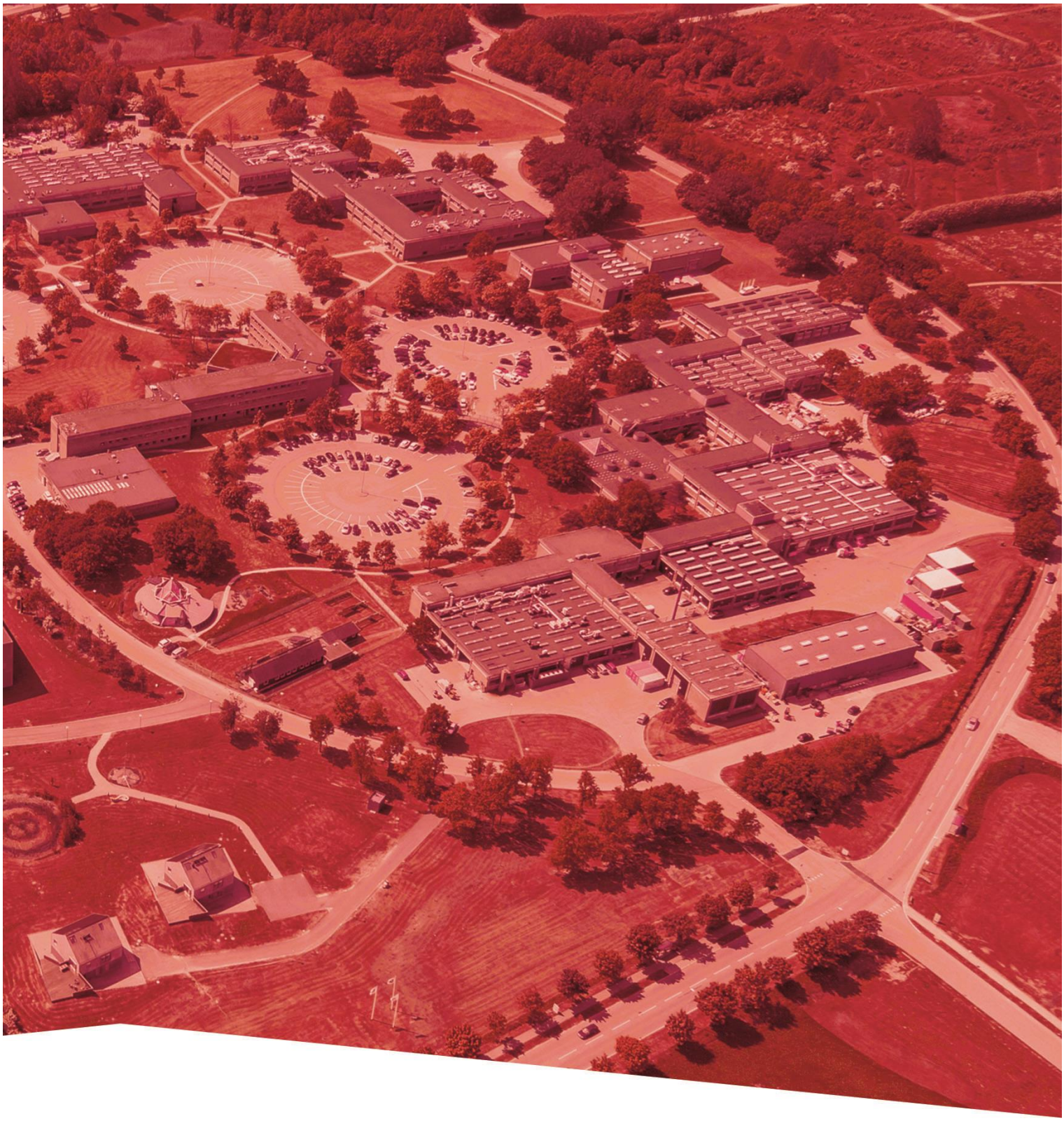

Heat-X Rotate - VERA test

November 2022

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Heat-X Rotate – VERA test

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Measurements and analysis done June 2021 to October 2022. Reporting October 2022

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1. Summary

Munters has developed a rotary heat exchanger, which in recent years has been installed in connection with poultry flockes in Denmark, Sweden, Germany, and the UK. The rotating heat exchanger is marketed under the name Heat-X Rotate.

Heat-X Rotate together with circulation fans have been tested in two poultry houses in Denmark.

The test is conducted according to VERA TEST PROTOCOL for livestock Housing and Management Systems, Version 3:2018-09. The Test period for farms 1 was from June 2021 to February 2022. The test period on farm 2 was from February 2022 to October 2022.

The test was a case-control study, where two identical broiler houses was included in each farm. At farm 1, each house had 23,000 chicken per house. At farm 2, each house had 30.000-32.000 chicken per house. The growth period analyzed was from day 1 to delivery of the first chicken to the slaughterhouse around day 31.

The primary test parameter was the ammonia emission. At farm 1 the ammonia emissions were reduced by 44% in the section with the heat exchanger connected (P<0,001). At farm 2 the ammonia emission was reduced by 29% in the section house with heat exchanger (P<0,001). In farm 2 there was no measurements in January and February and there were more broilers connected (33000 broilers/house) to the 20000 m^3/h Heat-X Rotate unit compared to Farm 1 (23000 broilers/house).

The heat exchanger did not have any brakes down or other operational problems during the test period. However, the test institution had a break down with their instrument during one batch of broiler at farm 1.

It took 20 minutes to clean the heat exchanger between each batch of broiler.

2. Background

In both the Netherlands and in Denmark it has been documented that the addition of heat and increased circulation of room air in poultry farms reduce the emission of ammonia.

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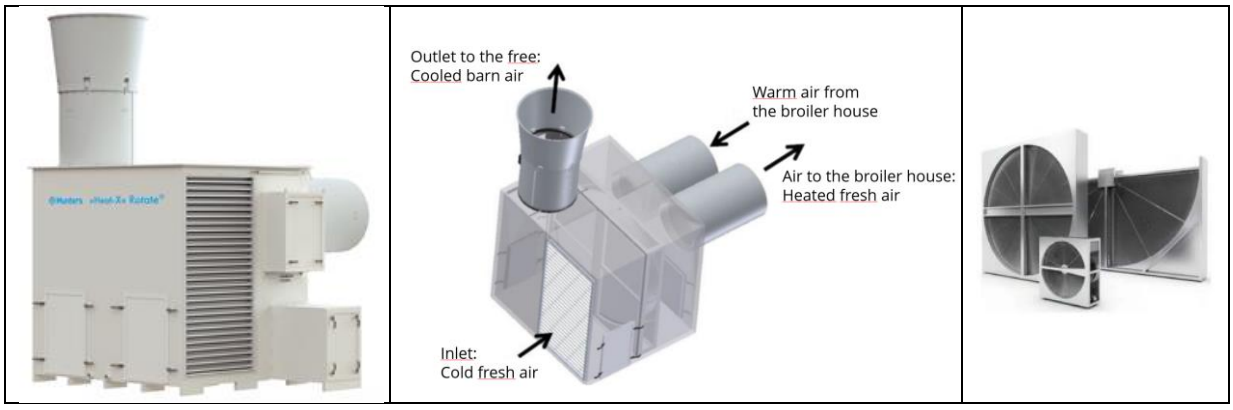
Munters has developed a heat exchanger with a rotating wheel. This is relatively easy to clean, which is very important in the poultry industry in order to control disease among the broilers especially between batches. During the use of the heat exchanger, the rotating wheel get cleaned automatic with compressed air.

Rotating heat exchangers has not previously been used in the livestock industry, but it is a well-known principle, and Munters has for years sold it to the industry.

The Munters rotating heat exchanger for livestock is called Heat-X Rotate, and it is available in two sizes 10 000 m^3/hour and 20 000 m^3/hour.



Figur 1. Heat-X Rotate

- To the left: Photo of Heat-X Rotate
- In the middle: Description of air in and out.
- To the right: Rotating wheel made of a huge number og small metal tubes that bring energy from exhausts air to inlet air, when the air passes the wheel

The heat exchanger sucks air from the barn and release the exhaust air to the surroundings through a traditional farm tube chimney outlet. There is also a fan that blows air into the barn. The outlet air and inlet air pass the Heat-X Rotate box. In the Heat-X Rotate box is the described electrically driven wheel, consisting of a series og metal channels in the direction of the air flow, which transfers energy from the hot exhaust air to the cold supply air.

The present report contains a test of Heat-X Rotate in two heards for broilers according to the VERA TEST PROTOCOL for livestock Housing and Management Systems, Version 3:2018-09.

3. Materiale and methods

The test was carried out in two broiler farms in Denmark.

The broiler farms had a numbers of broiler houses and two identical houses in each farm were selected to be included in the VERA test.

A heat exchanger from Munters called Heat-X Rotate was connected to one of the two selected houses at each farm. From the heat exchanger was an inlet tube system distributing the air from the heat exchanger to the room.

In the top of the broiler house with Heat-X Rotate a row of circulation fans were mounted and running. In farm 1 it was the existing circulation fans. In farm 2, 6 x Munters EDC24GHP circulation fans with a capacity of 7800 m^3/h were used. The circulation fans regulate up to 100% at 10% total ventilation and continue to run at 100% capacity until day 21, where the heat exchanger and circulation fans stops depending on an algorithm developed by Munters.

Description Farm 1

Each house has an area og 1236 m2. It is conventional broiler production with chickens of the Ross 308 breed. Approx. 23 000 day old chickens are stocked both in the test house with Heat-X Rotate and in the control house. The broiler density is approx. 37 kg/m^2 on growth day 31. On day 31-34, a number of chickens are taken out for partial slaughter. Few days after the house is emptied. The test period is from day 0 to the day where broilers are taken out of the flock – that means to day 31-34.

The heat exchanger Heat-X Rotate with a maximum capacity of 20 000 m3/hour was installed at the farm by the end of 2020, and the test was started in June 2021 and finished February 2022.

Figure 1. Test location at a broiler farm in Denmark

In farm 1, 11 Ø600 chimney extraction fans are installed in both the test and control house. One of the chimney fans are with variable speed and the rest is on/off regulated after Multi-step.

In each house is one EM50 fan. These are not used in the test as they are only used on very hot days.

Heating system is based at heating tubes along the building walls and the flow is regulated with a 0-10 V shunt valve. 2 x 106 kW (at 90°Celsius) heaters are used in each house in the beginning of a batch.

In the house with Heat-X Rotate, the variable fan included in the heat exchanger steps in as the first fan. Normally in Denmark it is the variable chimney fan, which step in as the first fan. In the house with Heat-X Rotate the variable regulated chimney fan step in as fan number 2.

Maximum ventilation in the two houses is the same, as the heat exchanger never run in the end of the batch. Munters has added an algorithm which calculate when the heat exchanger must stop.

Description Farm 2

Both houses are 86 meter long, and the houses has a width of 17 meter and 19 meters respectively. It is conventional broiler production. In the houses are approx. 30,000 and 32,000 broilers stocked, respectively.

The broiler density is approx. 39-40 kg/m^2 on growth day 32. On day 32 a part of the chickens is collected for partial slaughter. Few days after the house is emptied. The test period is from day 0 to the day where broilers are taken out of the flock – that means to day 32.

The heat exchanger Heat-X Rotate with a maximum capacity of 20 000 m3/hour was installed at the farm by the end of 2021, and the test was started in February 2022 and finished in October 2022.

Figure 3. Test location 2 at a broiler farm in Denmark

In farm 2, 11 and 12 Ø600 chimney extraction fans are installed in the two houses, respectively. Two of the fans in each house starts and runs simultaneously with variable speed, and the rest with on/off control after Multistep principle.

In each house is two EM50 fan. These are not used in the test as they are only used on very hot days.

Heating system is based at heating tubes along the building walls and the flow is regulated with a 0-10 V shunt valve. 2 x 106 kW (at 90°Celsius) heaters are used in each house in the beginning of a batch.

In the house with Heat-X Rotate, the variable fan in the heat exchanger steps in as the first fan. Normally in Denmark it is the variable chimney fan, which step in as the first fan. In the house with Heat-X Rotate the two variable regulated chimney fans step in as group number 2.

Maximum ventilation in the two houses is the same, as the heat exchanger never run in the end of the batch. Munters has added an algorithm which calculate when the heat exchanger must stop.

Measurement parameters

According to VERA TEST PROTOCOL for Livestock Housing and Management Systems the three primary measurement parameters are: 1) Ammonia mg/m^3, 2) odour OU_E/m^3 og 3) Particlesr (PM) mg/m^3.

The test of Heat-X Rotate focus at the primary measurement parameter "Ammonia". Heat-X Rotate does not have a negative effect at odour or particles, and due to that it is not nessasary to measure odour and particles in the test.

Primary measure parameter

The ammonia concentration is measured with Picarro.

The ammonia concentrations are measured in following points:

1) In control house below the variable regulated fans (not totally beneath but 10 cm in horizontal direction from the fan inlet, in order to secure cold air stream from outside doesn´t fall down during periods with rain and storm)
2) In experimental house below the variable regulated fans (not totally beneath but 10 cm in horizontal direction from the fan inlet, in order to secure cold air stream from outside doesn´t fall down during periods with rain and storm)
3) Outdoor 20 meter outside the houses (It is the ammonia generated in the houses which are measured, so the difference between inlet concentration and outlet are measured to calculate the emission from the houses)
4) In front of the heat exchangers exhaust.

Between the exhaust points and the picarro were installed tubes of the material polyetrafluoroethylene (PTFE). The tubes were insulated, and an electrical heat line was added to secure that no condensation will occure in the tubes.

Tubes and calibration were checked in the beginning and in the end and during run of experiment. Checks were done with test gas added to the tube ends next to the fans and outdoor. In one batch at farm number 1 the check failed when the winter started, due to not sufficient tight insulation. This batch of measurements were discarded. In the rest of tests, the Picarro and the calibration gas showed identical values.

Secondary measurement parameters
The VERA TEST PROTOCOL for Livestock Housing and Management Systems specifies a list of secondary measurement parameters. The secondary ""Mandatory" measurement parameters are included.

Parameter	Sampling (where, when og how often)	Measure method
Ventilation air flow (m^3/hour)	In each broiler house are fans running variable and on/off fans stepping in according to Multistep. Measurement vings from Munters are mounted in front of following exhausts 1) heat exchangers, 2) variable chimney fans and 3) the first on/off fan stepping in in each house. During the entire test period, the air flows for each measurements fan are logged every minute. Every 1 minute are logged which fans are running in the houses.	Munters measurements wings are installed. Measurement wings are calibrated by Technological Institute before mounting in the farm 1. Equipment from Veng system register round per minute and from this input, Veng systems software are set up calculate air flow in m^3/minute. Data are stored each 1 minute at a pc on the farm. The pc has installed Team viewer, and the Test Institution could follow the system from the office in order to check the system is running and download data regularly. Data describing which fans are running and data describing air

		flow through variable speed fans and on/off controlled fans give the option to calculate the air-flow through the house each five minutes.
CO_2 (ppm)	Measured in the same points and with the same frequency as the primary registration of the ammonia concentration.	The carbon dioxid concentration is measured with Picarro – see further details described above regarding primary registration parameter
Temperature (Celsius)	Measured outdoor in the shadow side of the building. Measured in the middle of the houses. Data are sampled every 1 minute in the entire test period.	Temperature sensors in house checked by Danish Technological Institute with Danak akkredited instrument type TSI VelociCALC 9596
Relative humidity (%)	In same points and with same measure frequency as temperatures – see above	As above
Number of chicken and their weight (Number/weight)	The farmers informed in advance the date for delivery of day-old chicken and the date for first delivery to the slaughterhouse. Beside that number of broilers and weight was informed.	Information provided by the farmer, who received the information from supplier of day-old chicken and slaughterhouse
Date for removal of bedding material in house	Done between batched and date noted.	Controlled by technician
Cleaning of house and heat exchanger	Done between batched and date noted.	Kontrolleret ved holdstart

Table 1. Secondary measurement parameters

4. Results and discussion

Test period for farm 1 was June 2021 – February 2022. After test at farm 1, the instruments were moved to farm 2. The Heat-X Rotate was not moved. It stayed at farm 1 and a new heat exchanger was mounted at farm 2. Test period at farm 2 was from March 2022 – October 2022.

Test location	Batch number	Date for batch start and first delivery to slaugh-ter-house
Farm 1	Batch 4 2021	18. June 2021 – 19. July 2021
	Batch 5 2021	6. August 2021 – 6. September 2021
	Batch 6 2021	27. September 2021 – 25. October 2021
	Batch 7 2021 (*)	15. November 2021 – 13. December 2021
	Batch 8 or Batch 1 2022	4. January 2022 – 1. February 2022
Farm 2	Batch 2 2022	4. March 2022 – 5. April 2022
	Batch 3 2022	22. April – 24. May 2022
	Batch 4 2022	10. June – 12. July 2022
	Batch 5 2022	29. July – 30. August 2022
	Batch 6 2022(**)	16. September – 18 October

Table 2. Batches in test

*: Batch was cancelled due to condensation of water in tubes connected to Picarro

**: Report was written before this batch ended, and the full batch was not included

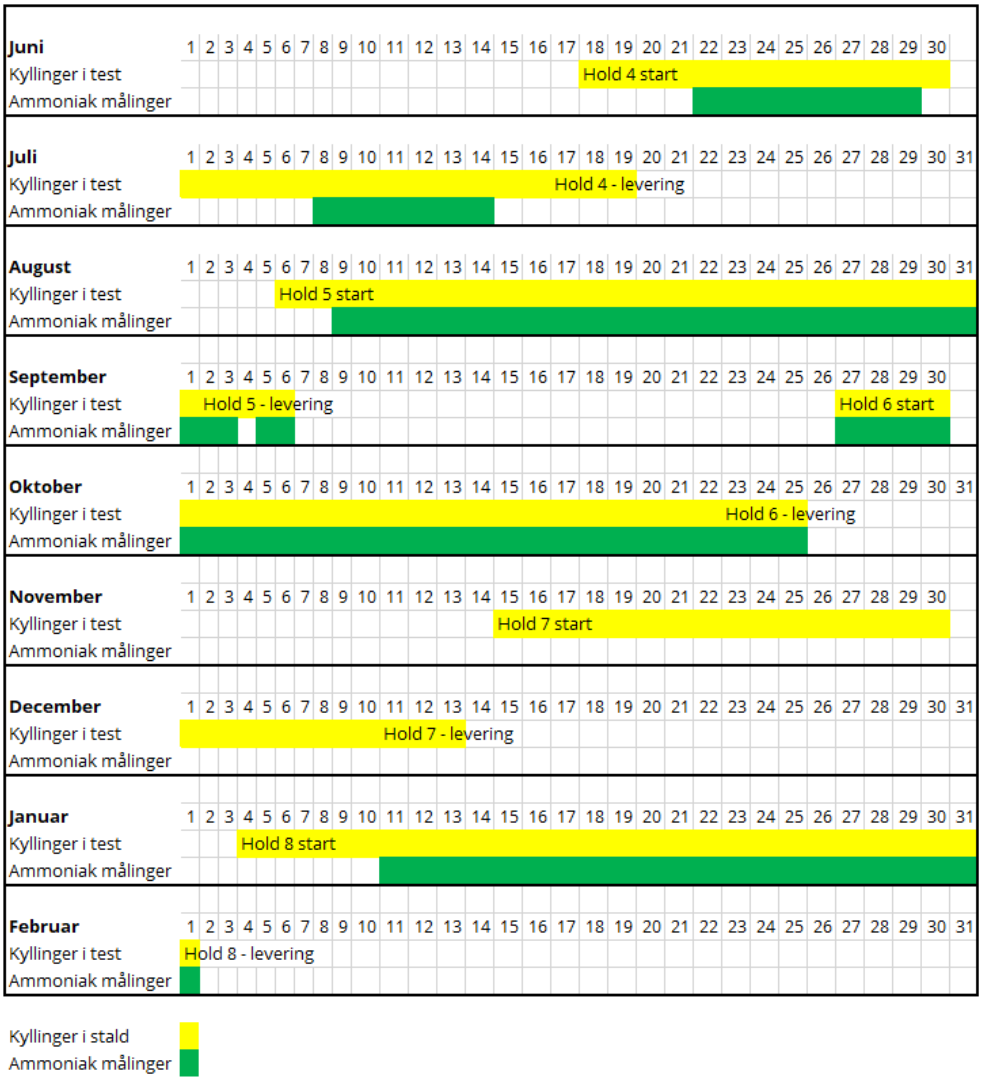


Figure 4. Overview of broilers in test in Farm 1, and days specified for measurements with Picarro.

During Batch 4 Picarro was delivered to University of Aarhus for check.

Batch 7 was discarded, regarding measurements with Picarro, as condensation of water was detected in the tubes.

Ammonia

In farm 1 was measured with Picarro during 4 batches of broilers in the period from June 2021 to February 2022.

In farm 2 was measured with Picarro in the period from March 2022 to September 2022.

When the data was analyzed, and the emission was calculated the data was divided in 3 periods for different sizes of broilers:

Period 1: Day 1 to 11
Period 2: Day 11 to 20
Period 3: Day 20 to delivery

Batch number	Period	Average NH_3 emission from control house (gram/hour)	Average NH_3 emission from House with Heat-X Rotate and circulation fans (gram/time)
Hold 4 2021	1 2 3	15,03 15,71 205,58	4,53 4,40 148,45
Hold 5 2021	1 2 3	15,5 93,14 225,75	6,16 10,45 115,49
Hold 6 2021	1 2 3	11,07 32,99 194,43	3,24 11,10 97,67
Hold 8 eller hold 1 2022	1 2 3	 55,14 182,72	 9,10 58,24

Table 3. Farm 1 – Ammonia emission from 2 sections divided in 3 growth periods

Period	Average NH_3 emission from control house (gram/hour)	Average NH_3 emission from house with Heat-X Rotate and circulation fans (gram/time)	Difference (gram/time)
1. Day 1-10	13,87	4,64	9,22
2. Day 11-20	49,24	8,76	40,48
3. Day 21 – delivery	202,12	104,96	97,16

Table 4. Farm 1 – Average ammonia emission for 3 growth periods

Period	Average NH_3 emission from control house (gram/hour)	Average NH_3 emission from house with Heat-X Rotate and circulation fans (gram/time)	Difference (gram/time)
1. Day 1-10	16,7	2,9	13,8
2. Day 11-20	79,3	46,3	33,0
3. Day 21 – delivery	190,9	153,4	37,5

Table 5. Farm 2 – Average ammonia emission for 3 growth periods

A statistical analysis (Analysis of variance) shows that the interaction between periods is small, i.e. there is basically the same pattern for the emission in the three growth period for each batch of broilers. The emission varies significantly within the 3 growth periods, and there is a significant difference in the ammonia emission between the two houses ($P<0,001$). Reduction of ammonia emission was 44% for Farm 1 during days of measurements and the reduction was 29% for Farm 2 during days of measurements. Measurements at Farm 2 did not include data from January and February.

Temperature and relative humidity

Table 6 shows the average of measured temperature og relative humidity. In Appendix are graphs for the whole period shown.

The temperature is the same in the control house and in the house with Heat-X Rotate and air circulations fan. This was also expected, as the ventilation was running due to the same wanted temperature control point. The relative humidity was lower in the house with Heat-X rotate in the beginning of the batch period.

Farm 1 – Temperature and humidity								
Measure period	18/6-19/7		6/8-6/9		28/9-25/10		4/1-1/2	
Measure days	32		32		29		29	
Outdoor -Temperature	19,6±0,9		17,6±0,5		12,6±0,8		5,6±0,6	
Batch	4, 2021		5, 2021		6, 2021		1, 2022	
Group	Control	Heat-X	Control	Heat-X	Control	Heat-X	Control	Heat-X
Temperature	28,1±0,8	28,5±0,7	28,5±1,0	27,5±0,9	29,5±0,9	27,9±0,9	29,6±0,7	28,2±0,9
Rel. humidity	65,0±1,6	61,2±2,6	62,4±1,1	58,3±1,1	61,0±1,3	56,1±2,5	63,0±0,9	54,9±2,7
Farm 2 – Temperature and humidity								
Measure period	7/3-7/4 2022		21/4-25/5 2022		9/6-13/7 2022		28/7-31/8 2022	
Measure days	32		33		32		35	
Outdoor -Temperature -Relative humidity	5,7±0,7 69,4±4,2		12,3±1,1 66,3±2,4		17,1±1,1 68,9±2,7		20,1±0,9 66,1±1,8	
Batch	2, 2022		3, 2022		4, 2022		5, 2022	
Group	Control	Heat-X	Control	Heat-X	Control	Heat-X	Control	Heat-X
Temperature	27,1±1,3	26,7±1,0	27,9±1,2	27,8±1,0	28,7±1,1	28,0±1,0	28,5±1,2	28,4±0,8
Rel. humidity	55,7±2,6	51,1±2,9	52,8±2,4	47,4±4,3	58,8±1,8	56,4±2,9	60,4±2,7	57,7±2,9

Table 6. Average Temperature and humidity and 95 percent confidence interval.

Air flow

Table 7 shows the average of measured airflow (m^3/hour). All measurements for the periods are illustrated in graphs in Appendix.

In farm 2 the house with Heat X-Rotate was 2 meter wider than the control house but the animals per square meter was the same. To compare the air flow, the number for the control house is multiplied by number of chickens in Heat-X Rotate house divided with number of chickens in control house = 32000/30000 = 1.06666.

Farm 1 – Air flow				
Measure period	18/6-19/7	6/8-6/9	28/9-25/10	4/1-1/2
Measure days	32	32	29	29
Control house (m^3/h)				
Heat- X house Heat-X Chimney fans Total (m^3/h)				
Farm 2 – Air flow				
Measure period	7/3-7/4 2022	21/4-25/5 2022	9/6-13/7 2022	28/7-31/8 2022
Measure days	32	33	32	35
Control house (m^3/h)				
Heat- X house Heat-X Chimney fans Total (m^3/h)				

Table 7. Average air flow (m^3/hour).

Carbon dioxide

Table 8 shows the average of carbon dioxide concentration. Graphs for the whole period are shown in Appendix.

Farm 1 – Carbon dioxide				
Measure period	18/6-19/7 2021	6/8-6/9 2021	28/9-25/10 2021	4/1-1/2 2022
Measure days	32	32	29	29
Control house (ppm)	1175±152	1557±126	2165±203	2977±196
Heat- X house Heat-X Chimney fans (ppm)	 839±159 1035±78	 953±169 1159±102	 1021±157 1360±164	 1011±145 1573±246
Farm 2 – Carbon dioxide				
Measure period	7/3-7/4 2022	21/4-25/5 2022	9/6-13/7 2022	28/7-31/8 2022
Measure days	32	22		31
Control house (m^3/h)	2183±185	1636±169		1099±102
Heat- X house Heat-X Chimney fans (ppm)	 1787±140 1289±176	 1012±203 1370±53		 927±60 728±104

Table 8. Carbon dioxide concentration (ppm) and 95 percentage confidence intervals.

5. Conclusion

Heat-X Rotate from Munters have been tested on two broiler farms after Case-Control design. On each farm two identical houses are selected, and the heat-X Rotate + circulation fans got installed in one of the houses.

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The test was based at VERA protocol in order to get on the Technology list in Denmark regarding ammonia reduction. That means parameters like odour and particles, which are not relevant, has been left out.

One farm had 23000 broilers per house and the other farm had 30000-32000 broilers per house. At each farm was installed a Heat-X Rotate with a capacity of 20000 m^3/hour.

The ammonia measurement was done with Picarro, and when measurements were finished at one farm the instrument was moved to the next farm. Total test period was 15 months. Test at Farm 1 was from June 2021 to February 2022 and test at Farm 2 was from March 2022 to October 2022.

The reduction of ammonia emission when Heat-X Rotate and circulation fans were used was:

- 44% at Farm 1and
- 29% at Farm 2

The reason for the lower reduction at Farm 2 could be because

- measurement period did not include the vary cold winter months and
- more broilers were included when testing a 20000 m^3/hour Heat-X Rotate

Appendix:

- Graphs
- Statistical calculations

Referencer:

1. VERA TEST PROTOKOL for Livestock Housing and Management Systems; version 3:2018-09, VERA Verification of Environmental Technologies for Agricultural Protection, VERA Secretariat 2018