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Sand losses out the pens in barn with free-stall housing system

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Abstract. Proper sand management can be a critical aspect in the selection and successful use of sand as a bedding material for dairy cows. In many regions and countries, use of sand as a bedding material is considered as a useful alternative solution in dairy farms, where non-organic matter can serve as an equivalent of straw and other organic materials, e.g. sawdust. Assessment of sand management in the barn with dairy cows involves numerous problems, such as sand consumption, frequency of filling in the sand, quality of sand, as well as cows' response to comfort conditions created by lying stalls covered with sand. This paper presents results of some investigations concerning sand losses in the barn with dairy cows. In practice, sand consumption is a result of natural occurrences, when cows leave lying stalls. Moreover, part of sand, together with faeces, is taken out of the stall when the lying area is handled by persons responsible for cleanliness and hygiene in the stall. This paper indicates, based on the authors' own observations and investigations, that an improper construction of lying stalls can result in the increased losses of the sand in the barn, which translates into financial losses. In addition, a number of methods of measurement, together with the details of the structure of sand losses in the barn with a free-stall housing system, were presented. The discussion develops the issue of effective use of sand as a bedding material in the barn with dairy cows, including the need to use technical equipment in order to keep the barn floors clean and ensure the cows' comfort.

Key words: bedding, cow, dairy farm, free-stall, keeping system, management, sand.

INTRODUCTION

Barn is the place where dairy cows, as well as other groups of cattle, should have the possibility to be kept in sustainable production environment (von Keyserlingk et al., 2009). The appropriate environment is essential for dairy cattle health and welfare (Vasseur et al., 2015).

The generally considered environment in dairy production, especially in the barn area, comprises many detailed factors responsible for the assessment of dairy effectiveness. The dairy effectiveness is created, first of all, in the cow feeding area (Phillips & Rind, 2001) and associated with the results obtained in the milking area (Lawrence et al., 2014). On the other hand, the dairy production environment and effectiveness can be determined by cow comfort created not only by microclimatic

conditions (Papez & Kic, 2015) but also cow lying comfort because adequate rest can be positively associated with productivity, health and welfare of dairy cattle (Solano et al., 2016).

The cow lying comfort involves the problem of the lying area and its assessment in the barn. Based on results of some investigations, Nordlund & Cook (2003) suggested that the lying surface was a particularly important component of the free-stall design. This assumption was supported by numerous experiments aimed at proposing some new and improved bedding materials (Tucker & Weary, 2004) and showing the effect of bedding quality (Fregonesi et al., 2007), the amount of bedding (Drissler et al., 2005) and bedding management (Wagner-Storch et al., 2003) on the time spent by cows in the lying position.

Certain investigations into the lying area for dairy cows emphasize the significance of the management practices associated with bedding types (Rowbotham & Ruegg, 2015). Proper bedding management shows long-term effects with regard to lying down in well-bedded stalls, compared with poorly bedded places (Tucker et al., 2003).

There are many bedding materials, more or less popular in barns, for dairy cows and heifers. As a bedding material of the lying area for dairy cows, sand is a valuable alternative to straw, sawdust and other organic materials. For the purpose of better identification of the sand used in barns, many investigations were developed in order to find the relationship between sand and cows, management practices and other dairy production indices. Management activities involving the amount of sand used on the stall surface can influence the cow's response; the lower the level of the sand in the lying area, the less time cows are likely to spend lying there (Drissler et al., 2005).

The abovementioned changes in the sand level are attributable to the decrease in the amount of sand covering lying stalls. Natural consumption of sand is caused by some activities of cows themselves and management practices in the lying area, i.e. cleaning (removing faeces) by persons responsible for bedding hygiene.

The problem of sand consumption in the barn may be a starting point for the identification of more details related to the effective management of sand as a bedding material. Sand losses are one of such details. The purpose of the paper was to investigate sand losses in the barn with a free-stall housing system.

The issue of sand losses posed some questions concerning quantity and quality aspects of such losses, as well as their causes. Generally, losses in the dairy production system, similarly to other production systems in agriculture, constitute an element of the sustainable production environment. Such losses of bedding material in the barn are associated with the assessment of dairy production effectiveness. Therefore, in order to discuss how to reduce sand losses, and thus, increase effectiveness of the bedding material management in the barn with cows kept in a free-stall housing system, it is reasonable to present the result of own investigation.

MATERIALS AND METHODS

Measurements of sand losses in the barn with dairy cows were conducted in a free-stall barn located at the University of British Columbia's Dairy Education and Research Centre in Agassiz (British Columbia, Canada) in the period between December 2015 and March 2016. The investigated, naturally ventilated (with curtained sidewalls) wooden frame barn consisted of 120 free stalls divided into smaller units, i.e. 10 pens with 12

stalls each. The lying stalls, in each individual pen, were arranged in 2 rows (with 6 stalls each), one row facing the feeding alley and the other facing the connecting alley (Fig. 1). The pens were equipped with stalls divided by individual partitions.

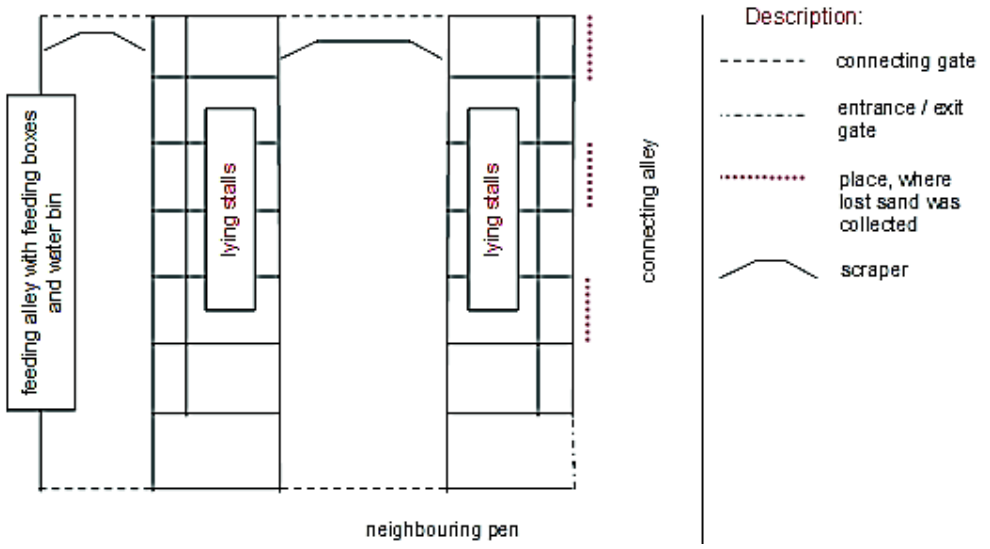

Figure 1. Diagram of (part of) the barn where measurements of sand losses were conducted.

In the investigated barn, the laying stalls were filled with sand. In order to spread the sand in the stalls, a tractor with an attached machine (spreader) had to move along the scraper alley (Fig. 1). During sand spreading, the scrapers were stopped at such a position as to enable the tractor to move along the scraper alleys without any hindrance. At the time of refilling the sand in the stalls, the animals were separated in each pen using chains to close the respective part of the pen.

Mechanical sand spreading in the stalls and animal activity were analyzed to investigate sand losses. Sand losses were measured only along one of the rows, i.e. the right-side row (Fig. 1). The front part of the lying stalls, along the right-side row, was open, without any additional wall dividing the stalls or connecting alley (opposite, the front part of the left-side row, was separated by a cement wall). During sand spreading in the stalls some sand was thrown over the stalls – onto the connecting alley. The connecting alley (between the row with the stalls and the curtained sidewall) along the pens was the place where the lost sand was collected and then measured.

Aim of the mechanical sand spreading in barn is to put all sand on the lying stalls. So sand spread out the stalls can be considered as a lost sand. Such sand is possible to put back to stalls but such activity consumes labour, time and energy. Moreover, use of tractor for such activity in the barn (Fig. 2) is the source of noise and exhaust gases, so the microclimatic conditions in the barn don't meet the animal needs. Moreover, handling of sand in the connecting alley can be additionally source of dust.

Figure 2. Lost sand in the connecting alley – part of the investigated barn.

In total, five pens bordered on the connecting alley in the barn concerned but for the purpose of sand loss measurements only a portion of the connecting alley, bordering on two of the pens, was considered. At the time of the experiment, a group of heifers were kept in these pens, including 11 or 12 animals per pen.

The sand from the connecting alley was not collected along the front part of the whole pen but only along the front part of three stalls per pen. Every other stall (odd one) from one pen and every other stall (even one) from the other pen were chosen to measure the amount of lost sand at their front part, along the connecting alley.

The sand from the connecting alley was collected with a shovel and a broom. It was first collected into a box, and then weighed. The net weight of the sand was determined as the difference between the gross weight (box with sand) and the tare (box weight). Measurement accuracy was ten grams. Moisture of the collected sand was not measured. Generally, in the farm concerned, sand was stored indoors, without exposure to rain, snow or other sources of water.

The width of the front part of the stalls taken into account for the purpose of the experiment, was also measured to an accuracy of one centimetre. The curb between the stall and the connecting alley was adequately marked in order to have the same reference points when the sand was collected.

The lost sand from the connecting alley was collected once a week (on the same day each week). At the time of the experiment, some additional data were collected, i.e. person responsible for sand spreading, date of sand spreading on the lying stalls, as well as date when the connecting alley was cleaned by the barn personnel. Four persons (employees of the farm) were involved in sand spreading and cleaning the connecting alley.

A printed version of the relevant sheet was prepared to collect data obtained from the barn measurements. In the next stage, the data were transferred into an Excel file for further analyses.

The recording of additional data facilitated interpretation of results of the investigations and the process of searching for the relationship between variables in the analysis.

Statistical analysis of all collected data was performed using the Statistica v.12 software, and the main factors were analyzed in terms of variance (ANOVA). The statistical model of the mass of the lost sand incorporated fixed effects of the stall, sand management and the operator. The level of significance (materiality) was established at $\alpha = 0.05$.

RESULTS AND DISCUSSION

The measurements were carried out in order to determine the scale of the problem of sand losses in the barn with a free-stall housing system. The scale of the problem can be determined by the amount of lost sand and the differences in sand losses attributable to different management practices in the barn. The management practices are possibly the effect of individual skills of persons responsible for sand distribution and levelling, frequency and accuracy of handling of the bedding surface in the lying area, etc.

The amount of the lost sand, collected from the connecting alley, ranged between 7.36 and 38.73 kg per distance limited by the width of one stall. Considering all collected data, the mean value ± SD was determined at 22.31 ± 11.07 kg of sand per distance limited by the width of one stall. Due to the fact that the measurements were performed once a week, the amount of the collected lost sand should be considered in relation to one week.

The following parameters were included in the analysis of variance: stall, new sand (sand management) and operator. The dependent variable in the analysis was the mass of lost sand (from the connecting alley).

Table 1 presents results of analysis of variance for the mass of the lost sand, which involved fixed effects of the stall, sand management and the operator.

Table 1. Analysis of variance for the mass of the lost sand including selected variables in the experiment

Effect	SS	df	MS	F	p
Stall	1,047.93	5	209.59	1.8571	0.116612
New sand	465.94	1	465.94	4.1287	0.046915
Operator	3,588.81	3	1,196.27	10.6001	0.000013

The results of the analysis of variance show a significant difference of mean values ($p < 0.05$) for two factors (variables), i.e. new sand (sand management) and operator. However, there was no significant difference of the mean value for the stalls considered in the experiment.

Figs 3 and 4 present the distribution of the two variables which showed significant differences of mean values in the analysis of variance.

The results of the investigations confirmed some of the previous assumptions that management practices and free-stall construction may affect the loss of the sand used as a bedding material for dairy cows (Gaworski & Rocha, 2015).

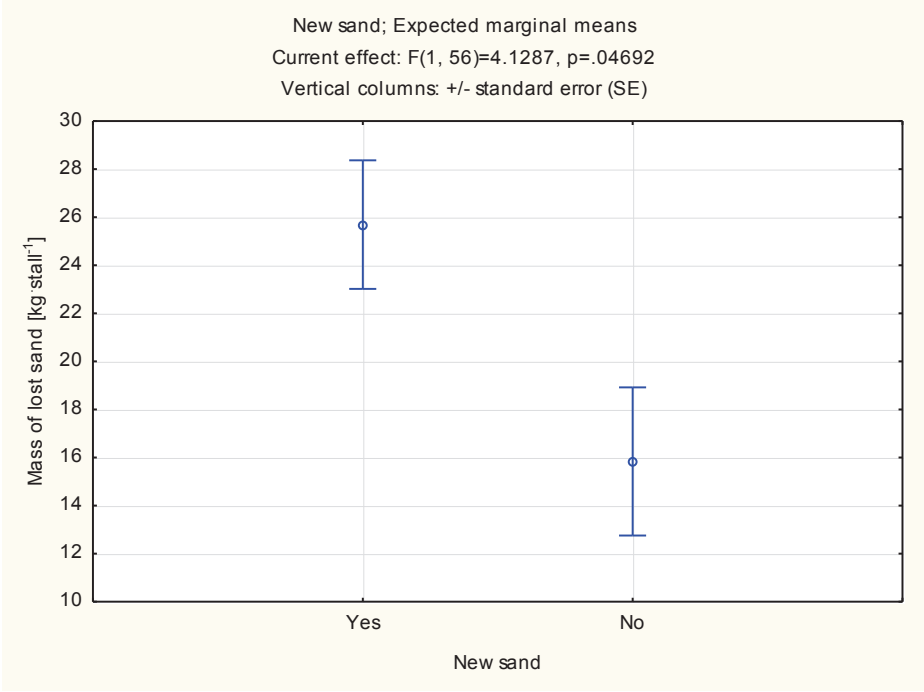

Figure 3. Distribution of marginal means ± standard error concerning mass of lost sand for the investigated variable: new sand (sand management).

The management practices include, first of all, the people responsible for keeping proper conditions in the lying area for dairy cows and other groups of cattle. It seems that the indication of individual skills of the employees who spread the sand on the lying stalls for animal herds is of essence. The results of the experiment, expressed by the mass of the lost sand in the connecting alley, show significant differences between individual persons working with the sand. The maximum difference between the amount of sand losses, considered individually for each person responsible for spreading the bedding material within the period of the experiment, was 23.29 kg (Fig. 4).

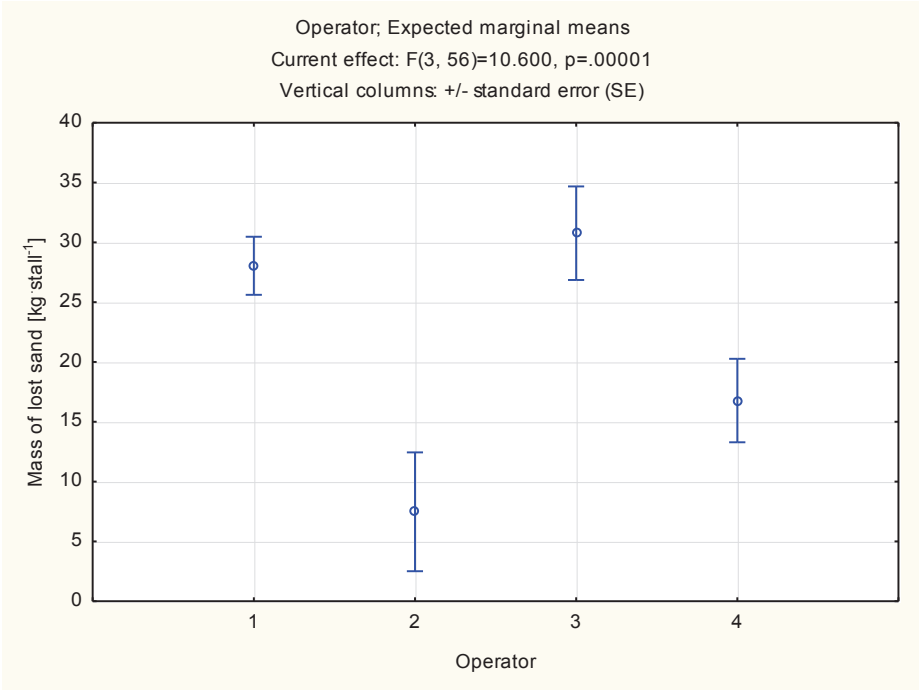

Figure 4. Distribution of marginal means ± standard error concerning mass of lost sand for the investigated variable: operator.

Individual skills and the approach of the employees responsible for sand management in the lying area for cows were discussed by Gaworski & Rocha (2016). According to their observations, persons responsible for taking the cows to the milking parlour and levelling the sand bedding seem to show a tendency to level mainly the rear part of the stalls. In order to achieve the effect of levelling, sand can be taken with a rake from the middle part of the stall to the rear zone of the lying stall, including reduced levelling of front part of the stall.

The significant difference in mean values for the new sand (Table 1, Fig. 3) shows the effect of sand management on the amount of sand losses collected in the connecting alley. The name 'new sand' was interpreted for two investigated options, i.e. sand collected directly after sand spreading (New sand – Yes, Fig. 3) and sand collected a week after the sand spreading (New sand – No, Fig. 3), when no new sand was spread. The second option confirmed the expected results of the investigations, i.e. smaller amount of lost sand collected from the connecting alley.

The problem of the investigated sand losses constitutes an alternative aspect when compared with the general problem of sand consumption in the lying area, especially for dairy cows. Detailed studies were developed to show not only how much sand was necessary to ensure the cows' comfort conditions in the lying stalls but also how much sand was used as a result of cow activities in the lying area. Stowell & Inglis (2000) recommended that at least 4 inches of 'workable' sand should be present in the stalls at all times. According to Stowell & Bickert (1995), sand usage rates can range from less than 1 to more than 10 cubic yards per stall per year, with an average of 4.6 cubic

yards/stall/year. Drissler et al. (2005) indicate that sand may be removed by the cows digging or by dragging the sand out when they exit the stalls, but further research is required to understand how the sand leaves the stall. Typically, cows kick 20 to 25 kg of sand per day out of each stall when the level of sand is above the curb, and 10 to 15 kg when it is below the curb (Rodenburg, 2000). A study of 57 Midwest dairy farms showed an average sand use of 24 kg (53 lb) per stall per day (House, 2010). Buli et al. (2010) suggested a possible distinction between the American and European systems of managing sand, i.e. sand usage in the American system is approx. 20–25 kg per stall per day, while in European systems, it is 5–8 kg per stall per day.

The discussions relating to the sand in the barn focus on the bedding material consumed in the lying area, including the special role of animals in the amount of natural sand use. However, taking into account other places in the barn, where sand consumption can be identified, seems relevant. The results of the investigations showed that improper construction of the lying stalls (too low front wall) can lead to increased amount of lost sand in the barn, which translates into financial losses, as well as the need for higher amount of labour in the barn.

In comparison with some organic materials, i.e. sawdust and straw, the operational cost of sand for bedding is lower, both in terms of obtaining the product and the handling of the beds. Though sand provides more comfort and hygiene, farmers were more satisfied with manure handling and bedding costs when used mattresses (Bewley et al., 2001). The own observations during the experiment showed that in spite of winter season and low temperatures out the door (temperatures lower than -5 degrees of Celsius) the sand bedding was high quality, especially when kept dry on the stalls.

Considering the amount of lost sand and the average price of sand, it is possible to calculate financial losses. Such losses may be understood as financial expense in the absence of the relevant technology to recycle and reuse the sand collected in the barn. In order to improve the bedding material management, a system of sand manure separation, into sand, solid and liquid faeces, could be used. This technology can reduce both environmental impact and financial losses. Such technology was used in the investigated barn, so sand (lost sand) transported by manure scraper could be separated and returned again to lying stalls. Sand losses in the transportation process and cleaning of the bedding removed from the stalls weren't included in the carried out investigation. It is inspiration to investigate such elements as part of the independent research.

In order to maintain clean cattle, clean housing is required (Ruud et al., 2010). The clean housing, of course, involves pens with animals, but perhaps considering the issue of cleanness throughout the barn would be more reasonable. With fewer amounts of the lost sand in the connecting alley, dairy production could be more balanced and systematic.

CONCLUSIONS

Sand management, used as a bedding material in the barn, can be inspiration for detailed investigations into solutions to identify and reduce sand losses, and thus, make dairy production more effective.

Sand losses in the barn, especially in some of the places connecting the pens to other parts of the barn, e.g. parlour, may be caused by some constructional features of the lying stalls neighbouring on the connecting alley. The investigations showed that

some constructional features, such as absence of a wall between the front part of the lying stalls and the connecting alley, can be decisive when it comes to losses of sand and such losses also depend on the persons responsible for sand management and the time when the measurements of the lost sand were taken (directly after sand spreading or later).

Sand losses in places other than a pen with dairy cattle can be taken into account in the structure of sand consumption in the barn with a free-stall housing system in order to determine, in a more precise manner, the amount of sand used in dairy production.

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