Cultivated barns for dairy cows

– An option to promote cattle welfare and environmental protection in Denmark?

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Introduction

Loose housing systems with free stalls can compromise welfare, cow comfort and cause a high risk of lameness and hock lesions, especially with inadequate positioning of stall hardware, limited space, hard lying surface or insufficient bedding (1,2,3,4). Concrete floorings systems may constantly be covered with urine and manure which may cause digital dermatitis and other hoof disorders. Deep bedded pack systems offer better cow comfort, e.g. increase lying time and reduce the incidence of hock lesions in comparison to stalls (5,6). Availability and costs of straw limit the use of deep bedded packs due to the high amounts of straw needed (approximately 10 kg per cow per day). Further drawbacks are the higher growth rates of pathogens such as *Escherichia coli* and *Streptococcus uberis* in straw bedding, which can lead to an increased incidence of mastitis and increased somatic cell counts in straw yards (7). Deep bedded packs generate a relatively high ammonia emission, and low oxygen concentration in the bedding may contribute to increased methane emissions (8). Slatted floors are no longer allowed in new buildings in Denmark unless special precaution is taken to reduce ammonia emission (9). In conclusion, we need new systems, which can improve cow comfort and health, and are economically and environmentally feasible in practice.

In the US, compost barns have been developed for dairy cows, which are based on a deep bedding of wood shavings. To enhance microbial activity the pack is stirred twice daily (10). While the farmers are content with cow comfort, longevity and ease of chores, their main concern was the economy and limited supply with costly bedding material (11).

A new system of cultivated compost barns was developed in the organic »Harduf« dairy in Israel 2006 (12). The system spread rapidly among farmers since then, and is today the most popular way to handle the lying areas in the Israeli dairies, although scientific literature on the system is still lacking. Lying area and alleys are covered with a bedded pack of composting manure, which

Abstract

Compost barns are loose housing systems, where regular cultivating of the pack with a heavy harrow enhances aerobic microbial activity and mixes manure and urine from the surface into the pack. Because of the positive impact on cow comfort and welfare, compost barns receive increasing attention in the US. Whereas in the US the composting process is enhanced by organic material, e.g. wood shavings, producers in Israel have developed a system, which does not need any organic material apart from the cows' manure and urine. The objectives of this pilot study were to investigate the composting procedure in three herds in Israel, the impact on the environment, cow comfort, and udder health. The pack surface and underlying layers were examined visually and ammonia concentration was measured. The producers were interviewed about management practices, health and welfare of the cows and their attitudes regarding the system. Production and milk data were retrieved from the Israeli Dairy Board. In each farm a random sample of cows was scored for hock lesions, other lesions, and cleanliness of udders, legs and tails. The results show that compost barns can work without supplementing organic material other than the cows' manure, and that the ammonia concentration above the compost was surprisingly low, suggesting a low ammonia emission. Cow cleanliness was significantly different in the three herds but acceptable in comparison to studies from cubicle systems. Scores of udder and leg hygiene were correlated. No hock lesions were found. The compost packs offered a dry, soft and non-smelling lying and walking area for the cows with excellent cow comfort. The farmers were content with the system, and perceived better udder health, observed cleaner cows and less work to maintain the pack compared to the ordinary Israeli system. Further research is necessary to explore the possibilities of adapting cultivated barns to the cooler climate in Denmark.

is the only organic material used, and is cultivated once or twice daily with a heavy harrow. With the constant oxygenation of the pack, aerobic microbial activity is enhanced and produces a surface like dry soil of a villa garden. No expensive material, stall hardware, alleys, or systems to store and treat the manure are needed. As the composted manure can directly be transported to the field, transportation costs are low compared to liquid manure and hazards for the environment are low compared to slurry. In short, this system may be an economically feasible alternative to existing free-stall housing and deep bedded back systems with positive effects on cow comfort, health and welfare and the potential for environmental advantages. The impact on the environment, especially ammonia emission will be of crucial importance for any consideration on transferring the cultivated barn systems to Denmark.

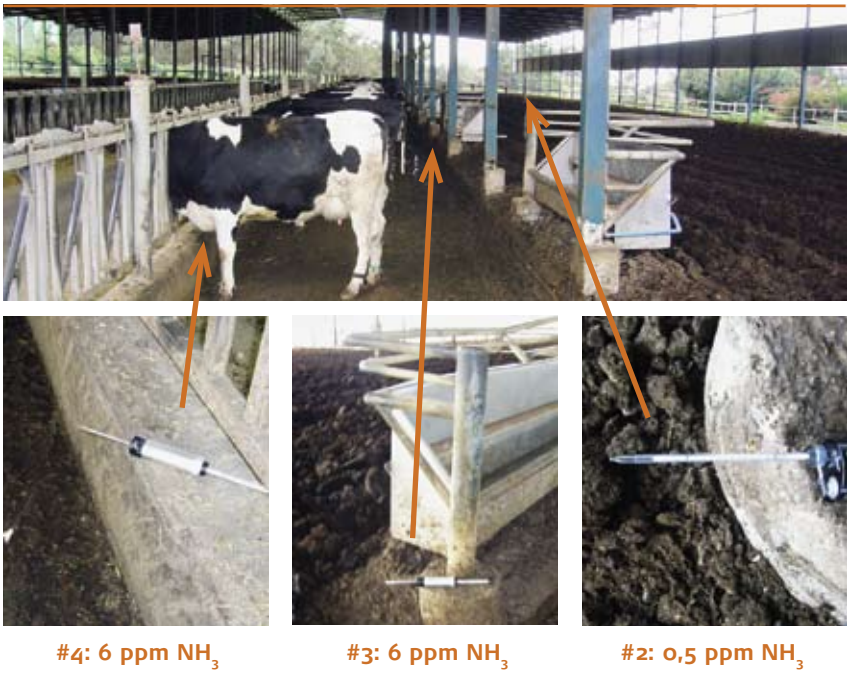

Figure 1. Ammonia concentration measurement in milking cow barn in farm 3, an organic Kibbutz

Location of the farm		Meters above sea level	N cows in the herd	Milk quota in tons	Average daily milk production (l) from milking cows in January 2010	Average daily milk production (l) from all cows in the herd in January 2010
Farm 1	Golan Heights	370	59	597	40.3	33.5
Farm 2	Golan Heights	440	458	5500	36. 4	33.3
Farm 3	Close to Mediterranian Sea	200	280	2500	36.0	30.6

Table 1. Herd characteristics of three dairy farms with compost system.

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Sammendrag

Kompoststalde er stalde, hvor dyrene holdes på et lag af kompost, som regelmæssigt bearbejdes med en kraftig harve. Bearbejdning har til formål at øge den aerobe mikrobielle aktivitet og blande gødning og urin fra overfladen ind i komposten. På grund af en positiv indvirkning på kokomfort og -velfærd har kompoststalde fået en stadig større opmærksomhed i USA. Mens komposteringsprocesserne i de amerikanske kompoststalde hjælpes på vej ved tilsætning af organisk materiale i form af savsmuld, har mælkeproducenter i Israel udviklet et system, som ikke behøver tilsætning af organisk materiale, udover det der kommer fra dyrenes gødning. Denne artikel indeholder resultater af en pilotundersøgelse, der på grundlag af besøg i tre israelske besætninger har til formål at vurdere, hvordan miljøet, kokomforten og yversundheden påvirkes af komposteringsprocedurerne. De israelskes mælkeproducenter blev interviewet om driftsforhold, køernes sundhed og velfærd samt om deres holdninger til systemet. Produktionsdata blev stillet til rådighed af de israelske mælkeproducenters organisation. I hver af de tre besætninger blev der, på baggrund af stikprøver blandt køerne, foretaget registreringer af hasetrykninger og andre læsioner, samt renligheden af yvere, ben og haler. Resultaterne viser, at komposteringsstaldende virker uden tilsætning af andet organisk materiale end det, der er i dyrenes gødning, og at ammoniakkoncentration over komposten var overraskende lav. Køernes renlighed var signifikant forskellig i de tre besætninger, men i alle tilfælde acceptabel i forhold til det, man finder i sengebåsesystemer. Vi fandt ingen hasetrykninger. Komposten i de besøgte stalde virkede tør, blød og næsten lugtfri. De besøgte producenter var alle tilfredse med systemet, og de havde en opfattelse af, at det forbedrede yversundheden, og gav renere køer i forhold til det system, der tidligere blev anvendt i Israel. Overordnet viser resultaterne, at der bør gennemføres yderligere undersøgelser af mulighederne for at tilpasse kompoststaldsystemet til det køligere klima i Danmark.

Figure 2. The compost is cultivated with a heavy harrow once daily while the cows are milked.

Milking cows produce approximately 50 kg manure and urine per day containing 45 kg water (13). Well functioning compost has a dry matter content of 40-50 percent (10), which means that around 40 kg water per cow per day must be removed to avoid increase of water content in the compost. Our preliminary estimates show that heat release from composting of the organic dry matter content in the manure is inadequate to generate the required reduction of water content, and, consequently, some of the water must be removed by ventilation. At Israeli climatic conditions it can be anticipated that natural drying alone is sufficient to remove virtually the water that must be removed. At colder climatic conditions like in Denmark, the drying effect of the ventilation air will periodically be insufficient to remove the water. The heat generation from the composting processes therefore becomes crucial for the function of the system.

To investigate the possibilities for transferring the cultivated barn system to Denmark, we decided to do a case study based on visit to three typical Israeli farms to answer the following questions:

1) How are these systems handled?
2) Is there an aerobic composting process that generates heat?
3) Is it likely that the system can be operated without exceeding the Danish ammonia emission limits?
4) Cow welfare: Are the cows clean? Do they have lesions?
5) Do these farms have acceptable udder health and milk quality?
6) Could the systems be adapted to Danish climatic conditions?

As we were interested to assess, if composting processes can work in chilly and rainy conditions, the farms were visited in January, the coldest month in Israel and the month where most precipitation is expected.

Materials and methods

Three farms representing typical production systems in Israel were visited: a family farm, a cooperative farm and a kibbutz farm. Herd sizes range was 50-500 Holstein Friesian cows (Table 1). All farms milked the cows three times daily. Farm 1 and 2 were conventional farms, farm 3 organic. A total mixed ration was delivered daily from a central feeding station. The farms were visited January 11th and 12th 2010, with slightly cloudy weather and temperatures ranging from 16 to 22˚C

Figure 3. Cultivated barn in a farm with robotic milking. The compost is in the entire animal accessible area apart from selection gates to the robotic unit.

Figure 4. Compost in farm 3 with small dry particles, which do not smell when rubbed in the palms of the hands

Handling of the system and evaluation of the compost

The farmers were interviewed regarding management of the system and their experiences/motivations. The compost area was examined visually, the consistency evaluated by walking through the compost and palpation of samples with the hands. The smell was evaluated. To detect possible heat generating processes the temperature of the compost was measured with thermometer approximately 20 cm below the compost surface in each farm. Precise estimation of ammonia emission in naturally ventilated livestock buildings require intensive measurements of concentration and air exchange (14), which was not possible in this study. We measured ammonia concentration just above the compost surface at several locations in the 100 m long and approximately 45 m wide open cultivated barn at farm 3 (organic Kibbutz, Figure 1).

Wind direction (determined with smoke) was approximately transverse to the building length direction and the wind speed at 1 m height was around 1 m/s. The Testo 405-v1 handheld instrument was used for wind speed and temperature measurements, and the temperature level was between 18 and 19°C. Kitagava detection tubes with 0.5 ppm detection limit and 1 ppm resolution were used to measure ammonia concentration at 5 points located at a cross section at the middle of the building length. Location of the measuring points and results are presented in table 2.

Cow welfare: Examinations on farm

In each farm, a random sample of at least 20 cows within a cow section was scored for hygiene level of udders (score 1-3), legs (score 1-4) and tails (manure present at tail area). Both sides of the body were examined for hock lesions and other skin lesions and the worst side registered.

Udder health and Milk Quality

Data from milk recording and other herd information was accessed from the Israeli Dairy Board by the third author. The farmers and/or managers were interviewed regarding their udder health strategies and their perception of udder health and milk quality before and after establishing compost barns.

Measurement	Location	Ammonia concentration, ppm
#1	Wind side of the building, 1 m height	<0.5
#2	Middle of the wind side of compost area, 0.2 m above compost	<0.5
#3	Transition between compost and concrete alley, 0.2 above surface	4
#4	At feeding fence foundation	6
#5	Lee side of the building, 1 m heigh	1

Table 2. Measured ammonia concentration in a milking cow barn in farm 3, an organic Kibbutz, January 12th 2010.

Results

Handling of the system

The cultivated barns were introduced between 6 months (farm 2) to 4 years (farm 3) prior to our visit. In farm 1 the compost was established based on a layer of an inorganic residual product from oil extraction similar to cat litter. In farm 2, a layer consisting of residuals from the paper industry was used. Farm 3 started the composting process based on a layer of dried manure from the barn before the compost system was introduced. All farmers stated that they had successfully established a compost system with these three different methods.

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Figure 5. Water vapor immediately after cultivating indicates a higher temperature in the compost in comparison to the air.

In all farms the compost was cultivated with a heavy harrow once daily while cows were milked (figure 2). The estimated labor time ranged from 10 minutes in farm 1 (section for approximately 50 cows) to 20 minutes in farm 3 (section for approximately 100 cows).

All farms had a concrete alley at the feeding fence. Farm 1 and 2 removed the manure scraped from the feeding area from the barn, so that a small storage capacity for manure was necessary. In farm 3 the scraped manure from the feeding area and the milking parlor/waiting area was distributed on the compost before harrowing. In a fourth farm - where we did an additional short visit - the entire barn area, including the area at the feeding fence, was covered with compost, which was dry with mainly a particle size of less than around 8 cm (Figure 3). In Israel it is recommend allocating at least 15 m^2 of compost area per cow if the feeding area is scraped and 20 to 30 m^2 if there is compost in the entire area. The compost is removed from the barns and spread directly in the fields when necessary. The farmers always leave a sufficient layer to enable the cultivation with the heavy harrows.

The compost area

The compost areas in the farms differed in consistency. In farm 1, the compost appeared relatively dry and did not stick to the boots when walking on the surface. The particle size was up to 10-15 cm, especially in parts of the barn close to the feeding alley. The tractor used for pulling the harrow in farm 2 had been out of order the last week before our visit, and, consequently, the compost surface appeared compressed, feeling slightly sticky when walking on the surface. To increase ventilation the farmer had switched on the ventilation system. The loosest and driest compost was found in farm 3, with mainly particle size of less than 8 cm and a fluffy consistency (Figure 4). The compost did not stick at the boots. Small lumps of material did not smell when broken and rubbed against the palms of our hands, which indicates absence of anaerobic processes.

In farm 3 we attended the cultivating process. During cultivation water vapor was visible, indicating a higher temperature of the compost in comparison to the air (Figure 5).

Assessment of possible heat generating composting processes

Temperature measurements did not show any significant temperature elevation in the compost at farm 1 and 2. At farm 3 the measured compost temperature varied between 25 and 42°C. Related to the actual air temperature, the temperature increase due to composting was between 7 and 24°C.

Ammonia measurements

The measurements showed that ammonia concentration were significantly lower above the compost areas than above the scraped concrete alley along the feeding fence (Figure 1 and Table 2).

Cow welfare: cleanliness and hock lesions

The cows remained undisturbed by the observer - observant, but relaxed (Figure 6). We observed significantly different cleanliness scores for udder and body in the three farms (Figure 7). On average 51.2 % of the scored udders were clean, ranging from 14.8 to 85 %. The proportion of dirty cows (leg score 3 and 4) ranged from 10 % in farm 3 to 90 % in farm 2, average 51.2 %. The cleanest cows were found in farm 3. The proportion of cows with manure around the tail area differed significantly between farms, and was 14.3 % in farm 1, 42.9 % in farm 2, 10 % in older cows in farm 3 and 40 % in first parity cows in farm 3.

Cleanliness of the body and cleanliness of the udder was highly correlated (Spearman rank coefficient 0.72, $P<0.0001$). We did not find a correlation between cleanliness of the tail area and cleanliness of the body and udder. Cleanliness of the body and udder reflect the condition of the compost, as those are the parts of the body in contact with the

Figure 6. Cows in a compost barn.

compost when the cows are lying down. Cleanliness of the tail area reflects the individual cow's condition, presence or absence of diarrhea and consistency of the manure in general.

All examined cows were free of hock lesions and other lesions associated with free-stall systems.

Udder health and Milk Quality

Farm 1 had the lowest somatic cell count (SCC) obtained from the monthly milk recording with an average of 133.000 ± 35.000 cells/ ml within the last 12 months. The total bacterial count (TBC) from the tank milk during the last 12 months was 7000. The farmer stated that he had 2 cases of clinical mastitis during the last year, but that he had not sent a milk sample to the udder health laboratory.

In contrast to farm 1, farm 2 had sent 130 milk samples from mastitis cases to the laboratory. The predominant mastitis pathogens isolated during the last 12 months were *E. coli* with 36 % of 188 isolates, followed by 19 % no growth and 8 % coagulase-negative staphylococci. According to the manager, *E. coli* was found in 70 % of all clinical mastitis cases. Approximately two cases of clinical mastitis per month were treated with antibiotics. The average SCC from milk recording was 214.000 ± 41.000 cells/ ml, the average TBC was 7000.

In farm 3 the average SCC from milk recording during the last 12 months was 229.000 ± 46.000 cells/ ml, the average TBC was 3000.

Before establishing a compost barn, all farmers/managers were concerned about the milk quality and udder health, because they expected difficulties to keep the cows clean. After introduction of the compost system, all three farmers/managers had the perception that their cows were cleaner than before and that they had less cases of clinical mastitis and less problem cows with high somatic cell counts. Farmer 1 had observed a drop in SCC, whereas the other managers could not see a change in SCC from milk recording after introduction of the compost system.

Discussion

The compost temperature measurement at farm 3 showed that the composting processes were capable of generating a significant temperature elevation in the compost although no additional organic substances were provided. This shows that composting processes may

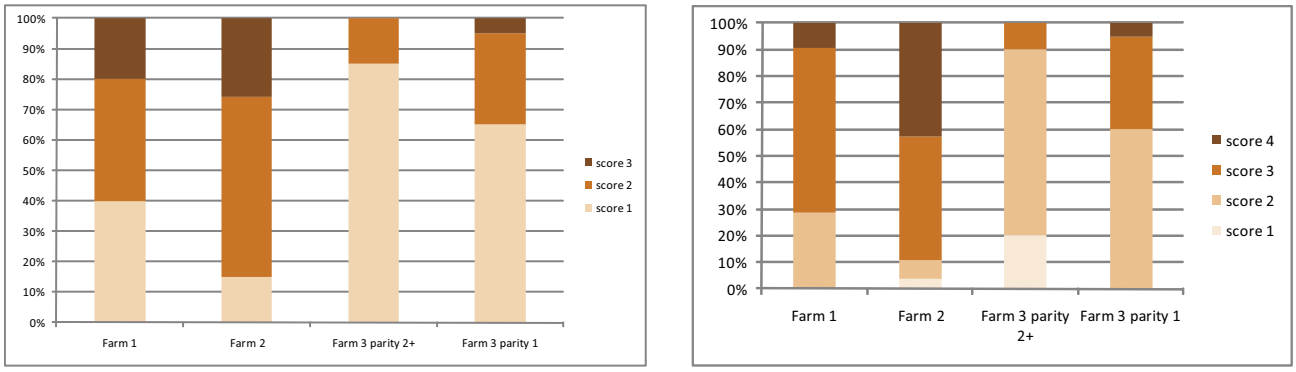

Figure 7. Udder hygiene scores (left) and leg hygiene scores (right) were significantly different in three farms with compost system (Fisher's exact test, P <0.0001). Score 1 = clean, Score 4 = large parts of the leg covered with dirt.

contribute to the reduction of water content in the compost. The measurements and the observations in farm 1 and 2 showed that it was possible to maintain relatively dry compost during Israeli winter conditions, even though the heat generation from compost was limited. The limited and variable temperature increase causes uncertainty about the ability of the composting processes to limit the growth of poential pathogenic microorganisms.

The ammonia concentration measurement #4 was located close to the scraped concrete alley, which is an environment that is comparable to the condition in typical Danish barns for milking cows. It is remarkable that the ammonia concentration at that point was more than 10 times higher than at measurement #2 above the compost in the wind side of the building. The explanation of the low ammonia concentration above the compost can probably be explained by a relative high carbon/nitrogen ratio in the compost, and that the major part of the accessible nitrogen is bound in microorganisms in the compost. In conclusion, our ammonia concentration measurements indicate that the cultivated barn system may meet the Danish ammonia emission restrictions.

We could not find any cows with hock lesions and other skin lesion which could indicate compromised cow comfort. Barberg et al. (15) found a low prevalence of cows with hair loss (24 %) and swollen hocks (1 %) in 12 herds with compost system. Those herds had compost barns with supplementation of fine wood shavings or saw dust, which may have some abrasive effects. The compost area in the three examined farms was soft and we found no particles with visible abrasive characteristics. The compost surface appeared dry or relatively dry and, consequently offered a very comfortable lying area.

The barn system in the three farms was not originally intended to be managed with compost. Therefore, the concrete areas in front of the feeding table still were a source of contamination of the hoofs with a mixture of manure and urine. The concrete alleys needed regular scraping, which also meant that a small storage area for manure close to the barn was necessary. In farm 3, all manure scraped from the feeding alley or the waiting area in front of the milking parlor was cultivated with the compost every day. Farm buildings intended for compost systems usually have a feeding fence that is in direct contact to the compost area, i.e. no concrete areas are necessary (Figure 3). This, in Israel so called »dry dairy« system, requires a large area per cow, and feeding has to occur on both sides of the barn to function properly. On the other hand, the opportunity to use all or part of the manure of the concrete covered feeding alley in the composting process might be the more realistic adaptation of the system to Danish conditions. In the summer, more or less of this manure will be mixed into the bedding, whereas in the winter storage capacity outside the barn will be needed.

Milk recording SCC and TBC from the bulk tank milk indicates that a sufficient milk quality can be achieved with cultivated barns, which is within the range of typical Danish farms (15). According to the farmers, the udder health improved with less cows having clinical mastitis. But because no registrations of treatments were available, we could not verify their statements. As expected, after one week without cultivation, farm 2 had the dirtiest cows. We observed a higher proportion of dirty cows (leg score 3 and 4) as Schreiner et al. (16), who reported an average of 30 % in 8 free-stall systems. The proportion of cows with clean udders was comparable to Schreiner et al. (16), 58 %, and Klaas et al. (17), 52.6 %, both studies from cows in free-stall housing systems. The quality of the compost appears to be related to the cow cleanliness (leg and udder scores) as the proportion of dirty cows was higher when particle size of the compost was higher and the compost more sticky.

Possible adaption to Danish climatic conditions

Danish climatic conditions from May to September are warmer than Israeli winter conditions (December to February).

Consequently, it seems reasonable to expect that the system can function in the summer period in Denmark. During the Danish winter period the drying effect of the ventilation air in open barns is very limited and therefore it is not likely that the system will work without additional actions to limit the water content in the compost. The obvious solution would be to add organic material like finely chopped straw to support the composting heat production.

Perspectives and conclusions

The results of this case study show that composting of manure within the barn in Israel is possible without supplementation of additional organic material. We have no indication of reduced milk quality or cow cleanliness. The good condition of the hocks indicates an excellent cow comfort in the system. The low ammonia concentration measurements indicate that composting of manure can be an option that meets restrictive Danish ammonia emission regulations.

Further research is necessary regarding the effect of different climatic conditions on the composting processes. To adapt compost systems to climatic conditions with higher precipitation and humidity during the winter months, the ability of appropriate organic material to bind the excessive fluid must be investigated.

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