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Research Paper

Residual soiling mass after dung removal in dairy loose housings: Effect of scraping tool, floor type, dung removal frequency and season

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Clean floors in dairy housing have a positive impact on claw health, cleanliness of the animals and ammonia-emission reduction. Key indicator of cleaning quality is residual soiling mass, i.e. the manure remaining on the floor after dung removal. The aim of this study was to show the effects of scraping tool, rubber mat type, solid floor type, dung removal frequency and season on residual soiling mass. The comparison two scraping tools and two rubber mat types in winter showed that the rubber mat type ($p = 0.001$) and the scraping tool ($p = 0.001$) influenced the residual soiling mass. The cleaning quality was better on the common than on the soft rubber mat and the hard rubber lip left less residual soiling mass versus the metal blade (means: 174 vs. 230 g m^{-2} on common; 230 vs. 243 g m^{-2} on soft rubber mat). Further two floor types (with and without 3% slope) and two dung removal frequencies (three and 12 times per day) were investigated in three seasons. The statistical analysis proved the season as significant ($p < 0.001$). Residual soiling mass in winter was smaller than in warmer seasons regardless of floor type and dung removal frequency. Within the summer dataset the floor type was significant ($p = 0.037$): the floor without slope showed less residual soiling mass in average 218 resp. 234 g m^{-2} with three resp. 12 dung removal events per day than the sloped floor with 280 resp. 303 g m^{-2}.

1. Introduction

Dung removal represents an important procedure in the daily operation in dairy housings and includes scraping off faeces, urine and other waste from floor surfaces (Fulhage, 1997). Clean floor surfaces have a positive influence on claw health (Somers, Frankena, Noordhuizen-Stassen, & Metz, 2005) and contribute to a reduction in ammonia emission (Braam, Ketelaars, & Smits, 1997; Braam, Smits, Gunnink, & Swierstra, 1997; Snoek, Stigter, Blaauw, Groot Koerkamp, & Ogink, 2017; Swierstra, Smits, & Kroodsma, 1995). Thus, achieving a good cleaning quality by improving the dung removal efficiency is necessary.

Various aspects should be considered in the context of cleaning quality. Dung removal in dairy housings with solid

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floors is performed with various technical systems (Pöllinger, 2001; Steiner & Keck, 2000). These systems differ not only in design and shape but also in materials of the scraping tools, which are in direct contact with the floor surface (Buck et al., 2013). Scraping tools in dairy housings are often equipped with a metal blade (Schrade, Steiner, & Keck, 2013). To improve cleaning quality, manufacturers recommend various rubber lips or brushes, especially when combined with rubber mats.

Floor surfaces equipped with rubber mats have a beneficial effect on cow comfort during standing and walking (Telezhenko, Lidfors, & Bergsten, 2007) and claw health (Vanegas, Overton, Berry, & Sischo, 2006), and they optimise the cleaning quality compared to other materials (Poteko, Schrade, Steiner, & Zähner, 2015). With regard to ammonia emissions, a solid floor with a slope and a dung removal system is a preferable system (Braam, Ketelaars et al., 1997; Braam, Smits et al., 1997; Swierstra et al., 1995; Zhang et al., 2005), because the slope enables a rapid urine drainage from the floor surface (Schrade et al., 2013; Steiner, Keck, Keller, & Weber, 2012). In contrast, dry soiling on the floor surface has a negative effect on cleaning quality, especially in warmer seasons because the crusts formed in the absence of liquids are difficult to remove (Zähner, Poteko, Zeyer, & Schrade, 2017).

Frequent dung removal on solid floor surfaces improves housing and cow hygiene (DeVries, Aarnoudse, Barkema, Leslie, & von Keyserlingk, 2012) and leads to reduced ammonia formation and release (Braam, Ketelaars et al., 1997). The dung removal frequency strongly differs in practice (Läpke, Pelzer, & Büscher, 2010; Strahm, 2013); for example, a survey on German farms showed dung removal frequencies from one to 48 times per day (Läpke et al., 2010). Frequencies of three, six, 12 and 24 dung removal events per day were investigated in a context of cow and housing hygiene in Canada (DeVries et al., 2012). The effect of dung removal frequency on ammonia emissions was investigated in a Dutch study in the 1990s, where a dung removal frequency of 12 times per day was compared with 96 times per day (Braam, Ketelaars et al., 1997), and in a German study with dung removal performed four, 10 and 20 times per day (Schiefler, Büscher, & Schmithausen, 2013).

Finally, seasonal climatic conditions may influence the dung removal efficiency. For example, the cleaning quality may decrease in warmer seasons. Particularly warm, windy and dry conditions facilitate the drying process of soiling on the floors and thus lead to smear layers and reduced cleaning quality (Hesterberg, 2007; Steiner, 2007).

The cleaning quality achieved by dung removal systems has rarely been investigated (Schrade et al., 2013). A systematic evaluation of factors that could affect cleaning quality would be helpful to compare and further improve dung removal systems. A suitable indicator of the cleaning quality is the residual soiling mass. It refers to the soiling remaining on the floor surface after dung removal (Hesterberg, 2007; Poteko, Schrade, Steiner, & Zähner, 2014).

In previous studies, researchers used various parameters for determining the amount of soiling or residual soiling (Table 1). For example, some used a visual evaluation scheme to estimate the type and proportion of soiled areas before dung removal on solid floors of exercise areas in cattle housing (Korth, 2008; Schrade et al., 2010). Others used a ruler to measure the height of soiling piles in defined areas on solid floors in dairy housings and exercise areas (Korth, 2008) or compared these metrics on solid and perforated floors in dairy cubicle housings (Næss, Ruud, & Bøe, 2014). However, estimating the extent of soiling before dung removal is not suitable for evaluating the cleaning quality of different dung

Table 1 – Overview of methods for determining the amount of soiling or residual soiling on floor surfaces in dairy housing systems revised after Poteko et al. (2015).

Method	Estimated parameter	Advantages and disadvantages	Scale of usage	Reference
Visual estimation	Proportion, type and height of soiling	+ Simple usage (visual, with a ruler) − Visual estimation, inexact	Practical scale	Korth (2008); Schrade et al. (2010)
Measurement with a ruler	Height of soiling	+ Simple usage (with a ruler) − Measurement only on spots	Practical scale	Næss et al. (2014)
3-D-surface measurement	Void volume on the floor	+ Exact estimation − Only void volume determined	Practical & pilot-plant scale	Steiner, Keck, and Weber, (2010), Steiner, Kilian, Haidn, and Keck (2010)
Determination with a filter-paper	Moisture on the floor	+ Simple realisation − Straw mass unconsidered	Practical scale	Meyer (1985), as cited in Benz (2002)
Collecting with a scoop	Mass of soiling	+ Simple realisation (with a scoop) − Inexact on rough surface texture − Limited experimental surface	Practical scale	Pfadler (1981), as cited in Benz (2002)
Collecting with a water vacuum cleaner	Mass of soiling	− Clogging of the vacuum cleaner tube with straw	Practical scale	Haufe (2006), as cited in Korth (2008)
Collection in removal channel	Mass of removed soiling	+ Practical usage − Soiling remaining in U-shaped rail	Practical scale	Sagkob et al. (2011)
Collecting with a scoop	Mass of soiling and residual soiling	+ Simple usage (with a scoop) − Inexact on rough surface texture	Pilot-plant scale	Läpke et al. (2010)
Calculated difference between total and removed mass	Mass of removed and residual soiling	+ Suitable for various floor surfaces − Limited experimental surface	Pilot-plant scale	Hesterberg (2007)