Notat: VERA-testplan

Projekt ”*Reduceret kvælstoffordampning ved hjælp af bio-forsuring af gylle”*.

I forbindelse med projektet er der udarbejdet en testplan til verifikation af JH staldservice A/S nye forsuringssystem til kvæg, der er baseret på bioforsuring forstået som enten en organisk syre eller en pre-fermenteret biomasse så som melasse.

Verifikationen er planlagt som en case/control, hvilket er lidt utraditionelt for test af miljøteknologi på kvægbesætninger, da de sjældent kan sektioneres. Vi har dog været heldige at finde to besætninger, der hver i sær består at to sammenlignelige malkestalde. Udfordringen er, at køer og kvier ikke er lige fordelt mellem sektionerne, derfor har vi foreslået at case/control sektionerne skifter plads efter et halvt år under både sommer og vinter forhold.

Den samlede test plan (på engelsk) kan læses i dette notat.

Beskrivelsen er anonymiseret i forbindelse med offentliggørelse.

TEKNOLOGISK INSTITUT

JH Staldservice
Test plan for JH Staldservice bio-acidification system for dairy farms

Document Information

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TABLE OF CONTENTS

1 INTRODUCTION

This test plan is designed for verification for JH Staldservice bio-acidification system for dairy farms following the DTI DANETV Test Centre Quality Manual.

1.1 Verification protocol reference

This test plan is designed to meet the quality requirements defined in the VERA Test Protocol for Livestock Housing and Management Systems, (VERA Test Protocol, Version 2 / 2011-29-08). This test plan will be carried out according to a test-control setup at two locations.

1.2 Name and contact of vendor

JH Staldservice bio-acidification system for dairy farms is developed and produced by JH Staldservice A/S, Lundholmvej 41, 7500 Holstebro. Contact person: Lars Forbech. Phone: +45 51 22 61 77, E-mail: lf@jhstaldservice.dk

The test is undertaken by DANETV Test Centre Danish Technological Institute (DTI) division AgroTech, Agro Food Park 15, DK-8200 Aarhus N, Denmark

Test responsible: Mathias Andersen, DTI, Agro Food Park 15, Skejby, 8200 Aarhus N. Phone: +45 72203308. E-mail: mata@teknologisk.dk

1.3 Technical experts

The technical experts assigned to this test and responsible for review of test plan and test report includes:

Internal experts:

Arne Grønkjær Hansen, DTI, Agro Food Park 15, DK-8200 Aarhus N. Phone: +45 72203319, E-mail: arnh@teknologisk.dk.

External expert:

Is to be decided by ETA Denmark.

2 TEST DESIGN

JH Staldservice bio-acidification system for dairy farms is tested in full-scale at two commercial dairy farm during a 12 months' period covering both summer and winter temperatures. The test will take place at two dairy cattle farms using a case/control setup. Each of the two farms contains two barns (compartments) with individual air inlets and outlets and separated manure system. The manure system is known in DK as the "ring channel system", which is characterized by slatted floor with interconnected manure channels. The manure is recirculated on a daily basis via a pumping well located outside the barns. During the test period one barn at each test site will serve as untreated reference (control), while in the other barn (case), the manure will be acidified in the pumping well using bio-acid with low pH-value in order to lower the pH-value of the manure to a preset pH-value of 5.5. After 6 months, the case and control compartments will switch place in order to rule out barn related bias.

2.1 Test site

2.1.1 Characterization of the test site

The test sites consist of two commercial dairy farms. Each farm has two separate barns (compartments), with separated pits and individual inlet and outlet for ventilation. The capacity of the housing systems is between 245 – 307 animals. The barns are designed as so called cubicle housing systems with cubicle bedding. The two compartments on each farm are nearly identical regarding build design. At farm 1 both compartments have partly slatted floor cleaned with cleaning robots. In farm 2 there are partly slated floors in both compartments which is cleaned daily with a staldkat machine. The cows are evenly distributed in farm 2, (+-2 %) and in farm 1 the number of heads very 7 %, and 19 % in one compartment is heifers.

The flooring systems are partly slatted floor. The manure from the cattle is collected in a circular pit under the slats. The bedding material is chopped straw. The cows are all fed with a mix of corn silage and grass silage balanced with soybean meal and wheat.

The ventilation systems are natural ventilation with regulated curtains and open kip. At farm 1 all cows are Holstein-Friesian with an average weight of 617 kg. The cows are milked automatically by milking robots. The average milk production per cow is 11,276 kg/year. At farm 2 all cows are Jersey with an average weight of 423. The cows are milked twice per day (7:00 and 19:00). The average milk production per cow is 11,000 kg/year.

Table 1-2 gives an overview of key characteristics of the dairy farms used in this test.

Table 1. Key characteristics of the dairy farm no. 1 used for test.

Parameter	**Test site characteristics** **Section 1+2**
Farm owners	depersonalized
Address	depersonalized, 6230 Rødekro

Contact Info	depersonalized
CHR no.	depersonalized
Grazing cows in summer	No. Heifers yes
Animal places N+S	245+267
Animal race	Holstein-Friesian
Weight range (kg)	617
Milk production l/year/cow	11,276
Bedding material	Chopped straw 300-500 g/place/day, rubber mats, Ökosan aprox. 10-12 kg./day
Straw-bedded area per cow	1.25 m wide 2.8 m long
Total accessible floor area per animal place	3035 m2/517 places =5,87 m^2/ place
Total accessible area per place	5076 m2/517 places = 9,8 m^2/ place
Number of cows	Compartment N + S: 184 + 245
Number of Heifers	44 in compartment N =19%
Number of calves	0
Bulls	0
Floor design	Slats
Manure removal system	Recirculated manure in circular pit
Scraper systems on top of slats	Scraper Robot
Cooling of slurry	No.
Feed composition	45% corn silage 45% grass silage, soybean meal, wheat
Feed analysis	3 x per year
Ventilation	Natural ventilation with automatically regulated curtains. Open kip
Agricultural advisor	depersonalized
Feeding	07.00-8.30

Table 2. Key characteristics of the dairy farm no. 2 used for test.

Parameters	**Test site characteristics** **Section 1+2**
Farm owner	depersonalized
Address	depersonalized, 9700 Brønderslev
Contact Info	depersonalized
CHR no.	depersonalized
Grazing cows in summer	Non
Animal places, north+south compartment	***307+294 =601***
Animal race	Jersey
Weight range (kg)	423
Milk production l/year/cow (km)	***11,000***
Bedding material	Straw 300-500 g/place/day
Straw-bedded area per cow	1.1 m wide 2.2 m long
Total accessible floor area per place	2,362 m2 floor/601 places =3.94 m^2/ place
Total accessible area per place	3790 m2/601 places = 6,3 m^2/ place
Number of cows	***601***
Number of Heifers	***0***
Number of calves	***0***
Bulls	***0***
Floor design	Slats
Manure removal system	Circular recirculation manure pit
Scraper systems on top of slats	mini truck (staldkat)
Cooling of slurry	No.
Feed composition	corn silage and grass silage
Feed analysis	Once per month
Ventilation	Natural ventilation. Open Kip. Regulated curtains. Can be supplemented with opening of windows
Agricultural advisor	depersonalized

Milking	07.00 and 19.00

2.1.2 Addresses

The test activities for the verification will take place at the following farms:

Farm no. 1

depersonalized

Farm no. 2

depersonalized

Overview of farm 1.

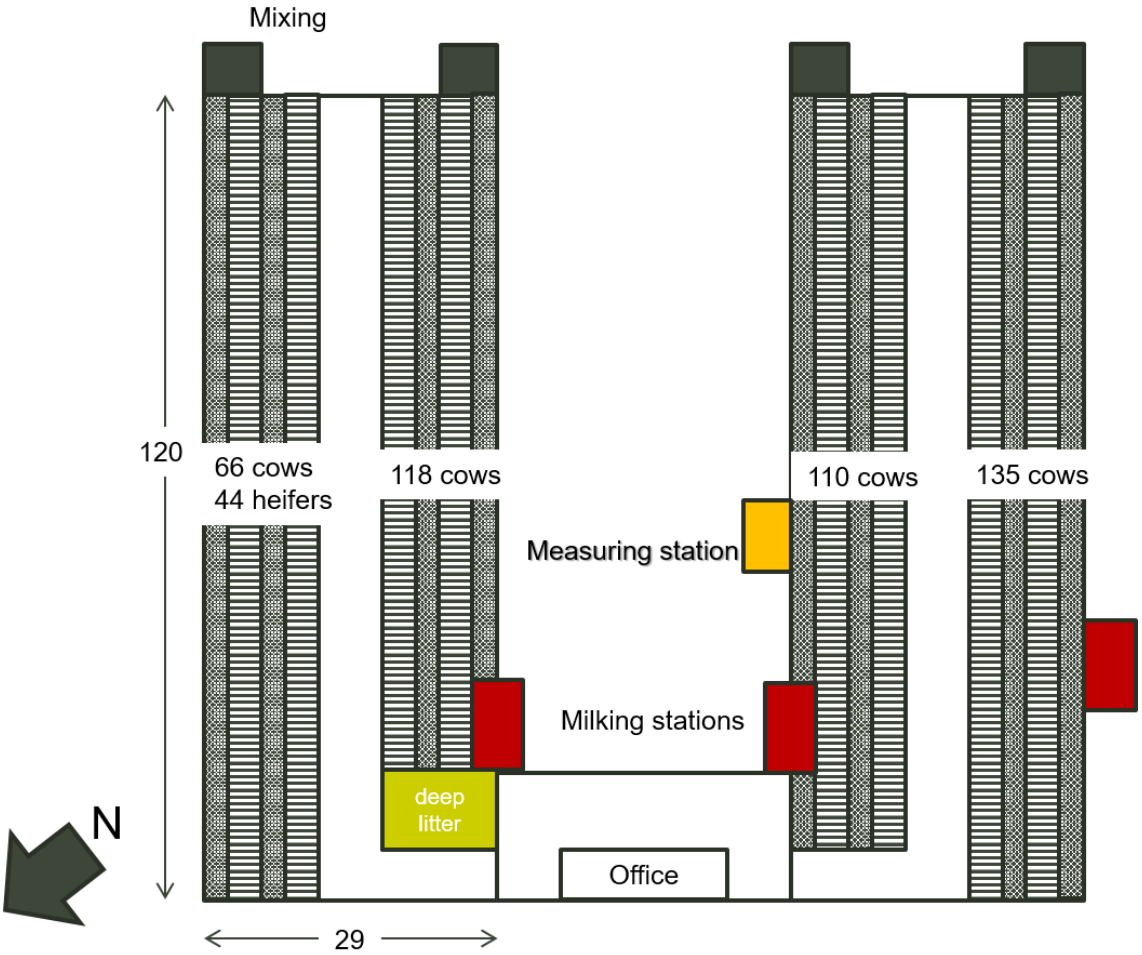

Figure 1 shows a diagram of the dairy farm house 1.

Overview of farm 2.

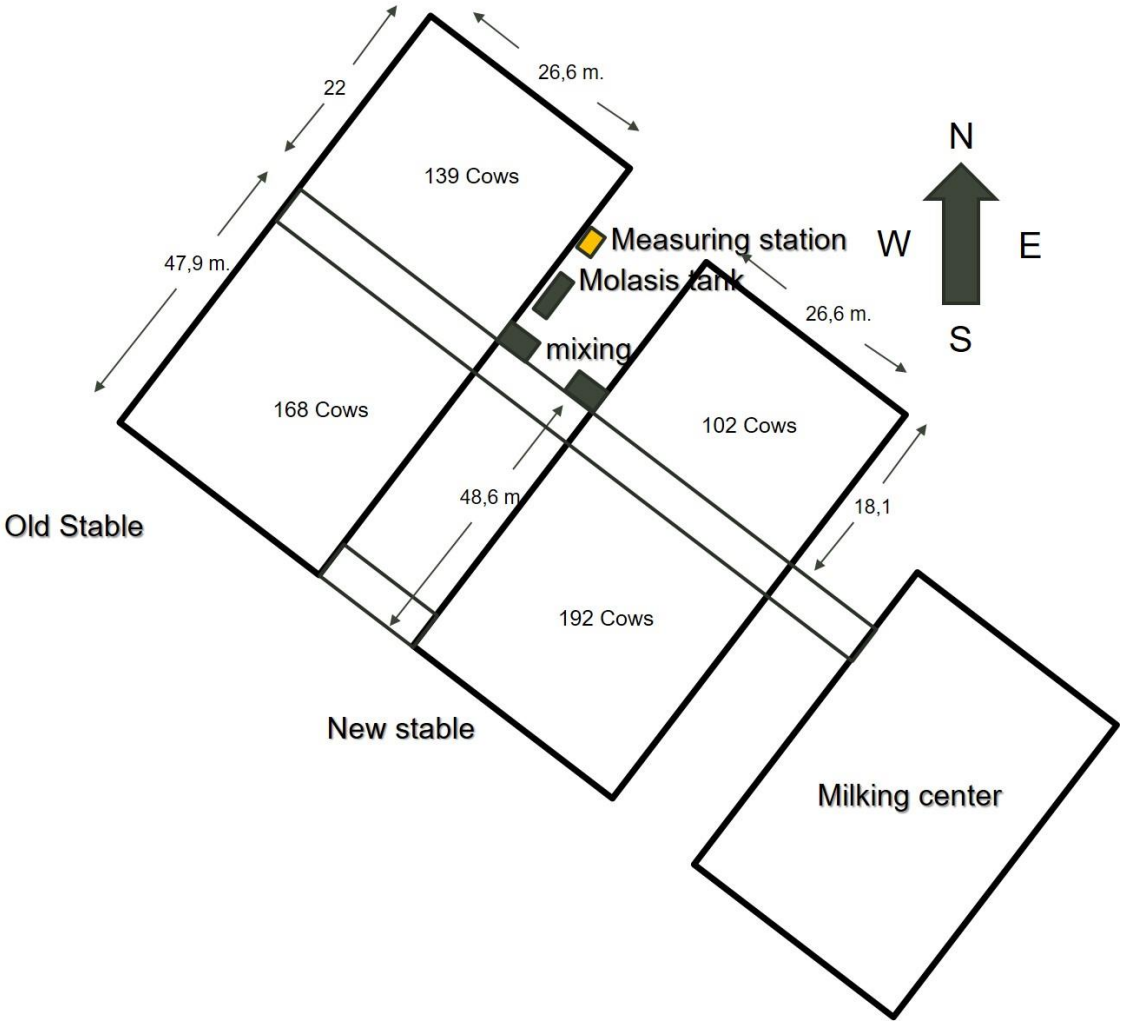

Figure 2 shows a diagram of the dairy farm house 2

2.1.3 Description of technology

Functional description of JH Staldservice bio-acidification system for dairy farms

The ammonia emission is reduced using the bio-acidification system. JH Staldservice has developed a new technique called Bio-acidification. The current acidification system has been developed for dairy production with a circular pit system.

The idea of the bio-acidification system is to acidify the manure in the pits with an organic acid or a pre-fermented carbon rich biomass (such as molasses) to acidify and to stimulate naturally occurring fermentation of the manure in the pits, resulting in a decline of pH. in comparison to acidification with an inorganic acid, bio-acidification uses an acidifying source that can both be consumed and produces in the manure pit. This process is very depended of the temperature. Bio-acidification has the advantage that all acid produced is biodegradable hence higher biogaspotential and reduced sulfate leaching.

Bio-acids is defined as fermented biomass that can be stored safely until it is added to the manure. Bio-acid can for example be molasses that have spontaneous been fermented by naturally occurring microorganism, which brings the pH down to around 4 and stabilising the product. Bio-acid contains therefore both a high density for fermenting bacteria's, organic acids from fermentation and a carbon rich biomass that are relatively easy degradable.

Organic acid such as acetic acid can be used to start up the process because development of foam can be controlled with slow addition. If af easy degradable carbon rich biomass is added when starting up a new system, uncontrollable foaming can occur. Startup with bio-acids is safest I spring with gradually increasing temperatures and with as few manure in the pits as possible. The possibility of adding an organic acid is not obligatory for the technology but practical in startup and also as a safety mechanism if bio-acid addition is insufficient.

The bio-acidification system for dairy farms includes the following key elements.

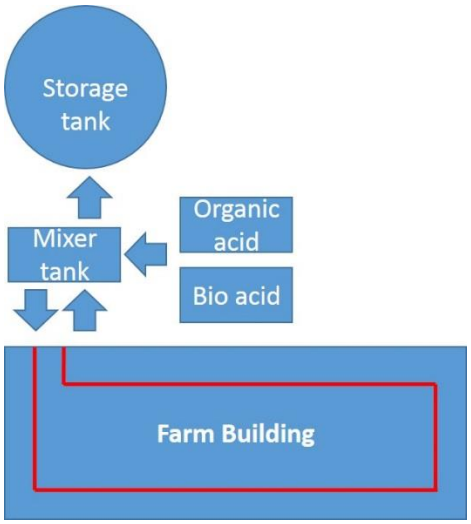

Figure 3 shows schematic overview of the bio-acidification system.

The manure acidification system for cattle farms includes the following key elements:

- Tanks with bio-acid and optionally organic acid, from where the bio-acid or organic acid is added.
- Mixing tank/ pumping well in which stirring, acid addition and pumping take place. The mixing tank is generally an existing tank.
- Fresh manure is mixed with bio-acidified manure and returned to the barn in the circular pit below the slatted floor.
  Storage tank, where acidified manure is stored after surplus manure is pumped from the mixing tank.
- Parameters such as pH, temperature and amount og bio-acid added, is being logged in a control unit used for controlling the process.

The bio-acidification works as follows:

At a present time, every day of the year acidification takes place in the following chronological order:

1. The two pH electrodes which are placed in the mixer tank are flushed with water.

2. Stirring of the manure in the mixing tank/tanks begins and manure from the mixing tank is propelled into the circular pit in the barn and recycled to the mixing tank. pH is measured after approximately 10 minutes of stirring.

3. After 10-20 minutes of stirring, a bio-acid is added from the acid tank to the manure in the mixing tank. A metering pump is used for this purpose. Bio-acid is added directly into the mixing tank at a programmed time. The addition time, which equals the acid amount, is calculated from the pH drop and the added bio-acid the provirus day/days.

4. The stirring stops, when all manure is acidified (depends of pit length and pump capacity normally after 30-60 minutes of stirring). Just before the stirring stops pH is measured and the value stored.

5. The process is repeated the day after and pH is again measured in the mixing tank. The amount of bio-acid added is calculated on the basis of the previous added amount and the effect on pH. If pH is reached no further bio-acid is added. If maximum bio-acid is added with no effect the system can be set to switch to an organic acid.

Dependent on the time when the daily acidification is set to run, manure is pumped into the storage tank. The manure is pumped to the storage tank until a preset minimum level in the mixing tank is reached. I case the farm delivers to at biogas facility, manure can be collected directly in the mixing tank/pumping well.

All processes such as stirring, pumping, addition of bio-acid and pumping to the storage tank are controlled automatically to reach the decried pH level. A PLC based control unit is controlling the acidification process. Logging of all measured pH and temperature values are uploaded to a web server, which can be accessed by a web interface. This gives an opportunity to continuously monitor and verify that the installation works properly.

The bio-acid used for acidification of the manure can contain organic acids such as acidic acid, lactic acid, formic acid, benzoic acid or an/or pre-fermented organic carbon rich such as molasses, beet pulp, ensilage or milk residues that can be further fermented to organic acids in the manure pit.

In this verification, pre-fermented beet molasses is used. see appendix 5, Data sheet for beet molasses.

Online data logging

JH Staldservice control system logs all actions by the bio-acidification system including:

- temperature
- pH
- acid consumption

2.2 Tests

2.2.1 Test methods

The overall principle for testing the performance of the JH Staldservice bio-acidification system for dairy farms is to measure the emission of ammonia from a dairy farm in a case/control setup. Emissions will be measured simultaneously at two separate compartments at the same farm location. One of the compartments will have installed bio-acidification while the other compartment will be control/referance. Half way through the test period, after 6 months, the case and control compartment will be switched at both farms to avoid any bias regarding even distribution of cows and heifers or house effects. Before test start and bio-acid addition, a pretest will be carried out to measure baseline ammonia emission from the two compartments. Emissions will be calculated as mean kg NH_3-N/HPU/year, kg NH_3-N/animal/year and kg NH_3-N/LU/year for the case and control compartments. The technology will be tested at two separate farm locations in a period of one year.

Emission calculations requires the determination of ventilation rates. In naturally ventilated building, ventilation rates cannot be measured by fans and have to be determined by using the tracer gas method.

The tracer gas used in this test is CO_2 produced by the animals. The production of CO_2 can be estimated from mainly the size of the animals and the milk production. The tracer gas method assumes even distribution of gases and that the dilution rate of CO_2 is equal to the one of NH_3.

The effect is measured over the basis of 12 months covering measurements during summer period and measurements during winter period. The primary performance parameter is ammonia

In addition to the primary performance parameters a number of operational parameters are measured throughout the test period. A list of the operational parameters is found in compartment 3.3.

2.2.2 Test staff

The test staffs involved in the test of JH Staldservice bio-acidification system for dairy farms are:

depersonalized

It should be noticed that the protocol requires “The applicant/manufacturer of the system or technology is not allowed to visit the farm during the test period unless contacted by the farm owner due to operational problems. In this case, the operational problems must be dated and described in the test logbook. In addition, a dated record must be made of when and how the problem was solved, to be signed by the farmer and the applicant/manufacturer when repairs have been completed.”

2.3 Test schedule

The test schedule is presented in table 2. Table 3 and table 4 present the test sample days for ammonia (Table 3) (Table 4).

Table 3 Test schedule for JH Staldservice, 2017-2018. Distribution of test periods.

Farm	Test 2017-2018										
	Nov.	January	February	marts	April	May	June	July	August	September	October
1.Rødekro											
2.Brønderslev											
1.Rødekro	South-West compartment = Control						North-East compartment = control				
2.Brønderslev	North-West compartment = Control						South-East compartment = control				

Table 4 Sampling dates for ammonia

Final Test Schedule for sampling ammonia		
Sampling period	**1. Rødekro**	**2. Brønderslev**
Period 1	20-27. Nov. 2017	29 Jan – 5 Feb
Period 2	12-19. Feb	12-19. Marts
Period 3	9-16. April	14-21 May
Period 4	4-11 June	11-18 June
Period 5	9-16 July	13-20 August
Period 6	10-17 September	15-22 October

2.3.1 Test equipment

Equipment used for the test is described in compartment 3.3 Analytical methods.

2.3.2 Type and number of samples

The sample types and the number of samples to be taken are described in compartment 3.3.

2.3.3 Operation conditions

Operational parameters like temperature, air humidity, and electrical consumption are recorded during the test. A description of the measurement of operational parameters is found in compartment 3.3.

2.3.4 Operation measurements

The measurement of operational parameters is described in compartment 3.3.

2.3.5 Product maintenance

JH Staldservice has the responsibility for the maintenance and reparation in case of break down during the test period. The farmer is responsible for reporting all problems with the bio-acidification system to JH Staldservice and DTI.

Irregularities and break downs during the test period are recorded by DTI's test staff. JH Staldservice is also responsible for reporting all the visit times to the farm and the reparations realized on the system during the test. There is a log book on the four test sites to write the extra activities on the farm during the test period.

2.3.6 Health, safety and wastes

Laboratory work during the test will be done according to the Danish rules for safe occupational health and the European regulations regarding work with chemicals. Field work will be done according to Danish rules for safe field work.

Chemicals used for the laboratory test are discarded according to Danish regulations for chemical waste by collection and destruction.

It is judged by the DTI test staff that the use of the JH Staldservice bio-acidification system does not imply any special health, safety or waste issues.

3 REFERENCE ANALYSIS

3.1 Analytical laboratory

Slurry samples from the dairy farm are analysed by AgroLab, AL-North ApS, Østerbro 4, 5690 Tommerup, DENMARK. Telefon: +45 78775454. E-Mail: Esben.Jensen@agrolab.eu

Reference analysis for slurry are analysed by Eurofins Danmark. Address: Smedeskovvej 38, DK-8464 Galten, Denmark. Phone: +45 7022 4266. E-mail: info@eurofins.dk.

3.2 Analytical parameters

In table 4 the primary analytical parameters are presented. Table 5 presents the operational parameters (secondary measurement parameters).

3.3 Analytical methods

In table 4 the analytical methods of the primary parameter are presented. In table 5 the analytical methods of the operational/secondary parameters are presented. Table 4 shows the primary measurement parameters consisting of the primary environmental pollutant emitted from the livestock housing unit which is the primary target of the environmental technologies for the dairy farms. As seen in Table 4 the primary measurement parameters are ammonia.

Table 5 shows the operational parameters, which include parameters that may influence the emission level of the primary environmental pollutant or which are relevant reference values. In addition, the table includes other secondary environmental pollutants.

All analytic parameters listed in those two tables are measured at the dairy farm.

Table 4 Primary analytical parameters and corresponding analytical methods.

Parameter	Analytical method	Number of samples	Sampling time
Ammonia	Picarro G2508 gas concentration analyzer	6 measuring periods evenly distributed during the test over one year	Min 48 hours 2 whole days

Table 5. Operational and secondary parameters and corresponding analytical methods.

Parameter	Analytical method	Number of samples	Sampling time
CO_2	Picarro G2508 gas concentration analyzer	6	Minimum 48 hours for multigas analyzer.
H_2S	Jerome 631-X™	6	on 30 minutes
CH_4	Picarro G2508 gas concentration analyzer	6	Minimum 48 hours
N_2O	Picarro G2508 gas concentration analyzer	6	Minimum 48 hours
Ventilation rate	Tracer gas method with CO_2-balance. Measurement of CO_2	6	Minimum 48 hours
Temperature	testo 174H - Mini temperature and humidity data logger	Continuous measurements in situ	
Relative humidity	testo 174H - Mini temperature and humidity data logger	Continuous measurements in situ	
Electricity consumption	Electricity meter	Continuous measurements in situ	
Slurry parameters (M) • Amount [kg] [m³] • pH • DM [%] • Organic DM [%] • N [%] [g/kg] • TAN [%] [g/kg] • C:N • P, K • Additives/residues	Accredited laboratory	6	
Wind • direction [°] • - speed [m/s]	HOBO weather station (Cup anemometer) Placed close to farm	Continuous measurements in situ	

Ammonia analysis

The ammonia concentration is measured with Picarro G2508 multigas analyzer using Cavity ring-down spectroscopy (CRDS) technology. Our Picarro G2508 multigas analyzer is custom made with PTFE coating and tubing and also higher flow through the measuring chamber in order to enhance precision and response for ammonia measurement. This method is used for online measurements, i.e., on sample each 5 min. Picarro 16 ports multiplexer is used then more than one sample location I required.

The NH_3 measurements are automatically corrected for temperature and interference with H_2O and CO_2, N2O and CH4.

The Picarro G2508 gas analyzer is tested with a standard pure NH_3-gas, before and after every verification test.

Reference measurements is performed periodically with Impinger system.

Sample tubes are placed in at both side of the barn and in the middle of the barn in the whole length of the building 3 meters a bow the floor. Each line has sampling point for every 10 meters equipped with critical orifices, and a dust filters. Air flows through the critical orifices are tested with a bobble flow-meter to ensure even distribution of air.

The sample air is pumped to the Picarro via an external membrane pump for each line to ensure high pressure drop trough the critical orifice and rapid stabilization of the concentration. The pump used is a: Capec L2 SE AC with a capacity of 8.0 l/min.

The sample tubes are between 80-100 meters long, the diameter of the tubes is between 6 – 8 mm.

The sample tubes are isolated and heated from the cow building to the analyze station to avoid condensation.

Odour

The technology is not believed to have any significant effect on odour emission which is why this test does not include olfactometrical measurements. The effect of the bio-acid is first of all to lower the pH, which pushes the chemical balance between ammonium and ammonia (NH_3) towards ammonium (NH_4) that immobilises in the liquid. When the pH drops to 5,5 it also has an antimicrobial effect because most microorganisms will be inhibited at this pH. Furthermore, most bio-acids contains acetic acid and other volatile short fatty acids which act as an uncoupling agent of the cell membrane potential and thereby arrest microbial metabolism. Acidification in general promotes protonization of short-chained volatile fatty acids in the acidified slurry. Oxygen consumption rate, methanogenesis and sulphate reduction were all reduced by more than 98% in the stored acidified slurry compared to untreatedslurry, (Lars D.M. Ottosen et all. 2009). Microbial degradation is thereby also reduced and odour emission with all probability likewise. Temporary raise in odour emission can occur when the system is started up and the manure is acidified from pH 7 to 5,5.

Dust

JH Staldservice is not claiming any dust reduction because the bio-acidification is not believed to have any effect on dust levels in the barn.

Detection limit and uncertainty

The detection limit for the Picarro G2508 gas concentration analyzer is for ammonia, is very low (<1ppb). In reality NH_3 are limited by the adsorption of these species to the surfaces of the experimental apparatus. On the countryside in Denmark NH_3 concentrations are rarely under 20 ppb.

One key issue is to estimate the ventilation rate and then to quantify the gaseous emissions. The quantification of ammonia emission from livestock houses with natural bio-acidification systems is a big challenge and it is associated with some uncertainties. The main issue is to measure the ventilation rate. In this test, CO_2 balance is used to calculate the ventilation rate, which is the most commonly used method for continuous measurements in naturally ventilated livestock buildings (S. Pedersen & K. Sällvik, 2002).

The CO_2-balance has several error sources such as the calculation of metabolic energy, the CO_2 produced per energy unit, the amount of CO_2 produced by manure, and the location of the CO_2 sampling points, (Samer et al., 2011).

Acid consumption

Bio-acid consumption is logged through the control unit where the total pumping time can be seen. The pumping time can be correlated to the actual amount consumption by calibration. The measured and automatically logged consumption is read out for every measuring period. Organic acid consumption is also logged for every measuring period by manual read out on a level meter. All deliveries of bio-acid and organic acid to the farm are noted in a log book.

Calculation of ventilation rate

Ventilation rates are required to estimate the amount of gases emitted from dairy buildings. The rate of production (P in m^3h^{-1}) of a specific gas in a dairy building is estimated as:

$P = q_V (C_{in} - C_{out}) = q_V \Delta C$

Where q_V (m^3h^{-1}) is the ventilation rate, and C_{in} (m^3/m^3) and C_{out} (m^3/m^3) are the concentrations of the gas inside and outside the dairy structure respectively.

P is calculated from the above formula under the assumption: 1 HPU = 1000 W = 180 L CO2 h^{-1} HPU^{-1} + 10% from the manure stored in the barn = 198 L CO2 h^{-1} HPU^{-1}, Petersen et al. (2008).

1 full-grown cow is approximately 1.3 HPU. The exact amount of HPU will be calculated with the formula here under.

Heifers

$$\Phi_{tot} = 7.64\, m^{0.69} + Y_2\left[\frac{23}{M} - 1\right]\left[\frac{57.27 + 0.302\, m}{1 - 0.171\, Y_2}\right] + 1.6 \times 10^{-5}\, p^3, \text{ W}$$

Y_2 = daily gain, 0.6 kg/day.

Cows

$$\Phi_{tot} = 5.6\, m^{0.75} + 22 Y_1 + 1.6 \times 10^{-5} p^3, \text{ W}$$

Y_1 = milk production, kg/day

P = Days of pregnancy.

Heifers are arranging 580 W. The correct output of the heifers will be calculated from the formula above.

For the above mentioned gas production rate to be valid, the air in the dairy building must be ideally mixed i.e. Cg should be constant all over the building and must not change with time. This is often not the case in real situations. Therefore, it is necessary to sample at different locations to get a representative sample of the gas concentration in a dairy building.

Example for average ventilation rate at farm one, first measuring period:

$$qv = \frac{P}{(C_{in} - C_{out})_t}$$

Where qv is the ventilation in m^3/h, P is the production of trace gas in m^3/h, and C_{in} and C_{out} is the concentrations of tracer gas in ppm (m^3 / m^3), respectively, inside and out.

$$qv = \frac{(241\ \text{HPU} \times 0.185\text{m3}\ CO_2\ h^{-1})}{(566 - 391) * 10^{-6}}$$

qv= 254,771 m^3/h

This correspond to: $\frac{qv}{\text{LU}} = \frac{254{,}771\ m^3 h^{-1}}{237} \approx$1075 $m^3/h/LU$

Calculation of emissions

The emission of a specific gas *g* is calculated by following equation:

$$E_g = qv \times \rho_g(t) \times (C_{in} - C_{out})_g$$

$$E_g = \frac{P}{(C_{in} - C_{out})_t} \times \rho_g(t) \times (C_{in} - C_{out})_g$$

Where E_g is the emission of a specific gas *g*, qv is the ventilation in m^3/h, *P* is the production of trace gas in m^3/h, ρ_g (t) is the density of the gas in kg/m^3 at a given temperature t, $(C_{in} - C_{out})_t$ is the difference in concentrations of tracer gas in ppm (m^3 / m^3), between, inside and out and $(C_{in} - C_{out})_g$is the difference in concentrations of the specific gas *g* in ppm (m^3 / m^3), between, inside and out

The densities used in this example is the densities at 20 ° C, 1 atm.

Densities used are:

ρ_{NH3}: 17.037g/mol x 1 atm/ (0.0821 x (273,15 K + actual temperature)) = 0.708 g/L

Example for average emission at farm one, first measuring period:

$$E_g = \frac{P}{(C_{in} - C_{out})_t} \times \rho_g(t) \times (C_{in} - C_{out})_g$$

E_g= 243 g NH_3/h

This corresponds to:

$$\frac{E_g \times 24 \times 365}{\text{LU}} = \frac{243\ \text{g NH3/h} \times 24 \times 365}{237} \approx 9\ \text{kg/year/LU}$$

Sample location for air

Below is a diagram of the sampling procedure. Sampling tubes are installed longitudinal in 3 parallel lines through the barn. Each line has several inlets. The middle line located in the center of the barn at a height of minimum 3 meters, out of reach of the cows and in the whole length of the barn. The lines outside the barn I located neer the inlet approximately 1 meter above the ground. For each 10 meter line a single sampling point for is installed. To allow a constant and controlled sampling flow rate, the sampling points is equipped with a critical orifice, and a dust filter. This allows to connect the sampling points to a single pump and to be analysed as a mixed sample, see figure 6--7. All the sample tubes are connected to the gas analyser in the mobile analyse station. If ΔC for CO_2 is higher than 50 ppm the sample is chosen as valid. If ΔC for CO_2 is lower than 50 ppm calculation of flow will have reduced accuracy with our current equipment. The line that is nearest the luv side will normally always be chosen as inlet, while the line in the middle normally will be outlet. I case of no wind or wind parallel to the barn, both lines in the sides will be inlet. Definition of sample points can either be established from the wind direction og from the flux of ammonia.

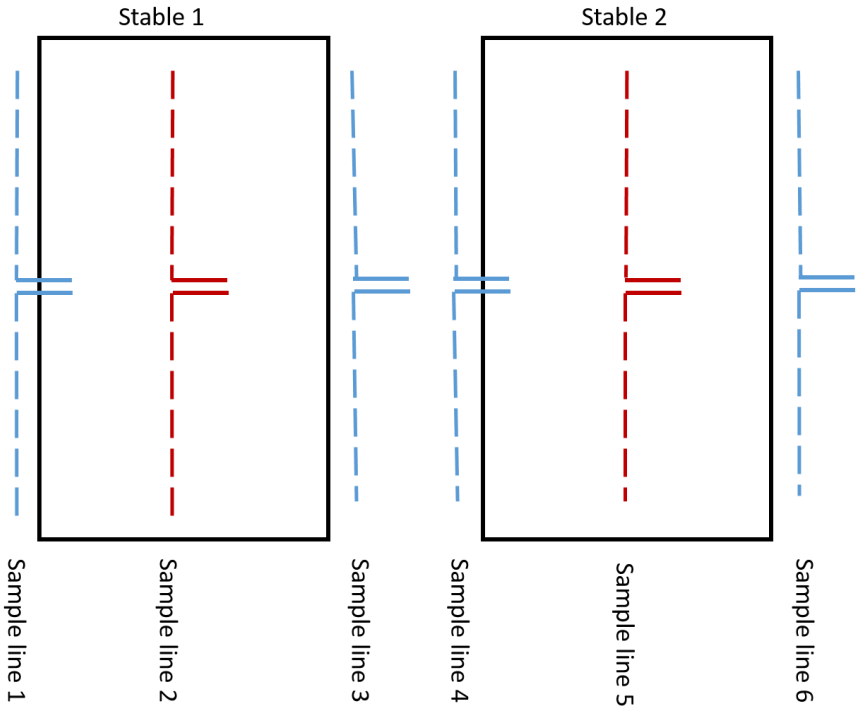

Figure 4 shows a diagram over two dairy barns seen from the top and the position of the sample line.

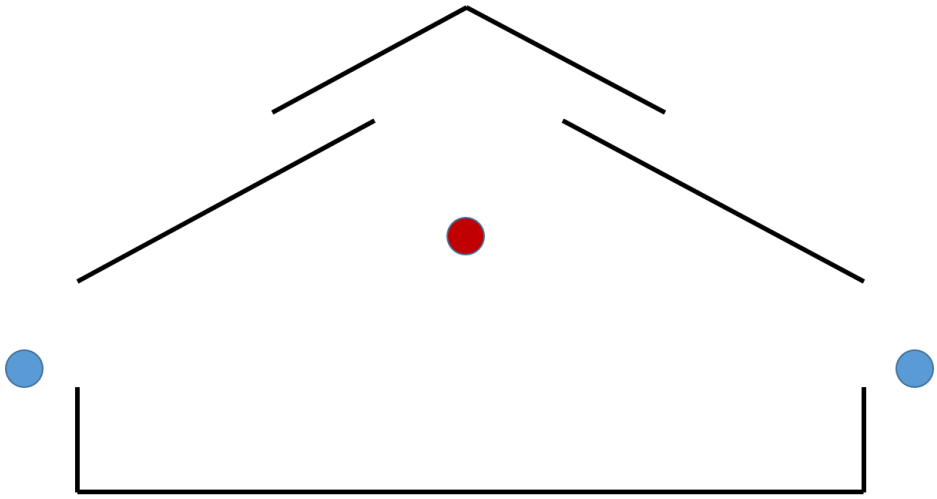

Figure 6 shows a cross compartment of the barn and the position of the sample lines.

Figur 5 sample lines outside and inside the barn. To the right a sampling point equipped with a critical orifice, and a dust filter

Sample procedure for slurry

Slurry samples can be obtained from the mixing tank. Sampling has to be done shortly after mixing. A 10 L bucket is used to obtain a representative sample. The manure is then homogenized and poured into 3 1 L bottles per barn. The total manure production for each barn is calculated from time, date and amount (slurry weight when removed). Data is logged manually by the farmer.

Sample procedure for feed composition

Feed samples are collected after each of the 6 annual measurement campaigns.

A 10 L bucket is used to obtain a representative sample. The feed is then homogenized and poured into 3 1 L bottles.

Electrical consumption

Electrical consumption of the system is measured with at power meter and manually logged after each measurement campaign.

Bio-acid consumption

Bio-acid consumption is measured with a tank gauge, and manually logged after each measurement campaign. Composition af Bio-acid can be found in appendix 5.

3.4 Analytical performance requirements

In table 6 the limits of detection and in some cases the uncertainty of the analytical methods is presented.

Table 6. Limits of detection for the analytical methods used.

Parameter	Analytical method	Limit of detection	Precision
Ammonia	Picarro G2508 Reference: Impinger	0 ppm	<1 ppb +0.05% of reading
CO_2	Photoacoustic multigas analyzer	380 ppm	<200 ppb +0.05% of reading
H_2S	Jerome 631-X™	0,003 ppm	5 % RSD
CH_4	Photoacoustic multigas analyzer	1,5 ppm	<5 ppb +0.02% of reading
N_2O	Photoacoustic multigas analyzer	0,3 ppm	<5 ppb +0.008% of reading
Ventilation rate	CO2-balance	---	2-50 %, (Ngwabie, 2011)

Temperature	testo 174H - Mini temperature and humidity data logger	0,05 °C	± 0.5 °C
Relative humidity	testo 174H - Mini temperature and humidity data logger	± 3 % RH	± 3 % RH

Note: The response of H2O and NH3 are limited by the adsorption of these species to the surfaces of the experimental apparatus. The precision is defined as standard deviation after 5 min.

3.5 Preservation and storage of samples

Slurry samples

Immediately after sampling the samples are stored in a cooled box and within 5 hours the samples are placed in a freezer until they are sent for analysis.

Feed samples

Immediately after sampling the samples are transported to the lab and placed in a freezer until they are sent for analysis.

4 DATA MANAGEMENT

Data management including filing and archiving procedures are described in the DTI Test Centre Quality Manual.

4.1 Data storage, transfer and control

Some data are collected and written down at the test site. Appendix 7 includes data recording sheets to be used for registration at the test site.

Some data are collected by electronic means at the test site and send via internet to a PC in the DTI main office. All this data has a backup.

Results from external laboratories are sent electronically by email or in paper version by mail.

Table 7. Data compilation and storage summary.

Data type	Data media	Data recorder	Data record timing	Data storage
Test plan and test report	Protected pdf-files.	Test responsible	When approved	Files and archives at DTI
Data manually recorded at test site	Data recording forms	Test staff at test site	During collection	Files and archives at DTI
Calculations	Excel files	Test responsible, DTI	During calculation	Files and archives at DTI
Analytical reports	Paper / pdf-files	Test responsible, DTI	When received	Files and archives at DTI

5 QUALITY ASSURANCE

The test will be following the DTI Test Centre Quality Manual, which is ISO 9001 compliant.

5.1 Test plan review

The test plan will be subject to internal review by Arne Grønkjær Hansen from DTI Test Centre.

External review of the test plan will be done by the technical expert assigned to this verification task.

5.2 Test system control

The stability of the test equipment will be controlled continuously by supervision and recording of data. Procedures for ensuring that test facilities and equipment are calibrated and fit for the purposes are described in the Quality Manual for the Laboratories of DTI. These procedures are subject to internal audits from the DTI Management.

5.3 Data integrity check procedures

All transfers of data from printed media to digital form and between digital media are checked by spot check undertaken by test responsible. If errors are found in a spot check, all data transfers from the specific data collection are checked.

5.4 Test system audits

Internal audits from DTI will be done following the procedure described in the DTI Test Centre Quality Manual.

5.5 Test report review

The test report will be subject to internal review by Arne Grønkjær Hansen from DTI Test Centre.

External review of the test report will be done by the technical expert assigned to this verification task as part of the review of the verification report. The verification report includes the full test report as an appendix.

6 TEST REPORT

The test report will follow the template of the DTI Test Centre Quality Manual and the VERA Test Protocol for Livestock Housing and Management Systems Version 2 / 2011-29-08.

6.1 Test site report

No specific test site report will be made unless it is judged necessary to make this report later. At the test site data are collected and registered on data reporting forms.

6.2 Test data report

No specific test data report will be made unless it is judged necessary to make this report later. All data recorded during the test including results from external analytical laboratories will be gathered and archived according to the DTI Test Centre Quality Manual.

6.3 Amendment report

In the test report there is a compartment on amendments to and deviations from the test plan. This compartment will compile all changes of the test plan occurring before testing with justification of deviations and evaluation of any consequences for the test data quality.

6.4 Deviations report

In the test report there is a compartment on amendments to and deviations from the test plan. This compartment will compile all changes of the test plan occurring during testing with justification of deviations and evaluation of any consequences for the test data quality.

A P P E N D I X 1

Terms and definitions used in the test plan

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
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 technology	The practical application of knowledge in the environmental area
Evaluation	Evaluation of test data for a technology product for performance and data quality
Experts	Independent persons qualified on a technology in verification
HPU	Heat producing unit (one HPU = 1000 w)
Method	Generic document that provides rules, guidelines or characteristics for tests or analysis
LU	Livestock unit (500 kg animal)
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 recognized standardization body that provides rules, guidelines or characteristics for tests or analysis
Target	The property that is affected by the product
Test Centre, test sub-body	Sub-body of the test centre that plans and performs test
Test center, verification sub-body	Sub-body of the test centre that plans and performs the verification
Test/testing	Determination of the performance of a product for parameters defined for the application

Word	DANETV
Vendor	The party delivering the product to the customer
VERA	Verification of Environmental Technologies for Agricultural Production
Verification	Evaluation of product performance parameters for a specified application under defined conditions and adequate quality assurance
RSD	Relative standard deviation

A P P E N D I X 2

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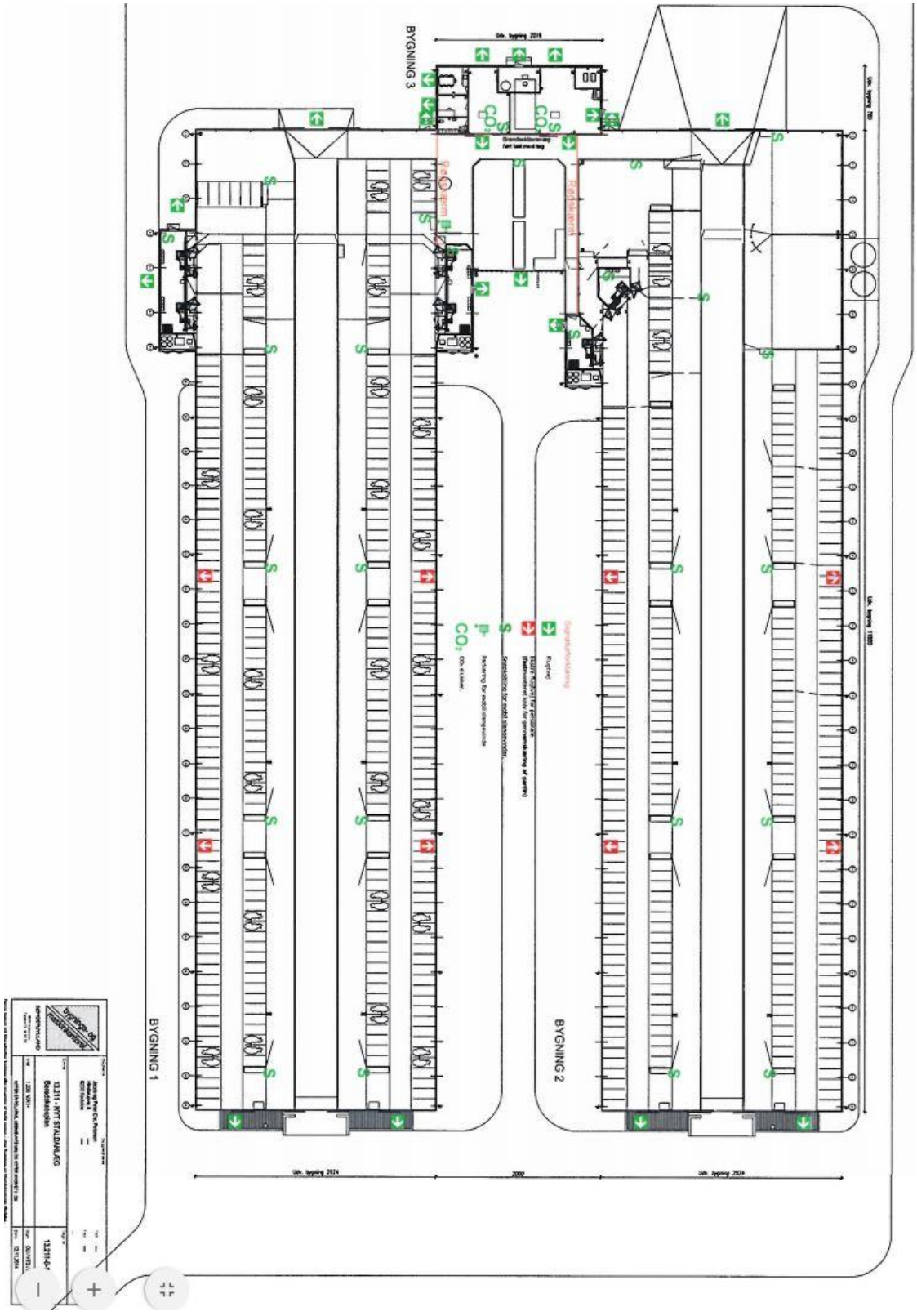
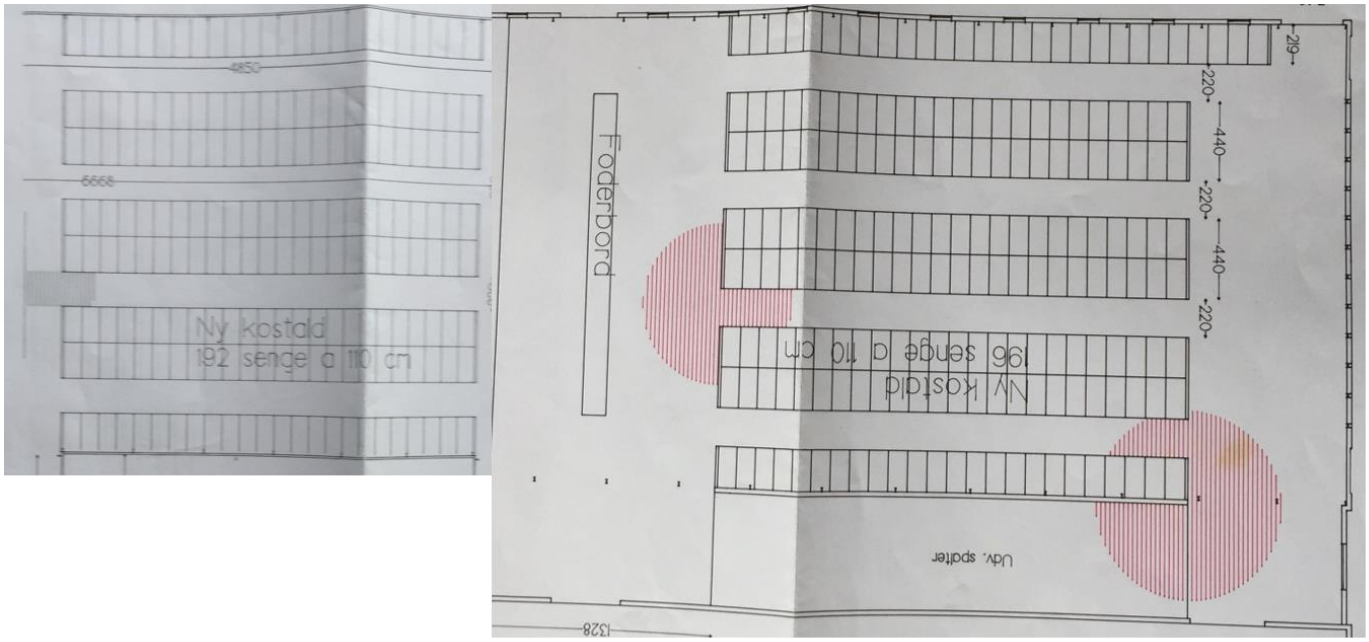
A P P E N D I X 3

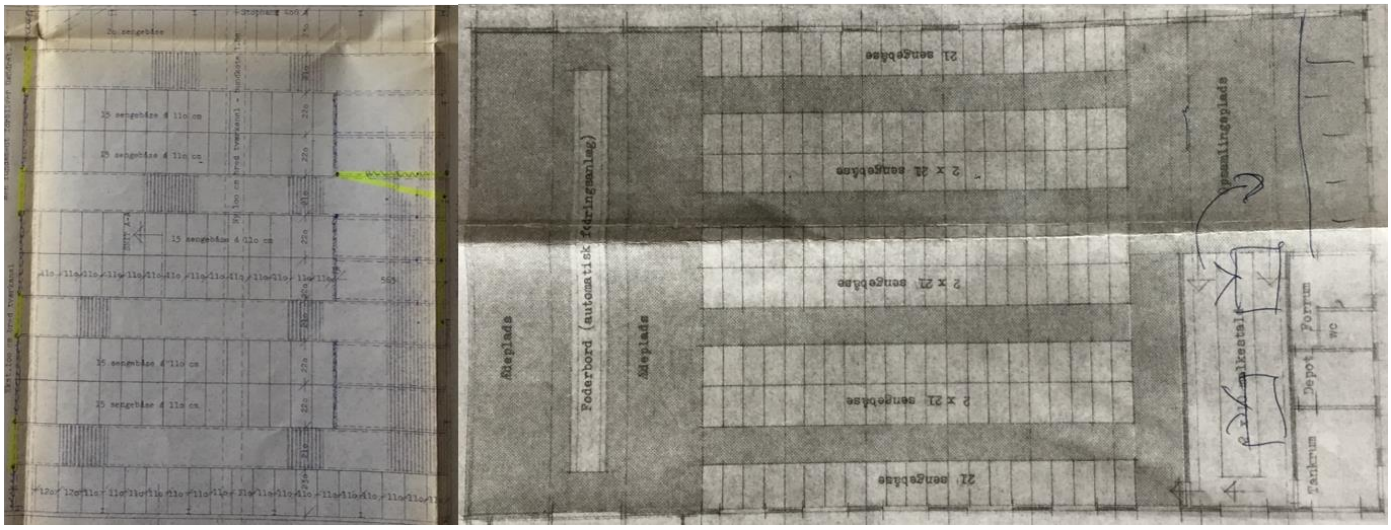
Technical drawings farm 1

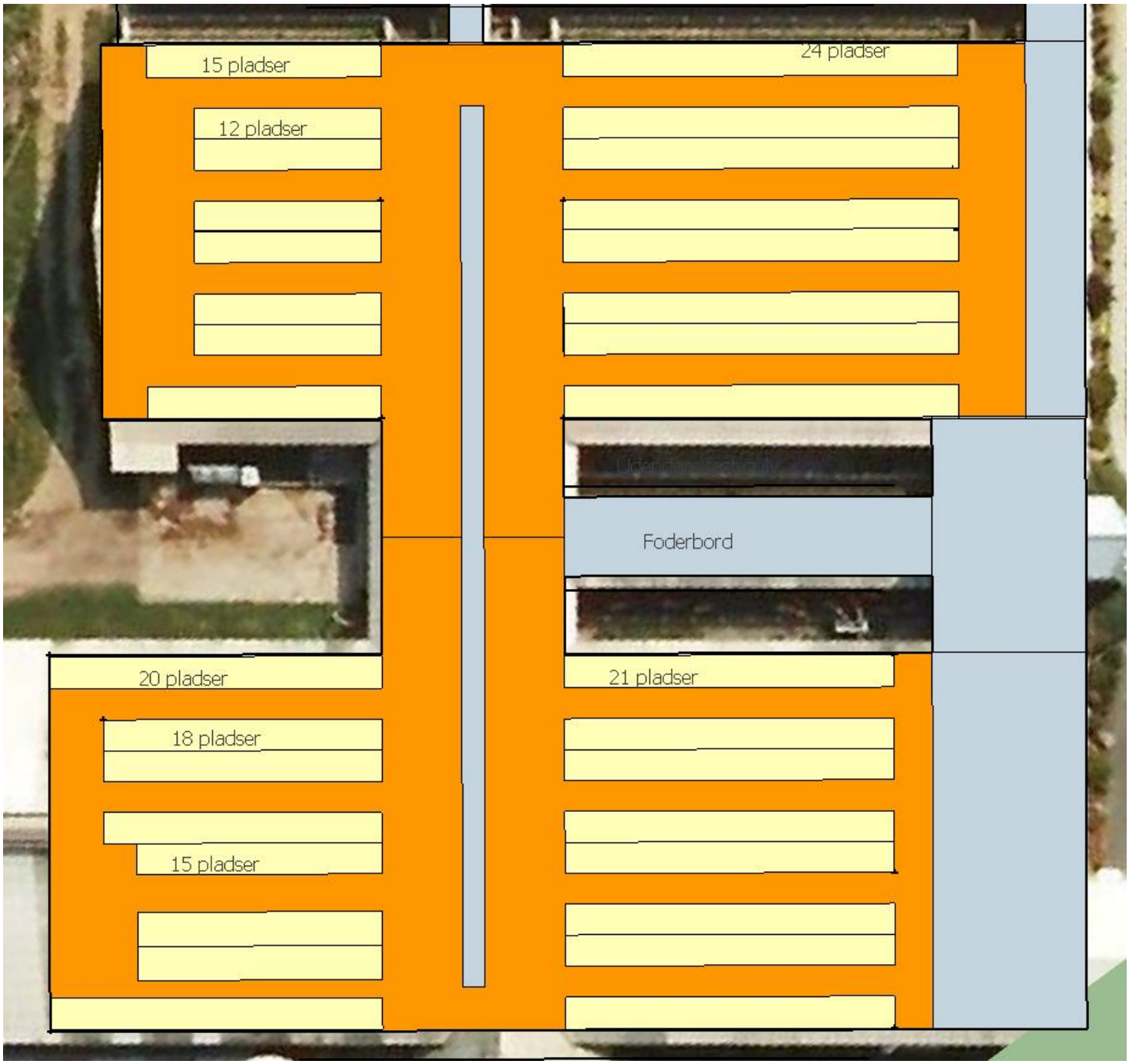


A P P E N D I X 4

Technical drawings farm 2






15 pladser
24 pladser
12 pladser
Foderbord
20 pladser
21 pladser
18 pladser
15 pladser

A P P E N D I X 5

Data sheet soya molasses

Nordic Sugar
Member of Nordzucker Group

Standardized Molasses

Sugar beet molasses / Roemelasse / Betmelass

Product Specification | PS 233655-4.3EN
Valid from: February 25, 2013

SAP QM no: 3202
Page 1 / 1

Description
Standardized molasses from sugar beets
Feed material.

Compliance
The product does not contain or consist of GMOs and is not produced from or contain ingredients produced from GMOs as defined in Regulations (EC) No 1829/2003 and 1830/2003.

Storage conditions
Shelf life: ..... 3 years

Product must not be reheated above 55ºC

Packaging/Material no
90117 ..... Betm spec off
90118 ..... Sugar beet molasses bulk
90158 ..... Molasses, 43% saccharose

Additional information
Produced in: Denmark
Produced in: Lithuania
Produced in: Sweden

Ingredients
Sugar beet molasses

Physical chemical
Sugar: [1] ..... min 43 %
Water ..... max 26 %

[1] Method of analysis 71/250/EEC

Microbiology
Analysis accordning to NMKL methods:

Yeasts ..... max 10000 CFU/g
Moulds ..... max 10000 CFU/g
Spores hemo. Bacillus spp ..... max 1000 CFU/g
Spores but. acid Clostridium spp ..... max 1000 CFU/g
Salmonella ..... Negative/25 g

A P P E N D I X 6

User manual

A P P E N D I X 7

Data reporting forms

TEKNOLOGISK INSTITUT

APPENDIX 7 – DATAREGISTRERING

Skema 03-02- XX (Akkreditering)

Projekt nr.: 1610345

Bedrift adresse:

	Section Nord			**Section south**		
	lactating cows	dry cows	Heifers	lactating cows	dry cows	Heifers
Number of animals						

	Canal 1	Canal 2	Canal 3	Canal 4	Canal 5	Canal 6
Airflow through all channels, ml/min						

Fermented biomass (Molasses) consumption is read out from system display, kg.	
Organic acid (acetic acid) consumption is read the acid from level meter on acid tank, kg.	

	Section Nord			**Section south**		
	pH 1	pH 2	temp °C	pH 1	pH 2	temp °C
Manure pH and temp, measured from manure samples.						

Check list	√
Manure samples 2 from each section are collected.	
Feed samples, 2 from each section are collected.	
Temp and relative humidity data are transferred from data loggers to the TI archive	
Weather data from weather station are transferred to the TI archive	
Emission data is downloaded from analyzer and transferred to the TI archive	
Feed control for period incl. Number of lactating cows, Milk production EKM, feed consumption by animal groups and raw protein percentage. Feed control is transferred to TI archive	