CBP barns in Denmark. The study population was a dynamic population of 461 Danish Holstein dairy cows. The study was conducted in an organic farm, whose owner wanted to extend his herd and was interested in implementing a CBP barn. The construction of a CBP barn was completed in December 2012. The older system, a FS barn with sand-bedded cubicles, was kept in function. First parity cows were excluded from this study. At December 4th 2012, all multiparous cows were randomly allocated to two groups based on their ID number which were allocated sequentially at birth. The odd numbered cows were housed in the FS barn (FS group). The even numbered cows were housed in the new experimental system, the CBP barn, (CBP group). All cows were fed and milked in the same way in the same milking parlour. Until December 4th 2012, all cows were housed in the FS barn and a group of 60-70 cows were kept in an older free-stall system on the farm. Throughout the experimental period, each group consisted of approximately 160 cows, with continuous replacement with fresh cows according to their ear tag number.

Study Period

SCC in the FS group and CBP group was followed for 17 months. SCC (cells/mL) was routinely measured on all lactating cows in the herd, approximately every month (so-called test-day records). The first test-day included in this analysis was the 15th of November 2011, approximately a year before the compost was introduced, to allow for effective adjustment for systematic effects of cow- and season-level factors. The study period ended with the milk recording in May 1, 2013, to ensure

that the results were not influenced by grazing in the summer period were the cows were not exposed to their barns to the same extent.

Data Collection

In the chosen period of 17 month, data from 16 test-days were available. 12 test-days prior to implementing of the CBP system and 4 test-days after implementation (experimental period). Test-day records were obtained by combining a sample from morning and evening milking. The sampling was carried out by the milking staff using the Tru-test milk meter. SCC was measured by Eurofins Steins Laboratory (Denmark), using a Fossomatic Cell Counter (Foss Electric, Denmark). The results were rounded to the nearest 1,000 cells/mL. The maximum level for SCC measurement was 9,999,000 cells/mL (FOSS Electric, 2008). I extracted data from the central Danish Cattle Database. Information about cow ID, parity, date of calving, DIM, and last measurement of SCC before dry off in previous lactation, was extracted on calving date level. SCC after calving was extracted at the 'date of test-day' level. Test-day results that had zero or missing values were excluded.

Test-day Data

The data set consists of 4,069 observations representing test-day measurements. On each test-day the measurements related to a cow ID were divided into the groups of odd and even numbers, FS-group and CBP-group respectively. This resulted in 32 test-day groups. There were between 105 and 150 SCC measurements per test-day group.

SCC measurements were not normally distributed and therefore SCC was transformed into Somatic Cell Score (**SCS**). This was done by the following formula: $SCS = \log_2 (SCC/100,000) + 3$, suggested by Shook (1982). 'Last measurement of SCC before dry off in previous lactation' was transformed in the same way (**SCS dry off**), and centered on the 50% percentile = 3.36. Test-day measurements from the first 9 days after the date of calving were excluded because there might be a naturally high SCC in these days due to colostrums and limited effect of intra mammary infection (Dohoo and Meek, 1982). DIM was centered on the 50% percentile = 181 days, to ensure meaningful interpretations and an intercept value representing a value of DIM existing in the data. Parity was divided into 2nd, 3rd, 4th, 5th and older. Measurements on the parities 6 and 7, which were included in '5th and older', amounted around 3% of all the test-day measurements. The number of cows included was 461. Cows were included if they had at least one test-day measurement during

the study period. Number of calvings per cow through the study period was: 1 calving (N = 276), 2 calvings (N = 171) and 3 calvings (N = 14). The total number of calvings throughout the study period was 660 calvings.

Because data were sampled over time, up to 16 observations in different test-days were from the same cow in the same lactation. I expected these test-day measurements to be correlated within cows in the respective lactations.

Statistical Analysis

A random coefficient linear model was specified to estimate effects of housing system on SCS according to principles and methods described by Littell et al. (2006). PROC MIXED in the SAS version 9.3 (SAS Institute, 2012) was used for statistical analysis.

An initial full model including main effects (parity, SCS dry off, test-day group, number of calvings per cow in the study period, and DIM) and all possible two-way interactions, quadratic effect of continuous variables, and cubic effect of DIM, was specified. The full model was reduced by backward elimination. Non-significant interactions were excluded one-by-one, and afterwards non-significant main effects were excluded. The significance level was set to $\alpha = 0.05$.

The final model included random effects (unstructured) of cows' calving dates and DIM within cows' calving dates, and fixed main effects of parity, SCS dry off, test-day group, and DIM. Two-way interactions included were DIM by test-day group and DIM by parity. Finally, the quadratic effect of DIM was included.

Model control was based on visual evaluations of a Q-Q probability plot, a histogram of residuals and a plot of residuals vs. predicted values. Variance homogeneity across groups was evaluated by boxplots of the conditional studentized residuals.

As part of another project, the cleanliness of most cows was scored by a member of the research team, at one milking every month. The cow ID and location was manually registered. In total from the five registration dates in the experimental period, there were 1576 cow-registrations on 463 cows. Misplaced cows were estimated by comparing data of the actually location of a cow, to the expected placement of a cow due to ID number. Shifts of cows between experimental groups were estimated by comparing registrations between registration dates.

Main Effects

The main factor of interest was the housing system. The other effects were included to ensure adjustment for relevant effects. The linear and squared effect of DIM adjusted for differences in stage of lactation. Stage of lactation, parity and season were reported to affect SCC by several authors (Dohoo and Meek, 1982; Brolund, 1985; Schepers et al., 1997). Season was taken into account by the effect of test-day group, and parity (2nd, 3rd, 4th, 5th and older) was included as a main effect as well. The relationship between different lactations of the same cow was taken into account by the effect of SCS dry off, which is an expression of the cows' history. Because there were repeated measures on the same cow in terms of several lactations per cow in the study period, number of calvings was tested as a fixed effect to adjust for the correlation between those repeated measures, however this effect was not statistically significant ($P = 0.63$).

Housing Systems

The CBP barn was designed with a central feed lane with a feed alley on each side and the compost bedded resting area adjacent to the walls in both sides. The feed alley was 4.15×139.2 m with a solid floor drained by 2% decrease to a longitudinal central drain (narrow slats). The feed alley was cleaned with automatic scrapers every second hour. The feed alley was separated from the resting area by a 0.8m tall (measured from the floor of the resting area) concrete wall. Above the wall there was a barrier and through some walkways there was access to the pack. Waterers were located adjacent to this wall. The outer concrete wall was 2.0 m high, measured from the floor in the resting area. The barn was constructed with a steel frame of 4 meters height. The roof was closed. The side walls were open with automatic curtains. There were 10 mixing fans in the roof, and a ventilation system in the floor. The ventilation system blew air from 4 ventilators, through a system of pipes in the concrete floor, out of 1240 smaller holes. The holes were 10 mm in diameter and the air was blown into the compost with 17 m/s, 5 min every two hours. The resting area measured 11.85×139.2 m in each side. The CBP group of approximately 160 cows was housed only in one side of the barn. Pack area in m^2/cow was approximately 10.3. Before housing, the pack was bedded with 1200 m^3 wood shavings and chips, equivalent to a layer of 0.7 m in height. Through the experimental period another 500 m^2 wood shavings and saw dust were added, when the owner assessed that the pack was getting too humid. The pack was cultivated twice daily while the cows were milked. Deep cultivation was performed every two weeks.

The FS barn was designed with a central feed lane, a feed alley with concrete floor and walking area with slatted floor. Scrapers were automatically every two hours. There were 166 cubicles which measured 1.2x2.2 m. The neck rail height was 1.25 m. The cubicles were bedded with 0.10-0.15 m sand and were scraped manually once a day.

Management

The farm is organic, which means that all treatments of IMI have to be done by the veterinarian and can only be initiated after diagnosis from bacteriological culturing. Additionally, preventive dry cow therapy is not allowed (Ministry of Food, Agriculture and Fisheries, 2012). The average milk production was 10,085 kg ECM per Cowyear through the last 12 months (Danish Cattle Federation, 2013). This production level was above the national average of 8,607 kg ECM per Cowyear, based on data from 329 organic Danish dairy herds with similar breed (Danish Cattle Federation, 2013).

Cows were milked two times a day in a side-by-side parlour with 2×28 places. The same staff was milking both groups, but it was not the same staff at each milking. Initially the FS group and then the CBP group were milked and between each group the floor was cleaned with cold water and the staff were changing their gloves. The milking procedure was observed the 18th March and the 8th April 2013. The milking was performed by two employees. The procedure was to dip teats of 3 to 4 cows in a pre-dip solution (Oxy Foam N or Trionet), cleaning teats of 3 to 4 cows with a moist wipe, and then forestrip teats, and attach the milking units on 3 to 4 cows. Post-dip was not used. The procedure was observed to be the same in both groups, except that some of the cows from the CBP group needed a longer cleaning of the teats, and some of them did still have visible soil on the teats when the milking unit was put on. There was no protocol for the strategy of mastitis detection and treatment in the herd.

All cows were fed a TMR (ad libitum) consisting of corn and grass silage, concentrates, vitamins and minerals, two times a day.

Dry off was performed seven weeks before expected calving. No dry cow therapy was used. Dry cows were housed in different ways, some similar to the experimental group they came from, others in the opposite system. In connection with dry off and calving, cows were not with certainty exposed to their customary barn for seven weeks.

RESULTS

Complete data from 4,069 observations (test-day measurements) were eligible for analysis. The observations were the sum of measurements from 16 test days in the herd. In the study period of 17 months, there were 660 calvings from 461 cows. There were up to 16 observations per lactation. The final model included the fixed effects of parity, SCS in previous lactation, test-day group, DIM, DIM by test group, DIM by parity and the quadratic effect of DIM.

Table 1 : Type 3 Tests of Fixed Effects. The Degrees of freedom, F value, and P-value for every fixed effect considered in this model.

Type 3 Tests of Fixed Effects				
Effect	Num DF	Den DF	F Value	Pr > F
Parity	3	655	18.50	<.0001
SCS dry off	1	655	43.23	<.0001
Test-day group	31	3342	1.65	0.0131
DIM	1	3342	5.07	0.0245
DIM*Test-day group	31	3342	1.81	0.0040
DIM*Parity	3	3342	5.09	0.0016
DIM*DIM	1	3342	4.51	0.0337

The Q-Q probability plot of residuals indicated some departures from the normal distribution as observations in both tails deviated a straight line. Comparison of the histogram with the normal distribution showed that the distribution was slightly negatively skewed. The variance across groups appeared homogeneous. However, there appeared to be more outliers in the high end of the SCS scale than in the lower (based on conditional residuals).

Convergence was obtained with four iterations.

The total variance in the model at the intercept was 0.99 from cow level and 1.38 from residuals. That is, the cow level variance constituted 0.99 / 2.37 = 42 % of the total variation. The coefficient of correlation between intercept and slope (cow level) was – 0.55.

22 of 816 cow-registrations in the CBP group had a number belonging to the FS group (were misplaced) and 36 of 760 cow-registrations were misplaced in the FS group. That is, on average

approximately 4% were misplaced at any given time. 36 out of 463 (7.8%) cows moved between experimental groups one or two times each.

The least square mean of the log 2 transformed SCC (SCS) from every test-day group were transformed back from SCS to SCC (corrected) and plotted in Figure 1.
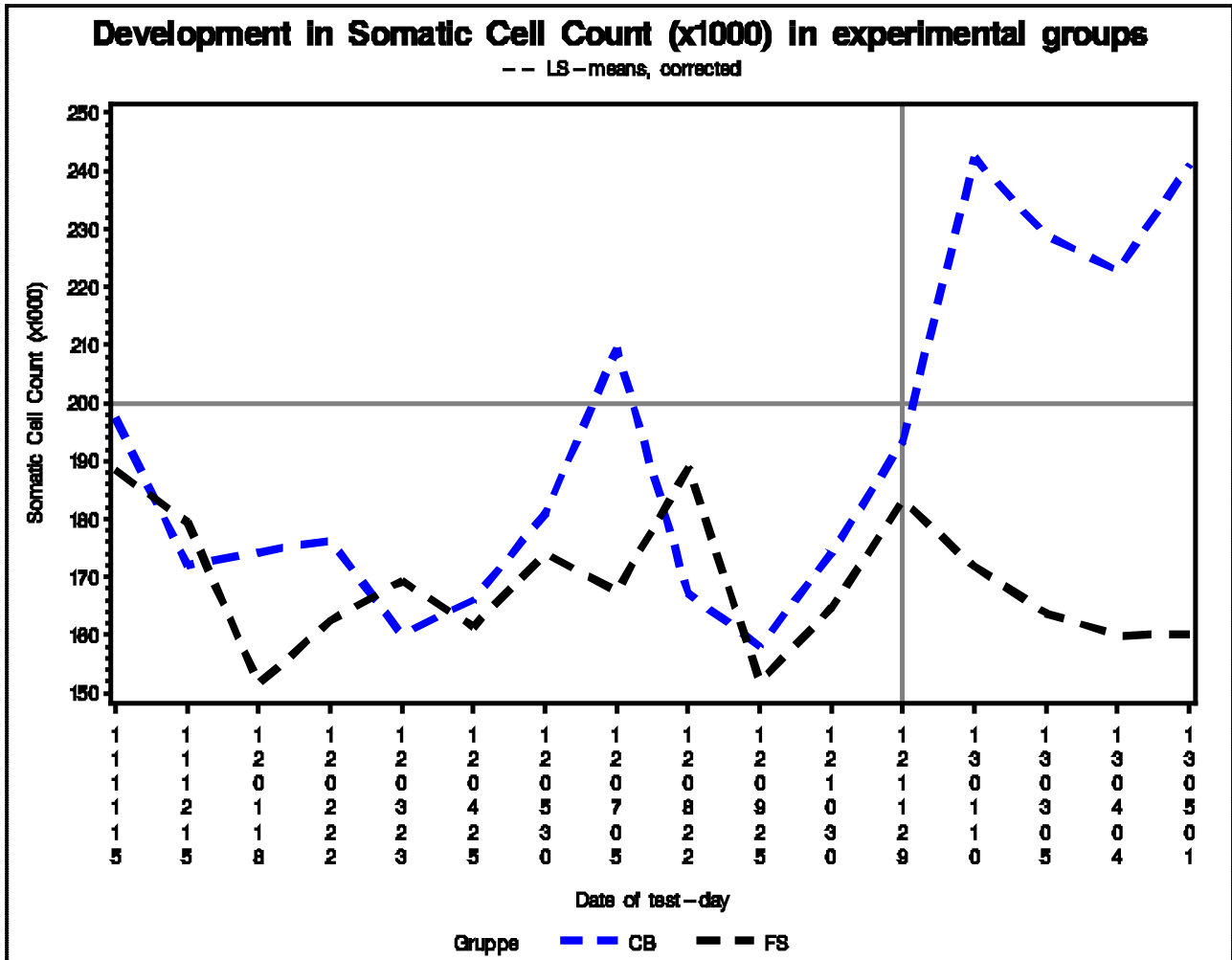

Figure 1: The development of least square means of SCC in the compost bedded pack group (CBP, blue) and the free stall group (FS, black) throughout the study period, ranging from the 15th of November 2011 until the 1st of May 2013. The vertical line marking the test-date "29th November 2012" marks the last test-day before the CBP group was moved to the CBP barn. The horizontal line at 200,000 cells/mL marks the upper limit for premium milk.

In the period before the CBP barn was introduced, SCC was below 200,000 cells/mL in both groups, except from one test day (5th July 2012). The SCC in both groups were following almost the same development through the year prior to the experimental period. After the CBP barn was

introduced, the SCC in the CBP group increased to a level between 225,000 and 245,000 cells/mL in the 5 month experimental period.

Figure 2 shows that the estimated difference in SCC between the experimental groups on herd test-day level was statistically significant ($p < 0.05$) during the time where the CBP group was exposed to the CBP barn. SCC was approximately 60,000 to 80,000 cells/mL higher in the CBP group compared to the FS group. There were no statistically significant differences between the groups in the time before CBP was introduced.
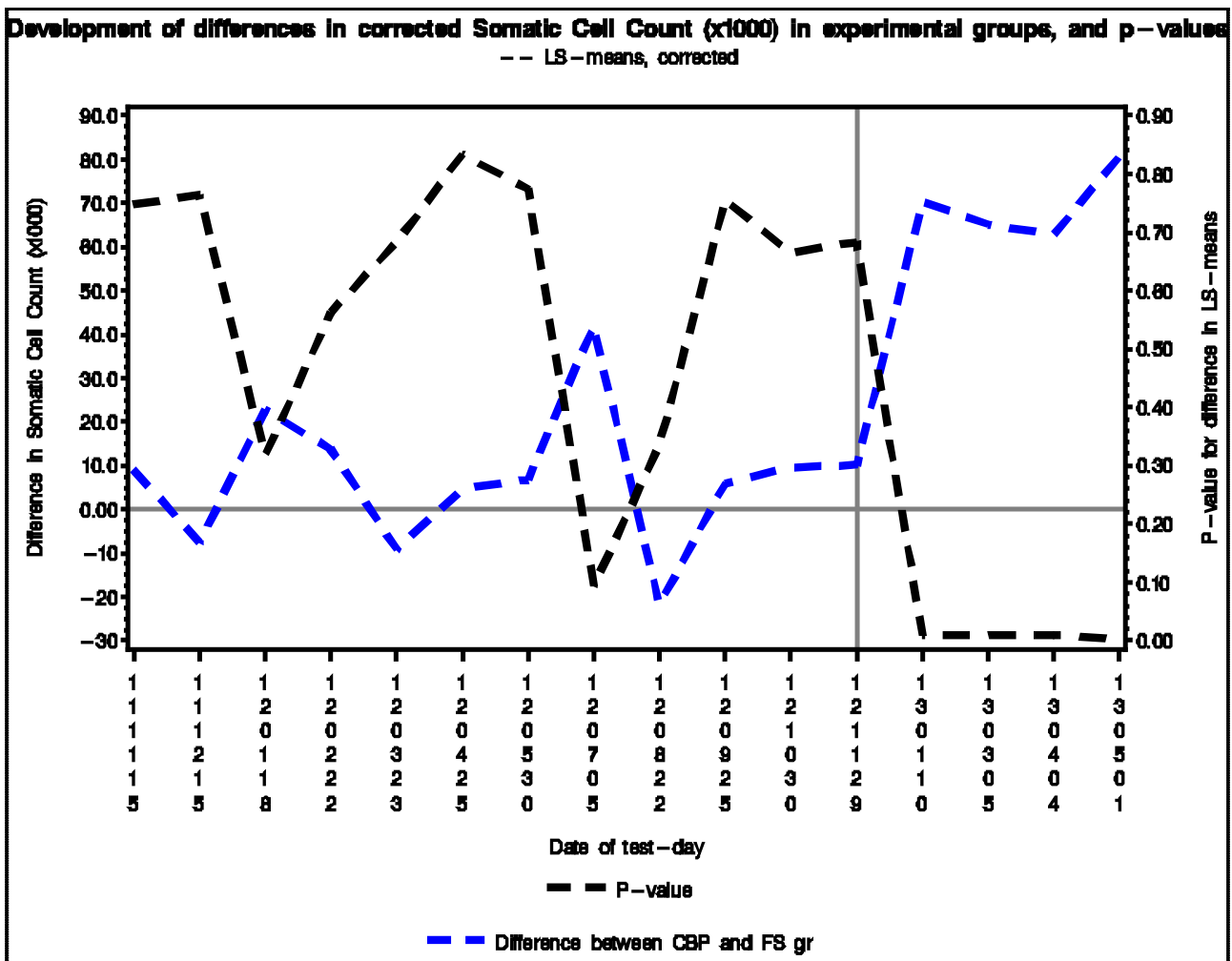

Figure 2 : The development of differences in least square means of SCC between the compost bedded pack group (CBP) and the free stall group (FS, blue) throughout the study period, ranging from the 15th of November 2011 until the 1st of May 2013. The black line represents the p-values for the corresponding difference. The vertical line marking the test-date "29th November 2012" marks the last test-day before the CBP group was moved to the CBP barn. The horizontal line at 0 is a mark of the difference between the groups being zero. The difference fluctuates around zero during the time before 29th of November 2012 with no p-values below 0.09.

DISCUSSION

Study Design, Compliance and Dropouts

In this study, a longitudinal randomized experiment was performed. The use of randomization is a very strong tool, because it maximizes the chance that the cows are comparable except from the 'treatment' (Habicht, 2011). The use of ID number can give a randomized allocation of the cows, but it can also be non-random if the ear tagging of calves is done according to a pattern (e.g. Odd numbers for heifers and even for bulls). According to the herd manager the ear tag numbers were chosen randomly, but for those cows bought from other herds the criteria for ear tagging were unknown. By checking the data I found that test-day measurements in the experimental period from bought cows were distributed evenly with 6.5 % to each experimental group, therefore the ear tagging can be considered as randomized.

An advantage of using ID number was that allocation was practicable to the staff, and it enabled this analysis to go back to before the experiment was started. Analyzing the development in SCC from a year before the 'treatment' began allowed adjustment for systematic effects of cow, stress and season, and made the effect of implementation of the CBP barn even more illustrative.

A disadvantage of using the ID number was that the study was not blinded. Blinding of a study is important for eliminating bias (Habicht, 2011). However it was not possible to make this study blinded because the staff could physically see which cows were housed in which system. There is a risk that the herd manager or staff could affect the results based on their own interests. For example the milking staff could be more alert to indications of IMI in one group, and call the veterinarian earlier in mastitis progression which could give a relatively decreased SCC compared to the other group. Also there could be an interest in allocating special cows to one of the groups in the belief that one of the systems would be beneficial to the cow, e.g. allocate a lame cow to the softer surface in the CBP barn, or not let a 'good cow' be exposed to the dirty CBP barn. As ID number was assigned before the study was planned, this allocating by interest could only happen by allocating a cow to the opposite group as planned. Only 4 % of cows were misplaced and there is no reason to believe that this wrong allocation had been done on purpose. Shifts (7.8 %) occurred most likely by accident in connection with the milking process and more shifts may have occurred in the periods between the registrations. The misplaced and shifting cows were not taken into account in my analyses because of the relatively small proportion and that the misplaced and shifting cows probably have 'diluted' the difference (Habicht, 2011) between the experimental groups.

The question is also, for how long the cow can be away from the initial (and expected) system before it is not representing the effect of the initial trial group? I assume that the longer the misplacement, the more the cows' SCC will adapt to the new conditions. By misplacement of a cow from the FS group to the CBP group, the new environment and the expected risk of infection could relatively fast show an increase in SCC, but if the risk is higher in the CBP barn for high SCC and these cows acquires chronic IMI, they may remain on a high SCC level even though misplacing themselves to a lover risk system. This discussion may be the same in evaluating the impact of housing through the dry period.

By including all data obtained in the trial, this analysis was done by the "intention to treat" (**ITT**) principle (Habicht, 2011). It should be noticed that an ITT analysis provides more information about the potential effects of a treatment policy, rather than a specific treatment. In the ideal trial all cows would stay within the herd and the 'treatment' group they were initially allocated to, throughout the study period. That is often not reality and in this study there were also drop outs according to culling, sale or death. However I found no difference in DIM between the CBP group and FS group (CI = [15 ; 130] and [12 ; 117] DIM respectively) for lactations that started after the CBP barn was implemented. This indicates that in the experimental period of five months there were no more drop outs in the first part of lactation from one of the groups compared to the other.

As mentioned there were cows in this study that made shifts between groups but all data was analyzed according to the initial 'treatment' (housing) assignment and not to the housing eventually received. Not all cows were included from the start and some dropped out, why there were cows included with only a single test-day measurement throughout the study period. This occurrence of missing data is an important problem in ITT analysis. There are, however, two strong rationales of using the ITT. First, the positive effects of randomization are maximized because potentially disturbing factors are balanced between the groups, and second, it estimates the effect in real-world clinical practice. The estimation of the effect of the real-world clinical practice is heavily weighted in this study, because implementing CBP barns in the Danish dairy industry needs information about real-world opportunities.

It must be mentioned that this experiment and analysis was conducted in a single herd. Therefore the results should not be generalized. According to this, external validity is bad, but no other farms were available and this trial was a unique opportunity to randomly distribute cows in two systems within the same herd.

Data Analysis and Factors affecting SCC

SCC measurements in this analysis were transformed to scores, SCS, suggested by Shook (1982). By this transformation the distribution became more normal. SCC was not normally distributed and showed a markedly heterogeneous variance among groups and a positive skewness, i.e. the mean was greater than the median. This was consistent with literature (Ali and Shook, 1980; Shook, 1982; Brolund, 1985). Shook (1982) compared different transformations of SCC and found that the most important was that the transformation included some kind of logarithmic transformation. By a visual evaluation of a histogram, a boxplot and a normal probability plot of my data transformed in three different ways (SCS, ln and $\log_{10}$), no clear difference in normality was found. It seems that the chosen transformation was equal to the other transformations, consistent with the findings by Shook (1982).

Model control showed only small problems with residuals. There is no reason to believe that there should be a difference in the distributions between the groups. There are some outliers in SCS data and they seem to be overrepresented in the high end of the scale, but this imbalance seems to be the same for all test-day groups, and may therefore not affect the analysis. Outliers will although increase the variance and make the difference less significant. However in a study with this number of measurements, the risk of not noticing a difference between the groups is small. It is possible to eliminate some of the outliers, but according to Littell et al., (2006) this is usually not the right action to take because important effects can be taken out of the model.

The statistical power of the study is indicated in Figure 2, which shows that a difference between the groups should exceed 60.000 cells/mL to approach statistical significance ($P < 0.05$).

The delimitation of DIM is not consistent between different studies. A review by Dohoo and Meek (1982) found different periods of five to fourteen days with increased SCC after calving, and Dohoo (1993) suggested that the first 11 DIM should be discarded from analysis of SCC in multiparous cows. The first DIM in this analysis should preferably have been day 14 to exclude that there was an effect from the naturally increased SCC associated with calving.

The fixed effects included in this model were included because of their capability to explain some of the variation in the SCC. The effects included were consistent with the ones from the literature (Dohoo and Meek, 1982; Brolund, 1985). SCC has been reported to increase during the lactation as a result of increasing prevalence of subclinical infections with time, which is the same reason why SCC increases with parity (or age). The late lactation increase has been explained by a dilution phenomenon caused by the decreasing milk yield (Reneau, 1986). Effect of SCC before dry off was

explained by 'carry over' of IMI and history of infection causing greater cellular response than no history of infection (Reneau, 1986). However the most important factor affecting SCC is IMI (Dohoo and Meek, 1982; Reneau, 1986).

According to the principle of dilution, adjustment for daily milk yield was recommended by Brolund (1985). In some way the data was adjusted for milk yield by including effects of DIM and parity, but including milk yield as a fixed effect could have had some effect on the results. If, for example, milk yield was generally higher in the CBP group because of e.g. improved cow comfort, as reported by Barberg et al. (2007), the SCC measured was relatively lower in the CBP group and the really difference between the groups was larger than assumed. This example would be consistent with the possibility that milk yield was directly affected by the housing system. It would be interesting to analyze the effect of the housing system on milk yield separately. It could be done in an analysis similar to the one performed in this study.

Various kinds of stress have been implicated as causing an increase in SCC (Dohoo and Meek, 1982). In this study, stress was not taken into account. It could be an important factor, but it is difficult to measure. In Figure 1 an increasing SCC in both groups through the autumn 2012 is seen. This is the period of building the new system hence it might have been a stressful period for the cows. It is possible that the increase in SCC in the CBP group in the experimental period was caused by stress according to the new system. It must be noticed that the cows were only exposed to the new system for five months, which could be considered as a necessary habituation period for the cows.

A lot of management factors are influencing SCC e.g. dry cow therapy, use of teat dip, sort of milking systems, mastitis treatment strategy, and mastitis detection abilities. Management factors however primarily affect SCC on herd level (Dohoo and Meek, 1982) and because the cows in this study are within the same herd, milked in the same parlour and by the same staff, it is assumed that the influences of the management factors are the same in both experimental groups. Although it must be mentioned that during the observation of milking procedures, it was seen that more of the cows from the CBP group were having dirty teats as the milking unit was attached (they also seemed more dirty as they came in), compared to the cows from the FS group. It was not a systematic observation, but insufficient cleaning of teats at milking can cause an increase in SCC (Larry Smith and Hogan, 2008) and this could be an example of a management factor that might have been different between the two groups.

Biological Explanations of Effects and Comparison with Other Studies

The higher level of SCC in cows in the CBP barn, compared to the cows in the FS barn, correspond with the expected results. It agrees with the theory of the higher bacterial count in organic beddings, compared to inorganic beddings like sand, causing an increased SCC (Hogan et al., 1989; Peeler et al., 2000). The increased SCC might be a result of dirty udders as suggested by Schreiner and Ruegg (2003) and Reneau et al. (2005). In a study by Lobeck et al. (2011), CBP barns were compared to FS barns with deep-bedded sand. It showed that, the cows in CBP barns had higher overall hygiene scores, and that the biggest difference between the housing systems was seen in the winter months. According to Shane et al. (2010a) a dry pack is needed to keep cows clean, and especially in the cold and humid winter months this could be a problem. In the Netherlands a big concern about the CBP barns is also that the pack remains wet in the winter (Galama, 2011). In this analysis it would have been relevant to adjust for the effect of hygiene scores on SCC, but the dataset of hygiene scores was not ready yet.

According to the difference in SCC between the two housing systems in this study, it must be mentioned that the bedding of sand is reported to be one of the beddings that causes the best hygiene (Hogan et al., 1989). An evaluation the CBP system as an alternative to SY for example, would probably not cause the similar concerns about increasing SCC, as the difference in SCC between that housing systems might have been less.

In the previously mentioned study by Lobeck et al. (2011) no difference in mastitis infection prevalence between housing systems was found, even though the difference in hygiene scores were reported. A comparison of mastitis infection rates before and after housing in CBP barns, by Barberg et al. (2007), found that in six out of nine herds there was a reduction in mastitis infection rates. From the results of these two studies it seems that IMI were not considered as a problem in CBP barns. A difference between the two studies by Lobeck et al. (2011) and Barberg et al. (2007), and this study, was that they evaluated the prevalence of mastitis, mastitis defined as test day SCC > 200,000 cells/mL, and in this study the SCC was evaluated as a continuous variable. Even though direct comparison of results is not possible, the different conclusions are remarkably.

As many factors influence the SCC and mastitis infection rates, there can be several reasons for the different conclusions. For example treatment rates and possibilities may differ between the studies, e.g. dry cow therapy was used for all cows in the study by Barberg et al. (2007). In the study by Lobeck et al. (2011) with comparison of different housing systems, many management factors could have affected the results from the different farms. Moreover both of the studies (Barberg et

al., 2007; Lobeck et al., 2011) included herds that had been established for at least one year. It must be mentioned that in a 'before and after' study like the study by Barberg et al. (2007), the level of SCC from the previous housing system might affect whether a decrease or increase in SCC was seen. The average SCC in the nine herds visited by Barberg et al. (2007) was 325,000 cells/mL after the CBP was implemented. In this study the highest average of test-day group was around 245,000 cells/mL (Figure 1), which indicates that the nine herds in the study by Barberg et al. (2007) had a relatively high level of SCC compared to what we have in Denmark where the average in Holstein herds in 2012 was 280,000 cells/mL (Danish Cattle Federation, 2013). In another study of six CBP barns in Minnesota, the average SCC was 425,000 cells/mL (Shane et al., 2010b).

Management of the pack was probably better in the other studies (Barberg et al., 2007; Lobeck et al., 2011) than in this study. I estimated without having all details that the amount of fresh dry sawdust added to the pack per m^2 resting area was around the double in the study by Barberg et al. (2007) compared to this study, with approximately the same stocking density. Added material could help keep the pack dry and in that way keep the cows clean. Both of the studies were conducted in Minnesota, where the climate might be different from the Danish, and help the evaporation from the pack. In this study the experimental period could be considered as a start-up period where everything was new to cows, staff, and research group. The management of the pack was a challenge. Furthermore the experimental period was during the Danish winter months with cold and humid climate, and sufficient evaporation was hard to maintain. The system might probably work better during the Danish summer period, but organic dairy cows must be grazing in the period 15th April to 1st of November (Ministry of Food, Agriculture and Fisheries, 2012), and therefore it is in the winter season there is a need for an efficient alternative housing system.

Other Effects and Perspectives

It was not a part of this study to evaluate the effect of the CBP barn to other production or health parameters than SCC. However an overall evaluation of the effect of the CBP barn would be necessary to evaluate the complete perspectives of the effect on SCC. There is no doubt that an increased SCC is not popular, but there can be some other effects that makes it accepted. If the health of hooves and legs is improved, the milk yield is increased, the reproduction becomes better, and clear environmental benefits of the CBP system is manifested, the disadvantage of increased SCC could probably be offset by benefits.

It must be mentioned that a SCC level above 200,000 cells/mL will deprive the farmer a bonus payment of milk. Furthermore there is a risk that the milk yield will decrease due to the increasing SCC (Dohoo and Meek, 1982). These economic losses must be compensated in another way.

Further experience on managing of the pack and enhancing evaporation from the pack, could presumably reduce the raise in SCC, and make the system more attractive.

Even though this study was performed in one single herd, and the effect only was evaluated in the first five months of the CBP barn being implemented, it is suggested that focusing on SCC and prevention of IMI is very important in the follow-up, new trials or implementation of CBP systems in the Danish dairy industry.

CONCLUSION

In this organic herd there was an increased SCC in the group of cows housed in the CBP barn compared to the group of cows housed in the sand bedded FS barn within the same farm.

The difference between the two groups of cows was significant in all of the four test-days in the experimental period. Results were adjusted for several factors with effect on SCC. The SCC was approximately 60,000 to 80,000 cells/mL higher in the CBP group compared to the FS group.

The level of SCC in the cows housed in the CBP barn was above 200,000 cells/mL throughout the experimental period of five months.

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