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Testing of property changes in recycled bedding for dairy cows

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Abstract

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The aim of this study was to analyse the change of the characteristics of different types of organic bedding in deepened stall base cubicles for dairy cows. The research was carried out in barn 1 using separated raw manure solids, in barn 2 using drum composted manure solids and for comparison a barn 3 was chosen, which used traditional straw as a bedding material. Dry matter of separated raw manure and drum composted recycled manure solids in sample 1 collected after 2–3 hours of bedding acclimatization in the stable were lower ($P < 0.05$) compared with sample 3 collected 2–3 hours before the new bedding was spread, but dry matter of straw in sample 1 was higher ($P < 0.05$) compared with sample 3. The values of the coefficient of thermal conductivity show that the bedding from recycled sludge slurry is a good insulant and absorbent. In addition, a determined increase of humidity at the end of the bedding interval does not cause dramatic changes of thermal performance.

Keywords: dairy cattle; separated manure solids; dry matter content; thermal conductivity

Barn features such as the lying surface, cubicle configuration and climate conditions affect stall usage and animal behaviour. For example, cows spend more time lying down and have higher frequency of lying events on their preferred lying surfaces (Tucker et al. 2003; Tucker, Weary 2004) and cows choose the option that is more comfortable, namely well bedded stalls. Lying time decreased progressively when bedded stalls were poorly maintained (Drissler et al. 2005; Fregonesi et al. 2007). When the stall was bedded with dry sawdust, cows spent 13.8 h/day lying down which reduced to 8.8 h/day when the bedding was wet. The use of large amounts of bedding in stalls can optimize cow comfort, minimize lameness, reduce hock lesions, and increase cow longevity if udder health is not compromised (Tucker, Weary 2004; Mihina et al. 2012). The prevalence of hock lesions was higher on farms using foam mattresses than on farms using deep-bedded freestalls (with box compost, sand or horse manure) (van Gastelen et al. 2011). Sand can be considered the ideal bedding source for dairy cows, but it is not preferred by all producers. Inherent properties of sand can make it difficult to handle in some manure systems. Alternative kind of conventional bedding can be

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obtained from mechanical separation of manure as long as the equipment is well maintained and operates properly. Interest in using recycled manure solids (RMS) as a bedding material for dairy cows has grown in some great milk producers. For most farms in recent study of Husfeldt, Endres et al. (2012) RMS were being used successfully as a source of bedding for dairy cows and somatic cell count was comparable to the average in the region and not excessively high. The type, amount and dryness of bedding can affect how much time cows spend lying down (Keys et al. 1976; Tucker et al. 2003; Tucker, Weary 2004; Drissler et al. 2005; Fregonesi et al. 2007). Bedding becomes wet when cows urinate and defecate, leak milk, and enter the lying area with dirty, wet hooves. Wet bedding can reduce the amount of time cows spend lying in free stalls and gives better conditions for bacteria growth. Each hour increase in resting time resulted in a gain of 1.7 kg of milk production (Grant 2007). Fregonessi et al. (2007) reported a decrease of 5 h/day in lying time on wet bedding (when dry matter of wet sawdust was 26.5%) compared with dry bedding (dry matter of kiln-dried soft wood sawdust was 86.4%). In the study of Reich et al. (2010) the results showed a decrease in the amount of time cows spend lying in the stalls as the dry matter content of sawdust decreased; this decrease was modest until dry matter decreased below approximately 60%, suggesting that cows may not have a strong preference for drier bedding when all options are relatively dry (i.e., between dry matter of 60% and 90%). RMS generally have a dry matter content of 30% to 40% depending on the mechanical process by which they were produced. In the study of Keys et al. (1976) dewatered manure solids (29% dry matter), dehydrated manure solids (90% dry matter) and sawdust (81% dry matter) were compared as bedding materials for dairy cattle, where the best results in lying time showed the driest one. On the other side, very dry sawdust have a dry matter content of approximately 90% prior to placement in the stalls, but it continued to drop over the next days to approximately 50% (Hogan et al. 1999). There is little evidence that drying the manure solids would be cost-effective from the perspective of reduced contribution to environmental mastitis, even if they were dried to 90% dry matter, and this would require a significant input of energy, the dry matter content would decrease significantly once placed in stalls, particularly in areas of the country where relative humidity is high (Smith et al. 2006).

The aim of this study was to analyse the change of characteristics of different types of litter in livestock environment during the summer period in relation to the dry matter content, its thermotechnical properties and management of moisture under typical operating conditions in Slovakia.

By utilizing of new technologies in bedding or in ventilation, improvement of living conditions and animal welfare can be achieved as well as reduction of pollutant concentration and reduction of their subsequent discharge into the atmosphere (Karandušovská et al. 2013). During the reconstruction of buildings for dairy cattle, it is suitable to opt for an automatic system to clean out dirty bedding, allowing higher cleaning frequency. As a bedding material, it is advisable to use separated manure solids. Animals are not disturbed by technique and pollutant or by cold in winter (Karandušovská et al. 2012).

MATERIAL AND METHODS

The organic bedding was evaluated in terms of changes of its physical properties – i.e. dry matter content and the coefficient of thermal conductivity in practical conditions. The experiment was carried in (north-south oriented) farms with Holstein-Friesian breed of dairy cows (average weight 580 kg) in south-western Slovakia in summer 2014. Three naturally ventilated buildings with curtained sidewalls for dairy farming were selected, which use different types of bedding and identical cubicle design and concrete alleys. In two of them the deepened stall base cubicles with the bedding based on RMS were used for more than 4 years (barn 1 and barn 2) and for comparison a barn that used traditional straw as a bedding material was used (barn 3) with the same parameters of cubicles (Fig. 1). The alleys closest to the feed bunk and between the two rows of cubicles measured 3.3 and 2.2 m in width, respectively.

The aim was to realize sampling of recycled manure and straw in a way to catch the trend of changes in their physical properties. Samplings from bedding in the lying area were planned in terms of the time (in relation to the state, which reflected the period of use) and in terms of sampling points (state based on exposure of localities in relation to the likelihood of contamination). The changes were observed under the normal operation course

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during which the bedding passes through with five repetitions within the summer. Each sample represented 5 kg of bedding collected by the same procedure at all measurement sites, usually every third cubicle.

First, the bedding material is prepared in a fresh state in the store, where it is influenced by its climate condition terms and the abidance time. Bedding is transported from this place in its original unused "clean" state into stable, where it is spread in the cubicles. Immediately after placing the bedding into livestock environment, the interval of its wearing starts, depending on the type of bedding, cubicle structure and the breeder's practice. The bedding acclimates at first in the barn to another interior air environment and between the 2nd and 3rd hour after it was spread, samples of bedding were taken. It is a state, when the fresh litter was distributed into a cubicle lying area in a layer thickness of 200 mm and the bedding was adapted in stable environment (sampling 1).

Then, the litter gradually pollutes in the process of using the lying area by animals. Our control indicator was the state of the litter in the middle of one bedding use interval – i. e. at the time about half of its pollution (sampling 2). And finally, when the litter was so dirty and worn that it would subservice its function, the last sampling was made, between 2nd and 3rd hour before the new bedding was spread (sampling 3), which was the end of its use in the stable. Then the cubicle cleaning is coming up – removing of degraded bedding and spreading of the new, clean bedding.

In terms of sampling points – four types of locations were determined, which were the same for the whole experiment (Fig. 1). Samplings were collected in preparatory storage (place 1), then from a cubicle lying area at the locality of the brisket barriers (place 2), and in the middle of lying area (place 3). Finally the area of rear curb was sampled (place 4) – at this point, the samples were not extracted directly from the place of fresh excrements.

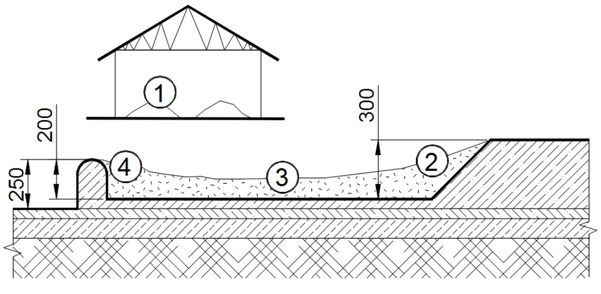

Fig. 1. Sampling places in storage and in lying area (cubicles width – 1,200 mm, length – 2,600 mm)

1 – preparatory storage; 2 – locality of the brisket barriers; 3 – middle of cubicle lying area; 4 – area of rear curb

Barn 1. Separated raw manure solids (SRMS) were used as bedding in deepened stall base of lying cubicles, which was added in each cubicle once in 8 days in an amount of 100–120 kg per cubicle and lying surface was cleaned and levelled every day. The bedding is made by passing the excrements of cattle through the screw press separator, where the liquid content is separated from the solids of slurry. Solid particles have a loose texture and are relocated as a primary material into the open storage – a place protected from rain and wind. The thermal-humidity consolidation is carried out by heat treatment, while this heat is generated by its own calorific bacteria. During the week, the separated material is partially thermally adjusted and moisture is gradually liquidated by digging as a fermentation process supported by turning. Subsequently that material is used as litter with the initial dry matter content of 27 to 30%.

Barn 2. This facility is characterized by using a litter consisting of dried drum composted manure solids (DCMS) and a low amount of ground limestone applied to the top of back part of the lying area (200–250 g per day and cubicle). Bedding material is produced from animal slurry in the separator, which is connected with the rotating drum. There the drying and sterilisation process – based only on the own heat from calorific bacteria ranging from 60°C to 68°C – takes place during 24 hours. Excess moisture is continuously sucked from the drum by axial fan. Thus, thermally prepared bedding has normally dry matter content from 36% to 40%. Bedding application was performed every other day (every 48 h), but the dirty parts of cubicles are treated and levelled locally during each milking, that is, three times a day, during every absence of animals.

Barn 3. Packed wheat straw stored all-season under shelter straight in front of stabling facility was used as a bedding material here and was changed every 24 hours. The polluted parts of cubicles were cleaned and formed locally two times a day.

The samples from all places were hermetically closed and immediately forwarded to the evaluation in a certified laboratory. Sample pre-drying was performed in the dryer HS 402 at the pre-drying temperature of 55 ± 5°C. Drying of samples

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Table 1. Results of the evaluation of thermal properties of various types of bedding (thickness 200 mm)

Bedding	Moisture content (%)	Thermal conductivity (W/m·K)	Thermal resistance (m^2·K/W)
Dry straw	10	0.06	3.333
Wet straw	58	0.30	0.869
Dry SRMS	38	0.18	1.111
Wet SRMS	74	0.32	0.625
Dry DCMS	23	0.15	1.333
Wet DCMS	62	0.22	0.909

SRMS – separated raw manure solids; DCMS – drum composted manure solids

was finished in drying equipment POL-Tote SLW 115 STD; the samples were dried at 105°C till the constant weight was reached.

Basic thermo-technical properties of recycled manure and straw were detected before changing the litter directly in cubicles by heat transfer analyser ISOMET model 2104 (Applied Precision Ltd. Bratislava, Slovak Republic) using needle probes (with measuring ranges 0.035–0.2 W/m·K and 0.2–1.0 W/m·K). Bedding from the brisket barrier place (as a "dry" material in Table 1) and from the rear curb (as a "wet" material in Table 1) were tested in the laboratory from the perspective of more precise examination. The thermal conductivity was tested according to STN EN 12667:2001 by means of guarded thermal plates on the Poensgen apparatus (VVÚM, Trenčín, Slovak Republic) and the density of the bedding was determined according to STN EN 1602:2013. Thermal resistance was calculated according to STN EN 730540:2013.

RESULTS AND DISCUSSION

Barn 1

The average dry matter content of SRMS in the place of litter preparation was 27.18 ± 0.96% in the summer measurements, without the evidence of differences between individual samplings ($P < 0.01$). The dry matter content in samples has increased (Fig. 2) during further samplings in the barn. Significant differences ($P < 0.05$) were found among these samplings (places 2, 3 and 4). The average dry matter content increased by 35.82 % in three locations in a cubicle 3 h after litter spreading compared with the state at storage.

In the second sampling, on the fourth day of this trial, the average dry matter content in cubicles was 51.61%. The increase was also due to the fact that the cubicles near the open wall were exposed directly to solar radiation and constantly prevailed summer weather with average monthly temperature 20.6 ± 5.9°C and an average relative humidity of 51.9 ± 17.6%. On the 8th day of our trial, 2–3 h before new litter was spread, the average dry matter content was 65.61%. The dry matter content increased after its placement by +31.75%, then by +73.07% and at the end by +141.42% compared with the state in store-room before spreading.

Barn 2

The average dry matter content of DCMS in storage – the place of litter preparation was 38.44 ± 1.41% in the summer measurements also without the evidence of significant changes in individual samplings ($P < 0.05$) (Fig. 3). Dry matter content

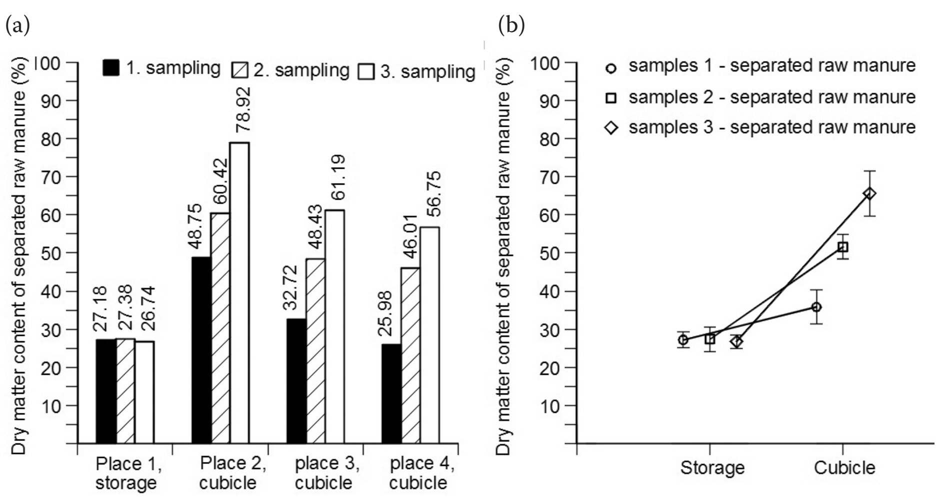

Fig. 2. Evaluation of dry matter content in barn 1, in which the raw separated sludge slurry was used as bedding material

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was gradually increased in the following samplings made in the stable 2 after 3 h after litter spreading to 61.85%, then to 67.10% between the two litter spreadings and 66.57% at the end before the next litter spreading. Between sampling in the cubicles, however, significant differences ($P < 0.05$) were not detected but all of them were statistically highly significant compared with the original state in the storage ($P < 0.01$).

By careful cubicle cleaning – 3 times a day – the range of dry matter content in individual samplings, and parts of boxes, differed only by 3–6% and they occurred in the homogeneous groups (dry matter percent in samples 2, 3 and 4), which seems to be also affected by the treatment with conditioner. The increase of dry matter content compared to properties in prepared state before the bedding was spread represented by +61.18%, then +74.64%, and +72.42% at the end.

Barn 3

The average dry matter content of straw before litter spreading was 90.88 ± 0.79%. In the first sampling (i.e. within 2–3 h after the spread of fresh straw into cubicles), the dry matter content was 88.12%, so it decreased on average by 3.63% (Fig. 4). In the second sampling the dry matter content was lower again, with an average dry matter content of 68.38%, i.e. from its original state it fell by a quarter of the original value in the store and at the third sampling, the average dry matter content was 48.01%, when it decreased by almost a half its original state in storage. This was confirmed by the ANOVA analysis, while the differences between the storage and the second and third sampling were statistically significant. Although the straw still absorbed moisture, further measurements did not continue because of the usual removal during milking and new litter was spread. Changes in dry matter content in the place of preparation of straw bedding were not significantly different ($P < 0.05$).

The thermal conductivity for calculation of thermal resistance of the tested bedding materials was detected in a certified laboratory; due to time the results of the driest and the dampest state of particular bedding were set. The results of evaluation are shown in Table 1.

The results of the measurements show that thermal performance of straw in the process of its use in stable worsens, while in the separated sludge slurry a significant improvement occurs due to over-drying in cubicles – especially in the brisket barrier and in the middle of the bed (thermal conductivity of SRMS ranged from values of λ_{SRMS} = 0.18 W/m·K to λ_{SRMS} = 0.32 W/m·K; thermal conductivity of DCMS from the value of λ_{DCMS} = 0.15 W/m·K to λ_{DCMS} = 0.22 W/m·K). At the end of the use of bedding, this material is more conductive due to the growing trend of moisture again. However, animals accept it in summer due to the better possibility of heat removal.

According to the dry matter content, there were no significant differences between the second sampling of straw and all samplings of DCMS in beds (Fig. 5). The values of the coefficient of thermal conductivity in Table 1 show that the DCMS is a very suitable bedding material for thermal welfare, good insulant and absorbent; and also at the end of the bedding interval the range of humidity does not cause dramatic changes in thermal performance. Detailed analysis in monitoring of the

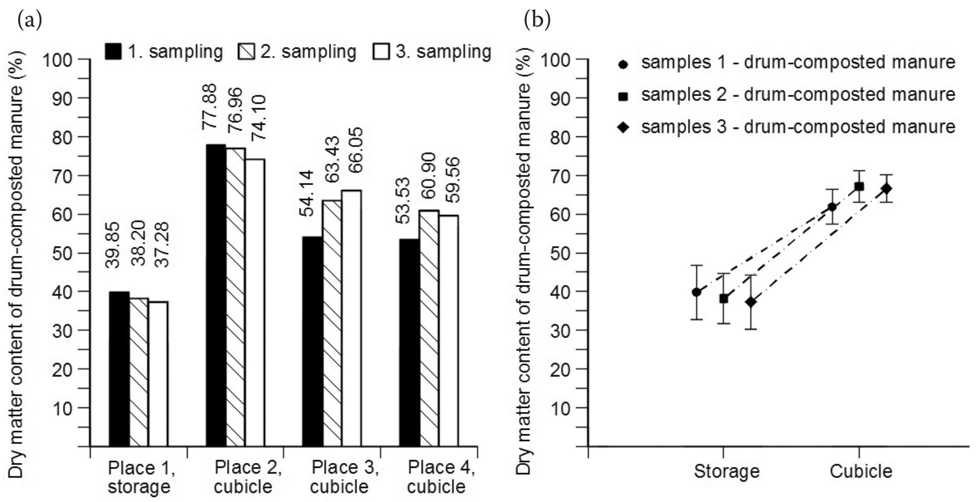

Fig. 3. Evaluation of dry matter content in barn 2, in which the dried drum composted separated sludge slurry is used as bedding material

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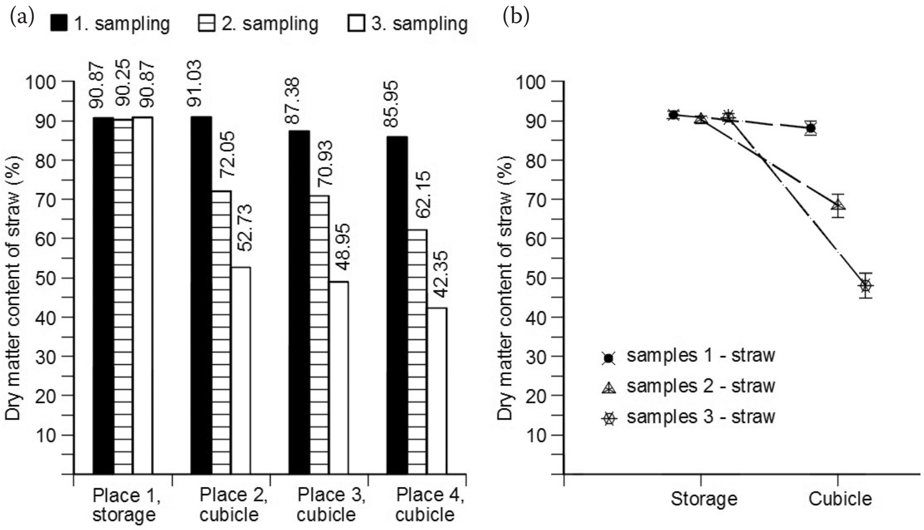

Fig. 4. Evaluation of dry matter content in barn 3, where the straw is used as bedding material

thermal properties over the time and in different climatic situations, however, requires additional detailed research.

Dairy cattle spend 8 to 16 h/day lying, which emphasizes the importance of the lying surface to the animal (Haley et al. 2001). Rest is important for dairy cattle and lying time is a measurable and usable indicator of animal welfare (Fregonesi, Leaver 2001). In the research carried out at the experimental Slovak dairy farms, cows lie from 10.2 to 11.3 h daily in properly treated deepened cubicles with bedding from separated raw manure solids (Lendelová et al. 2012). No bacteriological problems occurred during the four years of the use of this bedding material. According to Hogan and Smith (1997) the use of organic bedding materials in free stalls can provide a source of teat infection and exposure to common mastitis pathogens and management practices attempting to reduce bacterial exposure are often arduous and unsuccessful. Moisture is necessary for bacterial growth in bedding materials. It is important to keep bedding as dry as possible to minimize exposure to environmental mastitis pathogens. RMS have low initial bacterial counts of environmental mastitis pathogens, but counts rise exponentially within a few hours after being exposed to the cows and introducing bacterial contamination (Sorter et al. 2014). Composting can help decrease the pollutions of potential pathogens in materials being exposed to animals (NRAES 1992). Studies on the effects of composting bedding for dairy cows compared composted RMS and fresh RMS by survey of different farms (Husfeldt et al. 2012). Composted bedding from RMS only had an effect on bacterial counts before use as the beddings and were similar to those comparing fresh RMS untreated or treated with disinfectants before use as a bedding (Cole et al. 2016).

In our study, the dry matter content of separated manure solids in storage ranged from 27% to 38%, but after removing into the freestall beds it increased. This may vary depending on the type

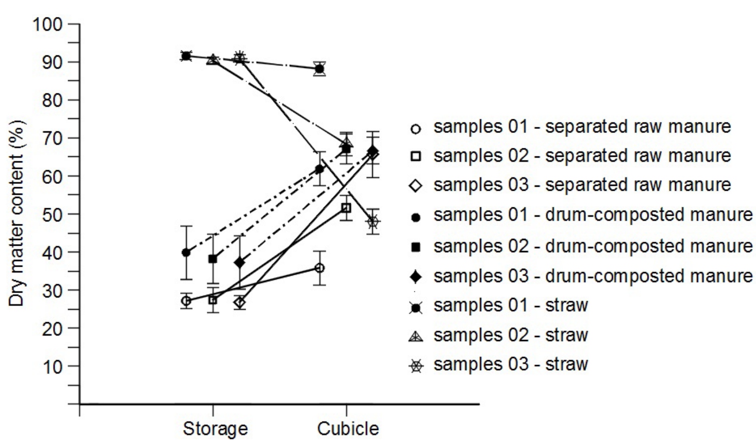

Fig. 5. Total nature of changes in solids content in individual litters between storage and monitored beds

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of mechanical device producing the manure solids – dry matter values of 20% to 35% are not uncommon (Smith, Hogan 2006). During periods of dry weather, the dry matter content from solids obtained under shades would be expected to be higher than those from the general corral environment and it was reported to change only slightly over the 6 days (Hogan et al. 1999). According to COLE et al. (2016), dry matter of composted RMS on first two days after spread into stalls was lower ($P < 0.05$) compared with fresh RMS. Dry matter on day 0 was lower ($P < 0.05$) compared with days 1, 2 and 6 within both composted and fresh RMS. Dry matter content on day 1 and 2 was reduced ($P < 0.05$) in both composted and fresh RMS compared with day 6. An increase in dry matter over time with the use of RMS as bedding was also seen by Husfeldt et al. (2012) and Sorter et al. (20014), who found out that dry matter increased during the week from 32% to 60%, with fans constantly moving the air above stalls throughout his trial. According to the study of Keys et al. (1976) dry matter content appears to influence cow preferences: cows chose to lie less in stalls with "dewatered manure solids" (29% d.m.), compared with "dehydrated manure solids" (81% d.m.) and sawdust (81% d.m.), at equal depth. Cows showed preference for cubicles bedded with separated manure compared to straw, sand and sawdust (Adamski et al., 2011). Longer lying times were recorded at commercial farms following a change from mats to deep beds with RMS (Feiken, Laarhoven, 2012). In our experimental farm, lying time in group of 43 dairy cows housed in deep bedded freestalls using separated raw manure ranged from 10.22 to 11.31 h/day/cow (Lendelová et al. 2012) and dry matter of recycled litter used here was not higher than 36%. Dry matter content of straw bedding in our study before spread into freestalls was 90% and then it decreased (on average to 48%) by almost a half of its original state in storage. It seems similar to very dry sawdust with dry matter content approximately 90% (Smith, Hogan 2006). Within 24 hours the sawdust dry matter content decreased (to 60–70%) and the dry matter content continued to drop over the next 5 days to approximately 50–60% (Hogan et al. 1999). Additional methods that help to keep stall bedding dry (use of a blower, good barn ventilation, adding equipment to remove moisture after separation) should help to reduce stall bedding moisture (Endres 2011) and they were used in our farms, too. The use of conditioners historically provided a reduction in mastitis pathogens in bedding for a relatively short time. The bedding with conditioners seemed to result in reduced bacterial counts for 24 to 48 h after treatment (Hogan et al. 2007) and this method was practiced with our best results in Barn 2.

Bedding is an important factor influencing cow comfort and lying time, and consequently milk production and dairy farm profitability. Using of separated manure as the bedding material in our country is a good alternative to conventional litters. In addition, the bedding process is also an economic consideration in a dairy enterprise. This ecologic cycle – not only with the costs for bedding but also by disposal costs can be saved, because it is a material produced directly on the farm and always available.

CONCLUSION

Bedding is an important factor influencing cow comfort and lying time, and consequently milk production and dairy farm profitability. Although in a humid and cold climate – sufficient evaporation and keeping of „green" bedding dry can be a problem, using of separated manure as bedding in the climate of Slovakia is a good alternative to conventional litters. Several studies have shown that increased moisture of organic bedding brings an increase in bacteriological and health risks. If the lying cubicles are too wet, it is important to monitor what is the dominant cause of unwanted situations. Bringer of additional moisture is particularly the case of animals defecating in the cubicle and the fetch of excrement with dirty legs from alleys. This may occur in the cubicles of various designs and with different types of bedding. RMS as bedding may tend to drying up in the environment of the stables in proportion to the season, stocking density and intensity of ventilation in the barn.

Our results showed that after spreading the separated sludge slurry into cubicles in the stable with freestalls filled with separated raw manure solids and those which use dried drum composted separated manure solids, there was a significant increase in dry matter during 2–8 days from starting dry matter of 27–38% to 65–67%, which is positive in terms of hygiene and comfort. The bedding has better absorption capability, is well formable and improves the thermal-insulation quality. It has shown a well-founded possibility of improving the

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initial moisture content of litter in lying cubicles by spreading a fresh layer of 100–200 mm on the free area with roofing above before applying it into stable, if possible. In the lying cubicles it is appropriate to modify the surface especially near the rear curb by heap up of dried litter from the area closely to the brisket board and from the area of the side dividers, where dry matter content is minimum two times higher and usually free of fresh excrements.

When the dry matter tends to decrease in a bed – it is important to address the elimination of external inputs causing hygienic risks. The level of hygiene in the cubicle beds using RMS is proportional to the care and periodicity of adding a new layer of litter, in order to be able to interact with the requesting state of the surface of a cow bed as soon as possible.

In addition, the bedding process is also an economic consideration in a dairy enterprise. This is an ecologic cycle – because not only the costs for bedding but also the disposal costs can be saved – since it is a material produced directly on the farm and always available. Detailed analysis in monitoring of the physical properties over the whole year and in different climatic situations, however, requires additional detailed research.

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