Dynamics of Odour Release from a Pig Stall – Part 2

Results of Parallel Measurements with Olfactometry and the “Electronic Nose”

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The heavily fluctuating operating conditions in pig husbandry due to climatic and biological changes (alterations of temperature and air flow rate between day and night as well as between summer and winter, increasing animal mass during the fattening process, etc.) exert a significant influence on the amount of actual odour emission. The examination programme of the presented project comprised the measurement of seasonal (fattening course), daytime-related, and short-term (feeding) dynamic effects of odour release, as well as the identification of potential factors which influence the amount of odour emitted. Parallel to “classic” olfactometry, an “electronic nose” with a chemosensor array of ten metal oxide sensors was employed. The largest odour emissions are measured on hot summer days, while the lowest emissions were determined on cold winter days. On the one hand, the sensor signals of the “electronic nose” exhibit considerable differences on days with large air flow rate alterations. On the other hand, continuous measurement with the “electronic nose” allows changes in the gas- and odorant composition of the exhaust air during the feeding times to be shown. From the measurement results, recommendations for odour sampling, the consideration of seasonal odour emission fluctuations in odour spreading calculations, and the use of “electronic noses” for the evaluation of odour emissions have been derived.

Keywords
Odour, olfactometry, electronic nose, chemosensor array, pig husbandry

Introduction

In the first part of this contribution [1], the problems and the goals of the examinations carried out, the trial equipment, the two methods used and the instruments for odour measurement - olfactometry and the “electronic nose” - , as well as the examination programme have already been presented and described in detail. The second, final part provides an overview of the measurements carried out during the examinations and presents exemplary results for individual aspects.

Results

Measurements with both the olfactometer and the “electronic nose” were carried out in three successive fattening periods in a pig stable with forced ventilation described in the first part of this contribution [1]:

- fattening period 1: 08/2000 until 12/2000 (autumn/winter)
- fattening period 2: 01/2001 until 05/2001 (winter/spring)
- fattening period 3: 06/2001 until 10/2001 (summer)

In all three fattening periods, the odour concentrations were analyzed olfactometrically using at least two odour samples per week. In addition, a larger number of odour samples (6-8) was taken on six days (i.e. mornings) for the olfactometric analysis of odour concentration. Moreover, several odour samples were analyzed olfactometrically at 16 feeding times.

Measurements with the “electronic nose” are also available from all fattening periods. The first fattening period was mainly used for orienting measurements which served to optimize the operational parameters of the “electronic nose” (measuring time, rinsing time, reference gas, etc.). For better adaptation to the problem to be examined, the measuring mode was changed from a semi-continuous mode of operation with short measuring- and rinsing periods (30-60 seconds and 2-5 minutes respectively) in the first fattening period to a quasi-continuous mode of operation with long measuring periods (75 minutes) and regular rinsing times (15 minutes) in the second and third fattening period so that rinsing was done between the feedings and continuous measurements were taken during the feedings. A total of 18 measurements over 24 hours along with numerous other measurements (during individual feeding times, etc.) were taken with the “electronic nose” (**table 1**).

In general, the odour samples for olfactometry were taken parallel to measurements with the “electronic nose”, which were either distributed over the day for the determination of the daily course or around one feeding period for the establishment of the feeding influence. Below, selected measurement results describing the different influences on odour release are presented. These results enable the significant dynamic effects of odour release and their consequences for the measurement results to be explained.

Temporal Influences

The temporal influences can be divided into seasonal, daytime-related, and short-term influences and are discussed separately below.

Influence of the Course of the Year

Figure 1 shows the course of the olfactometrically measured odour data over the three fattening periods. The fattening periods, which lasted approximately 4 months each, fell in different seasons, which influenced the amount of the temperature-controlled exhaust air flow rate. Due to the outside temperature, which is dependent upon the season, the first fattening period in autumn shows a tendentially falling air flow rate, while the second fattening period in the spring exhibits an increasing air flow rate. In the third fattening period in the summer, the air flow rate is mostly high. For the weekly measuring days, the mean values from two different odour samples taken at different daytimes are shown. The odour concentrations largely range between 1,000 and 3,000 OU m^{-3}. However, they may reach values below 500 OU m^{-3} in the summer and more than 4,000 OU m^{-3} in the winter. Odour emission fluctuates between 500 and 4,000 OU s^{-1} and is tendentially higher in the summer when air flow rates are large. Due to the increasing animal weight, the odour emission factor shows a decrease by a factor of approximately 2 in all three fattening periods and ranges from between 100 and 550 OU s^{-1} LU^{-1}.

All weekly odour data as well as the individual marginal conditions are shown in **Table 2, 3**, and **4**. The mean values of the temperature-, humidity-, and air flow rate conditions mainly reflect the seasons of the approximately 4-month fattening periods. The mean odour concentrations, -emissions, and -emission factors of the individual fattening periods exhibit values which correspond to the time of the year. Since, however, the fattening periods extend over at least two seasons due to their duration, the differences in the odour data between the individual fattening periods are reduced in some cases. Nonetheless, the second fattening period, which largely falls in the winter, shows the lowest average exhaust air flow rate and the highest odour concentration. During the third fattening period, which was characterized by summery weather conditions, the highest average odour emission and the largest odour emission factor were measured.

The seasonally varying outside temperature significantly influences the amount of the exhaust air flow rate of the temperature-guided ventilation control system, which causes large air flow rate differences between cold winter days and hot summer days. When the air flow rate over the emission-relevant surfaces increases, higher flow-over speeds are induced, which increase odour release. In **Figure 2** and **Figure 3**, the influence of the exhaust air flow rate on odour concentration and odour emission is shown. Tendentially, odour concentrations in large exhaust air

Table 1: Overview of the 24-hour measurements with the „electronic nose“

Date	Goal of the measurements	Odour samples
07.-08.02.2001	24-hour measurement	feeding
24.-26.04.2001	48-hour measurement	morning/feeding
02.-04.05.2001	48-hour measurement	morning
19.-21.06.2001	48-hour measurement with large day/night temperature amplitude	morning
26.-28.06.2001	48-hour measurement on hot summer days	feeding
18.-19.07.2001	24-hour measurement	feeding
24.-25.07.2001	24-hour measurement in hot and humid weather	feeding
14.-15.08.2001	24-hour measurement at hot temperatures	feeding
28.-29.08.2001	24-hour measurement at moderate temperatures	feeding
04.-05.09.2001	24-hour measurement at cool temperatures	feeding
11.-12.09.2001	24-hour measurement at cool temperatures	morning/feeding
18.-19.09.2001	24-hour measurement (cold night)	day/ feeding
25.-26.09.2001	24-hour measurement	day
31.10.2001	manual variation of the air flow rate	yes

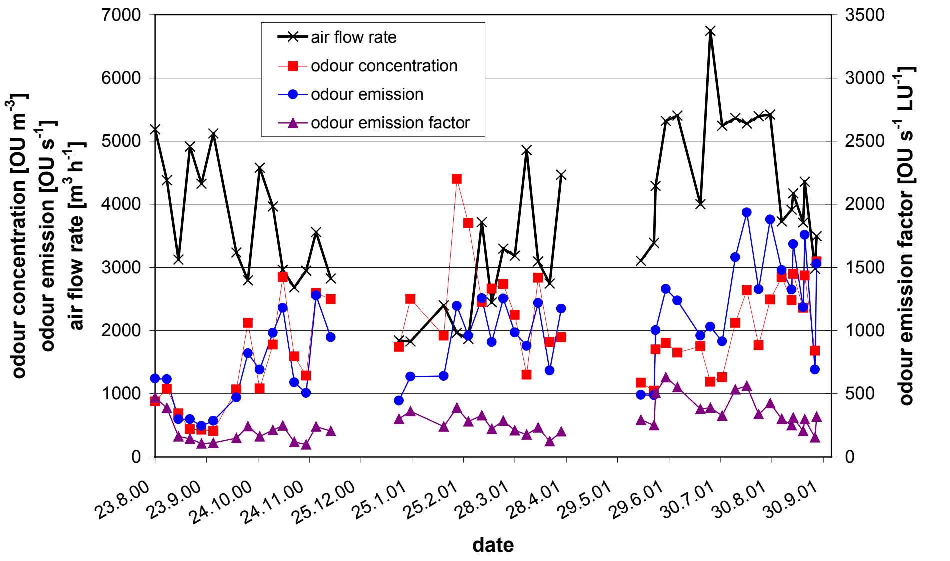

Figure 1: Course of olfactometrically measured odour concentration (average of two odour samples), odour emission, odour emission factor, and air flow rate over the three examined fattening periods

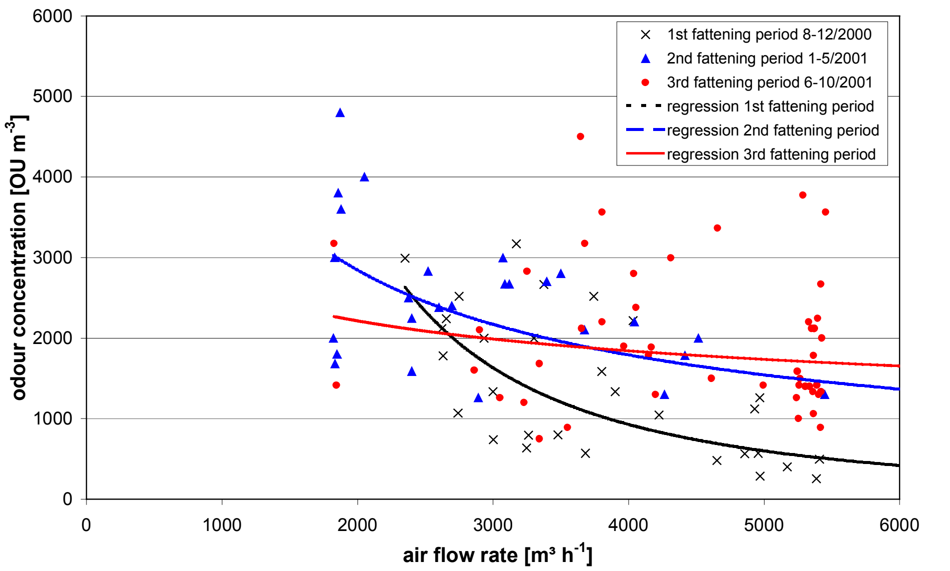

Figure 2: Influence of the exhaust air flow rate on odour concentration (determined based on weekly odour samples in the three fattening periods)

Table 2: Overview of weekly odour data and marginal conditions in the first fattening period (08-12/2000)

Date	sampling	Tempera-ture inside	relative humidity inside	Tempera-ture outside	Odour concentration		air flow rate	Odour emission	Odour emission factor	animal weight
		°C	%	°C	OU/m³	+/- dB	m³/h	OU/s	(OU/s)/LV	LU (500 kg)
23.08.2000	11:25	25.0	52	26.0	1259	1.8	4967	1737	659	2.63
23.08.2000	11:55	25.0	49	25.0	495	1.2	5408	744	282	2.63
30.08.2000	09:45	24.0	54	24.0	1586	2.3	3801	1675	528	3.17
30.08.2000	11:25	25.0	52	23.0	570	1.0	4957	785	247	3.17
06.09.2000	10:30	23.0	50	14.0	738	1.3	3001	615	166	3.72
06.09.2000	11:45	23.0	50	14.0	637	1.9	3247	575	155	3.72
13.09.2000	09:45	24.0	61	22.0	479	1.3	4651	619	149	4.15
13.09.2000	14:20	25.0	64	22.0	400	1.4	5171	575	138	4.15
20.09.2000	10:25	22.8	61	17.0	570	1.3	3682	583	125	4.67
20.09.2000	14:05	25.0	56	17.0	285	2.3	4971	394	84	4.67
27.09.2000	09:40	24.5	60	21.0	564	1.8	4858	761	146	5.20
27.09.2000	13:25	26.0	53	19.0	254	2.4	5385	380	73	5.20
11.10.2000	09:50	22.8	56	10.5	1333	1.4	2999	1110	176	6.32
11.10.2000	13:20	23.0	58	11.7	800	1.7	3478	773	122	6.32
18.10.2000	09:50	21.4	57	12.0	1998	2.0	2934	1628	241	6.76
18.10.2000	12:30	22.0	62	12.0	2242	2.1	2655	1653	245	6.76
25.10.2000	10:20	22.0	56	18.0	1044	1.5	4224	1225	142	8.64
25.10.2000	12:47	23.0	55	18.0	1121	2.1	4931	1535	178	8.64
02.11.2000	09:30	21.2	51	15.0	2217	1.9	4033	2484	268	9.28
02.11.2000	11:36	22.0	45	15.0	1333	1.8	3901	1444	156	9.28
08.11.2000	10:55	21.0	55	13.0	2517	1.8	2750	1923	201	9.57
08.11.2000	12:20	21.6	51	13.0	3171	0.9	3172	2794	292	9.57
15.11.2000	09:33	21.8	57	10.0	2117	2.1	2622	1542	156	9.89
15.11.2000	11:06	21.5	55	10.0	1067	1.7	2741	812	82	9.89
22.11.2000	08:48	20.8	45	12.0	1780	2.3	2632	1301	127	10.28
22.11.2000	12:20	21.2	54	12.0	793	2.1	3261	718	70	10.28
28.11.2000	10:15	21.2	56	12.0	2667	1.4	3375	2500	234	10.67
28.11.2000	11:00	21.8	61	12.0	2517	1.8	3744	2618	245	10.67
07.12.2000	08:59	20.2	49	8.0	2993	1.6	2351	1955	211	9.26
07.12.2000	14:04	21.3	43	8.0	1998	1.3	3302	1833	198	9.26
Mittelwerte		**22.7**	**54**	**15.5**	**1385**	**1.7**	**3773**	**1310**	**203**	**6.95**

Table 3: Overview of weekly odour data and marginal conditions in the second fattening period (01-05/2001)

Date	sampling	Tempera-ture inside	relative humidity inside	Tempera-ture outside	Odour concentration		air flow rate	Odour emission	Odour emission factor	animal weight
		°C	%	°C	OU/m³	+/- dB	m³/h	OU/s	(OU/s)/LV	LU (500 kg)
17.01.2001	09:55	20.4	31	-1.3	1800	1.3	1849	924	311	2.97
17.01.2001	12:45	20.8	37	4.2	1682	0.9	1833	856	288	2.97
24.01.2001	09:05	21.7	50	10.3	3000	1.8	1832	1527	434	3.52
24.01.2001	10:05	21.5	47	11.2	2000	1.6	1821	1012	287	3.52
13.02.2001	10:30	23.0	50	8.0	2245	1.3	2400	1497	280	5.35
13.02.2001	10:56	23.0	49	8.5	1587	1.7	2400	1058	198	5.35
21.02.2001	08:35	21.5	40	3.1	4800	1.2	1872	2497	406	6.14
21.02.2001	11:25	22.2	44	4.2	4000	1.6	2052	2280	371	6.14
28.02.2001	08:47	21.5	38	-0.5	3600	1.8	1879	1879	275	6.83
28.02.2001	11:42	21.9	38	4.3	3800	1.0	1856	1960	287	6.83
08.03.2001	13:05	23.1	51	12.1	2700	2.8	3395	2546	334	7.62
08.03.2001	15:15	23.9	58	14.5	2200	2.0	4043	2470	324	7.62
14.03.2001	10:09	22.5	42	5.4	2828	1.7	2520	1979	241	8.22
14.03.2001	10:18	21.5	41	5.4	2500	1.4	2376	1650	201	8.22
21.03.2001	10:15	22.1	47	10.6	2670	2.3	3087	2290	260	8.80
21.03.2001	12:30	22.3	46	12.0	2800	1.5	3500	2722	309	8.80
28.03.2001	09:45	21.7	42	7.2	2400	1.7	2696	1797	192	9.38
28.03.2001	11:25	22.3	45	10.8	2100	1.6	3675	2144	228	9.38
04.04.2001	10:05	23.0	39	14.8	1300	2.2	4265	1540	155	9.97
04.04.2001	11:25	23.6	40	16.6	1300	2.4	5447	1967	197	9.97
11.04.2001	09:20	21.5	45	6.9	2997	2.0	3072	2558	242	10.55
11.04.2001	11:45	21.5	40	8.6	2670	1.8	3119	2313	219	10.55
18.04.2001	08:55	21.0	38	6.0	2378	1.5	2600	1717	154	11.13
18.04.2001	11:08	21.3	37	7.1	1260	1.2	2891	1012	91	11.13
25.04.2001	10:08	22.4	43	13.5	1782	3.6	4415	2185	187	11.72
25.04.2001	11:36	22.6	46	14.8	2000	2.6	4515	2509	214	11.72
02.05.2001	15:55	28.4	27	29.9	704	1.5	8821	1725	503	3.43
Mittelwerte		**22.3**	**43**	**9.2**	**2411**	**1.8**	**3120**	**1875**	**266**	**7.70**

Table 4: Overview of weekly odour data and marginal conditions in the third fattening period (06-10/2001)

Date	sampling	Temperature inside	relative humidity inside	Temperature outside	Odour concentration		air flow rate	Odour emission	Odour emission factor	animal weight
		°C	%	°C	OU/m^3	+/- dB	m^3/h	OU/s	(OU/s)/LV	LU (500 kg)
12.06.2001	10:16	23.8	43	14.5	1600	1.4	2862	1272	379	3.35
12.06.2001	11:07	24.4	41	15.8	749	1.3	3343	695	207	3.35
20.06.2001	09:40	24.0	51	14.0	1200	1.5	3229	1076	274	3.93
20.06.2001	11:40	24.5	44	16.8	890	1.3	3551	878	223	3.93
21.06.2001	08:54	24.8	46	17.3	1900	1.0	3965	2093	527	3.97
21.06.2001	09:31	25.3	47	18.5	1500	2.3	4611	1921	484	3.97
27.06.2001	10:29	29.6	46	22.9	2200	2.3	5329	3257	773	4.21
27.06.2001	11:02	29.7	46	24.5	1400	1.7	5305	2063	490	4.21
04.07.2001	10:27	27.3	37	21.2	891	1.8	5417	1341	298	4.50
04.07.2001	10:38	27.5	37	21.6	2000	1.4	5426	3015	670	4.50
04.07.2001	10:45	27.5	38	21.6	2245	1.8	5395	3364	748	4.50
04.07.2001	10:55	27.8	39	21.8	1335	1.6	5420	2010	447	4.50
04.07.2001	11:02	27.9	38	21.7	1782	1.8	5364	2655	590	4.50
18.07.2001	11:56	24.9	53	16.1	2200	1.3	3804	2325	459	5.07
18.07.2001	12:11	24.7	56	16.0	1300	1.2	4198	1516	299	5.07
24.07.2001	12:37	30.6	46	25.1	1587	1.2	5245	2312	436	5.31
24.07.2001	12:45	30.6	45	25.0	790	1.7	8252	1811	341	5.31
31.07.2001	06:45	25.8	45	16.3	1414	1.7	4994	1962	351	5.59
31.07.2001	07:50	26.4	53	18.2	1400	1.2	5336	2075	371	5.59
31.07.2001	08:45	27.5	55	20.8	1059	1.3	5364	1578	282	5.59
31.07.2001	10:27	30.3	40	24.7	1414	1.9	5259	2066	369	5.59
31.07.2001	12:07	32.1	34	27.6	1260	1.9	5239	1834	328	5.59
31.07.2001	12:35	32.4	32	28.4	1000	1.4	5254	1460	261	5.59
08.08.2001	09:50	26.2	67	18.3	2119	2.0	5351	3150	532	5.92
08.08.2001	10:15	25.9	63	17.8	2119	1.0	5369	3160	534	5.92
08.08.2001	10:30	25.8	63	17.6	2119	1.8	5371	3161	534	5.92
08.08.2001	10:52	25.9	69	18.9	2119	2.0	5371	3162	534	5.92
15.08.2001	10:23	31.1	44	26.9	3775	1.8	5287	5544	804	6.89
15.08.2001	10:55	32.1	39	28.0	1498	1.6	5266	2191	318	6.89
22.08.2001	09:40	26.3	61	18.4	2670	1.6	5419	4019	511	7.87
22.08.2001	10:07	26.8	64	18.6	1300	1.4	5403	1951	248	7.87
22.08.2001	11:00	27.2	58	20.9	1335	1.0	5360	1988	253	7.87
29.08.2001	10:07	25.6	39	17.5	3564	1.3	5455	5400	610	8.85
29.08.2001	11:00	26.8	36	19.9	1414	1.9	5390	2117	239	8.85
05.09.2001	08:52	22.4	54	10.7	3564	1.8	3805	3767	383	9.83
05.09.2001	09:43	22.3	60	11.0	2119	1.8	3654	2151	219	9.83
11.09.2001	11:57	22.6	43	11.8	3175	1.4	3678	3243	304	10.66
11.09.2001	12:15	21.9	44	11.9	1782	1.3	4147	2053	193	10.66
12.09.2001	09:28	21.9	52	11.7	2800	1.5	4037	3140	291	10.80
12.09.2001	11:00	22.5	59	12.8	2997	1.3	4312	3590	332	10.80
18.09.2001	09:41	21.7	48	6.7	2828	1.5	3251	2554	219	11.64
18.09.2001	11:10	22.6	49	11.0	1888	1.0	4168	2186	188	11.64
19.09.2001	10:15	22.8	42	13.0	3364	1.5	4657	4352	369	11.78
19.09.2001	11:13	24.1	42	14.2	2378	1.7	4055	2679	227	11.78
25.09.2001	08:54	20.7	65	9.2	2100	1.0	2900	1692	188	9.00
25.09.2001	12:56	21.3	59	13.9	1260	0.8	3050	1068	119	9.00
26.09.2001	10:17	21.2	58	11.3	4500	2.5	3647	4559	475	9.60
26.09.2001	11:11	21.4	59	11.9	1682	1.2	3342	1561	163	9.60
01.10.2001	13:00	23.8	61	18.0	3175	1.2	1827	1612	155	10.40
01.10.2001	14:14	24.6	55	19.1	1414	1.5	1844	724	70	10.40
Mittelwerte		**25.7**	**49**	**17.8**	**1963**	**1.5**	**4552**	**2427**	**372**	**7.08**

flow rates – which mainly occur in the summer – are lower by a factor of 1.5 to 4 than in low air flow rates in the colder season (dilution effect). In the 2nd and 3rd fattening period, odour emission, which on average changes by a factor of 1.5 to 2, shows an increasing connection with the exhaust air flow rate. In the 1st fattening period, however, this connection is reversed, which is mainly caused by the very low odour concentrations and -emissions at the beginning of this fattening period. The strong scattering of the individual values must be attributed to the large fluctuations in the stall climate and the biological conditions, as well as uncertainty in olfactometric odour concentration measurement.

Influence of the Daytime

For the determination of the daily course of odour release and other parameters, measurements with the "electronic nose" were carried out on days which exhibited the largest possible differences in ambient and marginal conditions (table 1). Sensors 7 and 9 reacted with the highest signals to the gases and odorants in the exhaust air of the fattening pig stall. Sensors 1 and 3 also responded clearly. In some cases, they showed spontaneous signal alterations as a reaction to short-term changes in the gas- and odorant composition of the exhaust air. The remaining sensors reacted considerably less. For this reason, sensors 1 and 9 have been selected for the description of the sensor signals of the "electronic nose". Due to the great variability of weather-related and stall-internal conditions, the results are very heterogeneous. The following examples show the significant influences and connections which result from daytime-related influences. Due to the large number of measurement values, only a selection of the most important parameters is shown for clarity´s sake. **Figure 4** shows the course on two days with large temperature differences between day and night and, hence, correspondingly large air flow rate alterations. On these days, the sensor signals also exhibit heavy fluctuations with the signals running counter to the air flow rate. This can mainly be attributed to dilution in the exhaust air, which increases with growing air flow rate. In principle, this causes the gas- and odorant concentrations in the exhaust air to sink and also induces the sensor signals to diminish. Short-term alterations in the sensor signals mainly occur during the feeding times. This will be discussed in more detail below. On days with large day/night differences, however, the short-term signal changes are significantly smaller than the differences between day and night. Olfactometric odour concentration shows a decreasing trend during the examined morning and increases slightly again after manual air flow rate reduction. In principle, this also matches the course of the sensor signals. However, the uncertainty of the olfactometrically determined odour concentrations is so significant that the course of odour concentration cannot be established with certainty.

Figure 5 shows the daily course on an autumn day with moderate temperature- and air flow rate differences between day and night. When the exhaust air flow rate is larger during the day, the sensor signals decrease slightly in a similar manner. The feeding times, which on the one hand are characterized by a temporary increase in dust concentration (PM 10) in the exhaust air due to greater animal activity and on the other hand by an increase in the air flow rate during and after feeding for approximately 20 minutes, particularly stand out. This air flow rate increase is a consequence of the increased heat production of the animals during feeding, which a temperature-guided ventilation control system dissipates by increasing the air flow rate. Even during the feeding times, the reaction of the sensor signals is stronger at some times and weaker at others. In some cases, the expected increase in the sensor signals is overcompensated for by the dilution effect due to the air flow rate increase. Nevertheless, the feeding times

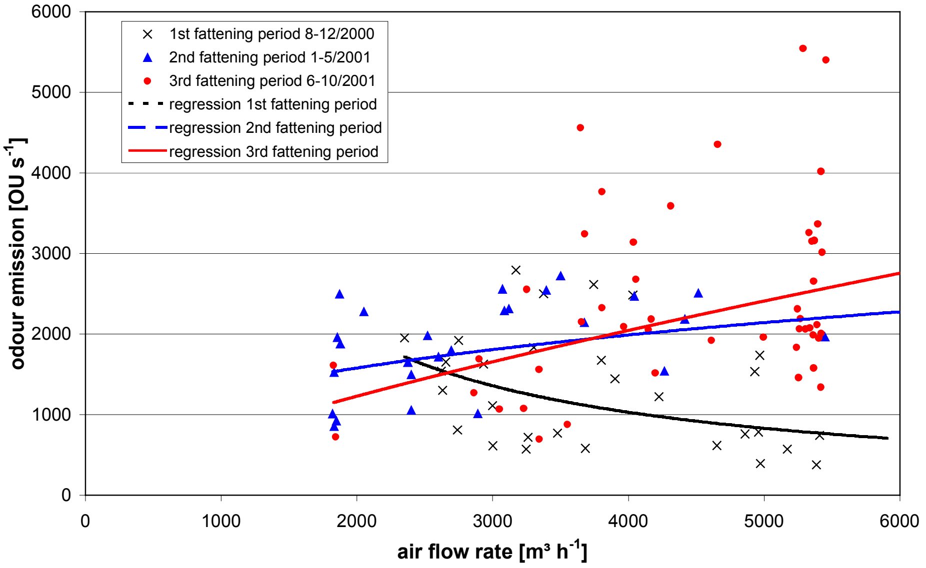

Figure 3: Influence of the exhaust air flow rate on odour emission (determined based on weekly odour samples in the three fattening periods)

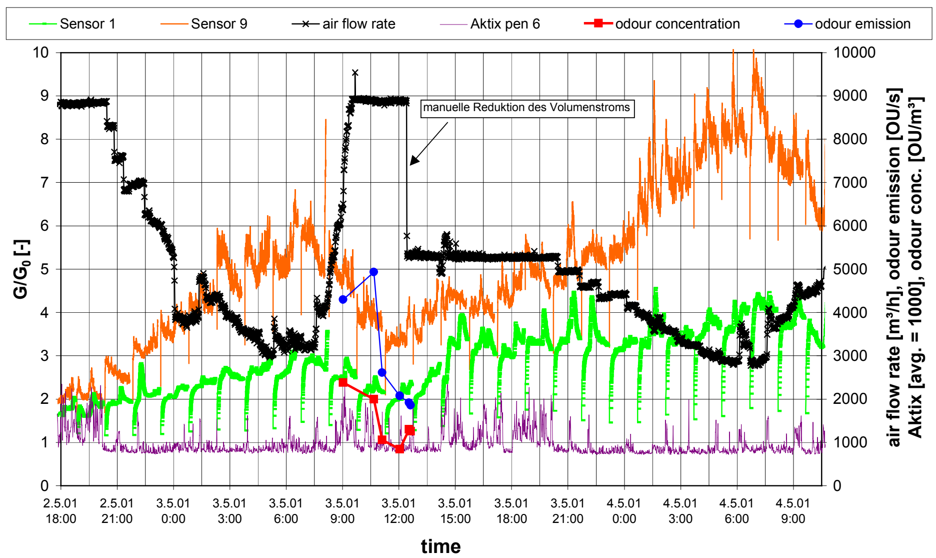

Figure 4: Daily course of selected parameters on two days with a significant air flow rate change between day and night

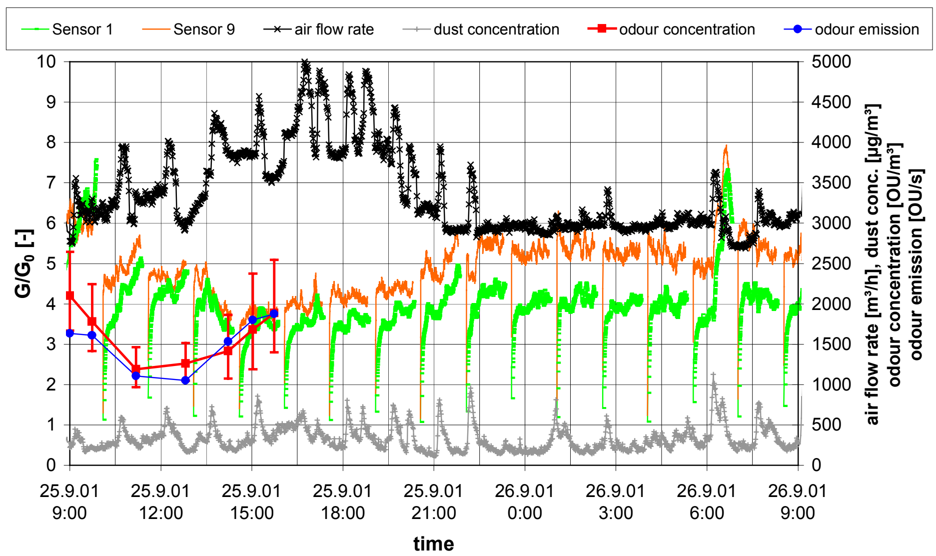

Figure 5: Daily course of selected parameters on an autumn day with moderate temperature- and air flow rate differences between day and night

are the most important regular events which alter the sensor signals. The strong increase in the sensor signals in Figure 5 at around 6 a.m. is not attributed to feeding, but rather to odour impact from outside, which will be discussed in more detail in the section "other external influences".

In this case, the course of the olfactometrically determined odour concentrations on 25 September 01 from 9:00 a.m. until 3:45 p.m. does not match the sensor signals. Mean odour concentration diminishes towards noontime and increases again during the afternoon. The course of odour emission is similar because the air flow rate does not change significantly. Given the fact that only one odour sample was analyzed per sampling time and taking the 95% confidence range of the individual measurements into account, which overlap significantly in some cases (figure 5), the temporal changes in odour concentration cannot be established with certainty for this day.

On a summer day with a virtually constant, maximum air flow rate, the significant alterations in the sensor signal height are mainly caused by the feeding times (**figure 6**). In the nightly measurement intervals, the sensor signals remain at a relatively uniform level, while as of the first feeding at 6.00 a.m. the sensor signals exhibit an increase after the beginning of the feeding. Due to the constant, maximum air flow rate, there is no dilution effect caused by a air flow rate increase. For this reason, the increase in the sensor signals is particularly pronounced.

Influences Due to Special Events

Influence of Feeding

In the presented daily courses, the significant sensor signal alterations of the "electronic nose" already allowed feeding to be identified as a particularly odour-relevant event during the course of the day. When the animals are fed, the feeding system dispenses the freshly mixed liquid feed to the feed troughs of each pen. Around feeding time, increased urinating and defecating of the animals are often observed as well.

Under the aspect of measuring technology, feeding is characterized by pronounced increases in the signals of the infrared sensors (average animal group activity) and dust concentration (PM 10) in the compartment and in the exhaust air for approximately five to twenty minutes (cf. figure 6). With a slight delay, the exhaust air flow rate often also exhibits a temporary increase (cf. figure 5) caused by the animal activity.

During feeding, some sensors of the "electronic nose" show an increase in the sensor signals, which can be clearly seen in Figure 6 and **Figure 7**. Due to the activity of the animals, the release potential of gases and odorants from excrement grows because new releasing surfaces are created, or fresh urine and faeces are even added. The altered gas- and odorant composition of the exhaust air is reflected by an alteration or an increase in the sensor signals of the "electronic nose". Within a few minutes, the sensor signals grow to a maximum value. The decrease in the sensor signals is then delayed until odour release reverts to its original level.

Before the beginning of the feeding, the olfactometrically determined odour concentration shows slightly higher values (figure 6 and figure 7). Due to the large variance range of olfactometry (shown in Figure 6 and Figure 7 within the 95% confidence range of each individual odour sample), however, it cannot clearly be distinguished from the other odour samples. In some cases, the olfactometrically determined odour concentrations grow during feeding. Often, however, they exhibit a decrease, which can also be observed during other measurements (see appendix). The reduction in odour concentration during feeding, however, contradicts the expectations and the sensor signals of the "electronic nose".

However, the increase in the sensor signals of the "electronic nose" during feeding cannot always be recorded very clearly. **Figure 8** shows two feeding times where the signals of sensors which usually react very strongly to alterations in

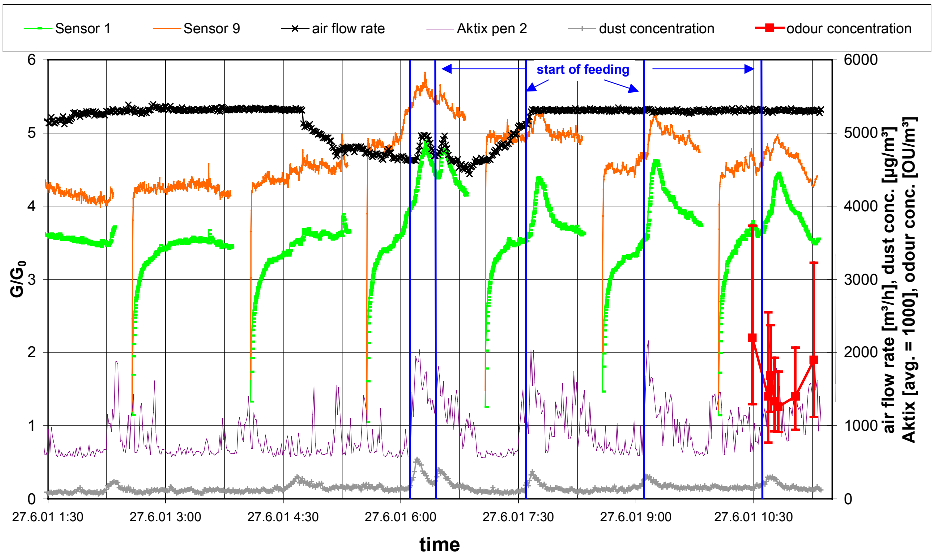

Figure 6: Daily course of selected parameters on a hot summer day with large air flow rates during the day and at night

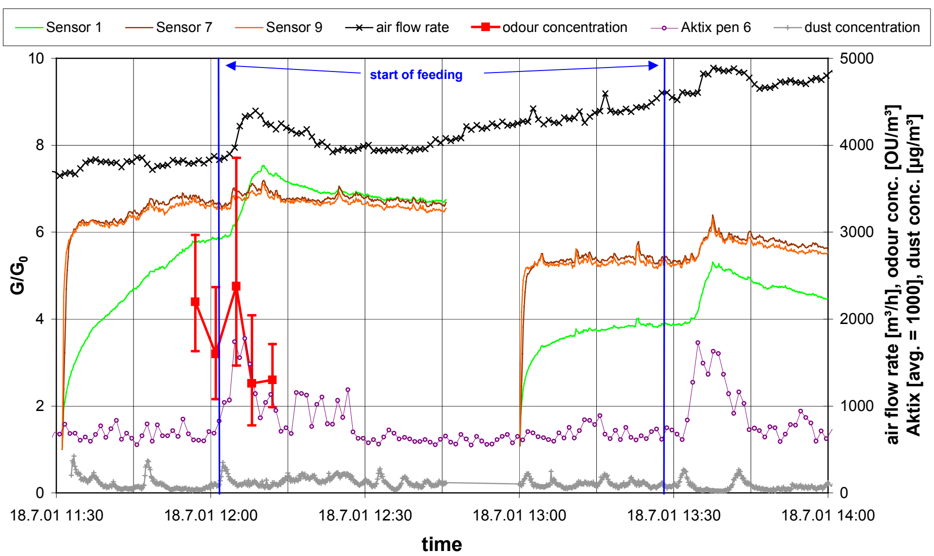

Figure 7: Course of selected parameters during two feeding times with air flow rate increase

gas- and odorant composition exhibit only a slight increase. Even the air flow rate is constant so that the sensor signals cannot be reduced by the dilution effect. Sensor 9 shows virtually no reaction to the feeding times. After air flow rate reduction, however, its signals increase significantly. Sensor 1 rather exhibits the opposite tendency, but signal alterations are small as well. The small signal changes must most likely be attributed to the very large air flow rate during this measurement, which leads to rather low gas- and odorant concentrations in the exhaust air and, hence, low sensor signals. This shows that the amount and the dynamics of odour release may differ significantly depending on the very heterogeneous ambient and stall-internal conditions.

Influence of Alterations in the Exhaust Air Flow Rate

It has already been described above how the exhaust air flow rate changes over the course of the year and the day and how these alterations affect odour release. Below, the effects of a strong short-term increase or reduction in the exhaust air flow rate on the sensor signals of the "electronic nose" and the olfactometrically determined odour concentrations are shown. In **Figure 9**, the exhaust air flow rate is altered manually by a factor larger than three. The sensors react very quickly to the dilution of the gas- and odorant concentrations caused by the larger air flow rate and vice versa. The sensor signals exhibit a significant alteration by ca. 30%. In comparison, the sensor signal change during the feeding at 1:35 p.m. is considerably smaller. Air flow rate alterations hence seem to have a stronger effect on sensor signal height than feeding events.

In the triple air flow rate, the olfactometrically determined odour concentrations are only approximately half as high as in the low air flow rate. This is particularly obvious during the second air flow rate increase. Larger air flow rates cause greater odour emissions than small air flow rates. This can be attributed to the improved conditions for the release of odorants due to higher flow speeds in larger air flow rates. It can be shown, however, that the proportional connection between the air flow rate and odour emission, which has often been described in the literature, does not exist [2] because odour concentration cannot be assumed to be constant.

Other External Influences

On many measuring days, the sensor signals of the "electronic nose" exhibited an extreme increase for a duration of approximately 20 to 30 minutes, mainly in the early morning hours.

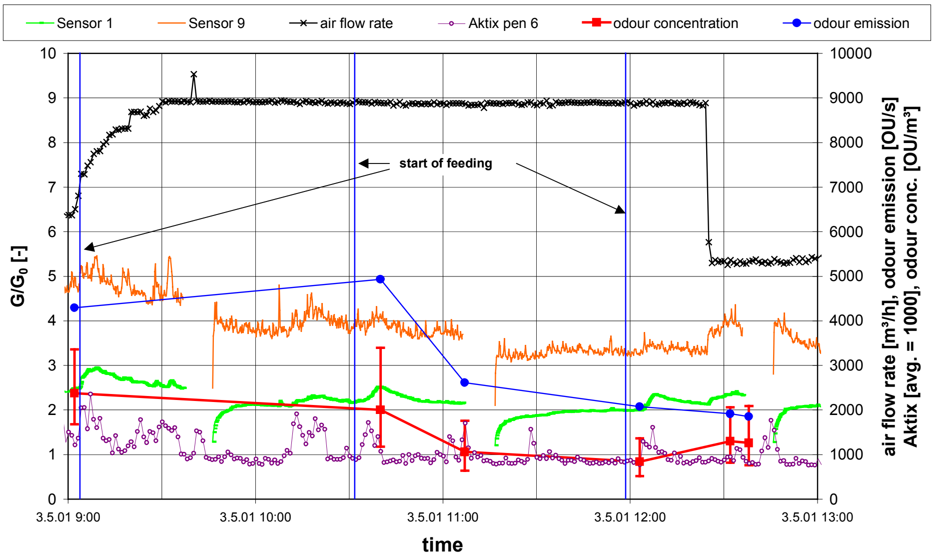

Figure 8: Course of selected parameters during two feeding times with constant air flow rate

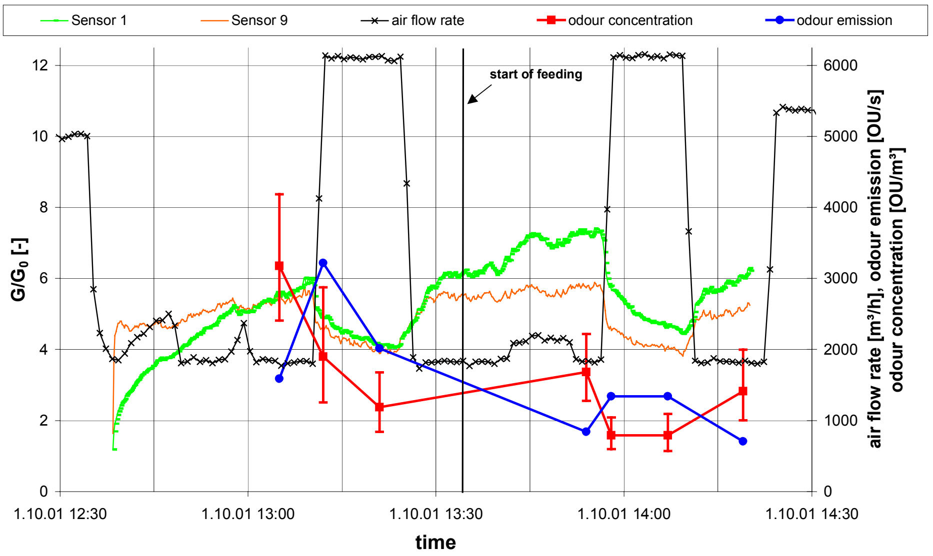

Figure 9: Course of selected parameters during controlled air flow rate alteration

Figure 10 shows an example of such an increase in the sensor signals at ca. 5:45 a.m. Since the signal increase did not occur during feeding time and since the ambient parameters measured parallel (animal activity, dust concentration, water content of the air, ammonia concentration, exhaust air flow rate, etc.) did not show any peculiarities, the cause had to be sought outside the stall. Ultimately, the reason found was that at these times liquid manure was pumped from the neighbouring cattle stall into the central slurry containers. The underground slurry pipe ran under the pig stall and had a service opening in the anteroom from which the fresh air was sucked into the fattening compartment. From this opening, significant odour emissions were released when the liquid manure was pumped off. Nevertheless, the use of an "electronic nose" allows additional, unknown odour sources to be detected due to the alteration in the sensor signal height. With a few single samples and olfactometric offline analysis, it would certainly have been impossible to determine this external influence.

Influences of Single Parameters

The significant influence of the exhaust air flow rate on odour concentrations and odour emissions over the course of the year and on the sensor signals over the course of the day along with the influence of short-term air flow rate alterations have already been shown above. Temperature, humidity, as well as ammonia- and dust concentration are other possible influencing factors.

The most important seasonal influencing variable is the alteration of the outside temperature. Due to temperature-guided

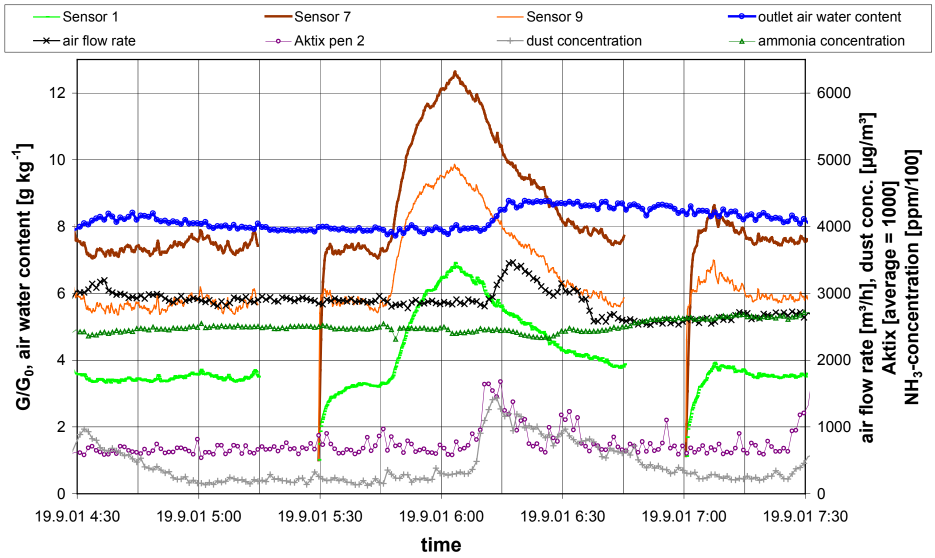

Figure 10: Increased sensor signals due to odour input from outside caused by the short-term pumping off of liquid manure from the neighbouring cattle stall

ventilation control and the temperature-insulated building shell, such alterations only exert a slight and strongly delayed influence on the temperature inside the stall so that the release conditions for odorants from emission sources inside the stall (excrement, animals, etc.) exhibit only moderate changes caused by temperature fluctuations. In general, however, no direct influence of temperature or temperature fluctuations on the temporal course of odour emission can be expected in a temperature-insulated stall with temperature-guided ventilation control.

A significant, direct influence of other parameters (relative humidity and the water content of the air, ammonia concentration, dust concentration) could not be established based on the collected measurement data. Most of these parameters as well as the sensor signals of the "electronic nose" may increase with growing animal activity during the feeding times. High temporal resolution of the time courses of the sensor signals and the individual parameters, however, shows that the measurement value increases are independent of each other and that they are exclusively caused by different mechanisms, which are simultaneously influenced by animal activity in the broadest sense. No cross sensitivity of the "electronic nose" sensors, in particular to humidity, was found in the usual humidity range.

Practical Usability of the Results

From the available measurement results, the recommendations described below, which concern odour sampling, the consideration of seasonal fluctuations of odour emissions in odour spreading calculations, and the use of "electronic noses" for the evaluation of odour emissions, can be derived.

Odour Sampling in Stalls

If odour samples can be taken from the exhaust air of an existing animal housing facility, odour concentration should be determined using odour samples which take the different seasons, the fattening stages, and the time of the day into account. With regard to the seasons, measurements should be taken on at least one typical cold winter day and one hot summer day, as well as on two days in the transitory period. On the measuring days, at least two odour samples should be taken early in the morning while the air flow rate is constant at a minimum level, at noontime when the air flow rate exhibits a constant maximum, and equally distributed in the morning and in the afternoon while the air flow rate is increasing or diminishing. If possible, the air flow rate should be kept constant during sampling. At all times, one must make sure that odour samples are not taken during the feeding and within 30 minutes afterwards. In this case, the parallel use of an "electronic nose" on sampling days allows sampling during pronounced emission peaks due to feeding or other influences to be recognized and avoided. All odour samples should be stored in a dark place until they are analyzed. Olfactometric analysis should be carried out on the same day, if possible within 8 hours. A total number of at least 24 odour samples per animal housing facility is required.

Consideration of Odour Emission Fluctuations in Odour Distribution Models

In odour distribution models for planning, the odour emission to be entered is estimated based on odour emission factors of a comparable housing system, which are available in the literature. If, in the case of complaints or in other cases, the animal housing facility is already in operation, odour samples for olfactometric analysis should be taken in accordance with the recommendations given above. Based on the analyzed odour concentrations and the corresponding exhaust air flow rates, which should be determined through measurements, if possible, the odour emissions are calculated. For this purpose, the daily average odour emissions must first be calculated for the individual sampling days, which must then be condensed into a yearly average odour emission value of the individual stall system. No matter if yearly mean odour emission is estimated using odour emission factors or determined based on analyzed odour samples, doubling the value of the assumed yearly average odour emission is recommended for the calculation of odour distribution on warm summer days in individual cases. The result should be taken into account in the final assessment of the nuisance situation, especially in the summer. As an alternative, the mean odour emission of the sampling day in the summer can also be used. For completion, 50% of the assumed yearly average odour emission or the mean daily odour emission of the sampling day in the winter can be considered for the situation in the winter.

Recommendations for the Use of "Electronic Noses"

On the one hand, the sensor arrays of the different commercially available "electronic noses" are equipped with different types and numbers of sensors. On the other hand, the sensor signals of the individual models have not been represented uniformly thus far so that harmonization would be necessary for better comparability of the different "electronic noses". First, at least a detailed description of the "electronic nose" used and the parameters employed would be required. Nevertheless, general recommendations for the use of "electronic noses" for the measurement of odour emissions from animal housing facilities can be given. Since the air around animal housing facilities is generally heavily polluted with odorants and other gases emitted by the stall itself and close-by manure storage places, the use of a synthetic (and therefore uniform) reference gas as reference air for the "electronic nose" is recommended. This reference gas can be produced from cleaned pressurized air, for example, with a relative humidity of ca. 50% and a temperature which is kept constant similar to the ambient temperature. This reference gas serves to guarantee a relatively constant zero value of the sensor signals and to rinse the sensors regularly. Due to the signal drift of the sensors, a maximum continuous measuring time of two hours is recommended. When determining the measuring- and rinsing times, the feeding times and operational rhythms in the stall must be taken into account.

In addition to using the "electronic nose" for the detection of undesirable odour emission peaks on sampling days so that the most representative odour emissions possible are able to be determined, nuisance-relevant emission peaks of animal housing facilities in general can be detected. Thus, the reasons for temporally limited complaints may be established. Moreover, the use of chemosensor arrays as sensors for the odour-guided control of ventilation systems is conceivable. A chemosensor array can be installed on both the emission side in the exhaust air shaft and on the input side, e.g. in the house of a neighbour who may be affected by potential nuisance. In this case, especially the question of the sensors long-term stability must be answered.

Summary

In the present research project, seasonal (fattening course), daytime-related, and short term (feeding) dynamic effects of odour release from a stall for fattening pigs were examined for a duration of three successive fattening periods. Over the course of the year, the largest odour emissions combined with the smallest odour concentrations occurred on hot summer days, while cold winter days were characterized by low odour emissions and the highest odour concentrations, which is mainly a consequence of the different exhaust air flow rates. With the aid of olfactometry, no clear daily course of odour emission could be proven. The sensor signals of the "electronic nose", however, showed clear differences between day and night, which is attributed to the different dilution effect of the individual air flow rates. The particular strength of the "electronic nose" resides in continuous measurement, which allowed significant alterations in the gas- and odorant composition of the exhaust air due to feeding times or other short-term influences to be shown. Olfactometrically, however, no clear increase in odour concentration due to short-term influences could be proven.

From the results, recommendations for suitable, representative odour sampling were derived, and suggestions for the consideration of seasonal odour emission fluctuations in odour distribution models were made. In addition, recommendations for the sensible use of "electronic noses" for the measurement of odour emissions from animal housing facilities were given.

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