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H.J.C. van Dooren, J.L. Zonderland, K. Blanken, S. Bokma

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Samenvatting NL:
Op Dairy Campus Leeuwarden zijn tussen augustus 2014 en juli 2015 case-control metingen verricht om de reductie van de ammoniakemissie van de Comfort Slat Mats met en zonder kleppen te bepalen. Deze metingen werden uitgevoerd volgens het daarvoor bestemde meetprotocol. De emissiereductie van de Comfort Slat Mat met kleppen was 32,3%. De emissiereductie van de Comfort Slat Mat zonder kleppen was 39,4%

Summary UK:
Between August 2014 and July 2015 case-control NH_3-emission measurements took place on Dairy Campus Leeuwarden to establish the emission of the Comfort Slat Mat with and without valve. Measurement were taken according the Dutch ammonia emission measurement protocol. The emission reduction of the Comfort Slat Mat with valves was 32.3%. The emission reduction of the Comfort Slat Mat without valves was 39.4%.

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Summary

Irish Custum Extruders Ltd.(ICE) and Beerepoot Stalinrichtingen BV (Beerepoot) contacted Wageningen UR Livestock Research to obtain ammonia emission measurements of the Comfort Slat Mat system (CSM) following the prescribed ammonia measurement protocol. The CSM consists of a curved mat fitted on concrete slats. Additionally there is a possibility to clip a valve on the mats to close the slots between the concrete beams. Both versions of the CSM (with and without valves) aim to reduce the ammonia emission from dairy housings by enhancing urine drainage to the pits. Additionally, the version with the valve aims to reduce the air exchange between the slurry pits and the animal confinement unit. Both versions (with and without valves) have a preliminary ammonia emission factor, issued by the Dutch ministry of Infrastructure and the Environment (I&M).

This report describes the outcomes of the case-control measurements performed on the Comfort Slat Mat with and without valves at Dairy Campus Leeuwarden. The objective was to determine the effect of the Comfort Slat Mats with and without valves on the ammonia emission from dairy housing.

Measurements were performed at two mechanically ventilated units of the animal facility for dairy cattle ‘Dairy Campus Leeuwarden’ (see paragraph 2.4) using the case-control approach. Each unit housed 15 cows. Management and care of the animals was similar for both dairy cattle units. The Comfort Slat Mats were mounted in unit 2 on a new concrete slatted floor in April 2014. Unit 3 was equipped with standard concrete slats for dairy cattle and acted as the reference. The first five months after installation were used as an adaption period to avoid improper measurements due to fresh concrete of new installed slatted floors in the measuring units and for further optimization of the system. Hereafter the measurements took place between August 2014 and July 2015. A measuring period of the Comfort Slat Mats either with or without valves (valve type Mark 3) consisted of four consecutive days starting on Monday and followed minimal two weeks after a change in configuration (mounting or removal of the valves). The Comfort Slat Mats unit and the reference unit were always measured simultaneously. Cow management, feeding and ventilation were similar for both units during measurements. A total of six measurements periods for both CSM with and CSM without valves was performed and distributed evenly between the start and end of the project.

Ammonia concentration of outgoing air was measured in both ventilation ducts of each unit. Ammonia concentration of the incoming air was measured at the bottom of the curtain that regulates the incoming airflow of each unit with a sampling line with 4 sampling points evenly distributed along the curtain. Sampling air was pumped constantly towards a multiplexer. At this 12 channel multiplexer, sampling lines of all four units were connected in two groups (A and B). Every 10 minutes the multiplexer switched connecting another channel of each group to a NOx-analyser (Teledyne-API T200). Before reaching the monitor the ammonia (NH_3) in the sampled air was thermally converted to NOx at temperatures higher than 700 ^oC with a known efficiency. NOx concentrations in the sampled air were measured and one minute averages were stored in a data logging system (Campell Scientific CR1000) combining time, multiplex channel and NOx concentration. Minute averages of the ventilation rate per unit were also stored in this data logger. Temperature and relative humidity were measured at two locations inside each unit close to each ventilator, at one location at each feeding lane close to the milking parlour, and at one location outside the barn (see Figure 4). A sensor of Rotronic Instrument Corp with an accuracy of 1,0 ^oC and 2% RH was used. Averages of 15 minutes were stored at the data logger.

The reduction of ammonia emission (ER) is calculated for each measurement period (i) as:

$$ER(NH_3)_i = 100\% * \left(1 - \frac{E(NH_3)_{csm}}{E(NH_3)_{ref}}\right)$$

Ammonia emission per measurement period (i) is calculated as the average emission per day (d) over 4 days of a week starting on Monday. Emission per day is calculated as average emission per hour (h) times 24, leaving the hours 6:00am-10:00am out since during this period the cows were milked and the curtains regulating the incoming air were up to be able to feed the cows.
The emission per hour is calculated as:

$$E(NH_3)_h = (C(NH_3)_{out} - C(NH_3)_{in}) * VR * 24$$

The hypothesis that the mean ammonia emission reduction per measurement period of the Comfort Slat Mats unit is equal to the zero is tested with a t-test both for the data with and without valves.

From the measurements can be concluded that:

- Relevant circumstances during measurements were representative for modern dairy farms.
- Relevant circumstances in both units were comparable during measurements
- Small differences in milk production between units did occur, but not influenced results in such a way that measurements should be omitted or final results are not valid.
- The reduction of the ammonia emission from the Comfort Slat Mats without valves was 39.4% ± 7.3% and was significantly higher than zero ($p<0.001$)
- The reduction of the ammonia emission from the Comfort Slat Mats with valves was 32.3% ± 13.3% and was significantly higher than zero ($p=0.002$).
- Emission reduction effects are only valid when the Comfort Slat Mat is scraped at least once every two hours.
- In contrary to expectations the valves used (type Mark 3) did not show an additional effect on the emission reduction. The emission reduction from the Comfort Slat Mat with or without valve did not differ significantly ($p=0.28$).
- Insight in the reasons and improvement of the valves need further research.

1 Introduction

Beerepoot Stalinrichtingen BV is the Dutch representative of Irish Custom Extruders Ltd. (ICE) for the sale and service of the Comfort Slat Mats (CSM), in The Netherlands known as “Groene Vlag vloer”. The CSM consists of a curved mat fitted on concrete slats. Additionally there is a possibility to clip a valve on the mats to close the slots between the concrete beams. Both versions of the CSM (with and without valves) aim to reduce the ammonia emission from dairy housings by enhancing urine drainage to the pits. Additionally, the version with the valve aims to reduce the air exchange between the slurry pits and the animal confinement unit. Both versions (with and without valves) have a preliminary ammonia emission factor, issued by the Dutch ministry of Infrastructure and the Environment (I&M), and are therefore included in the list of ammonia emission reducing housing systems listed in the Annex 1 of the “Regeling ammoniak en Veehouderij” (Rav). Table 1 gives an overview of the Rav-codes and preliminary emission factors[1] currently assigned to these systems. In general, these preliminary emission factors are based on model calculations or indicative emission measurements on a small scale.

Table 1
Overview of Rav numbers and preliminary emission factors for the Comfort Slat Mats. Emission factors are expressed in kg NH_3 per year per animal place

Description	Valves	Category	Number	Preliminary emission factor after 1-8-2015	Preliminary emission factor until 31-7-2015	
				Without grazing	With grazing	Without grazing
Comfort Slat Mats	Yes	A1.09	BWL2010.30.V2	6.0	4.1	4.7
Comfort Slat Mats	No	A1.10	BWL2010.31.V2	9.5	6.4	7.4

This preliminary ammonia emission factor includes the obligation to perform emission measurements to establish a final emission factor. These measurements should comply with the ammonia emission measurement protocol (Ogink et al, 2013). This Dutch measurement protocol is comparable to the VERA protocol for livestock housing and management systems (VERA, 2011). VERA is a collaboration between German, Danish and Dutch governmental representative bodies. VERA aims to harmonize test procedures and measurement protocols for verification of environmental technologies for agricultural production, in order to make measurements from test institutes from different countries comparable and exchangeable. Both the Dutch protocol and the VERA-protocol offer the opportunity of case control measurements (see chapter 2.1).

Within this framework, ICE and Beerepoot Stalinrichtingen BV contacted Wageningen UR Livestock Research to obtain ammonia emission measurements following the prescribed ammonia measurement protocol. These measurements will be used to apply for a final ammonia emission factor. After consulting the technical advisory commission of the Rav (TAC-Rav), a modified measurement protocol was accepted. It was agreed to perform case-control measurements on one location (i.c. Dairy Campus Leeuwarden), and absolute emission level measurements on two other locations on practical farms.
This report describes the outcomes of the case-control measurements performed on the Comfort Slat Mat with and without valves at Dairy Campus Leeuwarden. The objective was to determine the effect of the Comfort Slat Mats with and without valves on the ammonia emission from dairy housing.

[1] The emission factor of the reference system (A1.100) changed on 1-8-2015 from 11.0 to 13.0 kg ammonia per animal place per year. Emission factors of other systems were scaled to this new value. At the same moment the threshold value changed from 9.5 kg to 11.0 kg ammonia per animal place per year for new housing systems. Besides, the difference between grazing and zero grazing is no longer included in the emission factor.

2 Materials and methods

2.1 Measurement strategy

Measurements were performed following the measurement protocol described in Ogink et al. (2013) for ammonia (NH_3). Shortly, this protocol specifies the implementation of six measurements of at least 24 hours, evenly distributed in a calendar year (approximately every two months) and over the production cycle of the animals, taking into account the agronomic requirements as presented in the measurement protocol. For each measurement, the following data (per dairy cattle unit) were collected:

- Feeding and production data and other agronomic requirements as described in paragraph 2.4.
- The concentration of ammonia in the outgoing air and in the incoming air (background) of each unit, using the method described in paragraph 2.5.
- The ventilation rate per unit using the method described in paragraph 2.5.
- The temperature and relative humidity in all the measured units and of background, using the method described in paragraph 2.5.

General information of the measurements is given in paragraph 2.2. The emission reduction principle is described in paragraph 2.3.

2.2 General information

Measurements were performed at two units of the animal facility for dairy cattle 'Dairy Campus Leeuwarden' (see paragraph 2.4) using the case-control approach. Management and care of the animals was similar for both dairy cattle units. The Comfort Slat Mats were mounted in unit 2 on a new concrete slatted floor in April 2014. The first five months after installation were used as an adaption period to avoid improper measurements due to fresh concrete of new installed slatted floors in the measuring units and for further optimization of the system. Hereafter the measurements took place between August 2014 and July 2015.

Unit 2 was equipped with the Comfort Slat Mats. Unit 3 was equipped with standard concrete slats for dairy cattle and acted as the reference. Both units were equipped with a slat scraper. However the scraper in unit 3 (reference) was detached from the cable and not in function during all measurements as slat scraping is not part of the reference system. The CSM in unit 2 were scraped once every two hours. The Comfort Slat Mats (unit 2) were alternatingly measured with and without valves. Valves were mounted or removed from the mats by simply lifting the mats from the concrete beams. No water was used for cleaning.

A measuring period of the Comfort Slat Mats either with or without valves consisted of four consecutive days starting on Monday and followed minimal two weeks after a change in configuration (mounting or removal of the valves). The Comfort Slat Mats unit and the reference unit were always measured simultaneously. Cow management, feeding and ventilation were similar for both units during measurements.

At the start of the project a representative group of 32 cows was selected from the available cows at Dairy Campus containing cows with different production level, lactation stage and number of lactations. These 32 cows were evenly divided over the two units in such a way that average production level, days in lactation and number of lactation were comparable for both units. During the experimental period cows were replaced in both groups because of calving or culling. Aim was always to keep the two groups comparable.

2.3 Description of the emission reduction principle of the Comfort Slat Mats

The emission reduction principle of the Comfort Slat Mat is based on fast drainage urine to the slurry pits. To enhance the drainage the mat is curved and made of smooth non adhesive material.
The Comfort Slat Mat is made up of three different specialised chemically resistant materials. Each material has a function and when combined allows the mat to operate as a single unit. There is a hard wearing curved smooth surface on top to promote the urine and waste to the slot. This design feature aims to reducing the ammonia from the floor. The centre of the mat is designed for the comfort and welfare of the animal which can be made of different softness of material depending on the size of the animal. The smaller the animal the softer the material. This means that the small animal can achieve the same grip and comfort as the large animal by using different materials which also prevents lameness. This does not affect the life of the mat. The third material is used to create a spring loaded mechanism to allow the mat to fit around the slat so that it stays in place. All three components are combined to create the Comfort Slat Mat. As an example a cross section of the mat is presented in Figure 1**.**

Figure 1 *Example of the Comfort Slat Mat on a beam of a concrete slatted floor.*

The Comfort Slat valve mechanism is a longitudinal profile that can be attached to the end of the leg of the Comfort Slat Mat and sits in each slot on a slatted floor. Its function is to close the slot in order to reduce the air exchange between pit headspace and rest of the housing and at the same time allow the animal liquid and solid waste pass freely to the pits. At Dairy Campus valve type “Mark 3” was used (see Figure 2).

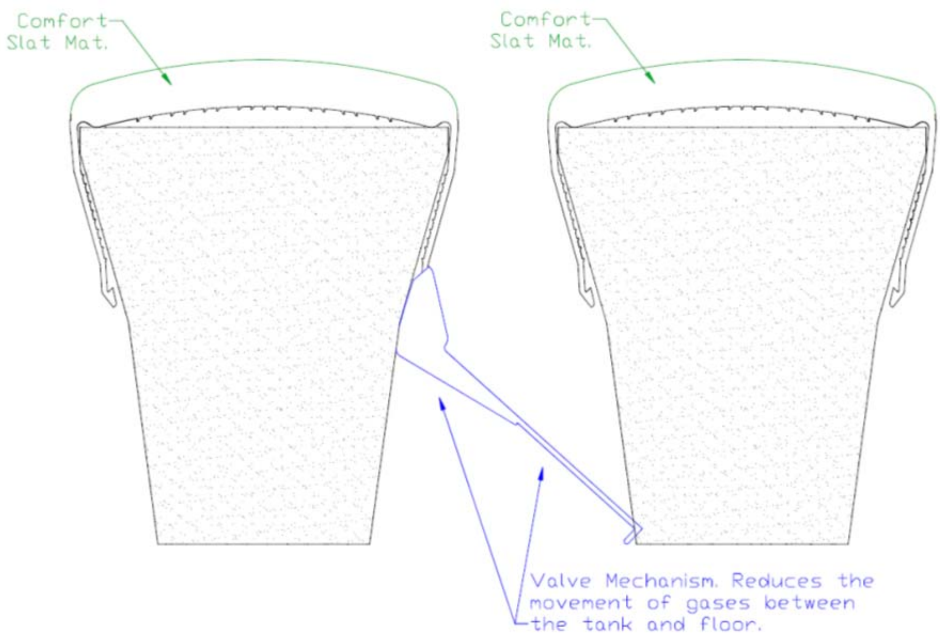

Figure 2 *Cross section of the Comfort Slat Mat with valve type "Mark 3".*

2.4 Dairy Campus

Dairy Campus is a dairy research farm of Wageningen UR Livestock Research (WLR) that is located at the Boksummerdyk 9 in Goutum, near Leeuwarden (The Netherlands). An aerial view of the farm is given in Figure 3. The floor plan of the main building for housing of the dairy cows is given in Figure 4. In the centre of this building around 60 cows are housed in four identical units located around a central milking parlour. Each unit consists of sixteen cubicles, one walking alley, a feeding lane for roughage distribution, a water trough and a concentrate feeder. Slurry is stored in pits underneath each unit separately. Each unit is ventilated independently from the others by means of two mechanical ventilators that run at the same rate. In every unit one of these ventilators is equipped with a free running fan anemometer to measure the actual ventilation rate. Ventilation rate is per unit controlled by a computer.

The inlet of air into the unit is regulated with a curtain blocking the front side of the units (see Figure 5). During measurements the lowest point of the curtain is around 50 cm above floor level and only pulled up during feeding times.

At the entrance of the milking parlour a waiting area of around 8 m^2 is separated from the rest of the unit by gates.

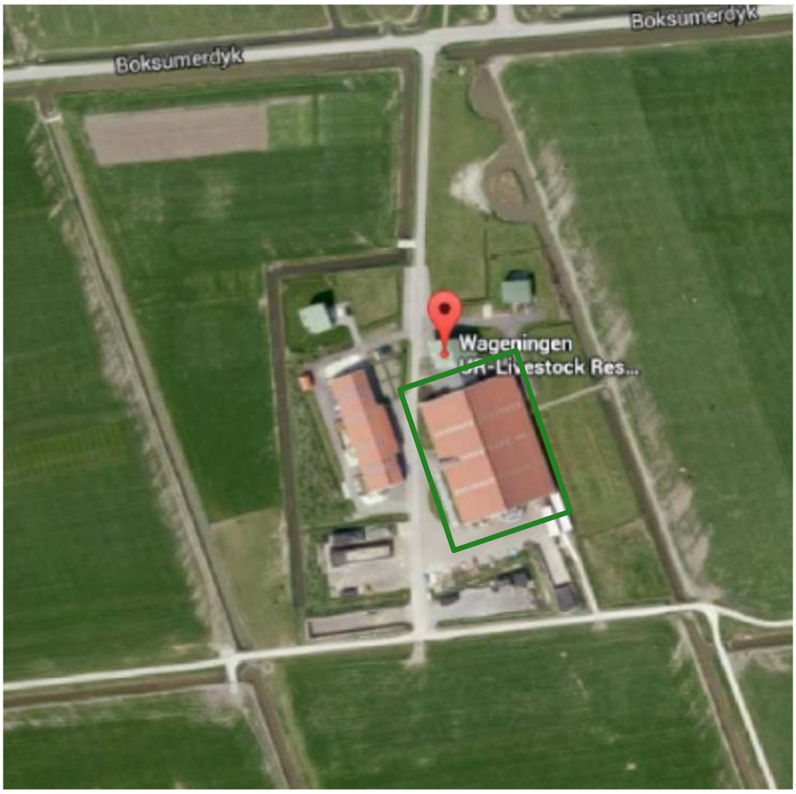

Figure 3 *Aerial view of research farm Dairy Campus Leeuwarden (53.18°N 5.76°E) (North is top of picture). The dairy cattle facility is framed in green.*

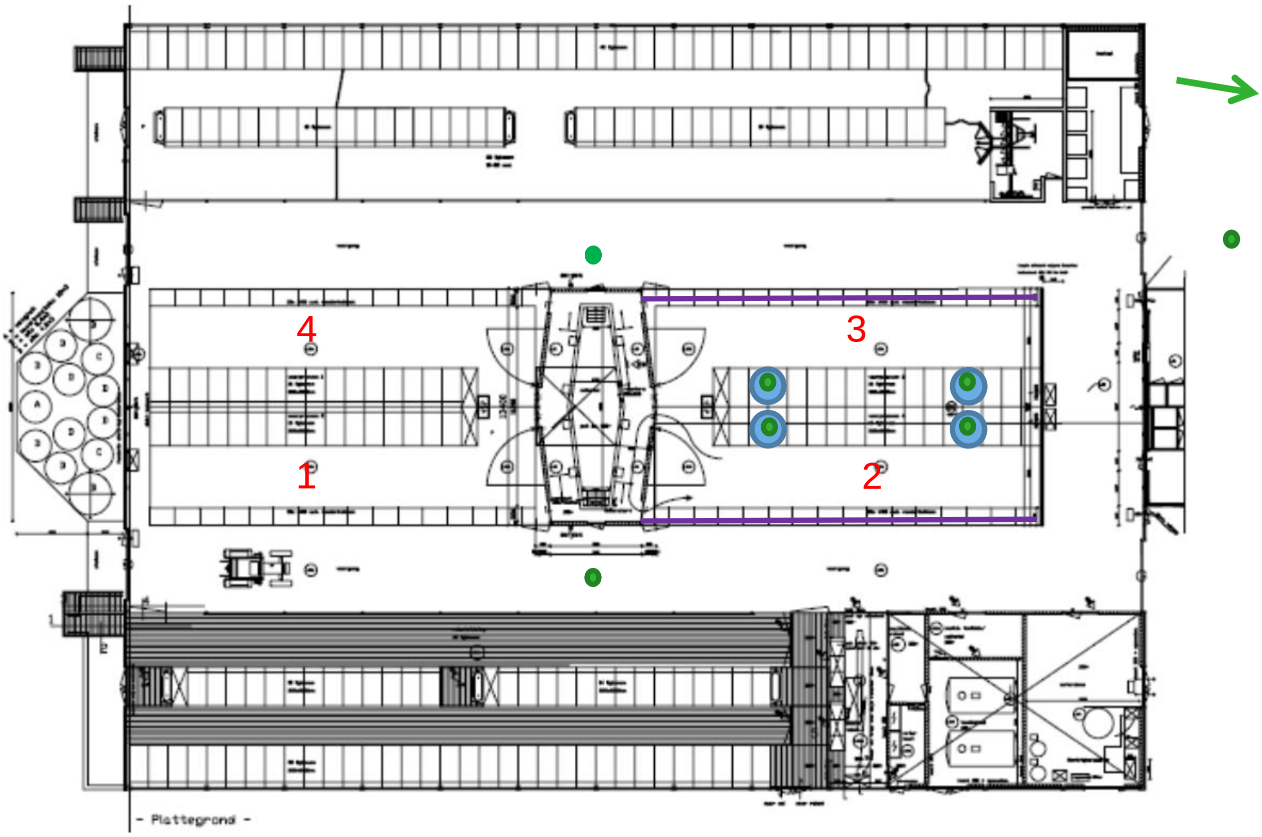

Figure 4 *Ground plan of research barn with unit numbers. Red figures: measuring unit number; Blue circles: ventilators with sampling of outgoing air; Green circles: temperature and relative humidity sensors; Purple line: the sampling line of incoming air; Green arrow: North).*

The Comfort Slat mats were mounted in unit 2 on new installed concrete slatted floor elements in April 2014. During all measurements unit3 acted as a reference. Further detailed information of unit 2 and 3 is presented in Table 2.

Table 2
Overview of characteristics of research units 2 and 3 at Dairy Campus Leeuwarden

Characteristic	Unit 2 Comfort Slat Mats	Unit 3 Reference
Orientation housing (N/S)	See figure 3	
Ventilation systems	Mechanical ventilation	
Ventilators per unit/Ventilation control	2 (Fancom 80cm/1 with ATM80)/FC14	
Ventilation capacity per unit (max) (m^3/h)	41500	
Ventilation regulation	Fixed at 40% of max capacity	
Dimensions units (lxw) (m)	21.7 x 5.7	
Number of animal places (cubicles)	16	
Available lying area (m^2)	38.7 (1.1 x 2.2 m)	
Available walking area including waiting area (m^2)	83.0	
Available walking area excluding waiting area (m^2)	75.0	
Available walking area per cow excluding waiting area (m^2)	4.7	
Material walking area	Comfort Slat Mats	Concrete slatted floor
Slurry removal from floor	Slatted floor scraper	None
Frequency of slurry removal from floor	Every 2 hours	-
Slurry pits depth (m)	1.45	
Slurry pits surface (m^2)	132.1	
Slurry pits capacity (m^3)	191.5	
Feeding	TMR (60% grass silage, 30% maize silage)	
Feeding times	Once a day in the morning	
Milking system	Milking parlour with two stands for every unit	
Milking times	Twice a day at fixed milking intervals	
Grazing	No	
Animal health, welfare and hygiene	No remarks, normal care and management	

2.5 Measuring devices

Ammonia concentration of outgoing air was measured in both ventilation ducts of each unit. Ammonia concentration of the incoming air was measured at the bottom of the curtain that regulates the incoming airflow of each unit with a sampling line with 4 sampling points evenly distributed along the curtain. Sampling air was pumped constantly through the 3 PE sampling tubes per unit (2 outgoing air and 1 incoming air) towards a multiplexer. At this 12 channel multiplexer, sampling lines of all four units were connected in two groups (A and B). Every 10 minutes the multiplexer switched connecting another channel of each group to a NOx-analyser (Teledyne-API T200). Before reaching the monitor the ammonia (NH_3) in the sampled air was thermally converted to NOx at temperatures higher than 700 ^oC with a known efficiency. NOx concentrations in the sampled air were measured and one minute averages were stored in a data logging system (Campell Scientific CR1000) combining time, multiplex channel and NOx concentration. Minute averages of the ventilation rate per unit were also stored in this data logger. Operating temperature of the NOx converters was checked daily. The NOx analyser was controlled daily for general functioning and calibrated twice a year on site (zero and span) using standard gasses traceable to international standards.

Temperature and relative humidity were measured at two locations inside each unit close to each ventilator, at one location at each feeding lane close to the milking parlour, and at one location outside the barn (see Figure 4). A sensor of Rotronic Instrument Corp with an accuracy of 1,0 ^oC and 2% RH was used. Averages of 15 minutes were stored at the data logger. An overview of the measuring devices is given in Figure 6.

Figure 5 *Overview of curtain regulating the incoming air in pulled up position. The purple line and arrows indicates the sampling line with two of the four sampling point along the bottom side of the curtain.*

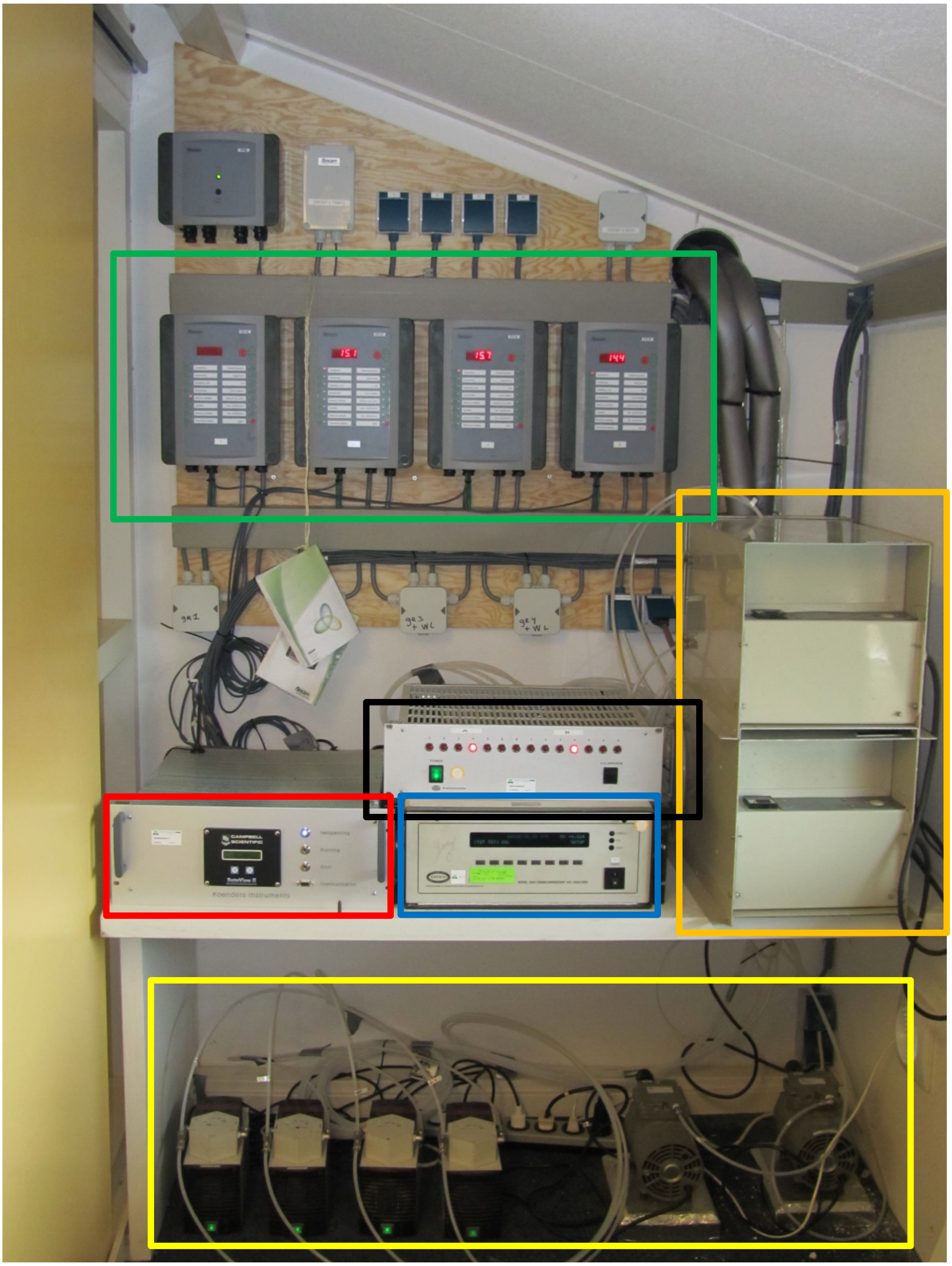

Figure 6 *Overview of NOx analyser (blue), multiplexer (black), data logger (red), ammonia converters (orange), ventilation controllers (green) and pumps (yellow).*

2.6 Emission calculations

The reduction of ammonia emission (ER) is calculated for each measurement period (i) as:

$$ER(NH_3)_i = 100\% * \left(1 - \frac{E(NH_3)_{csm}}{E(NH_3)_{ref}}\right)$$

With:
$E(NH_3)_{csm}$ = Average ammonia emission of the comfort slat mats with or without valves per measurement in g/day.
$E(NH_3)_{ref}$ = Average ammonia emission of the reference with or without valves per measurement in g/day.

Ammonia emission per measurement period (i) is calculated as the average emission per day (d) over 4 days of a week starting on Monday. Emission per day is calculated as average emission per hour (h) times 24, leaving the hours 6:00am-10:00am out since during this period the cows were milked and the curtains regulating the incoming air were up to be able to feed the cows.
The emission per hour is calculated as:

$$E(NH_3)_h = (C(NH_3)_{out} - C(NH_3)_{in}) * VR * 24$$

With:
$C(NH_3)_{in}$ = Average ammonia concentration of the incoming air per hour (g/m^3)
$C(NH_3)_{out}$ = Average ammonia concentration of the outgoing air per hour (g/m^3)
VR = Average ventilation rate per hour (m^3/h)

The final emission reduction of the comfort slat mats with or without valves is calculated as the average over the measurement periods.

The hypothesis that the mean ammonia emission reduction per measurement period of the Comfort Slat Mats unit is equal to the zero is tested with a t-test both for the data with and without valves.

3 Results

The Comfort Slat Mats with valves were measured 6 times. The Comfort Slat Mats without valves were measured 7 times. The distribution over a year of the measurements is graphically presented in Figure 7. The 5th measurement of the Comfort Slat Mats without valves at day number 54 (marked red) is not included in the calculation of the emission reduction for reasons explained later.

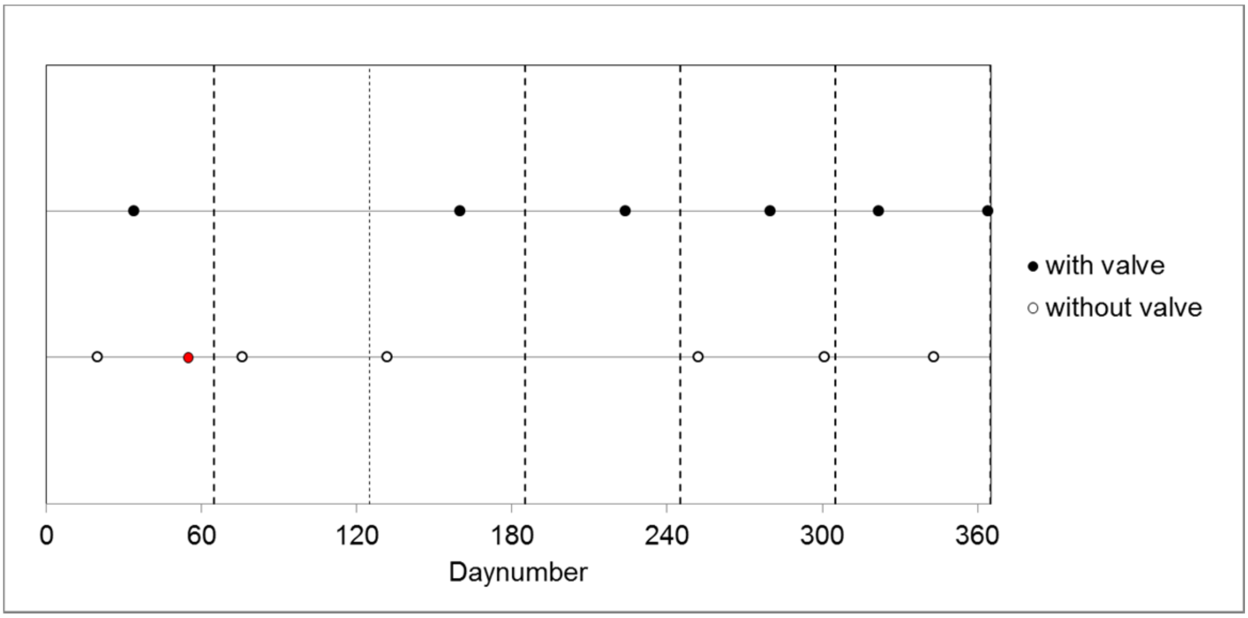

Figure 7 *Distribution of measurements over the year. On the x-axis the number of the first day of the measurement period in a the year 2014 or 2015.*

In Table 3 and Table 4 the detailed results of each measurement are presented.

CO2 concentration was measured using Dräger tubes and never exceeded 3000 ppm during measurement periods.
The feed ration consisted for more the 50% of roughage (mainly grass silage and maize silage) and contained more than 160 gram crude protein per kg of dry matter. Cows were fed with an average of 38.6 kg per cow (15.1 kg dry matter per cow) TMR and 4,8 kg of concentrate.
During measuring periods no slurry handling (pumping, removal or mixing) took place.
Average ventilation rate ranged between 902 and 942 m^3/h per cow.

Milk urea content of all cows individually were determined by Qlip every four weeks. Mean values per unit are presented in table 4 & 5.. When milk sampling did not take place during the measurement week, the average of the two adjacent samplings are presented.

Table 3

Overview of ammonia emission results per measurement of Comfort Slat Mats with valves

Measurement	1	2	3	4	5	6	Average
Week	33	41	47	53	6	24	
Starting date	11/8/2014	6/10/2014	17/11/2014	29/12/2014	2/2/2015	8/6/2015	
Day number	223	279	321	363	33	159	
Temperature outside	16.9	14.2	8.7	5.1	1.9	14.9	9.2
Unit temperature (CSM)	19.5	16.4	11.7	9.8	7.4	16.7	13.6
Unit temperature (Reference)	18.9	16.3	12.7	9.7	7.0	16.5	13.5
Number of cows (CSM)	16	16	16	16	15	15	16
Number of cows (Reference)	17	16	16	16	14	16	16
Average milk production (CSM) [kg/d]	25.3	27.5	29.9	27.9	26.3	20.5	26.2
Average milk production (Reference) [kg/d]	18.6	21.1	24.8	23.0	24.7	20.7	22.2
Milk urea content (CSM) [mg/100 g milk]	15	23	26	24	20	19	21
Milk urea content (Reference) [mg/100 g milk]	16	21	26	24	20	19	21
Milk protein content (CSM) [%]	3.4	3.3	3.7	3.7	3.8	3.7	3.6
Milk protein content (Reference) [%]	3.7	3.5	3.7	3.7	3.6	3.9	3.7
Milk fat content (CSM) [%]	4.3	4.3	4.5	4.8	5.0	5.0	4.6
Milk fat content (Reference) [%]	4.7	4.3	4.4	4.8	4.7	5.1	4.7
Air flow (CSM) [m^3/h]	14,151	14,142	14,129	14,153	14,150	14,152	14,146
Air flow (Reference) [m^3/h]	14,151	14,142	14,139	14,149	14,148	14,149	14,147
Average NH3 concentration (CSM) [ppm]	2.8	2.1	2.6	2.1	2.3	2.3	2.4
Average NH3 concentration (Reference) [ppm]	2.7	2.4	3.5	2.6	2.7	2.2	2.7
Average NH3 background (CSM) [ppm]	1.5	1.2	1.2	1.4	1.9	1.4	1.4
Average NH3 background (Reference) [ppm]	1.1	1.0	1.5	1.5	1.7	0.9	1.3
Average NH3 emission (CSM) [g/d]	319	229	343	189	104	230	235
Average NH3 emission (Reference) [g/d]	377	338	482	278	237	323	339
NH3 emission reduction [%]	15.3%	32.2%	28.9%	32.2%	56.2%	28.8%	32.3%

Table 4

Overview of ammonia emission results per measurement of Comfort Slat Mats without valves

Measurement	1	2	3	4	*5*	6	7	Average (n=6)
Week	37	44	50	4	*9*	12	20	
Starting date	8/9/2014	27/10/2014	8/12/2014	19/1/2015	*23/2/2015*	16/3/2015	11/5/2015	
Day number	251	300	342	19	54	75	131	
Temperature outside	15.3	11.7	4.6	0.4	*4.4*	6.2	11.2	8.2
Unit temperature (CSM)	18.9	15.0	10.5	6.9	*11.0*	11.9	16.2	13.2
Unit temperature (Reference)	18.5	15.0	10.2	6.5	*10.4*	12.2	15.9	13.0
Number of cows (CSM)	15	16	15	15	*15*	15	17	15
Number of cows (Reference)	14	16	15	15	*15*	15	16	15
Average milk production (CSM) [kg/d]	27.5	27.1	26.6	24.8	*26.1*	24.3	21.6	25.3
Average milk production (Reference) [kg/d]	22.4	23.6	22.3	23.5	*23.9*	22.1	21.4	22.5
Milk urea content (CSM) [mg/100 g milk]	21	17	18	19	*18*	20	19	19
Milk urea content (Reference) [mg/100 g milk]	20	18	20	19	*18*	20	18	19
Milk protein content (CSM) [%]	3.5	3.4	3.6	3.7	*3.8*	3.8	3.7	3.6
Milk protein content (Reference) [%]	3.5	3.7	3.8	3.7	*3.7*	3.6	3.8	3.7
Milk fat content (CSM) [%]	4.6	4.5	4.6	4.9	*4.7*	4.8	5.1	4.7
Milk fat content (Reference) [%]	4.3	4.6	4.7	4.8	*4.9*	4.7	4.9	4.7
Air flow (CSM) [m^3/h]	14,152	14,151	14,114	14,152	*7,221*	14,150	14,152	14,145
Air flow (Reference) [m^3/h]	14,150	14,150	14,147	14,148	*7,214*	14,149	14,153	14,150
Average NH3 concentration (CSM) [ppm]	3.0	2.0	2.4	2.2	*2.9*	2.2	2.1	2.3
Average NH3 concentration (Reference) [ppm]	2.6	2.4	2.7	2.5	*3.1*	2.9	2.2	2.6
Average NH3 background (CSM) [ppm]	2.3	1.4	1.5	1.8	*1.4*	1.6	1.2	1.6
Average NH3 background (Reference) [ppm]	1.4	1.4	1.2	1.7	*1.4*	1.7	0.9	1.4
Average NH3 emission (CSM) [g/d]	179	159	238	109	*180*	147	208	173
Average NH3 emission (Reference) [g/d]	287	244	373	196	*210*	304	306	285
NH3 emission reduction [%]	37.8%	34.6%	36.0%	44.6%	*14.4%*	51.7%	32.0%	39.4%

Ventilation rate during measurement 5 of the Comfort Slat Mats without valves was accidentally not set at the normal rate. This measurement is therefore not used in further calculations of emissions reduction. Average reduction of the Comfort Slat Mats with and without valves and results of the statistical analyses are given in Table 5.

Table 5
Overview of ammonia emission results for Comfort Slat Mats with and without valves.

Valves		Number of Measurement	Ammonia emission (g/day)	Difference g/day	Reduction %	P
Yes	CSM	6	235	104	32.3%	0.002
	Reference	6	339			
No	CSM	6	173	112	39.4%	<0.001
	Reference	6	285			

The reduction of the ammonia emission from the Comfort Slat mats without valves was 39.4% ± 7.3%. The reduction of the ammonia emission from the Comfort Slat mats with valves was 32.3% ± 13.3%.
The emission reduction of Comfort Slat Mats both with and without valves is significantly higher than zero.
The differences of ammonia emission reduction between CSM with and without valves was not statistically significant (p=0.28).
Emission results of the reference unit did not differ significantly between the measurement periods with and without valves (p=0.23).

4 Discussion and conclusions

4.1 Discussion

The case-control approach excludes a lot of possible farm and management effects on the ammonia emission like feeding, ventilation rate and climate conditions, and is therefore a powerful approach to measure ammonia emission effects of (in this case) the Comfort Slat Mats. Possible systematic differences between the two units however can still influence the results and cannot be corrected for. However no indication arose from earlier measurements in these units that this is the case.

The results from these measurements will be part of a larger dataset that also will include results from two practical farms at which emission measurement took place.

Equal circumstances in both units during measurement and compliance with the agronomical requirements are the main elements to discuss.

4.1.1 Equal circumstances

The circumstances in the two measuring units were comparable with the range of circumstances that can be expected at a modern dairy farm like milk production (kg), urea concentration, feed ration, available area (m^2) per cow, ventilation rate (m^3/h) per cow and temperature difference with outside temperature. Moreover the circumstances in the paired observations (reference vs treatment) were comparable. This is essential for case-control measurements. Only milk production was not always comparable between units. A higher milk yield is often associated with higher ammonia emission. However, Ogink et al. (2014) found no significant effect of milk production on ammonia emission in practice. But even if this effect is playing a role in these measurements, it will have worked 'against' the Comfort Slat Mats as the production in the unit with the CSM was always higher than in the reference unit at the same time. The higher milk yield in the CSM unit is in our opinion due to a bias as a consequence of the small amount of cows is each unit and the limitations in keeping all desired factors (production stage, urea content and milk yield) comparable. However some effect of CSM on milk production can't be excluded.

4.1.2 Compliance with agronomic requirements

The measurement protocol mentions several agronomic requirements to assure that emission measurements do not take place under circumstances that are not relevant or representative for practice. Some of these agronomic requirements were not met completely during the measurements. However, it is not likely that this has influenced the results in such a way that measurements should be omitted or final results are not valid.

- Figure 7 shows that for both the CSM with and without valves in one period of two month, two measurements took place and in another period none. This does not comply with the measurement protocol that state that all measurement should be evenly distributed over a year in six two months period. The two measurements in the same period took place with an interval of 42 and 49 days difference for CSM with and without valves respectively. That is long enough to assume that they were independent. Also total distribution of the measurements over one year was not skew.
- The average milk production in the reference unit was lower than 25 kg per cow. This does not comply with the measurement protocol that state that milk production should be minimal 25 kg per animal per day. Differences however were small and as argued before effects on ammonia emission are not likely.

- The number of animals in the reference unit was on two occasions 14. That is one less than the minimum of 15 stated in the measurement protocol. No significant effect is expected but if any effect took place it worked ‘against’ the Comfort Slat Mat.

It was expected that the use of valves on the CSM would increase the emission reduction compared to the CSM without valves. That effect was not found in these measurements. One reason could be that the valve did not close the slots sufficiently. Air exchange between pit and rest of the unit is reduced but still possible to some extent. And because concentrations of ammonia will rise in the pits headspace because of the reduced air exchange, no nett emission reduction is measured. Another reason can be that the valve is closing the slot too good not allowing the animal liquid and solid waste pass freely to the pits. The solid waste than accumulates in the slots saturated with urine and acts as an additional emission source causing again no extra emission reduction. Further research is needed to identify the cause and improve the effect of the valve. This further research has been initiated already by ICE and Beerepoot.

The emission reductions of the Comfort Slat Mats were achieved using a floor scraper once every two hours. The currently realized reduction results are therefor only valid for the Comfort Slat Mat in combination with the use of a floor scraper.

4.2 Conclusions

- The ammonia emission reduction of the Comfort Slat Mat with and without valves was measured during 2 time 6 measurements between August 2014 and July 2015 using the case control approach.
- Relevant circumstances during measurements were representative for modern dairy farms.
- Relevant circumstances in both units were comparable during measurements
- The reduction of the ammonia emission from the Comfort Slat mats without valves was 39.4% ± 7.3% and was significantly higher than zero ($p<0.001$)
- The reduction of the ammonia emission from the Comfort Slat mats with valves was 32.3% ± 13.3% and was significantly higher than zero ($p=0.002$).
- Emission reduction effects are only valid when Comfort Slat Mat is scraped at least once every two hours.
- Ammonia emission of the reference unit did not differ significantly between the measurements with and without valves ($p=0.23$).
- In contrary to expectations the valves used (type Mark 3) did not show an additional effect on the emission reduction. The emission reduction from the Comfort Slat Mat with or without valve did not differ significantly ($p=0.28$).
- Insight in the reasons and improvement of the valves need further research.

References

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To explore the potential of nature to improve the quality of life

Wageningen UR Livestock Research
P.O. Box 338
6700 AH Wageningen
The Netherlands
T +31 (0)317 48 39 53
E info.livestockresearch@wur.nl
www.wageningenUR.nl/livestockresearch

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