Measurements of Odour Emissions

Use of Means of Olfactometry and Chemical Sensor Arrays for the Comparison of Different Housing Systems for Fattening Pigs

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Due to the increasing sensitivity of the population, the measurement of undesirable odours from agricultural animal husbandry has become a problem which may no longer be neglected. For this reason, objective odour registration is necessary.
In this contribution, the results of a comparison of different housing systems for fattening pigs by means of olfactometry and a multisensor array are documented. The great advantage of the chemical sensor array measurements over olfactometry mainly resides in the continuous registration of measurement values as compared with the small number of samples collected during olfactometric measurements. A long-term comparison of a conventional warm house and two different outdoor climate stall compartments on the same farm allowed the odour emissions of the different housing systems to be assessed. During three measuring periods distributed over one year, olfactometric measurements were taken daily. In addition, continual chemical sensor array measurements were conducted during one of the observation periods. As compared with the conventional temperature-insulated, partially slatted stall with forced ventilation, a reduction of the odour emission potential of the outdoor climate experimental compartments with partially slatted floors or litter was proved during all three measuring periods.

Keywords
Emission, odour, monitoring, housing systems, fattening pigs, chemical sensor array

Introduction

As a result of denser population, more and more residents feel bothered by odour, especially from farm animal husbandry. Therefore, the odour emissions of different housing systems for fattening pigs were measured in a long-term trial. In this contribution, the results of olfactometric odour measurements during three measuring periods in different seasons are published. Additionally, continuous odour monitoring by means of a chemical sensor array was carried out during one of the evaluation periods.

Experimental Farm

Due to multi-factorial influences, system comparisons of housing systems for fattening pigs on several farms are virtually impossible. For this reason, a new outdoor climate house for 600 fattening pigs with resting pens and a partially slatted floor on a liquid manure basis was built on a farm. On this experimental farm with a total of 1,000 places for fattening pigs, a conventional warm house with a slatted floor (kW) for 52 animals, an outdoor climate house with resting pens and a partially slatted floor (AKt), and an outdoor climate house with resting pens and a littered dung area (AKe) for 64 animals each can be directly compared in three separate main experimental units.

Approach

Exhaust Air Volume Flow
For the continuous measurement of the exhaust air volume flow from freely ventilated outdoor climate houses, a method suitable for practical investigations is not yet available. Balance measurements (CO_2 balance, H_2O balance, and heat balance) as well as tracer gas measurements are too imprecise or too time consuming for continuous measurements and cannot be employed continually because tracer gas release and -sampling are adapted to the wind direction. For these reasons, the two outdoor climate experimental compartments are encapsulated air-tight according to the dynamic chamber method. The rest of the outdoor climate house serves as a reference compartment (AKt0).
In general, outdoor climate houses for fattening pigs are built at right angles to the main wind direction (here: west), which causes a transverse air flow in the stall due to the predominant wind direction. In accord with this phenomenon, a funnel-shaped extension is attached to the outer spaceboard walls on the west side of each of the two outdoor climate experimental compartments examined, through which air flows into the stall. Analogue to this, the same funnel-like extensions, equipped with a centrally fitted exhaust fan, are attached to the opposing east side of the experimental compartments.
A temperature regulator is used to control this exhaust fan. For this purpose, a temperature sensor continually measures the temperature in the non-encapsulated outdoor climate house (AKt0) and transmits it as set temperature for temperature control. At the same time, the actual temperature is measured in the encapsulated outdoor climate experimental compartment with a partially slatted floor (AKt) and continuously compared with the set temperature by the temperature regulator. Depending on the deviation of the two set- and actual values, the temperature regulator sends a control signal to the two frequency converters which control the exhaust fans of the two experimental compartments. This approach has been chosen because, given the same ambient parameters (temperature, wind speed and -direction, humidity, radiation) and the same number of animals in the stall, the temperature is a measure of the amount of air which flows through the experimental compartments. The exhaust air volume flow can thus be measured easily with the aid of downstream measuring fans [1].

In the conventional warm house with forced ventilation, the exhaust air volume flow was also registered with measuring fans.

Figure 1 summarizes the experimental design: the odorant concentrations are measured at the air exits of the experimental compartments. With the aid of a measuring point change-over switch, the experimental compartments are sampled one after another. The measured odorant concentrations and the exhaust air volume flows measured at these times are then used to calculate the odorant emission flows. The sample ducts out of FEP (tetrafluoroethylene-perfluoropropylene) are heated in order to prevent condensation and adsorption at the inner walls of the hoses. The odour samples for the olfactometer group are also taken in the measuring cabin after the switching of the measuring points.

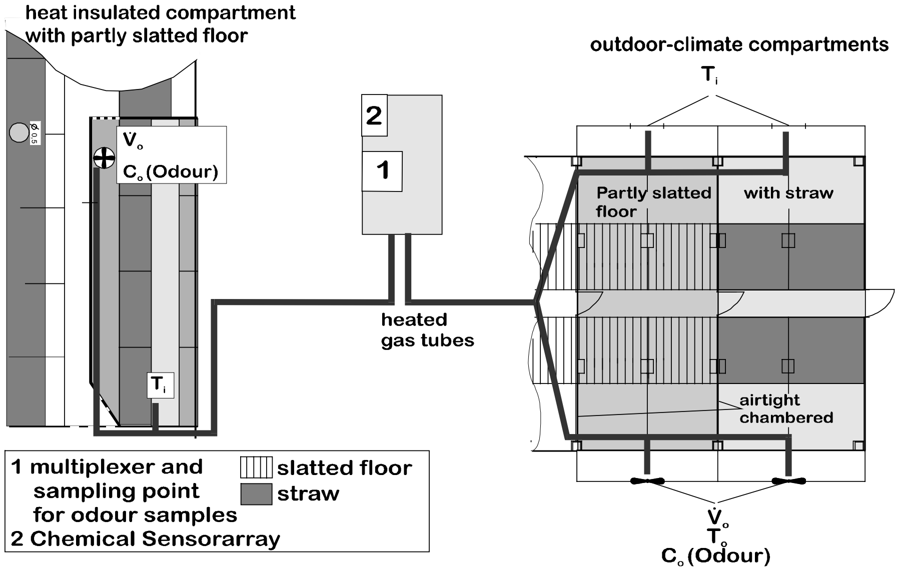

Figure 1: Experimental design for the measurement of the odour emission rates of the three experimental compartments

Results

Odorant concentration

By means of olfactometry [2, 3] (olfactometer according to Mannebeck, TO4), the odorant concentrations in OU/m^3 at the different measuring points were determined in the exhaust air of the outdoor climate experimental compartments and in the conventional warm house during three 8-10 day investigation periods in April 1999, August 1999, and January 2000. The measured odorant concentrations are shown in **figure 2**.

During all three measuring periods, the average odorant concentrations from the outdoor climate experimental compartments range significantly below those of the conventional warm house (figure 2). During the April measurement (G1), the average odorant concentration amounted to 74 OU/m^3 in the AKt and 83 OU/m^3 in the AKe. In the kW, concentrations were four to five times higher during the same measuring period, reaching 365 OU/m^3. During the August measurement (G2), the concentrations in the two outdoor climate experimental compartments were approximately as high as during the April measurement. The odorant concentrations in the warm house, however, averaged 197 OU/m^3 - only less than half as high as during the April measurement, but still 2 to 3 times higher than in the outdoor climate experimental compartments. The lower odorant concentration in the conventional warm house must be attributed to the exhaust air rate at the individual sampling time, which was higher during the August measurement (G1: 4,000 m^3/h; G2: 5,000 m^3/h).

During the winter measurement, the odorant concentrations in both outdoor climate experimental compartments (G3) ranged between 32 OU/m^3 (AKt) and 27 OU/m^3 (AKe) and were thus again considerably below the concentrations measured in the kW (221 OU/m^3). In addition, the concentrations in the outdoor climate experimental compartments are only approximately half as high during G3 as during the two other experimental periods, which must be put down to the low average outside temperatures of -4.0°C at that time (G3) and the low stall temperatures, which averaged 5.6°C.

With regard to the odorant concentrations, the two outdoor climate experimental compartments exhibit virtually no differences. The differences between these compartments and the conventional warm house, however, are significant. The ranges of variation shown in figure 2 (standard deviation of the odorant concentration measurement during measurements extending for several days in one experimental compartment each) overlap almost completely in the two outdoor climate experimental compartments and hence do not enable the two systems to be distinguished. The distance to the warm house, however, is significant.

During the experimental period G2 (August 1999), continual monitoring with a chemical sensor array (already described in reference [4]) was carried out in addition to the olfactometric measurements. The sensor measurements were conducted at all three measuring points within the different housing systems by sampling all three measuring points once per hour. These sensor measurements were calibrated using the olfactometric odorant concentrations (**figure 3**).

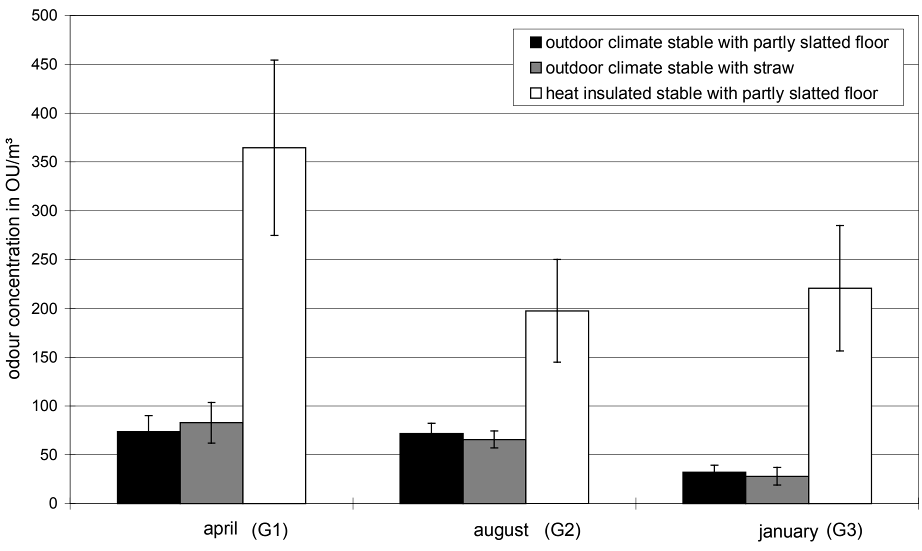

Figure 2: Average odorant concentration in OU/m^3 at the olfactometer TO4 (with standard deviation of the odorant concentration during each measuring period)

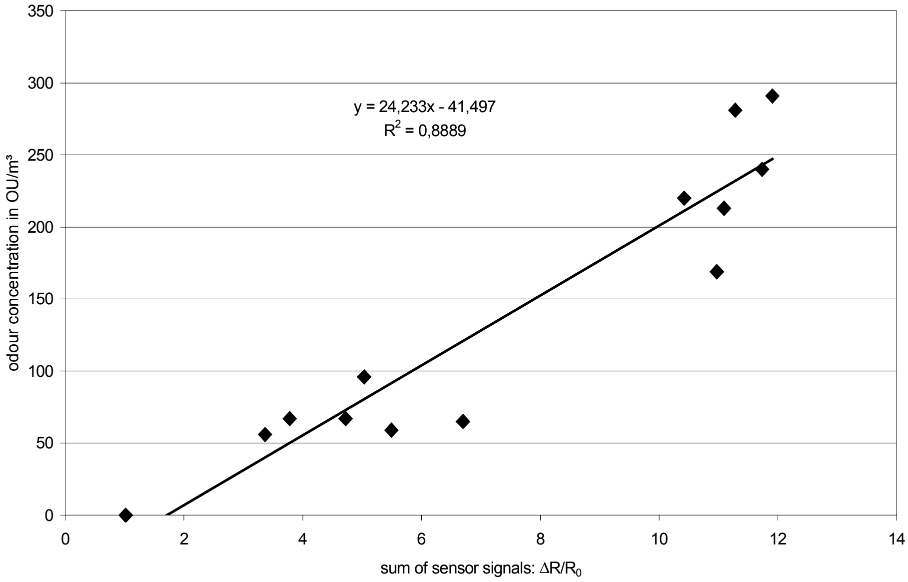

Figure 3: Regression of the sum of sensor signals and odorant concentration

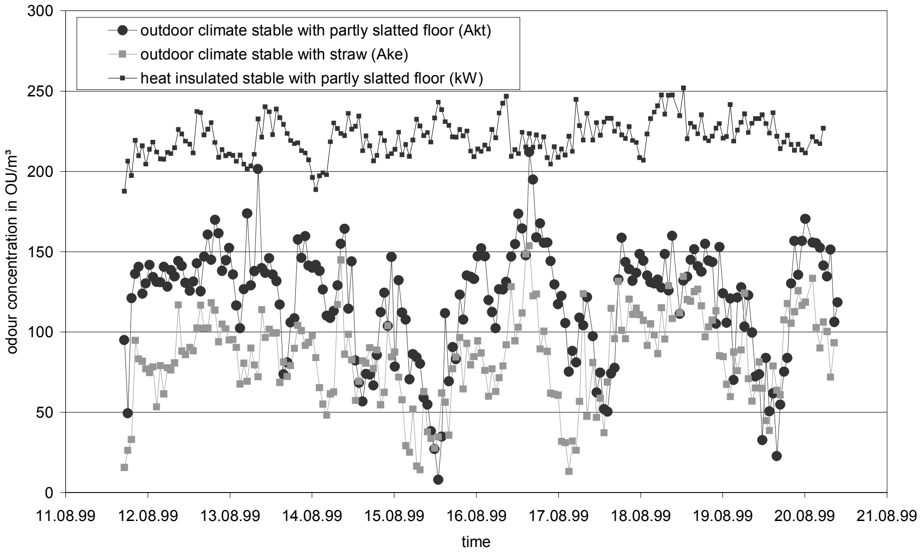

Figure 4: Odour monitoring using an olfactometrically calibrated chemical sensor array during the August measurement (G2)

Table 1: Mean exhaust air volume flows during the odorant concentration measurements and their relative standard deviation, referred to the average value

	Conventional warm house	Outdoor climate house with a partially slatted floor	Outdoor climate house with litter
	Ø exhaust air flow in m³/h (± standard deviation in % from the mean value)		
G1	4000 (± 23)	8300 (± 30)	8400 (± 30)
G2	5000 (± 0)	7900 (± 24)	7700 (± 17)
G3	3000 (± 45)	5400 (± 52)	5000 (± 56)

With the aid of the regression shown above, the odorant concentration in the different housing systems is documented continuously, using the observation period G2 as an example. This monitoring is shown in **figure 4**.

Consistent with the measurement values established through olfactometry, the continual measurement shows constantly higher odorant concentrations in the warm stall than in the two outdoor climate house compartments. The variability of the concentrations in the area of the outdoor climate experimental compartments was also shown to be greater than in the warm house. The conventional, discontinuous method of olfactometry does not allow such temporal dynamics to be measured. With this newly developed method, housing systems can be compared continually over a longer period with regard to odorant concentrations.

Odour Emission Flow

The odour emission flow in OU/time unit is calculated by multiplying the odorant concentrations shown above by the current exhaust air volume flows during the individual time period (**table 1**). The thus calculated odour emission flows which occur in the different housing systems during the three measuring periods are shown in **figure 5**. In contrast to the odour emission rate, which will be discussed below, the term „odour emission flow in OU/time unit" does not yet comprise a standardization with regard to the animal mass.

In comparison with the the odorant concentrations shown in OU/m^3, the odour emission flows from the three examined housing systems converge because significantly lower concentrations are multiplied by an exhaust air volume flow which is higher by the factor 1.5 in the outdoor climate experimental compartments (cf. table 1). During all measuring periods, the resulting odour emission flows from the outdoor climate experimental compartments nevertheless range below those of the conventional warm house. During G1, the odour emission flows in the outdoor climate experimental compartments are at 170 OU/s (with partially slatted floors) and at 190 OU/s (with litter) as compared with 410 OU/s in the conventional warm house. During G2, the odour emission flows in the two outdoor climate experimental compartments amount to ca. 150 OU/s, while they reach only 275 OU/s in the conventional warm house. During G3, the very low emission flows of 40 OU/s and 30 OU/s respectively in the two outdoor climate experimental compartments with a partially slatted floor and litter contrast with 190 OU/s from the conventional warm house.

As with the results of the odorant concentration measurement, the differences between the outdoor climate kennel house with a partially slatted floor and the outdoor climate house with litter are only small. This difference between the two experimental compartments also clearly manifests itself in the standard deviation, which is shown as a bar in figure 5. Here, the standard deviations of the two outdoor climate experimental compartments always overlap, while the AKe and the kW during the April measurement and the AKt and the warm house during the August measurement (G2) merely converge. The difference between these two experimental compartments and the conventional warm house, however, thus proves to be significant.

In order to make the measured emission flows comparable, they are correlated with the total animal mass in the experimental compartments during the odour measurement and standardized for 500 kg of live mass (LM). These calculations yield the values shown in **figure 6** for the investigation periods G1-G3. **Table 2** contains the animal weights required for the calculation of these odour emission rates.
The standardized odour emission rates (figure 6) provide the same result as the emission flows and the concentrations. The two outdoor climate experimental compartments differ only slightly and, due to the overlapping standard deviations, not unambiguously. The difference between these compartments and the average odour emission rate of the conventional warm house, however, is clear, and the standard deviations of the mean values during the measurements do not overlap either.
Since the number of animals in the outdoor climate experimental compartments and in the conventional warm house differs (table 2) in contrast to the average weights, the total animal mass in the conventional warm house is lower than in the outdoor climate experimental compartments. Therefore, the differences between the emission rates are more pronounced here than in the odour emission flow.
Consistent with olfactometry, the continuous measurement with a chemical sensor array shows higher average odour emission rates from the warm house than from the outdoor climate experimental compartments (**figure 7**). This method additionally enables the temporal dynamics of the measurement values to be registered. It becomes clear that the measurement values in the area of the outdoor climate experimental units exhibit high variability, which must be attributed to the influences of the temperatures and the volume flows.
Once again, the benefits of continual measurement become obvious here. As shown above, daytime-related fluctuations of the odour emission rates cannot be measured by means of the olfactometric method.

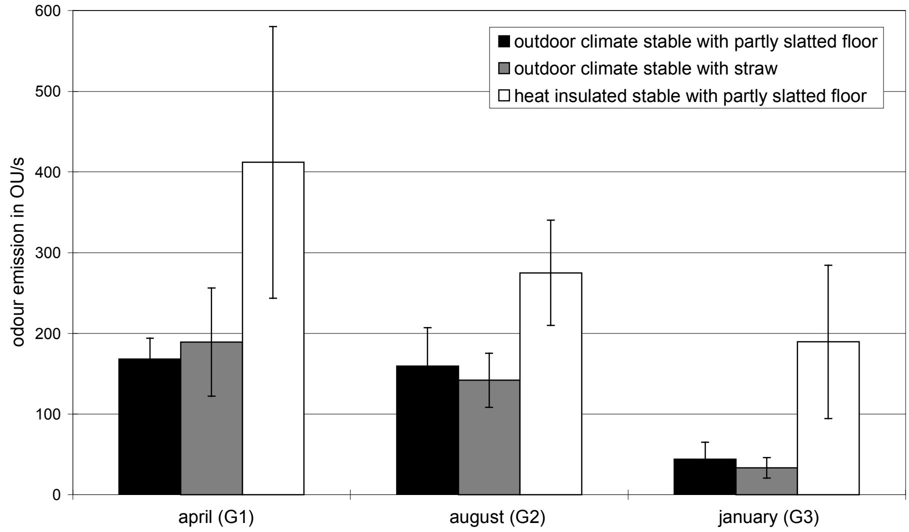

Figure 5: Average odour emission flow in OU/s (with standard deviations of the odour emission flows during each measuring period)

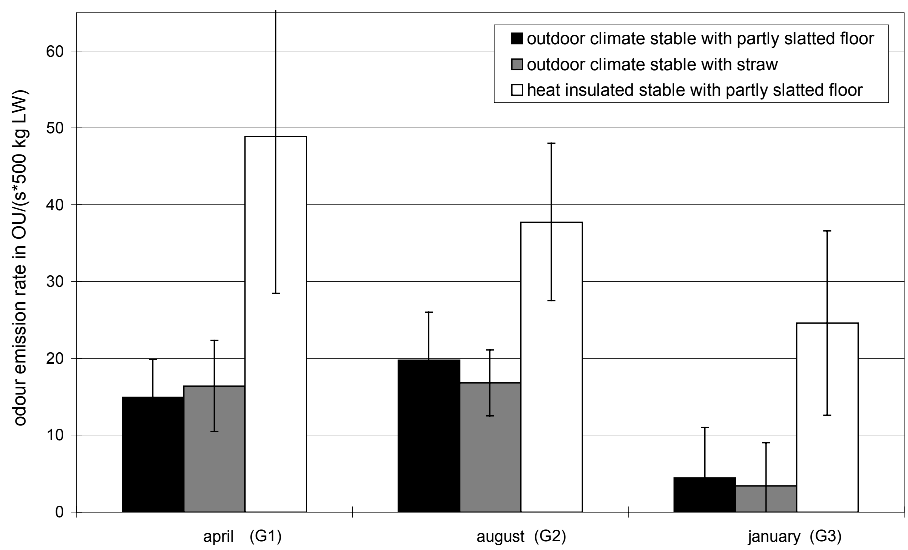

Figure 6: Odour emission rates in OU/(s*500 kg LM) (with standard deviations of the odour emission rates during each measuring period)

Table 2: Number of the animals and corresponding animal weights during odour maesurement

	Conventional warm house			**Outdoor climate house with a partially slatted floor**			**Outdoot climate house with litter**		
		animal weight in kg			animal weight in kg			animal weight in kg	
	Number of animals	Ø	Σ	Number of animals	Ø	Σ	Number of animals	Ø	Σ
G1	52	81	**4227**	64	88	**5620**	64	90	**5770**
G2	52	70	**3591**	64	63	**4008**	64	66	**4202**
G3	52	74	**3844**	64	77	**4908**	64	77	**4928**

Evaluation of the Results

During three measuring periods, which were distributed over one year, olfactometric measurements were taken daily. In addition, measurements with a chemical sensor array were conducted continuously during one of the observation periods.

As already described in reference [4], it was again possible here to document the suitability of the chemical sensor array technology for the measurement of odours from agriculture. Such monitoring can therefore measure odour emissions outside the usual worktime of the test persons of an olfactometry group. The suitability of the chemical sensor array technology was clearly proven [3; 4]. For this reason, it will be possible in the future to employ this technology directly for long-term monitoring and the assessment of process-technological measures.
With regard to magnitude, the odour emission rates measured for the kW of 48.9 (G1), 37.8 (G2), and 24.6 (G3) OU/(s*500 kg LM) are at the same level

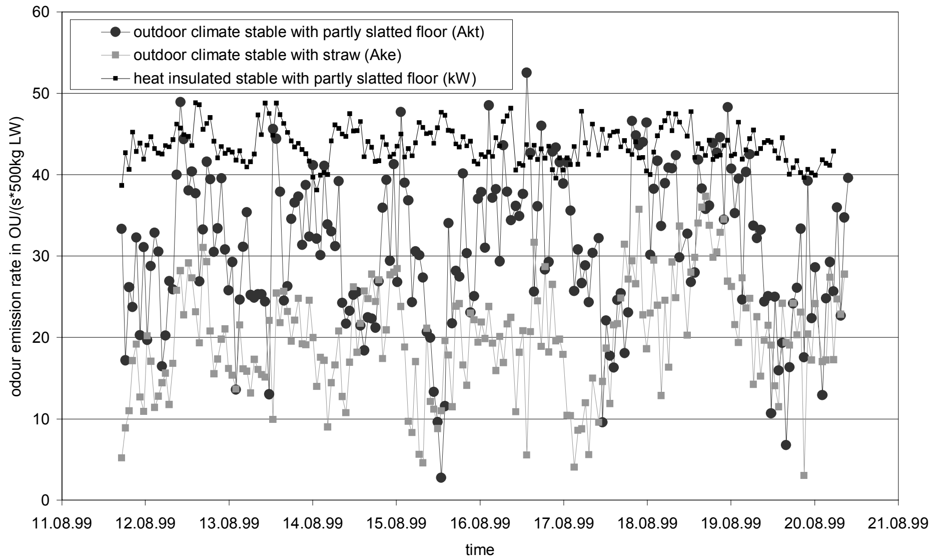

Figure 7: Odour emission monitoring using an olfactometrically calibrated chemical sensor array during the August measurement (G2)

as the results of references [5, 6, 7, 8] and [9] in [10] in a partially slatted floor and a fully slatted floor of 52 OU/(s*500 kg LM) or 39-78 OU/(s*500 kg LM) respectively. The results of the author´s own measurements during all measuring periods (G1 to G3) fall into the lower range. For the results of the author´s own measurements in the outdoor climate experimental compartments, which yielded values of 14.9, 19.8, and 4.4 OU/(s*500 kg LM) in the AKt and 16.4, 16.8, and 3.4 OU/(s*500 kg/LM) in the AKe, no comparable data can be found in the literature. With regard to the odour emission rates, no differences were established between the two outdoor climate experimental compartments. In comparison with the conventional warm house (kW), emission rates from the outdoor climate experimental compartments are lower by the factor 2 in the summer, averaging 18.3 OU/(s*500 kg LM), and by the factor 7 in the winter with an average of 3.7 OU/(s*500 kg LM).

Due to the limited representativeness of the selected measuring periods, the absolute amount of the measured emission rates can only serve as orientation. Given the same influence of the farm manager and identical ambient conditions, however, a comparison of the examined systems is possible. As compared with the conventional temperature-insulated, partially slatted stall with forced ventilation, a reduction of the odour emission potential in the outdoor climate experimental compartments with a partially slatted floor or with litter was proved in these experiments during all 3 measuring periods.

In this project, it has not been examined whether and to what extent the different spreading mechanisms, which result from the design of the fresh- and exhaust air openings of the outdoor climate houses in comparison with the conventional warm houses, exert an influence on the odour input at varying distances from the stall.

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