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Particle separation technology for bedding materials and roughages

With respect to the reduction of airborne particles in equine husbandry, the treatment of the main sources of dust contamination (bedding materials, roughages) must be brought to the fore. Therefore, the aim of this study was to analyze the influence of the treatment of diverse bedding materials and roughages under standardized laboratory conditions with the new particle separation technology on the generation of airborne particle and on the mould content. The particle separation resulted in an airborne particle reduction up to 90 % in particle fractions PM_{20}, PM_{10} and $PM_{1.0}$ ($PM_{2.5}$ up to 70 %) and a reduction in mould content of up to 92 %.

Keywords
dust, content of mould, particle separation, horse husbandry

Abstract
Landtechnik 66 (2011), no. 5, pp. 373–376, 3 figures, 2 tables, 5 references

The equine respiratory tract is very sensitive to airborne dust, which is a mixture of organic material including bacteria, bacterial and fungal toxins, fungal spores, urine, dung, pollen and other feed and animal components [1]. The most common respiratory disease, considered as "occupational diseases" of horses, is the COB (chronisch obstruktive Bronchitis) respectively the RAO (recurrent airway obstruction) [2]. One of the main causes of respiratory disease in horses is high concentrations of airborne particles (dust) in the stable air. The primary sources of airborne particles in stable air are different bedding materials and roughages [3, 4]. However, not only dust but also mould spores are known to play a central role in the development of respiratory disease [1]. Accordingly, the aim of this study was to analyze the influence of the treatment of diverse bedding materials and roughages under standardized laboratory conditions with a machine using a dry-air particle separation technology on the subsequent generation of different airborne particle fractions and the mould spores content. The development of the technology was done by the company Hurkyson (Post box 98, NL-6865 ZH Doorwerth, The Netherlands).

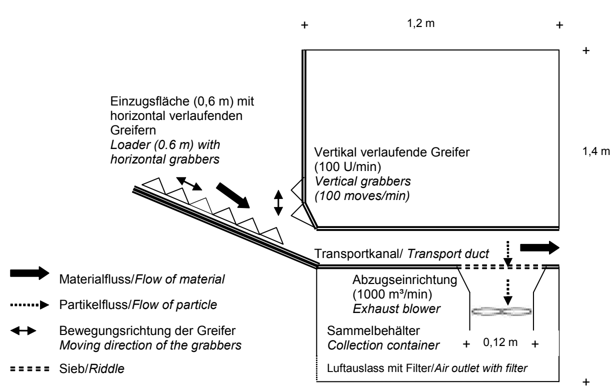
Treatment of the materials with particle separation technology

Following four types of bedding material and two types of roughage were subjected to the same treatment with the new particle separation technology **(Figure 1)**. After treatment, the reduction of airborne particles and mould spores content were analyzed.

- Wheat straw (length 20 – 30 cm, harvested August 2008, square bales 90 x 120 cm)
- Wood shavings (length 0.5 – 4.0 cm, 25 kg pack; Allspan Barneveld, The Netherlands)
- Flax shives (length 1.0 – 2.0 cm, 21 kg pack; Lavor, The Netherlands)
- Hemp shives (length 0.5 – 3.0 cm, 15 kg pack; HempFlax, The Netherlands)
- Hay (length 20 – 35 cm, harvested June 2008, first cut, square bales 90 x 120 cm)
- Haylage (length 25 – 35 cm, harvested June 2008, first cut, round bales 125 x 120 cm)

The machine **(Figure 1)** consists of a loading and feeding plate with numerous horizontal grabbers, which are in continual motion (100 moves/min). The input material is loosened, distributed evenly over the plate's surface and moved in the direction

Fig. 1



Particle seperation technology with collection container (1.2 x 1.4 x 1.0 m) of the transportation canal. Vertical grabbers, which move upwards with sudden jolting movements (100 moves/min), are situated in front of the transportation canal, thereby ensuring a continual flow of material into the machine (ca. 2.5 kg/min.). The actual separation system is situated in the transportation canal. It separates particles out of the material using a constant air flow (1000 m³/h). The particles are then captured in a collecting sump. The treated material is pushed into a container due to the pressure from the constant supply of material flowing into the machine. For every trial (n = 3), 5 kg of each separate type of material was treated with the particle separation technology.

Experimental procedure

The airborne particle concentrations produced by the different materials (treated/untreated) materials were detected continuously online with a gravimetrically measuring particle analyzer TEOM 1400a (Rupprecht & Patashnick Co., Franklin, MA USA), which was installed directly into two special dust chambers **(Figure 2)**. For the differentiation of the airborne particle concentration, the TEOM 1400a detected four different particle fractions using four different sampling inlets, which were installed at a height of 0.4 m in one chamber:

- PM_{20} ≤ 20 µm (total suspended particulate matter, aerodynamic diameter <20 µm)
- PM_{10} < 10 µm (aerodynamic diameter <10 µm, thorax passable)
- $PM_{2,5}$ < 2,5 µm (aerodynamic diameter <2.5 µm, alveolar passable)
- $PM_{1.0}$ < 1,0 µm (aerodynamic diameter <1 µm, alveolar passable)

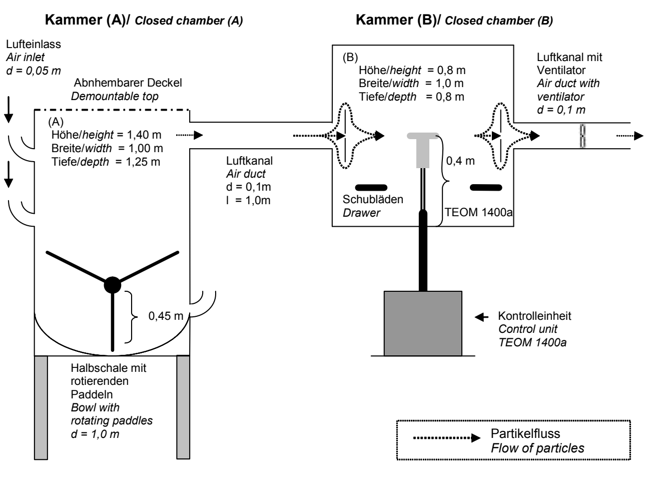
A pan (diameter 1.0 m) with three rotating paddles (1.0 x 0.45 m) were integrated in the first chamber (A; 1.0 x 1.4 x 1.3 m). The surface of the paddles consisted of wire mesh (mesh size 0.05 x 0.05 m). The chamber had three openings (diameter 0.05 m) for the intake of fresh air. The cleaning and filling of Chamber (A) was done by opening its cover. The joints were sealed using silicon. The two chambers were connected by a tube (length 1.0 m; diameter 0.1 m). Another tube (length 0.6 m; diameter 0.1 m) leading out of Chamber (B) contained a ventilator that transported the air out of Chamber (A) into Chamber (B) at a constant speed and from there to a separate room. The air speed (v) in the tube between the two chambers was a constant 3.6 m/s, which caused an air flow through the two chambers of 2.31 m³/min. For determining the presence of mould spores, two manually operated drawers were installed in chamber B, so that Petri dishes (d = 9.0 cm) with a special agar (Yeast Extract Glucose Chloramphenicol Agar FIL-IDF) could be placed inside for two short intervals (10 and 20 seconds) (n = 3).

A 1.5-kg sample of the material to be tested was weighed and placed in Chamber (A) by removing its cover. The material was distributed equally between the paddles (0.5 kg) and the chamber was closed. The measurements started and ended with the starting and cessation of the paddle motor (14 rotations per minute [rpm]). The particle concentrations were measured continually over a 90-minute period. The mould samples were taken during the measurements of the PM_{10} fraction. So that approximately the maximum mould production [CFU/m³] of the material could be determined, the two Petri dishes were first placed inside Chamber (B) 15 minutes after the start of the measurements.

The statistical evaluation was carried out with the software program SAS 9.1 (SAS Inst. Inc., Cary NC, USA). The average maximum airborne particle concentration (C_{max}) of all particle size fractions and materials were evaluated. In addition, the mean mould spore content (10 sec.; 20 sec.) was analyzed. The analysis of variance (ANOVA) was computed using the GLM procedure, which estimates the influence of the material and processing, and the interaction between both on the airborne particle and mould generation. The data are reported as least square means (LSM) ± standard error (SE). The significance level was P≤0.05 (t-test).

Results and discussion

Fig. 2



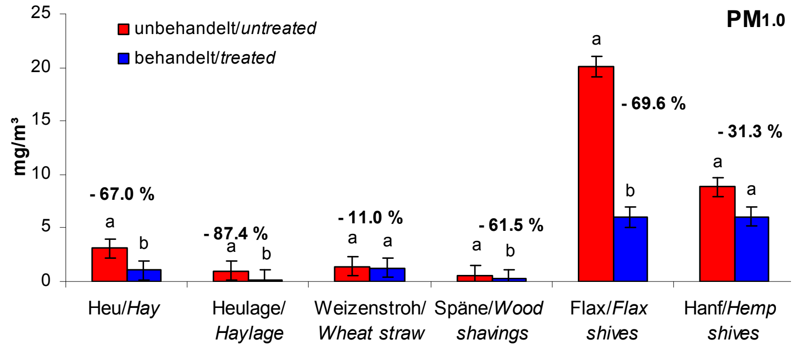
Outline of the closed chambers (A) and (B) with particle analyzer TEOM 1400a

Table 1

Influence of treatment on the mean maximum generation of airborne particles (C_{max}) for all materials in the particle fractions PM_{20}, PM_{10}, $PM_{2.5}$ and $PM_{1.0}$

Effekt der Behandlung *Effect of treatment*		**Partikelfraktionen** *Particle fractions*			
		PM_{20}	PM_{10}	$PM_{2.5}$	$PM_{1.0}$
C_{max}	Signifikanz (P-Wert) *significance (P-Value)*	< .0001	< .0001	< .0001	< .0001
	Reduktion [%] *reduction [%]*	- 72.1	- 64.8	- 73.1	- 57.7

Fig. 3



C_{max} ($PM_{1.0}$) and standard errors of all materials. a,b = different letters within a material means the values differ significantly (P <0.05); (-) = reduction [%] in the generation of airborne particles due to the treatment (effect of treated vs. untreated materials)

Effect of particle separation on the C_{max}

The analyses of the Cmax revealed a significant effect of the particle separation. **Table 1** shows the results.

The particle separation treatment led to a significant reduction of Cmax in the PM_{20} fraction by 72.1 % ($P < .0001$), in the PM_{10} fraction by 64.8 % ($P < .0001$), in the $PM_{2.5}$ fraction by 73.1 % ($P < .0001$) and in the $PM_{1.0}$ fraction by 57.7 % ($P < .0001$). Considering to the particle reduction of the respective materials, the highest reduction in the roughages was found in the $PM_{1.0}$ fraction **(Figure 3)**.

No significant reduction **(Figure 3)** as a result of the separation treatment was found only in the $PM_{1.0}$ fraction in the treated wheat straw (P = 0.8456) and treated hemp (P = 0.2268). The obviously lower initial concentrations found in the untreated materials of this fraction in comparison to the initial concentrations of the PM_{20} and PM_{10} fractions could be the reason for the reduced reduction effect found in these smaller-sized fractions. The treatment of the wood shavings led to a significant reduction in the $PM_{1.0}$ fraction of 61.5 % and in the $PM_{2.5}$ fraction of 90.1 %. A significant reduction of more than 50 % could be found in the PM_{10} and $PM_{2.5}$ fractions for all the bedding materials as a response to the separation treatment.

The treated haylage PM_{20} fraction with an airborne particle reduction of 12.3 % showed no significant difference to the untreated haylage (P = 0.0524). The reason could have been due to its high moisture content (25.0 %); the moisture content

Table 2

Mean mould content (LSM [CFU/m³]) and standard error (SE) in untreated and treated materials in the 10- and 20- second samples and the effect of treatment (E; - = reduction, + = increase of mould content [%])

Materialien *Materials*	**Bearbeitung** *Processing*	**Schimmelpilzgehalt** *Content of mould*					
		10-Sekunden-Probe *10-second samples*			**20-Sekunden-Probe** *20-second samples*		
		LSM	**SE**	**E**	**LSM**	**SE**	**E**
Heu *Hay*	unbehandelt/*untreated*	61,0	5,8		72,3	4,5	
	behandelt/*treated*	8,7	5,8	- 85,8	20,3	4,5	- 71,9
Heulage *Haylage*	unbehandelt/*untreated*	37,0	8,2		86,0	14,1	
	behandelt/*treated*	49,0	8,2	+ 32,4	74,0	14,1	-14,0
Weizenstroh *Wheat straw*	unbehandelt/*untreated*	383,3	82,5		450,0	106,5	
	behandelt/*treated*	46,0	82,5	- 88,0	84,3	106,5	- 81,3
Späne *Wood shavings*	unbehandelt/*untreated*	586,7	12,6		600,0	8,8	
	behandelt/*treated*	44,3	12,6	- 92,4	77,0	8,8	- 87,2
Flax *Flax shives*	unbehandelt/*untreated*	67,0	25,1		93,0	4,4	
	behandelt/*treated*	94,7	25,1	+ 41,0	63,0	7,5	- 32,3
Hanf *Hemp shives*	unbehandelt/*untreated*	62,7	9,2		71,0	14,6	
	behandelt/*treated*	47,3	9,2	- 24,5	59,7	14,6	- 16,0

of the other materials was under 15 %. Such moisture present in the haylage especially binds large dust particles (≤20 µm), which are only minimally removed by dry separation treatment [5]. In comparison, the treated hay did have a significantly lower airborne particle concentration than the untreated hay ($P = 0.0008$). The effect of treatment on the PM_{10} and $PM_{2.5}$ fractions was obviously lower in the hay than in the haylage.

In terms of bedding materials, the largest effect of the particle separation treatment could be found in the wood shavings in the PM_{20} fraction. The treated wood shavings generated an 89.4 % lower airborne particle concentration as the untreated wood shavings (reduction in treated wheat straw -83.9 %, treated flax -60.5 %, treated hemp -72.3 %). A possible reason for this lower effect in flax and hemp could be that these materials produced new particles as a result of breakages and abrasion during the treatment.

Effect of particle separation on the mean mould spore content

The generation of mould spores (10-sec. sample) was only significantly reduced by subjecting the materials to particle separation in the wood shavings (from 586.7 to 44.3 CFU/m³; 92.4 %), wheat straw (from 383.3 to 46.0 CFU/m³; 88.0 %) and hay (from 61.0 to 8.7 CFU/m³; 85.8 %). **Table 2** shows the results.

In the 20-sec. samples – as with the 10-sec. samples – only the treated wood shavings, wheat straw and hay generated significantly lower mould spore content than the untreated materials, whereby the greatest effect was in the wood shavings (-87.2 %) and straw (-81.3 %).

Conclusions

The results of this study show that the particle separation technology implemented here can be used for roughages and bedding material to cause a manifold reduction in the generation of airborne particles, not only in the coarse particles but also in those that penetrate into the thorax and alveoli. The release of mould spores could also be significantly reduced by the separation treatment, although there was a high degree of material-specific variation.

Literature

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