Rokkedahl Energi. Ammonia Emission from Broiler Houses. Effects of the Agro Clima Unit Heat Exchange System.

Test Report

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1 INTRODUCTION

This test report is prepared as part of the verification of the ammonia abatement effect of Agro Clima Unit, following the AgroTech Test Centre Quality Manual.

1.1 Name and contact of proposer

The Agro Clima Unit is developed by the Dutch company Agro Supply. In Denmark Agro Clima Unit is marketed and sold by Rokkedahl Energi, Nymøllevej 126B, Kølby, 9240 Nibe, Denmark. Website: www.rokkedahl-kylling.dk/rokkedahl-energi.aspx.

Rokkedahl Energi contact: Mark Rokkedahl. E-mail: adm@rokkedahl-energi.dk. Phone: +45 30 28 72 10.

1.2 Name of test body and test responsible

The test was performed by DANETV, AgroTech, Agro Food Park 15, DK-8200 Aarhus N, Denmark.

Test responsible: Martin Nørregaard Hansen. Phone +45 3092 1784. E-mail: mno@agrotech.dk

1.3 Reference to test plan and specific verification protocol

This test report was made to meet the requirements defined in the verification protocol and test plan for Agro Clima Unit used for reducing ammonia emission from broiler production systems.

1.4 Deviations to test plan

Due to problems with the measuring equipment and the continuous measurement of ventilation rate, it was not possible to calculate a continuous emission profile for the full length of the production cycles. To avoid that the periodic malfunction of measuring systems influenced the calculation of technology effect, data was excluded from both the case and control sections when a measuring problem was observed in one of the test sections.Therefore, the ammonia emission could not be calculated for all days in the production cycles. The measurement period was scheduled to last approximately 30 days per production cycle. Due to malfunction of measurement equipment the number of measurement days were reduced by 5, 13, and 12 days for period 1, 2, and 3 respectively.

2 TEST DESIGN

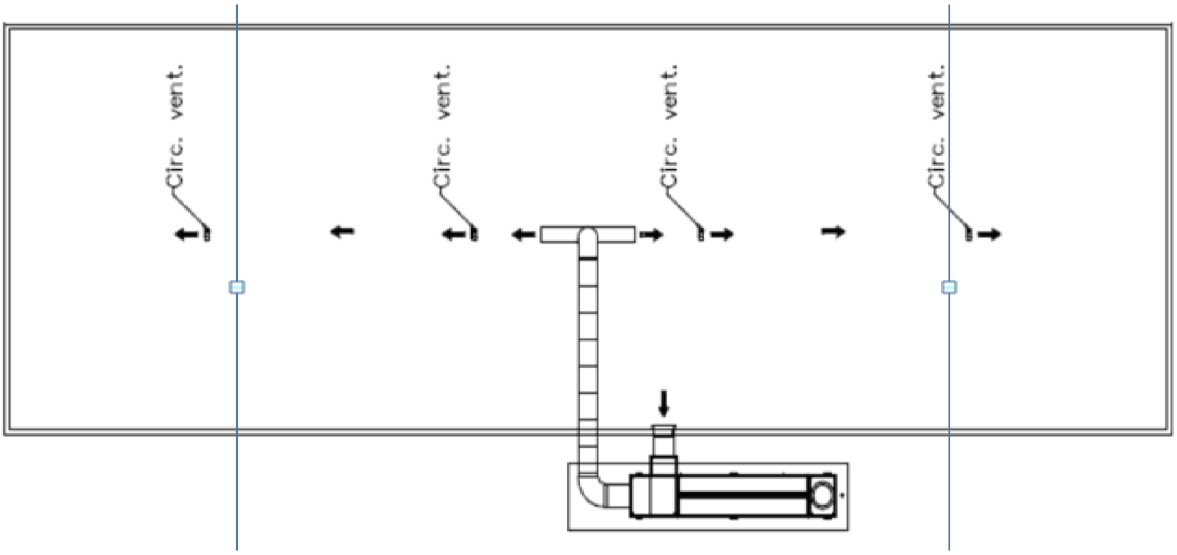
2.1 Technology description

The technology evaluated is the Agro Clima Unit (ACU) Clima^{+} 200, type 2.5 developed by the company Agro Supply. Chicken production has a high energy requirement, especially in the first part of the production period due to the high temperature requirement of newly hatched chicken. The inhouse temperature in broiler houses follows a preset temperature schedule. The temperature is normally regulated by use of inhouse gas burners and/or pre-heating of inflowing air. The Agro Clima Unit is a heat exchange system that utilize the thermal energy of the air leaving the chicken house to heat and dry incoming air by a countercurrent heat exchange system. The potential ammonia emission reducing principle of the Agro Clima Unit is the drying of the manure layer caused by the heat exchanger and the in-house air circulation that is included in the system. The heated incoming air that has passed through the Agro Clima Unit is blown into the house at the top of the building. The system includes an internal mixing of in house air which potentially results in homogenisation of in-house temperatures and improved drying of the manure layer.

The Agro Clima Unit is normally situated next to the chicken house (Figure 1). Air is drawn through the Agro Clima Unit to the ridge of the chicken house and distributed to the front and back side of the building by means of four additional in-house supporting vents. This results in an improved distribution of the fresh air in the building. When air is drawn by ridge vents the in-coming air is mixed with the air from the Agro Clima Unit by means of circulation vents. The mixed air is pushed towards both ends of the building at the top of the house. The mixed air is then pushed back towards the centre of the pen above the chicken and the litter layer.

The ACU Clima$^+$ 200, type 2.5 has a max air capacity of 22,300 m^3 air h^{-1}. In the first weeks of the production cycle, when the need for heating is high and the need for air exchange is low, the air flow through the ACU was gradually increased from 8 to 100 % of the max air capacity of the ACU. In the last part of the production cycle, when the need for air exchange was higher than the max capacity of the ACU system, the ventilation was performed by both the ACU system and the ridge ventilation system. Three weeks after the introduction of the broilers to the housing section, when external heating of the broiler houses was no longer required, the air exchange through the ACU system was reduced to 75 % of its max air capacity.

Figure 1. Picture of the Agro Clima Unit situated outside a poultry house. Ventilation air to and from the poultry house are drawn through the Agro Clima Unit by a countercurrent principle to utilise the heat content of out flowing air to heat up inflowing air.



Drawing of the air circulation system inside the broiler house. Air is drawn through the Agro Clima Unit to the ridge of the broiler house and distributed to the front and back side of the building by means of four additional in-house supporting vents.

The user manual of the Agro Clima Unit can be seen in Appendix D.

2.2 Test site

2.2.1 Housing system

The study was performed as a comparative continuously on-line measurement of the ammonia (NH_3) emission from two equal commercial broiler housing sections where one of the housing sections was equipped with the ACU system (case test section), while the other broiler house was equipped with a traditional heating and ventilation system (control test section) (Figure 2).

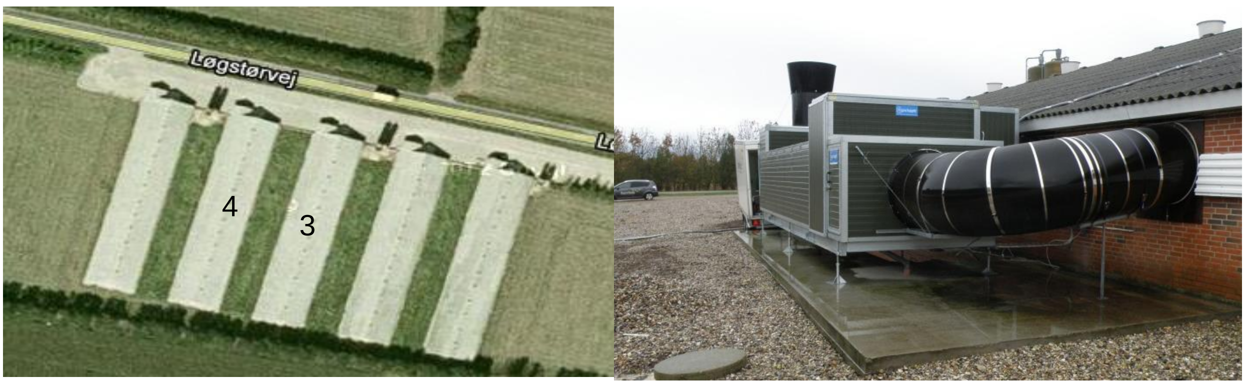


Figure 2. The left picture shows an aerial photo of the two test broiler houses. The house denoted 4 is the control test section, while the house denoted 3 is the case test section. The right pictures shows the Agro Clima Unit situated outside test section 3.

The test farm (Haubro, Aars) consists of five commercial broiler houses (Figure 2). Each house has the capacity of 31.000 broilers per production cycle. The chicken production in both sections was a traditional Danish litter mat production system. In both sections newly hatch chickens was introduced to a cleaned housing system littered by a thin sawdust litter mat before taking out of production approximately one month later, when a fraction of the broilers was taken out of production. A few days after the rest of the broilers were taken out of production leaving the houses empty. After the end of the production cycles all manure was removed, and the houses were throgully cleaned before new bedding material and chickens were introduced.

2.2.2 Adress of test sections

The two test sections were situated at the address Løgstørvej, 9600, Haubro, Aars (Vest-himmerland). The two test sections were part of a five equal housing sections having equal housing design, and number of broilers, and equal production, feeding, and ventilation system.

2.2.3 Description of ventilation system

The two test sections were equipped with a traditional negative pressure roof ventilation system. The air exchange during the 12 roof ventilation ducts was continuously on-line measured by anemometers (Ø-600, Stienen). The air exchange through gable ventilators was measured by registration of running hours and max ventilation capacity. The measurement of the ventilation through the ACU unit was continuously measured by the aneomometer (Ø-360) integrated in the air outlet duct leading to the ACU. The houses characteristics can be seen in table 1.

Table 1. Key characteristics of the broiler test sections involved in the test.

Parameter	Test site characteristics
Size of the livestock unit involved in the test	Hatch chickens (45 g) - 30/35 days old (ca. 1800 g)
Stock density	31.000 chickens/section
Floor design	Solid floor covered with saw dust litter
Feeding system	Dry food feeding
Manure removal system	The litter mat was removed at the end of each production period
Ventilation system	Traditional negative pressure system with wall and roof control device
Ventilation	Mechanical negative pressure ventilation system (SKOV, model DOL92A)
Ventilation (Max.)	Roof ventilation capacity: 165.600 m^3 per hour Gable fan capacity: 2 x 40.300 m^3 pr. hour ACU capacity (only test section): 22.300 m^3 pr. Hour

2.3 Methods

The overall principle for testing the performance of Agro Clima Unit was to compare the emission of ammonia from a test section attached an Agro Clima Unit (case section) with the emission of ammonia from a equal test section without an Agro Clima Unit (Control section). As broilers are housed in mechanically ventilated housing systems, the emission was measured by simoultaneously on-line measurements of ventilation rate and concentrations of ammonia in ingoing and outgoing air.

Emission measurements from livestock housing systems require measurement of the air exchange (ventilation) of the housing systems. The ventilation rate was continuously on-line measured by air anemometers (Stienen, d = 600mm) situated in ventilation ducts during the test periods.

The concentrations of ammonia in ingoing and outgoing air were continuously on-line measured by use of an on-line automatic photoaccustic multigas analyser (INNOVA, 1412), connected to an automatic mulitipoint sampler (INNOVA, 1307). Air was drawn by pumps from the sampling points to the measuring equipment through insulated and heated Teflon tubes to avoid vapor condensation in tubes and the measuring system. The measured levels of gas concentrations in in- and outflowing air were inspected daily to detect filter blocage and sampling failure. When measurement failure took place in one of the test sections, all data of that measurement day was excluded to avoid unequal sampling conditions.

The emission of ammonia from the the test units was quantified by the following equation:

$$E_{NH3_t} = \sum_{i=1}^{i=3} \sum_{t=1}^{t=n} V_{i_t}\, x\, (C_{in_{i_t}} - C_{out_t})$$

where
E_{NH3_t}= Emission of ammonia from the housing systems at time t, mg NH_3 h^{-1}
i = Type of ventilation (roof ventilation, Agro Clima Unit ventilation, gable wall ventilation)
n = the number of measurement during the sampling period
V_i = Air flow, m^3 air h^{-1}
C_{in_t} = Ammonia concentration in outgoing air at time t, mg NH_3 m^{-3} air
C_{out_t} = Ammonia concentration in ingoing air at time t, mg NH_3 m^{-3} air
t = measurement event

The daily emission of ammonia per housed broiler was quantified by the following equation:

$$E_{NH_3} = \sum_{j=0}^{n} \frac{24}{N_j}\, x\, \bar{E}_{NH3_j}$$

Where
E_{NH3} = Daily ammonia emission per chicken, mg NH_3 $animal^{-1}$ day^{-1}
n = Length of the measurement period, days
j = Measuring day
N_j = Total number of broilers in test section
$\bar{E}_{NH3_t}$ = Mean measured ammonia emission per test section at day j, mg NH_3 h^{-1}

The ammonia emission from both case and control sections was measured in three production cycles each lasting approx. 30 days. To incorporate a potential climatic effect, the three measuring periods were performed during summer, autumn and winter conditions.

Ammonia was the primary performance test parameter. In addition a number of operational parameters were measured throughout the test period. A list of the operational parameters can be seen in the table 2.

Table 2. Measured parameters and involved analytic methods and detection limits

Parameter	Analytical method	Limit of detection	Uncertainty
NH_3	ISO 7150/2, Photo acoustic multigas analyser	0,20 mg/^{m3}	15 % RSD
CO_2	ISO 7150/2, Photo acoustic multigas analyser	1,5 mg/^{m3}	---
CH_4	ISO 7150/2, Photo acoustic multigas analyser	0,4 mg/^{m3}	---
N_2O	ISO 7150/2, Photo acoustic multigas analyser	0,03 mg/^{m3}	---
Temperature	VE10 universal input from VENG system combined with a temperature sensor	---	0,2 °C
Relative humidity	VE14 universal input from VENG system combined with a humidity sensor	---	---
Ventilation	Air anenometers, ø 600, Stinen.	---	---

In addition to the parameters listed in table 2, the number of dead broilers, on/of periods of use of gable ventilators, in house CO_2 concentrations, air temperature and humidity, and the daily consumption of feed and water were registrated daily by the test site responsible.

This test was planned and conducted to comply with the methodologies described in the Test Protocol for Livestock Housing and Management Systems developed under the VERA-program. The intention is that the results of this DANETV verification of Agro Clima Unit can be used as part of the documentation needed for a VERA verification statement.

2.4 Test Schedule

The test schedule is presented in table 3.

Table 3. Test schedule.

Task	2012								2013	
Week no.	**37-38**	**39-40**	**41-42**	**43-44**	**45-46**	**47-48**	**49-50**	**51-52**	**1-4**	**4-8**
Test plan preparation	X	X								
Practical planning	X	X								
Period for testing		X	X	X	x	x	X			
Test report drafting							X	x		
Test report quality assurance									x	x
Test report final version									x	x

2.4.1 Measurement periods

- First period: Start 16th August 2012 and finished 17th September.
- Second period: Start 5th October and finished the 3rd November.
- Third period: Start 20th November and finished the 23th December.

The data gaps in the measurement periods is caused by technical problems of the sampling equipment and the air exchange measurements. These are further described in point 3.2.

3 TEST RESULTS

3.1 Test data summary

The ammonia emission from broilers produced in equal test section with and without the ACU heating system was quantified continuously from the start of the production cycles until a fraction of the broilers was taken out of the production system approximately 30 days later. The ammonia effect of the ACU system was quantified for three production cycles.

Table 4 shows the duration of the three test periods and the number of broilers housed in the test sections during the three test periods.

Table 4. Start and end of production cycles and the number of broilers at start and end of the production cycles.

	Test section	Start of production cycle	End of measurement period	No. of broilers start	No. of broilers end
1	ACU	16.08-2012	17.09-2012	30.100	29.516
1	Control	16.08-2012	17.09-2012	30.900	30.260
2	ACU	05.10-2012	05.11-2012	31.900	31.409
2	Control	05.10-2012	05.11-2012	31.900	31.412
3	ACU	22.11-2012	24.12-2012	30.500	29.729
3	Control	22.11-2012	24.12-2012	30.400	29.748

The first measurement period (Period 1) took place between the 16th of August and the 17th of September 2012. Results were not obtained during the first five days of the production cycle due to technical problems related to the quantification of the ventilation rate in the control section.

The second measurement period (Period 2) took place between the 5th of October and 3rd of November 2012. Due to malfunction of sampling equipment in the periods between the 6th to 10th of October, 18th to 22th of October and 1st to 3rd of November data are not shown for these dates.

The third measurement period (Period 3) took place between the 20th of November and the 23th of December. Due to malfunction of sampling equipment in the periods: 24th to 26th November, 30th of November – 3th of December, 8th – 10th of December, and 13th – 14th of December data are not shown for these dates.

The daily NH_3 emission from broilers produced in houses with or without the ACU system is shown in Figure 3. Levels of emission were found to increase during the production cycle for all three periods. In period 1 ammonia emission was found to be lower from the broilers produced in the test section attached the ACU system for the first 20 days of the production cycle. In period 2 lower emission from the test section attached the ACU was observed during the full period of measurement. In period 3 lower emission was observed from the case section during the first 25 days. In this period the ventilation of the case section was performed mainly by the ACU system. In general, it was observed that the higher proportion of the total ventilation requirement that was performed by the roof ventilation system, the closer were the emission levels of the test and case section (Figure 3 and Figure 5).

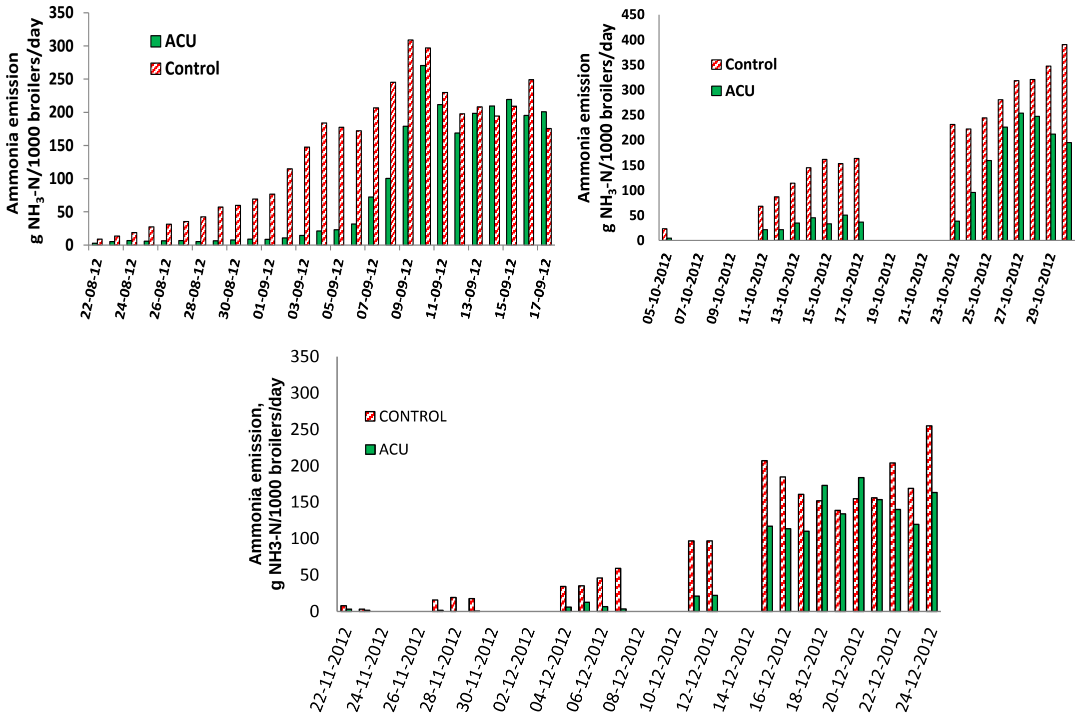


Figure 3. Measured daily emission of ammonia nitrogen (NH_3-N) from broilers produced in a house attached the Agro Clima Unit (ACU) and a house without the use of the Agro Clima Unit (Control).Ammonia volatilization is shown in g of ammonia nitrogen (NH_3-N) per 1000 broilers per day. The top left diagram shows results for broilers produced during August and September, the top right diagram shows the results during October and November. The lower diagram shows results for broilers produced during November and December. Missing data is a consequence of measurement equipment malfunction.

The ammonia emission from the broilers was in all periods low in the first part of the production cycle (Figure 3). A gradual increase of emission was observed during the production cycles. The increase was observed to be earlier and higher from the control section, while a later and lower increase was observed from the ACU section. This pattern was observed during the first part of period 1 and 3 and during the full production cycle in period 2. The reason for the difference between the periods 1, 2 and 3 is expected to be caused by the difference in total ventilation requirement for the three periods. Higher outdoor temperatures in period 1 than in period 2 and 3 (Figure 4) caused higher ventilation requirement in period 1. Because of that only a minor fraction of the total ventilation was performed by the ACU system in the last part of the production cycle. The lower outdoor temperatures in period 2 and 3 caused lower ventilation requirement in the last part of the production cycles. Thereby a higher share of the total ventilation was performed by the ACU system in period 2 and 3 (Figure 5).

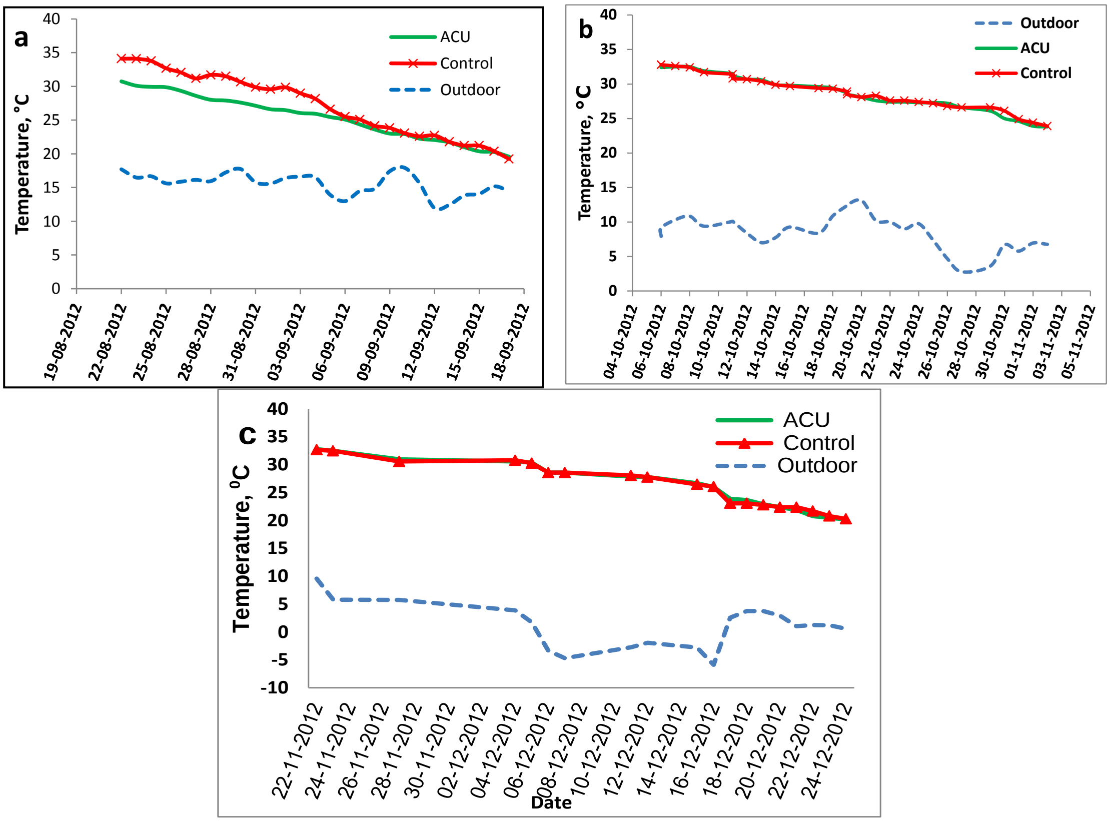


Figure 4. Average daily temperature measured outside and inside case and control sections during the three measurement periods 1(a), 2 (b) and 3 (c).

The ventilation requirement in broiler houses depends on the chickens' age and air humidity and temperature of in-house air, which in the last part of the production cycle is depending on outdoor temperature. The total ventilation of the ACU test sections and the control sections was equal (Figure 5), however, while ventilation of the control section was performed only by mechanical roof vent ducts, the ventilation of the ACU section was performed by both mechanical roof vent ducts and the ACU system. When the ventilation requirement is low in the first part of the production cycle, all ventilation in the ACU section was performed by the ACU system. Later in the production cycles, when the ventilation requirement increased, a decreasing part of the total ventilation requirement was performed by the ACU ventilation system (Figure 5). The gable fans were not used during the three test periods.

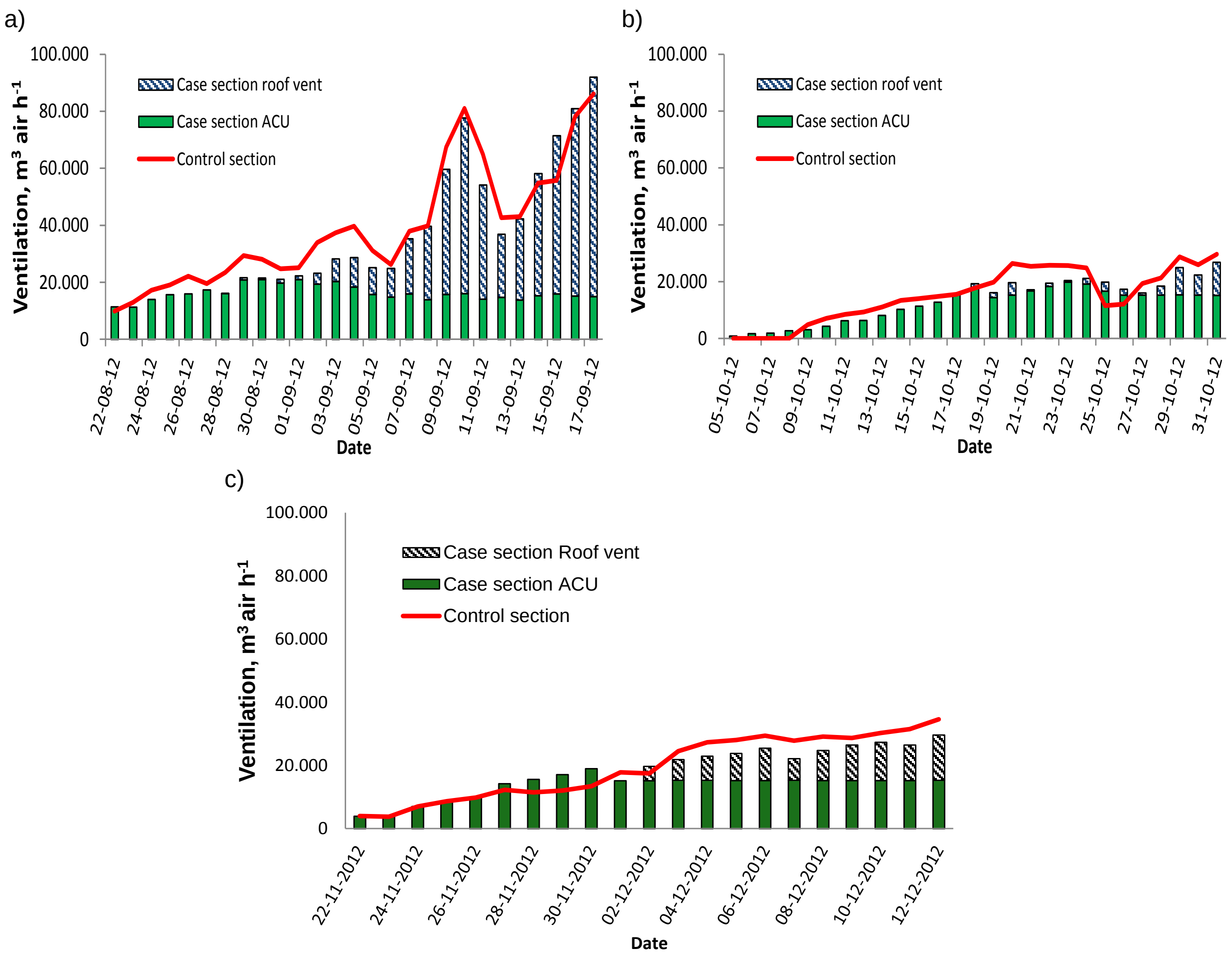


Figure 5. Ventilation via the different ventilation systems. The case section was ventilated by a combination of the ACU and the roof ventilation system (Roof vent). The control section was only ventilated by roof ventilaton. The gable fans were not used in any of the three measuring periods. Diagram a shows the results from period 1 (Aug.-Sept.), diagram b shows results from period 2 (Oct.- Nov.), and diagram c shows the results from period 3 (Nov.-Dec.)

In all three measuring periods it was found that the ammonia emission was reduced by use of the ACU system (Figure 3). The main reason for the reduction is expected to be that the use of the ACU causes a dryer litter mat and thereby a reduction of the transformation of uric acid into ammonium

The total ammonia emission per 1000 broilers produced in a housing system with and without use of the ACU system can be seen in Table 5. The ACU system was found to reduce ammonia emission from broilers by 42 % in period 1, by 49 % in period 2, and by 33% in period 3.

Tabel 5. Measured ammonia volatilization and the ammonia reduction effect of the ACU system per 1000 broilers produced in a production period of 30 days.

Test period	*Ammonia loss*	*Unit*	*Control*	*ACU*	*Difference, kg*	*Difference, %*
1	Ammonia loss	Kg NH_3/1000 broilers	5.07	2.96	2.11	41.6
	Ammonia-N loss	Kg NH_3-N/1000 broilers	4.18	2.44	1.74	41.6
2	Ammonia loss	Kg NH_3/1000 broilers	7.01	3.59	3.41	48.7
	Ammonia-N loss	Kg NH_3-N/1000 broilers	5.77	2.96	2.81	48.7
3	Ammonia loss	Kg NH_3/1000 broilers	3.84	2.58	1.26	32.7
	Ammonia-N loss	Kg NH_3-N/1000 broilers	3.16	2.12	1.04	32.7
Mean of the periods	**Ammonia loss**	**Kg NH_3/1000 broilers**	**5.30**	**3.04**	**2.26**	**41.0**
	Ammonia-N loss	**Kg NH_3-N/1000 broilers**	**4.37**	**2.50**	**1.87**	**41.0**

3.2 Test performance observation

In this section the observations during testing are described:

- The 20th of August problems were observed with the air anemometer at house 4. The system was repaired and restartet the 22th of Aug.
- A breakdown in the measuring system the 8th of October from 8:00 am to the 9th of October at 1:00 pm.
- The 11th of October one of the air filters was blocked, and the 13th of October an electronic failure was found in the connection to the heat exchanger air anemometer. This gives a period from the 9th to the 15th of October where emission could not be calculated.
- A breakdown in the gas measuring system from the 14th of October at midday to the 16th of October at 1:00 pm.
- The photoaccustic multigas analyzer (Innova) stopped measurement due power failure the 23th of October at 2:00 am. The system was restarted the 24th of October at 10 am.
- A breakdown in the control of the ventilation rate in house 4, the 24th and 25th October.
- The 29th of October a change of the measurement instrument (innova) software was required.
- A filter stop was detected the 24th of November and repaired the 26th of November at 2:00 pm.
- The 28th of November a problem was detected with the air anemometer situated in the control section. The air anemometer was changed the 3rd of December at 1:00 pm.
- A breakdown of the measurement instrument (Innova) between the 8-10th December. A new software program was installed the 10th of December.

3.3 Test quality assurance summary including audit results

During the test period the data sampled by the the online multigas analyser (Innova) was checked by manual sampled gas sampling equipment (Kitagawa ammonia and carbon dioxide gas detection sampler). The gas samples were pulled with a hand pump through a glas tube giving a color reaction. The concentration of ammonia and carbon dioxide is visually read on the tube.

Online measurement of in-house air temperature and humidity were checked with mini data logger (Testo, 174 H) situated in control and case sections.
Furthermore the stability of the test equipment was controlled continuously by daily supervision and recording of data. Procedures ensuring that test facilities and equipment are calibrated and fit for the purposes are described in the Quality Manual for the Laboratories of AgroTech. These procedures are subject to internal audits by the AgroTech Management.

3.4 Amendments to and deviations from test plan

Deviations of test plan are found in Appendix C

4 REFERENCES

[1] AgroTech (2009): AgroTech Test Centre Quality Manual. Not published.

A P P E N D I X *A*

Terms and definitions

Word	DANETV
Analytical laboratory	Independent analytical laboratory used to analyse test samples
Application	The use of a product specified with respect to matrix, target, effect ,and limitations
DANETV	Danish center for verification of environmental technologies
(DANETV) test center	Preliminary name for the verification bodies in DANETV with a verification and a test sub-body
Effect	The way the target is affected
(Environmental) product	Ready to market or prototype stage product, process, system, or service based upon an environmental technology
Environmental technolo-gy	The practical application of knowledge in the environmental area
Evaluation	Evaluation of test data of a technology product for performance and data quality
Experts	Independent persons qualified on a technology in verification
Matrix	The type of material that the product is intended for
Method	Generic document that provides rules, guidelines or characteristics for tests or analysis
Performance claim	The effects foreseen by the vendor on the target (s) in the matrix of in-tended use
Performance parameters	Parameters that can be documented quantitatively in tests and that pro-vide the relevant information on the performance of an environmental technology product
Procedure	Detailed description of the use of a standard or a method within one body
Producer	The party producing the product
Standard	Generic document established by consensus and approved by a recog-nized standardization body that provides rules, guidelines or characteris-tics for tests or analysis
Target	The property affected by the product
Test center, test sub-body	Sub-body of the test center that plans and performs test
Test center, verification sub-body	Sub-body of the test center that plans and performs the verification
Test/testing	Determination of the performance of a product for parameters defined for the application
Verification	Evaluation of product performance parameters for a specified application under defined conditions and adequate quality assurance

A P P E N D I X B

Test data report

Air temperature and humidity and daily ammonia emission levels Period 1

	Temp. (°C)		Humidity %			g NH3-N/1000 kyllinger/dag	g NH3-N/1000 kyllinger/dag
Dato	House 3/ACU	House 4	House 3/ACU	House 4	Outdoor	House 3/ACU	Control
22-08-2012	30,75	34,11	52,34	44,43	17,71	2,55	8,86
23-08-2012	30,10	34,10	53,34	44,38	16,49	5,05	13,57
24-08-2012	29,93	33,77	52,58	44,11	16,68	6,77	18,70
25-08-2012	29,88	32,69	54,56	47,12	15,62	5,86	27,41
26-08-2012	29,34	32,06	54,06	48,09	15,87	6,36	31,31
27-08-2012	28,60	31,18	52,90	48,58	16,14	6,73	35,27
28-08-2012	28,02	31,70	58,16	55,22	15,95	5,21	42,49
29-08-2012	27,91	31,50	58,16	52,46	17,24	6,31	57,36
30-08-2012	27,60	30,66	55,61	53,10	17,75	7,64	59,62
31-08-2012	27,13	29,88	53,33	53,05	15,78	8,72	69,33
01-09-2012	26,62	29,58	53,50	54,11	15,59	8,61	76,81
02-09-2012	26,48	29,86	60,82	60,60	16,41	10,73	114,73
03-09-2012	26,05	28,98	58,89	59,03	16,62	14,27	147,65
04-09-2012	25,94	28,17	62,59	62,33	16,54	21,15	183,98
05-09-2012	25,46	26,63	57,42	59,67	13,93	22,88	177,58
06-09-2012	25,09	25,53	58,38	63,59	12,99	31,62	172,17
07-09-2012	24,35	25,09	61,57	63,70	14,50	72,31	206,71
08-09-2012	23,61	24,15	61,70	64,87	14,85	100,23	245,11
09-09-2012	23,01	23,84	68,21	67,22	17,42	178,89	308,92
10-09-2012	22,93	23,06	70,43	69,89	17,93	270,60	296,86
11-09-2012	22,25	22,60	71,65	71,25	15,62	211,59	229,83
12-09-2012	22,05	22,73	65,90	67,25	11,95	168,68	197,88
13-09-2012	21,71	21,78	64,51	67,30	12,44	198,37	208,38
14-09-2012	20,99	21,24	70,26	71,17	13,83	209,61	194,53
15-09-2012	20,38	21,21	69,23	69,81	14,07	219,25	209,15
16-09-2012	20,26	20,40	70,49	70,45	15,18	195,15	249,08
17-09-2012	19,58	19,24	68,58	69,08	14,50	200,73	175,65

Air temperature and humidity and daily ammonia emission levels Period 2

	Temp. (°C)			Humidity %		g NH3-N/1000 kyllinger/dag	g NH3-N/1000 kyllinger/dag
Dato	House 3/ACU	House 4	Outdoor	House 3/ACU	House 4	House 3/ACU	Control
05-10-2012	32,40	32,80	7,91	47,00	50,00	0,68	0,00
06-10-2012	32,40	32,80	9,15	47,00	50,00		
07-10-2012	32,50	32,60	10,32	50,00	50,00		
08-10-2012	32,50	32,40	10,83	50,00	50,00		
09-10-2012	31,90	31,70	9,38	50,00	50,00		
10-10-2012	31,50	31,40	10,09	50,00	50,00	4,63	23,13
11-10-2012	31,20	30,80	10,10	50,00	50,00		
12-10-2012	30,70	30,70	8,37	50,00	51,00		
13-10-2012	30,60	30,40	7,00	52,00	51,00		
14-10-2012	29,90	29,90	7,73	51,00	53,00		
15-10-2012	29,80	29,70	9,26	53,00	54,00		
16-10-2012	29,60	29,40	8,37	54,00	55,00	21,47	68,09
17-10-2012	29,40	29,30	10,89	54,00	55,00	21,47	87,08
18-10-2012	28,70	28,90	12,39	55,00	57,00	34,76	113,92
19-10-2012	28,50	28,50	12,48	57,00	58,00	45,34	144,95
20-10-2012	28,10	28,10	13,12	57,00	59,00	33,40	161,42
21-10-2012	27,60	28,30	10,20	58,00	60,00	50,41	153,09
22-10-2012	27,40	27,60	9,99	61,00	61,00	36,46	163,30
23-10-2012	27,40	27,60	9,00	61,00	63,00		
24-10-2012	27,30	27,40	9,75	52,00	64,00		
25-10-2012	27,30	27,20	7,38	47,00	64,00		
26-10-2012	27,20	26,80	4,68	50,00	65,00		
27-10-2012	26,60	26,60	2,78	52,00	66,00		
28-10-2012	26,10	26,60	3,57	52,00	68,00	38,68	231,32
29-10-2012	25,00	26,10	6,69	56,00	69,00	95,76	221,97
30-10-2012	24,60	24,90	5,77	58,00	70,00	159,54	244,31
31-10-2012	23,90	24,40	6,94	58,00	71,00	226,00	280,70
01-11-2012	23,80	23,90	6,75	58,00	72,00	254,10	318,69
02-11-2012	23,00	23,50	6,78	61,00	72,00	247,54	320,78
03-11-2012	22,00	22,80	5,82	61,00	72,00	212,03	347,51
04-11-2012	21,00	21,80	6,13	63,00	73,00	195,04	390,57

Air temperature and humidity and daily ammonia emission levels Period 3

	Temp. (° C)			Humidity (%)		g NH3-N/1000 kyllinger/day	g NH3-N/1000 kyllinger/day
Dato	House 3/ACU	House 4	Outdoor	House 3/ACU	House 4	House 3/ACU	House 4
22-11-2012	32,8	32,7	9,60	41	46	3,24	7,93
23-11-2012	32,5	32,5	5,81	50	49	1,79	3,09
24-11-2012	31,9	32	4,10	50	50		
25-11-2012	31	31,8	5,67	50	50		
26-11-2012	31	30,9	6,90	50	50		
27-11-2012	31	30,6	5,76	50	50	1,65	15,77
28-11-2012	30,6	30,8	3,88	51	50	0,00	19,17
29-11-2012	30,4	30,3	1,75	41	51	0,80	17,57
30-11-2012	29,9	29,9	0,26	41	52		
01-12-2012	29,8	29,7	-0,84	43	52		
02-12-2012	29,4	29,3	-3,59	46	53		
03-12-2012	28,8	28,5	-0,91	44	54		
04-12-2012	28,6	28,6	-3,33	45	55	6,04	34,32
05-12-2012	28,6	28,6	-4,70	43	57	12,83	35,32
06-12-2012	27,9	28,1	-2,73	44	58	6,68	46,02
07-12-2012	27,8	27,8	-1,93	46	61	3,68	59,06
08-12-2012	27,7	27,8	-3,26	46	61		
09-12-2012	27,6	27,5	-0,18	48	62		
10-12-2012	26,8	26,8	-1,81	51	64		
11-12-2012	26,7	26,5	-2,77	55	64	21,24	96,92
12-12-2012	26	26,1	-5,86	56	65	22,20	97,02
13-12-2012	25,7	25,7	-4,84	56	68		
14-12-2012	24,4	24,3	-0,86	55	67		
15-12-2012	23,9	23,1	2,57	55	67	117,36	207,13
16-12-2012	23,7	23,1	3,75	57	68	113,67	184,73
17-12-2012	22,9	22,8	3,75	58	70	110,28	160,93
18-12-2012	22,4	22,4	2,94	58	70	173,24	151,94
19-12-2012	21,9	22,4	1,04	60	70	134,36	138,94
20-12-2012	20,8	21,7	1,26	60	72	183,82	154,84
21-12-2012	20,5	20,8	1,20	59	74	153,80	156,11
22-12-2012	20,2	20,3	0,56	60	75	140,13	204,11
23-12-2012	20	20	0,38	61	74	119,86	169,07
24-12-2012	21	22	4,33	66	75	163,58	255,05

A P P E N D I X   C

Amendment and deviations report

Deviations to the test plan

Due to problems with the measuring equipment and the continuous measurement of ventilation rate, it was not possible to calculate a continuous emission profile for the full length of the production cycles. To avoid that the periodic malfunction of measuring systems influenced the calculation of technology effect, data was excluded from both the case and control sections when a measuring problem was observed in one of the test sections.Therefore, the ammonia emission could not be calculated for all days in the production cycles. The measurement period was scheduled to last approximately 30 days per production cycle. Due to periodic malfunction of measurement equipment the number of measurement days were reduced by 5, 13, and 12 days for period 1, 2, and 3 respectively.

A P P E N D I X   D

User Manual

The user manual of Agro Clima Unit is included in a separate file. Contact Rokkedahl Energi or AgroTech to get a copy of the user manual.