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Effect of liquid additives on the airborne particle generation of oats

The generation of airborne particle from feeds is often neglected, but especially during the feeding airborne particles can generate in the horse's direct breathing zone and be inhaled. Therefore, the aim of this study was to analyze the effect of three different liquid additives (water, oil, molasses) in three different concentrations (1, 2 and 3 %) mixed with cleaned whole or rolled oats on the generation of airborne particles under standardized laboratory conditions. By the addition of 1 % oil, a reduction in the PM₂₀ fraction of 90.6 % could be achieved. The same dosage of water or molasses only resulted in a reduction of 60.4 or 69.1 %, respectively.

Keywords

Airborne dust, liquid additives, particle separation, feeds, horse husbandry

Abstract

Landtechnik 66 (2011), no. 6, pp. 443–447, 3 figures, 2 tables, 6 references

■ The influence of increased concentrations of airborne particles in stable air on respiratory disease in animals and humans has been proven in numerous studies [1]. Especially the equine respiratory tract is very sensitive to airborne dust. It could be proven in various investigations that the highest generation of airborne particles occurs from bedding materials and roughage feed [1, 2]. Although horses are usually offered a small amount of oats per day which they consume within a few minutes a not unimportant concentration of airborne particles can also occur from oats [3]. Uncleaned whole oats generated a mean PM₂₀ fraction concentration of 9.4 g/m³, while cleaned oats generated 2.5 g/m³. Just the dry cleaning of oats (sieving and suction cleaning of particles) led a reduction in particle generation of up to 80 % (PM₂₀, PM₁₀) [3]. Another option for reducing airborne particles, which has been primarily investigated in pig husbandry, is the mixing of concentrated feedstuffs with animal fat or plant oil, whereby a reduction in the feed dust of 35–70 % could be achieved [4]. Accordingly, the aim of this study was to analyze the effect of three different liquid additives in three different concentrations mixed with cleaned whole or rolled oats on the generation of airborne particles (PM₂₀, PM₁₀, PM_{2.5}) under standardized laboratory conditions.

Materials and Methods

The effect of adding a fluid to a feed on the airborne particle generation was investigated under standardized conditions us-

ing cleaned whole and rolled oats. A total of 800 kg of commercial cleaned whole oats (harvested in September 2009; weight per litre = 530 g) was used for the analyses. All of the oats came from a single batch and were automatically cleaned using the Aspirateur OPTIMA 2002 NA (Company ZUTHER GmbH, Karwitz, Germany). Half (400 kg) of the cleaned oats were rolled with the roller mill "Universal" (Company Sommer Maschinenbau, Osnabrueck, Germany). Three different liquid additives were chosen for this investigation.

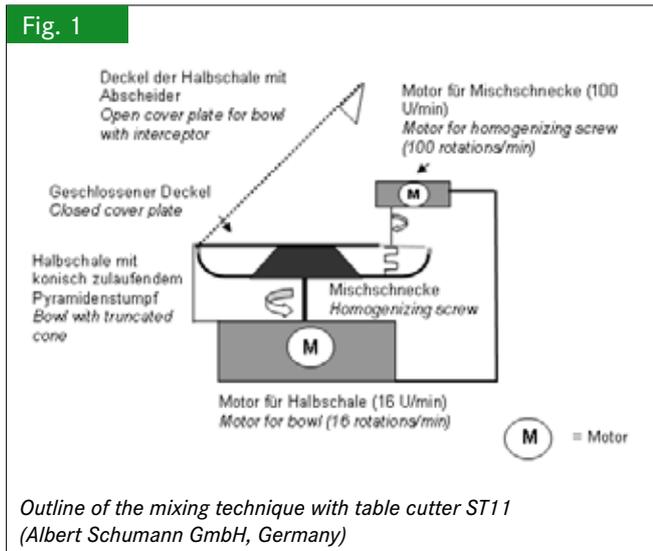
- tap water
- rapeseed oil (APTI, Zentrale Handelsgesellschaft - ZHG - mbH, Germany)
- sugarbeet molasses (42 % sugar content; MIAVIT GmbH, Germany)

To calculate the most effective amount of liquid additive required to reduce the airborne particle concentrations, each of the liquid additives was added to 2 kg oats in three different concentrations.

- 1 % (20 g = 20 ml water, 23 ml rapeseed oil, 18 ml molasses)
- 2 % (40 g = 40 ml water, 46 ml rapeseed oil, 36 ml molasses)
- 3 % (60 g = 60 ml water, 69 ml rapeseed oil, 54 ml molasses)

Mixing technique and method

The mixing of the two components (oats and liquid additive) was done with a mixing machine, the table cutter ST11 (Albert Schumann GmbH, Germany) (Figure 1). This consisted of a 15-cm deep, closed bowl (diameter = 55 cm), turned by a motor at a constant speed (19 rotations/min). A vertical homogenizing screw was inserted into the bowl through a slit (width 1 cm; length 5 cm) in the lid. The mixing screw turned counter to the rotatory movement of the bowl at 100 rotations/min. For each of the airborne particle measurements, 2 kg oats (whole or rolled) were weighed out and placed in the bowl of the mixer. After starting the mixer's two motors (for the bowl and for the



homogenizing screw), the liquid additive was injected through the slit in the mixer's lid into the oats. The mixing process lasted 5 minutes. Once completely mixed, the oats/additive mixture was reweighed and immediately placed in the funnel tube on the outside of a special dust chamber (1 x 1 x 1.5 m) including a bowl, which simulated the trough.

Measurement and analysis techniques of airborne particles

The airborne particle concentrations from the oats (whole and rolled) mixed with different additives were continuously detected online with a gravimetrically measuring particle analyzer TEOM 1400a (Rupprecht & Patashnick Co., Franklin, MA) over a 60-minute period, which was installed in a special dust chamber (1 x 1 x 1.5 m). For the differentiation of the airborne particle concentration, the TEOM 1400a detected the following three different particle fractions using three different sampling inlets.

- PM₂₀ (total suspended particulate matter)
- PM₁₀ (thorax passable)
- PM_{2.5} (alveolar passable)

In order to simulate normal horse feeding, the feed samples were let into the chamber via a funnel tube and slider plate at the back of the chamber. The measuring of the particle fraction concentrations started with the opening of the slider plate (3 repetitions per sample inlet, oat type, additive and concentration = 162 measuring periods). Another 18 airborne particle generation measurements were undertaken using the whole or rolled oats without additives (3 repetitions per sample inlet and oat type) so that a total of 180 measurements each lasting 60 minutes were performed in this study. To exclude any possible effects of the mixer on the degree of airborne particle generation, the control samples were also placed in the mixer for 5 minutes before they were used for the measurements.

Statistical analysis

The statistical evaluation of the data was carried out with the software program SAS 9.1 (SAS Inst. Inc., Cary NC, USA). The

analysis of variance (ANOVA) was computed using the GLM procedure, which estimated the influence of "additive" and "concentration" and the interaction between both on the airborne particle generation. The significance level was $P \leq 0.05$ (t-test). In addition the mean fixation capacity of oats (whole, rolled) and also the mean flow velocity of all additives were analyzed. The data are reported as least square means (LSM) \pm standard error (SE).

Further analysis

As fixation capacity of oats in this study, the amount of liquid additive is defined, which were taken from oats by absorption or adhesion. To quantify the fixation capacity of the oats, 50 g oats (whole or rolled) was weighed and then saturated in 150 g of each of the three additives for two hours. Then the materials were drained through a fine-pored sieve (2 mm) for five minutes. A mesh size of 2 mm was chosen because the liquid additives could slowly drop through and this size of mesh did not become clogged with any of the additives ($n = 3$). Furthermore, the flow velocity of the additives was detected. Fifty millilitres of each additive was filled in a hopper with an outflow tube (length of tube = 6 cm, diameter = 0.6 cm). The delivery port was closed with a slider plate. After one minute, the slider plate was opened and the time which the additive needed to flow out was measured (testo 425; Testo AG, Germany) ($n = 3$). The timer was stopped when optically no fluid could be seen in the hopper.

Results and Discussion

Flow velocity of additives and fixation capacity of oats

The flow velocity of the three additives (50 ml) was such that the water required a mean time of 3.34 seconds to flow over a distance of 6 cm through a funnel (diameter = 0.6 cm). The rapeseed oil required almost twice as long for the same distance (6.83 sec). The molasses was the most viscous fluid, requiring 33.44 seconds. In consideration of the individual additives, the highest fixation capacity of both types of oats was for molasses ($P < .0001$) (Table 1).

A sample of 50 g rolled oats could fix 75.24 % of the molasses (150 mg), whereas whole oats only 31.75 %. Rapeseed oil was fixed the least by both types of oats (whole 15.97 %; rolled 33.65 %) compared to either water or molasses. A possible reason for this could be the flow characteristics of the additives. Water had the lowest flow velocity (viscosity), whereby it can be concluded that water would be more rapidly absorbed by the oats, and so penetrate into the intracellular space, than the more viscous additives, rapeseed oil and molasses. This would confirm the findings that rapeseed oil is less absorbed by solid materials than water [5]. It was found that oats (both whole and rolled) absorbed respectively adhered significantly more molasses than water. This could be due to the higher viscosity of molasses and its high sugar content (42 %) causing it to adhere more strongly to the outside of the grain and so not be absorbed by the grain.

Table 1

Mean fixation capacity (LSM \pm SE) of whole and rolled oats depending on liquid additive

Flüssigzusatzmittel Additives	Ganzer Hafer/Whole oats			Gequetschter Hafer/Rolled oats		
	Wasser Water	Öl Oil	Melasse Molasses	Wasser Water	Öl Oil	Melasse Molasses
Absorptionsfähigkeit [%] \pm SE Fixation capacity [%] \pm SE	23,20 ^a \pm 1,37	15,97 ^b \pm 1,37	31,75 ^c \pm 1,37	50,51 ^d \pm 1,37	33,65 ^c \pm 1,37	75,24 ^e \pm 1,37

a,b,c,d,e = LSM der Absorptionsfähigkeit mit unterschiedlichen Buchstaben unterscheiden sich signifikant voneinander ($P \leq 0,05$).
a,b,c,d,e = LSM of fixation capacity with different letters are significantly different ($P \leq 0,05$).

Airborne particle analysis - Effect additive -

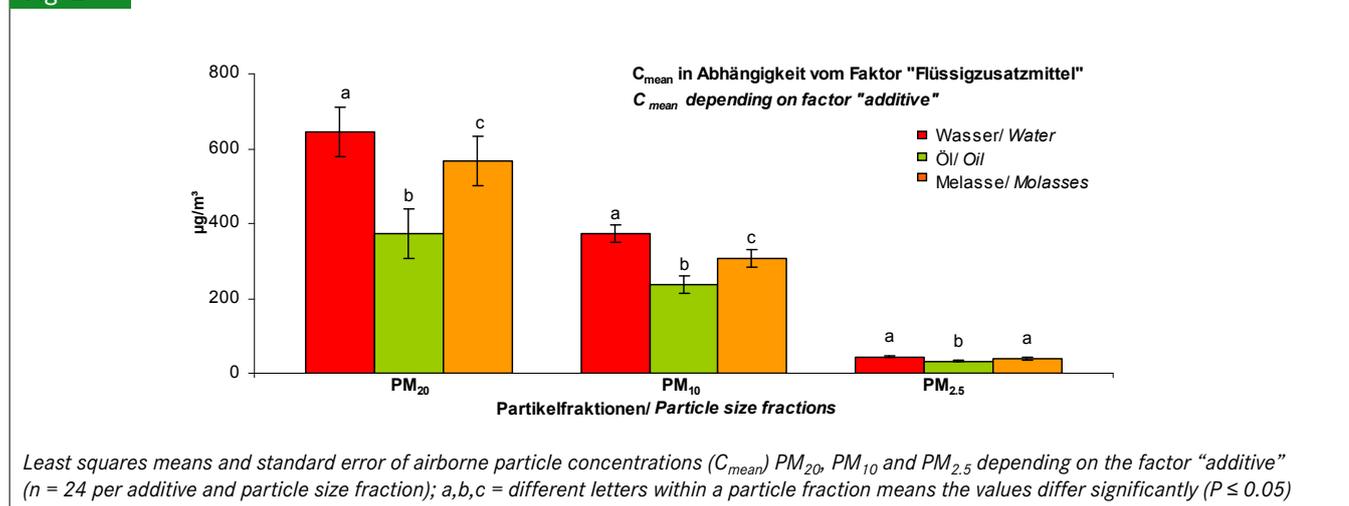
Within the three liquid additives, the addition of rapeseed oil had the highest effect in all of the particle fractions. **Figure 2** shows the mean airborne particle concentrations (C_{mean}) in relationship to the factors "additive". The oats-oil mixture generated the lowest mean PM_{20} fraction ($372.2 \mu\text{g}/\text{m}^3$) compared to the oats-water mixture ($643.4 \mu\text{g}/\text{m}^3$; $P < 0.0001$) and the oats-molasses mixture ($565.4 \mu\text{g}/\text{m}^3$; $P = 0.0008$). In the PM_{10} fraction, the oats-oil mixture ($236.8 \mu\text{g}/\text{m}^3$) had a lower airborne particle concentration than the oats-water mixture ($372.8 \mu\text{g}/\text{m}^3$) or the oats-molasses mixture ($305.9 \mu\text{g}/\text{m}^3$) (36 % and 2 %, respectively). In both of these particle fractions, the airborne particle generation of the oats-molasses mixture was significantly lower than with the oats-water mixture (PM_{20} $P = 0.0427$; PM_{10} $P = 0.0015$). There were no significant differences between the two mixtures in the $PM_{2.5}$ fraction (**Figure 2**). The oil film on the surface of the grain enables the dust particle to be completely engulfed, thereby preventing a renewed dispersal of the dust particles. This could be one possible reason for the highest airborne particle reduction by oil. Salyer et al. [5] described the adhesion as an important characteristic of rapeseed oil. Adhesion is a measurement of a fluid's ability to cover a solid surface: the higher the adhesion the greater the fluid can cover the surface of a solid. The oil

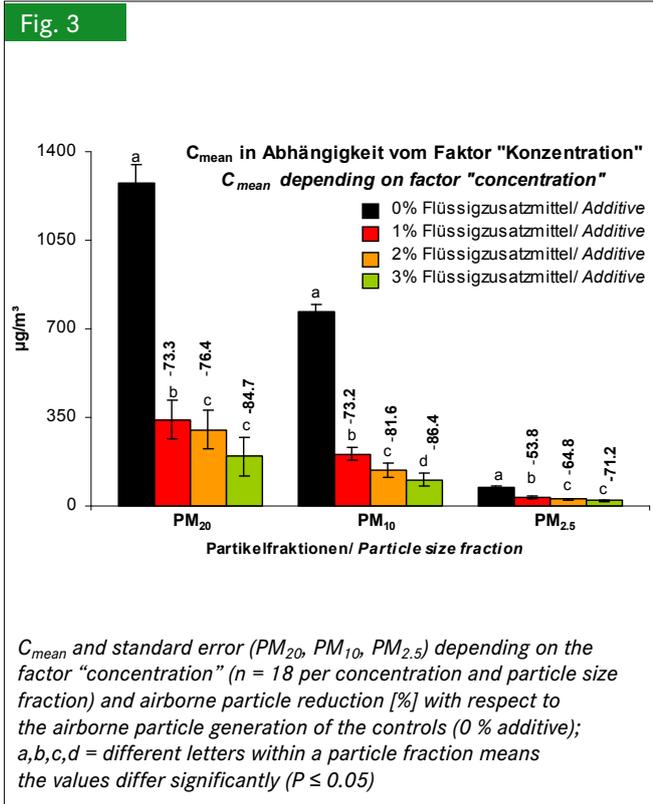
film on the surface of the grain enables the dust particle to be completely engulfed, thereby preventing a renewed dispersal of the dust particles.

Airborne particle analysis - Effect concentration -

As a consequence of the addition of 1 % of any of the additives, there was a significant ($P < 0.0001$) reduction in the airborne particle generation compared to the controls (**Figure 3**). There was also a significant reduction in airborne particle generation in all fractions when the additive was increased from 1 % to 2 %. There was only a significant reduction in the PM_{10} fraction by increasing the additive concentration further from 2 % to 3 % ($P = 0.0025$). The presence of 3 % additive resulted in a reduction in airborne particle generation of 84.7 % in the PM_{20} fraction ($PM_{10} = -86.4 \%$; $PM_{2.5} = -71.2 \%$) (**Figure 3**). Furthermore, the percentage reduction of airborne particles was roughly the same for all three additives in the PM_{20} and PM_{10} particle fractions. The reduction was much smaller in the $PM_{2.5}$ fraction. It appears that the separation efficiency is lower with smaller particles. One possible reason for this could be due to the cluster formation, whereby it is mainly the larger dust particles ($\leq 20 \mu\text{m}$) which form clusters when their moisture content is increased due to their larger surface area. These clusters are then removed from the air's total dust content by sedimentation [6].

Fig. 2





Airborne particle analysis - Interaction between "additive" and "concentration"

The interaction between the factors "additive" and "concentration" had only a significant effect on the airborne particle generation in the PM₁₀ fraction (P = 0.0016). The mixture of oats and 1 % rapeseed oil generated the lowest airborne particle concentration of 81.2 µg/m³ (-89.4 %) in this fraction (P <.0001) compared to the addition of water (300.3 µg/m³) or molasses (236.2 µg/m³) at the same dose. Again, at an addition of 2 %, the oat-oil mixture generated the lowest airborne particle concentration (PM₁₀) compared to water (P <.0001) or molasses (P = 0.0024). Through the addition of 3 % rapeseed oil to the oats, a 95 % reduction in airborne particle generation was achieved. The concentrations of airborne particles in the mixtures containing either 3 % water or 3 % molasses were significantly higher than the addition of 3 % rapeseed oil (P <.0001 and P = 0.0349, respectively) (Table 2).

Conclusions

The addition of water caused the lowest reduction in airborne particle generation, while the addition of rapeseed oil caused the highest reduction. It can, therefore, be concluded that from the point of reducing airborne particle generation, rapeseed oil is clearly a better additive than either molasses or water. In this study, the mixing of the oats with the liquid additives was done immediately before they were used (i.e. feeding in practice) so that predictions over possible, time-related storage influences (mould formation, rancidness) on the mixture could not be made.

Another reason could be the much lower initial concentration (control) of the PM_{2.5} particle fraction, so that a smaller reduction effect would be expected for these particles.

Table 2

Least squares means (LSM) and standard errors (SE) of C_{mean} [µg/m³] depending on the interaction between factors "additive" and "concentration (C)" and the reduction in airborne particle generation (E [%])

Flüssigzusatzmittel/Additive	C	Partikelfraktion/Particle size fraction						
		PM ₂₀		PM ₁₀		PM _{2.5}		
		LSM+ [µg/m ³]	E [%]	LSM++ [µg/m ³]	E [%]	LSM+++ [µg/m ³]	E [%]	
0-Probe/None	0 %	1273,1 ^a		768,7 ^a		73,3 ^a		
	Wasser/Water	1 %	504,6 ^b	- 60,4	300,3 ^b	- 60,9	43,5 ^b	- 40,7
		2 %	485,2 ^b	- 61,9	219,9 ^{bc}	- 71,4	33,1 ^{bc}	- 54,8
		3 %	310,7 ^{bc}	-75,6	202,4 ^c	- 73,7	26,8 ^c	- 63,4
Öl/Oil	1 %	120,3 ^c	- 90,6	81,2 ^d	- 89,4	24,9 ^{cd}	- 66,0	
	2 %	51,2 ^e	- 96,0	58,9 ^{de}	- 92,3	15,3 ^e	- 79,1	
	3 %	44,3 ^e	- 96,5	38,4 ^e	- 95,0	15,0 ^e	- 79,5	
Melasse/Molasses	1 %	393,2 ^b	- 69,1	236,2 ^{bc}	- 69,3	33,2 ^{bc}	- 54,7	
	2 %	365,2 ^{bc}	- 71,3	146,2 ^c	- 81,0	28,8 ^{cd}	- 60,7	
	3 %	230,2 ^c	- 81,9	72,4 ^d	- 90,6	21,6 ^d	- 70,5	

a,b,c,d,e = LSM mit unterschiedlichen Buchstaben innerhalb einer Partikelfraktion unterscheiden sich signifikant voneinander (P < 0,05) (LSM* [SE = 132.6]; LSM** [SE = 46.9]; LSM+++ [SE = 5.8]).
 a,b,c,d,e = LSM within each particle fraction with different letters are significantly different (P < 0.05).

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