Statement of Verification

EU Environmental Technology
Verification pilot program

Technology: Controlled Heat Sanitization
BACESS Bio Fertilizer Production Unit BBFP-U

Registration number: VN20230001

Date of issue: 14. December 2023

The verification process, whose results are summarised in this Statement, complies with the EU-ETV General Verification Protocol v.1.3 and with the EN/ISO 14034:2018 on Environmental Management: Environmental Technology Verification

Verification Body		**Proposer**	
Name:	ETA-Danmark A/S	Name:	BACESS A/S
Contact:	Thomas Bruun	Contact:	Jørgen Løgstrup / Mikkel Dalsgaard
Address	Göteborg Plads 1 DK-2150 Nordhavn	Address:	Jægersborgvej 1, DK-9520 Skørping, Denmark
Telephone:	+45 72 24 59 00	Telephone:	+45 23 84 65 11 / +45 42 95 12 11
E-mail:	tb@etadanmark.dk	E-mail:	info@bacess.dk
Web:	www.etadanmark.dk	Web:	https://bacess.dk/

Signed, 14. December 2023

Thomas Bruun
Verification Responsible, CEO

Proposer

DANAK
INSP Reg. Nr. 9099
Medlem af EA MLA

Statement of Verification is available at:
https://www.etadanmark.dk/da/etv/gaeldende-etv-verifikater

TABLE OF CONTENTS

1 TECHNOLOGY DESCRIPTION

When using the sanitization/composting technology, biomass is loaded into the composting chamber which is closed, insulated and controlled. Oxygen concentration and temperature is monitored during composting process, and air is blown from the bottom (or top) of the chamber and through the biomass. The biological process develops heat, whereby the temperature in the material (biomass) rises to above 70°C in less than 48 hours. This ensures that the material (biomass) is sanitized, and that disease germs and weed seeds are rendered harmless.

The sanitization/composting technology is developed in two versions, namely a container model with a reactor volume of 25 m3 and a silo model with a reactor volume of 6 m3. The two models use the same principle as well as hardware steering components, control- and monitoring software system. Process parameters can be adjusted to the same level, e.g., the air flow per m3 of biomass. The exhaust air from the

process is cleaned in a subsequent biological air cleaning filter based on rockwool, compost and straw. The air cleaner treats the exhaust gasses from the composts process and is an integrated part of the composting technology.

The process is constantly monitored via a sensor system that continuously measures temperature and oxygen content throughout the entire process. Process data is collected and processed via an PLC, which then automatically controls and optimizes the process by regulating and controlling the oxygen supply. All process data is registered and saved continuously (log file). Real-time graph/curve of the process is monitored via SCADA Software (Supervisory control and data acquisition) and can be printed as hard copy at any time. With SIM-card connection, it is possible to achieve Remote Control of the BACESS BFP-U Process Control System.

The technology is intended for sanitization/composting of various types of organic waste.

2 APPLICATION

The goal of this chapter is to reach a clear understanding of the technology, its intended application and impacts, the matrices, purpose, and technical conditions for the technology are listed hereunder.

2.1 Matrix

The type of material that this composting technology is intended for is various types of organic waste such as biowaste: Waste that can be broken down by nature, i.e., garden-park waste, food and kitchen waste from households, restaurants, catering companies and retail stores, as well as similar waste from food processing companies., digested slurry fibers from biogas plants (degassed fibers), sewage sludge mixed with structural material e.g., garden park waste etc.

2.2 Purpose

The measurable property that is affected by the technology and how it is affected. The purpose of the technology is to:

- Hygienize waste biomass by a heat treatment of minimum 70°C for at least one hour to reduce the occurrence of the pathogenic bacteria. This will result in a hygienic product that can be handled and used on the free market which is a prerequisite for reuse of the waste resources and recycling of nutrients.
- Reduce the total emission of ammonia and greenhouse gasses compared to conventional composting technologies without controlled aeration.
- Convert the waste to a biofertilizer / compost product with the following properties/effects.
- Enhance fertilizer effect of the water-soluble N and P in the final compost.
- Increase in the plant availability of P in ash which is co-composted with waste biomass.
- Significantly enhance the protection effect of the biofertilizer against fungal plant diseases
- Increased water-holding capacity of the growth substrate

2.3 Conditions of operation and use

Details of operational conditions during sampling that may affect the interpretation of the test results, ex. robustness/vulnerability to changing conditions of use.
The technology was tested on three different types/mixtures of waste biomass which was composted in two consecutive test runs on two different composting units at two different locations.

The process during composting was optimized by controlling the aeration depending on measured temperature and oxygen content. Temperature during the process was documented, emissions of ammonia was measured after the air cleaner. Biomass samples was taken before and after composting for analysis of pathogens and nutrient content. The resulting biofertilizer from each of the three test runs was tested in growth experiments with tomato to document fertilizer effects and the effects on plant diseases as well as analyzed for effects on water-holding capacity.

2.4 Verification parameters definition summary

This section describes the parameters that were examined in the verification of BACESS Bio Fertilizer Production Unit BBFP-U.

2.4.1 Performance parameters

The performance parameters tested for each biomass and test run are shown in table 1, and below a list of environmental parameters and operational parameters.

Table 1. The performance parameters tested for the two test runs for each of the three biomasses that were sanitized/composted.

Parameter	Sampling conditions	Biomass 1		Biomass 2		Biomass 3	
		Location A		Location B		Location B	
		Degassed fiber fraction from biogas plant		Sludge+garden waste+ash		Food waste+horse manure	
		Run 1	Run 2	Run 1	Run 2	Run 1	Run 2
Temperature during sanitization/composting	Continuous measurement of temperature during composting max. 10 days run, minimum 12 hours after 70°C has been obtained for minimum 1 hour.	X	X	X	X	X	X
Reduction in pathogenic bacteria	Representative biomass samples before and after sanitization/composting for analysis of pathogens. 2 replicate samples per biomass per run.						
- E. coli		X	X	X	X	X	X
- Enterococcus		X	X	X	X	X	X
- Salmonealla		X	X	X	X	X	X

Ammonia loss	Representative biomass samples before, after sanitization/composting for total N analysis. 2 replicate samples per run, before and after sanitization/composting	X	X				
	Continuous measurements of NH_3 emission, inlet, outlet from sanitization/composting unit and outlet from airfilter unit. Max. 10 days per run, minimum 12 hours after 70°C has been obtained for minimum 1 hour.	X	X				
Loss of CO_{2e}	Continuous measurements of emission of CO_2, N_2O, CH_4, inlet and outlet of the system. Max. 10 days per run, minimum 12 hours after 70°C has been obtained for minimum 1 hour.	X	X				
Plant nitrogen value	Representative samples of biomass after sanitization/composting, mixed from the two runs. Approx. 10 L per run per biomass, resulting in 20 L mixture per biomass	X	X	X	X	X	X
	Measurement of plant growth in plant assay. Two proportions of compost:sand per biomass, 6 replicate pots per proportion per biomass with one tomato planted per pot. Measurement of plant growth 4-6 weeks after planting.	X		X		X	

P availability for plants in ash	Representative biomass samples before and after sanitization/composting for analyses of P. Two replicate samples per run, both before and after sanitization/composting.			X	X		
Fungal plant diseases	Representative samples of biomass after sanitization/composting, mixed from the two runs. Approx. 10 L per run per biomass, resulting in 20 L mixture per biomass	X	X	X	X	X	X
	Measurement of disease occurrence in plant assay with inoculation on tomato plants. Test of *Fusarium oxysporum f. sp*. With 3 replicates per biomass	X		X		X	
Water-holding capacity	Representative samples of biomass after sanitization/composting, mixed from the two runs Approx. 10 L per run per biomass, resulting in 20 L mixture per biomass.	X	X	X	X	X	X
	Measurement of water-holding capacity. Two proportions of compost:sand per biomass, 3 replicates per proportion per biomas.	X		X		X	

2.4.2 Operational and secondary parameters

Additional parameters that were logged and supplied by the proposer:

- Up time/down time during each test run.
- Process temperature at three depths in the composting chamber throughout each test run.

- O_2 concentration in air outlet of the sanitization/composting unit.
- Power consumption for each test run.
- Air temperature: Ambient air temperature and atmospheric humidity was measured by Testo 174H dataloggers.
- Wind speed: Data was obtained from Danish Meteorological Institute.
- Flow: Was measured by fan wheel anemometer, in combination with ventilator performance.

2.4.3 Environmental parameters

Since the obtained data may depend on the weather and environmental conditions during sanitization/composting, environmental parameters were also logged as described in Table 2. Environmental parameters logged during the composting tests.

Table 2. Environmental parameters logged during the composting tests.

Environmental parameters	Units
Time of year	Month
Wind speed (data from Danish Meteorological Institute)	m s^{-1}
Atmospheric humidity	RH
Air temperature	˚C

3 TEST AND ANALYSIS DESIGN

The technology was tested on three different types/mixtures of waste biomass which was composted in three consecutive test runs on the composting utility. The process during composting was optimized by controlling the aeration depending on measured temperature and oxygen content. Temperature during the process was documented, emissions of ammonia was measured after the unit. Biomass samples was taken before and after composting for analysis of pathogens and nutrient content. The resulting biofertilizer from each of the three test runs was tested in growth experiments with tomato to document fertilizer effects and the effects on plant diseases as well as analysed for effects on water-holding capacity.

The test design was based on the specific verification protocol, the test plan as well as documents from BACESS A/S describing the technology for sanitization/composting of different biomasses to produce a safe biofertilizer product. The measured parameters were the chosen key parameters for evaluation of the claims announced by BACESS A/S prior to the test.

The project was divided into three main phases

1. Pre-test and optimization: During the pre-tests, the sanitization/composting equipment was optimized and tested in terms of temperature development etc.

2. Test runs with sanitization/composting of three biomasses: In the real test runs, the sanitization/composting process was tested during two separate sanitization/composting cycles for each of three different biomasses/biomass mixtures. During these test cycles, temperature, energy consumption and emissions were monitored, and samples were tested for content of E. coli, enterococci and Salmonella.

3. Various tests of biofertilizer products: After termination of the test runs in phase 2, various tests were done on the performance of the three resulting biofertilizer products, i.e., regarding fertilizer effect, plant availability of P, plant disease suppression effects and effect on water-holding capacity.

3.1 Existing and new data

Existing data regarding the various claims are briefly described below.

Hygienization effect of composting:
It is well documented that the heat generated during the thermophilic phase of the composting process can inactivate the great majority of potential risk organisms such as human pathogens as well as weed seeds. Hence, proper composting is expected to inactivate human pathogenic bacteria such as *E. coli* and *Salmonella* spp. (Termorshuizen & Alsanius, 2016). Hence, both *E. coli* and *Salmonella* spp. Are expected to be eliminated by exposure to 55°C for one hour or 65°C for 15-20 minutes (Jones & Martin, 2003).

Reduction in ammonia and CO^2 emissions from composting:
The effect of biological air cleaning has previously been demonstrated by (Domino 2006) and (BACESS 2006)

Fertilizer effect of N and P in compost:
Initial experiments with composted degassed fibres from a biogas plant were performed at Økologihaven with the herb species dill, parsley, coriander and basil. The results indicated that this product was suitable as a biofertilizer which gave growth comparable to a standard fertilizer when applied at a dose of 10% (by volume) in mixture with 90% sphagnum peat. (Dalsgaard, M. 2020)

Plant availability of P after co-composting:
Mixing of wood ash into organic waste prior to composting is known to improve compost quality and may reduce the amount of compost required to raise pH to suitable levels, e.g. in poor tropical soils (Bougnum et al., 2011). The effect on P availability in ash after co-composting has not been clearly documented.

Protection against fungal plant diseases:
Research on American universities have demonstrated the ability of compost to combat fungal plant diseases such as Pythium root rot and Phytophthora root rot (US EPA, 1997). Australian research has also demonstrated that compost can suppress wilt caused by *Fusarium* spp., damping off caused by *Fusarium*, *Pythium*, *Rhizoctonia* and *Sclerotium* spp. As well as stem and root rot caused by *Fusarium*, *Rhizoctonia*, *Pythium*, *Sclerotium* and *Aphanomyces* spp. (Compost for soils, 2009). The scientific literature on the role of compost in reducing soil-borne plant diseases is thoroughly reviewed by Zinati (2005) and Mehta et al. (2014) and also indicates, that compost can be used to help fighting plant diseases and, hence, reduce the need for application of chemical pesticides.

Effect on water-holding capacity:
Application of compost as soil amendment has been shown to positively affect the water retention of soil (Zemánek, 2011).

3.1.1 Accepted existing data

No data from previous tests have been used for calculation of the performance parameters. It means that the verification is based solely on measurements done by the test institute in the test period specified.

3.2 Laboratory or field conditions

Laboratory conditions

The microbial and soild samples were stored in cooling boxes with freezing elements and sent directly to the laboratory and analysed within 24 hours from sampling. The analyses were performed by Eurofins Agro Testing, Vejen, Denmark
Eurofins Agro Testing is not accredited to perform these analyses on compost *per se*, however, the laboratory is accredited by DANAK (DS EN ISO/IEC 17025 DANAK 168) to perform analysis of *E. coli* in waste, sludge and sediment, analysis of *Enterococcus* species in wastewater and various other matrices, and analysis of *Salmonella* in sludge, sediment and impure water.

Field conditions

The two composting units were tested at two separate locations where all additional performance parameters, operational parameter and environmental parametres were measured or supervised by Danish Teknological Institute. Alle measurmenst were performed according to best scientific practis.

3.3 Matrix compositions

The tree types of biomasses that the composting units were tested on were;

1. Degassed fiber fraction from biogas plant,
2. Sludge mixed with garden waste plus ash,
3. Food waste mixed with horse manure.

Biomass 1: Degassed fiber fraction from a biogas plant. The fibers were delivered on 14th of June 2022 from Nature Energy's biogas plant in Videbæk, Denmark, which is running with a temperature of 52°C and an average hydraulic retention time of 30 days. The feedstock used in the biogas plant was approx. 90% slurry and deep litter from animal production with the remaining feedstock being mainly organic waste from dairy production. The fiber fraction was separated from the digestate on 13th June 2022 by means of a screw press and a decanter centrifuge.
Biomass 2: Sludge + garden waste + ash. Garden waste was delivered by Bornholms Affaldsbehandling in Rønne. Sludge from municipal wastewater was delivered by Bornholms Energi & Forsyning (BEOF). Fly-ash from combustion of straw was delivered from the combined heat and power plant Fynsværket.
Biomass 3: Food waste + horse manure. Food waste was collected from private households on Sealand and delivered by Gemidan, Ølstykke. Horse manure/deep litter was delivered by BOFA on Bornholm and used for giving structure in the biomass during sanitization/composting. Food waste and horse manure were mixed and weighed as described for Biomass 2.

3.4 Test and analysis parameters

Her at list of the test and analysis parameters that were used in this test:

- Temperature during sanitization/composting
- Concentration of NH3, CO2, N2O and CH4 before and after air cleaning
- Biomass weight, before and after process
- Reduction of pathogenic bacteria in biofertilizer
- Plant nitrogen value in % of growth height
- Dry matter content
- Total N

- Ammonium N
- Nitrite + nitrate N
- Total P
- Total K
- Total Mg
- Total Ca
- Total S
- Density
- Total C
- C/N ratio
- pH
- Electrical conductivity and salt
- Total P
- Citrate soluble P
- Water soluble P
- Effect on P availability
- water-holding capacity for growth substrate
- Suuppression of fungal plant diseases
- Up time/down time during each test run.
- Process temperature at three depths in the composting chamber
- O2 concentration in air outlet of the sanitization/composting unit
- Power consumption for each test run
- Air temperature
- Humidity RH%
- Wind speed
- Flow through composting unit

3.5 Tests and analysis methods summary

A total of six composting test runs were performed during the project. The test runs represented two test sites and three types of biomasses as shown in Table 3. The test runs and the sampling of biomass for various test and analyses are described in summary below for the performance parameters.

Table 3 Overview of the six composting test runs.

Site	Composting system	Biomass	Test run number	Time of test run
A, Fyn	Container system	Digested fiber from biogas plant	1	Wednesday 15th June 2022 15.30 – Monday 20th June 2022 9.00
A, Fyn	Container system	Digested fiber from biogas plant	2	Monday 20th June 2022 13.00 – Thursday 23rd June 2022 14.00
B, Bornholm	Silo system	Sludge + garden waste + ash	1	Tuesday 12th July 2022 15.45 – Monday 18th July 2022 08.00
B, Bornholm	Silo system	Sludge + garden waste + ash	2	Tuesday 19th July 2022 16.00 – Tuesday 2nd August 2022 07.00
B, Bornholm	Silo system	Food waste + horse manure	1	Thursday 8th Sep. 15.45 – Thursday 15th Sep. 2022 10.30
B, Bornholm	Silo system	Food waste + horse manure	2	Monday 19th Sep. 15.30 – Monday 26th Sep. 2022 11.00

Test methods summary

- Temperature during sanitization/composting (Continuous measurements PT100 temperature probe)
- NH3, CO2, N2O and CH4-loss after air cleaning, in % of the total N and in the initial biomass per ton dry matter of initial biomass (Picarro G2508, Impingers (ISO 21877), CRDS)
- Initial biomass weight, for calculation of emission per ton DM (gravimetric method)
- Air flow (Wheel anemometer)

Analysis methods summary

Reduction of pathogens

- Reduction of pathogenic bacteria in biofertilizer (CEN/TR 16193 method C, DS 2401, CEN/TR, 15215-3, DS 266:1988)

Plant nitrogen value

- Plant nitrogen value in % of growth height (Tomato plant growth assay)

Nutrient content in biomass before and after sanitization/composting

For each biomass type, compost from test run 1 and test run 2 were mixed in equal proportions by volume to achieve a representative compost for the experiments with plant nitrogen value, suppression of plant diseases and water-holding capacity. For initial characterization of the three compost types, a sample of approx. 1 kg of each compost type was analysed by Eurofins for the following parameters:

- Dry matter content (DIN EN 13040: 2008-01 / Gravimetric, JY0BK)
- Total N (EF 152/2009 mod / Kjeldahl, titrimetric, DHN13)
- Ammonium N (EF 152/2009 mod / Kjeldahl, titrimetric, DHA07)
- Nitrite + nitrate N (DS 223/ DS 230:1988 mod. / Titrimetry, CAH66)
- Total P (DS 259:2003, DS/EN ISO 11885:2009 / ICP-OES, CA503)
- Total K (DS 259:2003, DS/EN ISO 11885:2009 / ICP-OES, CA504)
- Total Mg (DIN EN 13650:2002-01, JY0BT)
- Total Ca (DIN EN 13650:2002-01, JY0BS)
- Total S (DIN EN 13650:2002-01, JY0HK)
- Density (Methodenbuch zur Analyse organischer Düngemittel, / Gravimetric, JY08Y)
- Total C (ISO 10694 / Dumas, TCD, CAH0M)
- C/N ratio (calculated, DR323)
- pH (Internal Method Radiometer, GLP / Potentiometric, DHR01)
- Electrical conductivity and salt (EC) (DIN EN 13038: 2012-01 / Conductometric, JY07A)

Analysis of availability of P in ash before and after compost-ing

Plant availability of P in compost and other organic fertilizers can be evaluated by chemical extraction with various solvents and is often expressed as percentage of total P in the fertilizer

- Total P (DS 259:2003, DS/EN ISO 11885:2009 / ICP-OES, CA503)
- Citrate soluble P (Metode for jordforb. del1: 3.1.4: 1978, SM 3120, ICP-OES, CA142+CAI31+CAI33)
- Water soluble P (DS 259:2003, SM 3120, ICP-OES, CAE49+CAA26)
- Effect on P availability (Calculation from chemical analyses)

Water-holding capacity

- Increase of water-holding capacity for growth substrate compared to substrate without addition of biofertilizer (ISO 11274 (15))

- Suppression of fungal plant diseases (Disease symptoms was scored according to the severity scale reported by Rongai et al., 2017)

3.6 Parameters measured.

The performance parameters that were measured in the verification including sampling methods and measurement methods are defined in table 4.

Table 4 Definition of performance parameters, sampling conditions and measurement methods.

Parameter	Unit	Sampling conditions	Where	Measurement method	Existing legal requirements and/or BAT values
Temperature during sanitization/composting	°C	Continuous measurements	Top, middle and bottom of container/reactor	PT100 temperature probe Control measurements are done using a Testo 440	At least 70°C for at least 60 minutes (Miljøstyrelsen, 2010; Retsinformation, 2020)
Reduction of pathogenic bacteria in biofertilizer compared to initial biomass before sanitization/composting		Representative biomass samples taken before and after sanitization/composting, from individual runs	From mixture of biomass before and after sanitization/composting		
- *E. coli*	CFU/g WW			Method sheet MM0003 and MM0017 from www.reference-lab.dk , CEN/TR 16193 method C, Eurofins analysis UMEZ7	<100 CFU/g WW in compost (Miljøstyrelsen, 2010)
- Enterroccocus	CFU/g WW			Method sheet MM0007 from www.reference-lab.dk, DS 2401, Eurofins analysis UMP3B	<100 CFU/g WW in compost (Miljøstyrelsen, 2010)
- Salmonella	Detection or not			Method sheet MM0008 from www.reference-lab.dk, CEN/TR 15215-3, DS 266:1988, Eurofins analysis UMPMW	Must not be detected in 100 g (Miljøstyrelsen, 2010)
Ammonia loss after air cleaning, in % of the total N in the initial biomass	% of total N	Continuous measurements	Inlet and outlet	Picarro G2508, Impingers (ISO 21877), CRDS	BAT, Natur 2000

Loss of CO_2 equivalents (CO_2, N_2O, CH_4) per ton dry matter of initial biomass	CO_{2e} per ton DM	Continuous measurements	Inlet and outlet	CRDS, Picarro G2508	NA
Initial biomass weight, for calculation of emission per ton DM	Ton DM	Weighing of total batch of biomass in each of the two runs with degassed fiber	When loading the sanitization/composting unit		
Air flow	m^3/h	Continuous measurements	Outlet of the sanitization/composting unit.	Lindab Ultralink. Control measurements was performed with wheel anemometer.	NA
Nutrient content in biomass before and after sanitization/composting	g kg^{-1} DM	Representative biomass samples taken before and after sanitization/composting, from individual runs	From mixture of biomass before and after sanitization/composting	Chemical analyses	NA
- Total N	mg/kg DM	-	-	EF 152/2009 mod / Kjeldahl, titrimetric. Eurofins analysis DHN16	NA
- NH_4-N	mg/kg DM	-	-	EF 152/2009 mod / Kjeldahl, titrimetric. Eurofins analysis DHA08	NA
- NO_3-N	mg/kg DM	-	-	DS 223/222/Lachat. Eurofins analysis CAH66	NA
- Total K	mg/kg DM	-	-	DS 259:2003, DS/EN ISO 11885:2009 / ICP-OES. Eurofins analysis CA504	NA
Plant nitrogen value in % of growth height after 4-6 weeks compared to conventional chemical fertilizer (same N concentration)	% difference in plant height	Representative samples of biomass after sanitization/composting, mixed from the two runs per biomass	From mixture of biomass after sanitization/composting	Tomato plant growth assay	NA
P availability for plants in ash with and without co-		Representative biomass samples taken before and after	From mixture of biomass before and after	Chemical analyses	Max. 30 kg total P per ha per year

composting with waste biomass		sanitization/composting	sanitization/composting		
- Total P	mg/kg DM	-	-	DS 259:2003, DS/EN ISO 11885:2009 / ICP-OES. Eurofins analysis CA503	NA
- Citrate soluble P	mg/kg DM	-	-	ISO 15959:2016. Metode for jordforb. Del1: 3.1.4: 1978, SM 3120, ICP-OES. Eurofins analysis CA142+CAI31+CAI33	NA
- Water soluble P	mg/kg DM	-	-	DS 259:2003, SM 3120, ICP-OES. Eurofins analysis CAE49+CAA26	NA
- Effect on P availability	% increase in citrate soluble P and water soluble P as proportion of total P			Calculation from chemical analyses	NA
Suppression of fungal plant diseases such as *Fusarium*, *Verticillium*, *Pythium* or *Phytophthora* compared to standard growing medium	-	Representative samples of biomass after sanitization/composting, mixed from the two runs per biomass	From mixture of biomass after sanitization/composting	Tomato plant growth assay with *Fusarium oxysporum* f. sp. *Lycopersici* and *Rhizoctonia*. Disease symptoms was scored according to the severity scale reported by Rongai et al., 2017.	NA
	0 = No symptoms				
	1 = slight yellowing of one or two leaves				
	2 = more extensive yellowing of basal and median leaves, with some leaves wilted				
	3 = severe yellowing of leaves, 50 % of leaves wilted and growth inhibited				
	4 = widespread symptoms, all leaves yellow, rot on roots, vascular discoloration in the stem, and severe stunting				
	5 = dead plants				
Increase of water-holding capacity of growth substrate compared to substrate without addition of biofertilizer	% water holding capacity	Representative samples of biomass after sanitization/composting, mixed from the two runs per biomass	From mixture of biomass after sanitization/composting	Appendix 2, ISO 11274 (15)	NA

4 VERIFICATION RESULTS (PERFORMANCE, OPERATIONAL AND ENVIRONMENTAL PARAMETERS)

Hygienization temperature

Table 5 Key parameters for temperature development during the six composting test runs.

Location	Test run	Biomass	Duration of test run	Duration to reach 70°C			Maximum temperature			Total duration at ≥70°C		
			Total	Top	Centre	Bottom	Top	Centre	Bottom	Top	Centre	Bottom
			Hours	Hours	Hours	Hours	°C	°C	°C	Hours	Hours	Hours
A, Fyn	1	Degassed fiber	113.5	45.5	58.8	66.5	71.8	81.7	70.9	9.9	9.9	1.6
A, Fyn	2	Degassed fibber	73.0	13.2	10.6	31.7	80.3	84.1	80.7	30.5	33.1	12.0
B, Bornholm	1	Sludge + garden waste + ash	136.3	111.5	56.8	88.9	73.6	76.7	77.2	24.3	79.1	46.9
B, Bornholm	2	Sludge + garden waste + ash	327.0	320.9	269.2	290.9	70.5	71.4	70.7	5.8	57.5	23.8
B, Bornholm	1	Food waste + horse manure	162.8	38.8	33.7	34.1	85.7	82.7	81.2	123.8	129.0	128.5
B, Bornholm	2	Food waste + horse manure	163.5	20.3	18.4	16.5	85.0	86.0	83.0	142.7	144.7	146.6

Temperature was measured with three probes located in the top, center and bottom part of the biomass. The tests have verified that the composting technology can sanitize/hygienize waste biomass by increasing the temperature to minimum 70°C for at least one hour.

Reduction of pathogenic bacteria

Table 6. Ratio of the occurrence of pathogenic bacteria in the biomass after versus before composting/sanitizing of three types of biomass. No statistical analysis was performed for E. coli and Salmonella in degassed fiber fraction, because there were only trace amounts and no variance between samples.

Biomass	**Ratio of pathogenic bacteria, after/before composting**			
	E. coli			
	Ratio	Confidence limits for ratio		P value
		2.5 %	97.5 %	
Garden waste + sludge + ash	9.237	0.509	167.7	0.103
Food waste + horse manure	0.162	0.015	164.6	0.752
	***Enterococcus* species**			
	Ratio	Confidence limits for ratio		P value
		2.5 %	97.5 %	
Degassed fiber fraction	0.576	0.038	2.62E+08	0.365
Garden waste + sludge + ash	0.968	0.004	1.460	0.976
Food waste + horse manure	0.028	0.003	0.284	0.023
	Salmonella			
	Ratio	Confidence limits for ratio		P value
		2.5 %	97.5 %	
Garden waste + sludge + ash	0.552	0.083	3.671	0.476
Food waste + horse manure	0.005	0.001	3.82E+117	0.942

Conclusions

The elevated temperature did not result in any significant reduction of E. coli. There was however at significant reduction in the bacteria genus Enterococcus for the 3. Biomass containing food waste + horse manure.

Overall, the ability of the composting technology to reduce the occurrence of pathogenic bacteria was demonstrated to some extentint.The occurrence of both *E. coli* and *Enterococcus* was reduced in one test run with food waste + horse manure, and *Salmonella* was reduced in one test run with garden waste + sludge + ash and one test run with food waste + horse manure. However, the statistical analyses indicated that composting only caused a significant reduction in the occurrence of *Enterococcus* in food waste + horse manure.N-loss and CO2-eq emission

Table 7. Mass loss of fresh matter, dry matter and total N during composting test runs with digested fibre fraction.

Test run	**Fresh weight of biomass, kg**		**Dry weight of biomass, kg**		**Weight of N, kg**		**Mass loss, %**		**N loss, %**	**N loss, Kg**	**Mass loss, Kg**	**CO2 Mass loss, Kg Gravi-metric**	**CO2 Mass loss, Kg CRDS ex-trapo-lated**	**Total kg. CO2-eq/tDW extrapo-lated**
	Initial	Final	Initial	Final	Initial	Final	FW	DW						
#1	15300	11520	4047	3070	99	75	24.7	24.1	24.1	23.86	977	1389	287	27
#2	13300	12000	3425	3216	84	78	9.8	6.1	6.9	5.80	209	296	326	163

Due to malfunction of the air filter and the subsequently air insufficiency and prolonged composting presses, data from the first run should not be used in the conclusions.

The measurements period in the second run was only present in 33 hours out of 73 hours test duration, which is why the average emission rates should be extrapolated to the whole test period.

The Nitrogen loss the total composting period, in the second run with biomass 1, was 5.6% of the total N content in the initial biomass which is close to the 6.9% N-loss measured gravimetrically.

The extrapolated CO2-eq emission measured by the cumulated CO2, N2O and CH4 for the duration of the entire period of the second run is 163 kg CO2-eq ton-1 DW.
A mass loss of 209 kg. for de second run equals a stoichiometric CO2-mass-loss of approximately 296 kg CO2, which is only 9% lower than the extrapolated cumulated CO2 -mass loss of 326 kg. This supports the extrapolated CO2-eq emission measured.

Plant nitrogen value

Table 8. *Calculated mineral N use efficiency for the mineral N applied with the compost in the growth experiment with tomato plants. The N fertilizer efficiency was calculated based on the dose-response relationship for plant dry weight for mineral fertilizer.*

	Treatment	Dose of mineral N applied (NH_4+NO_3+NO_2) (g/pot)	Measured plant dry weight(g)	Predicted plant dry weight at the applied dose of mineral N (g)	Mineral N use efficiency (%)
1	Sand + full nutrient solution	533.6	15.8	-	-
2	Sand without fertilization	0.4	1.3	-	-
3	75% sand + 25% compost 1	89.7	4.2	3.7	111.7
4	50% sand + 50% compost 1	179.0	5.2	6.2	84.1
5	75% sand + 25% compost 2	42.8	2.8	2.5	112.4
6	50% sand + 50% compost 2	85.3	3.0	3.6	82.9
7	75% sand + 25% compost 3	54.5	1.4	2.8	50.2
8	50% sand + 50% compost 3	108.7	1.4	4.2	33.8

The growth of tomato plants was improved in substrate mixtures with compost compared to pure, unfertilized sand, and the plant dry weight increased with increasing dose of mineral nitrogen (ammonium + nitrite + nitrate) applied per pot with the compost which proves the N fertilizer effect of the compost. For all three compost types, the mineral N fertilizer efficiency was highest for the mixtures with 25% compost compared to the mixtures with 50% compost. For both compost 1 and 2, the mineral N fertilizer efficiency was 112% at a dose of 25% compost in the mixture whereas it was 83-84% at a dose of 50% compost in the mixture. For compost 3, the mineral N fertilizer efficiency was considerably lower with 50 and 34% in mixtures with 25 and 50% of compost, respectively.

Effect of compost on fungal diseases

Table 9. Estimated values for disease severity, plant height and plant weight in the plant disease suppression experiment which was running 6 weeks after infection. Letters indicate LSD groupings within soil type; within a parameter and within a soil type, values followed by the same letter are not significantly different (P=0.05).

Soil type	Plant disease	Disease severity index					Plant height (cm)	Plant weight (g fresh weight)
		Fusarium (%)				*Rhizoctonia* (%)		
		Week 3	Week 4	Week 5	Week 6	Week 6	Week 6	Week 6
1. 100% soil	1. Uninfected	11.1 a	5.6 a	26.7 a	33.3 a	0.0 a	131.7 b	329.6 b
	2. *Fusarium*	0.0 a	11.1 a	35.6 a	46.7 a	3.7 a	112.9 a	295.1 ab
	3. *Rhizoctonia*	0.0 a	5.6 a	26.7 a	40.0 a	0.0 a	101.0 a	256.5 a
2. 85% soil, 15% compost 1	1. Uninfected	11.1 a	16.7 a	26.7 a	40.0 a	0.0 a	127.9 b	438.4 b
	2. *Fusarium*	0.0 a	22.2 a	22.2 a	28.9 a	0.0 a	139.6 b	448.4 b
	3. *Rhizoctonia*	11.1 a	5.6 a	22.2 a	31.1 a	3.7 a	114.3 a	309.2 a
3. 85% soil, 15% compost 2	1. Uninfected	11.1 a	33.3 a	33.3 a	46.7 a	0.0 a	120.4 a	314.4 a
	2. *Fusarium*	0.0 a	22.2 a	35.6 a	48.9 a	3.7 a	118.8 a	312.2 a
	3. *Rhizoctonia*	0.0 a	16.7 a	33.3 a	40.0 a	11.1 a	115.3 a	344.5 a
4. 85% soil, 15% compost 3	1. Uninfected	0.0 a	16.7 a	31.1 a	51.1 a	0.0 a	120.0 a	257.7 a
	2. Fusarium	0.0 a	5.6 a	40.0 a	48.9 a	7.4 a	124.3 a	251.0 a
	3. Rhizoctonia	0.0 a	0.0 a	22.2 a	37.8 a	0.0 a	112.0 a	292.6 a

Infection of tomato plants with *Fusarium* and *Rhizoctonia* reduced plant height significantly with 14-23% and plant weight significantly with 10-22%. Addition of 15% of compost 2 or compost 3 resulted in growth of infected plants that was not significantly different from the growth of uninfected plants. Addition of 15% of compost 1 also resulted in plant growth which did not differ significantly between plants infected with Fusarium and uninfected plants, whereas plants infected with Rhizoctonia had poorer growth. Overall, the results indicate that addition of the tested compost types can have a significant protection against the negative effect of the two fungal diseases on growth of tomato plants.

Availability of P in ash before and after composting

The composting process was expected to increase plant available P in ashes, but the fractions of citrate-extractable P and water-extractable P decreased slightly but non-significantly by 5.9 and 1.3 percentage points, respectively. Therefore, it could not be verified, that the composting process can increase the plant availability of P.

Water-holding capacity

It is not verified that the water-holding capacity of growing substrate can be increased up to 10 volume percent by addition of biofertilizer. The content of plant-available water per pot was increased by 4.6 volume percent when adding 25% compost 3 to sand.

Operational parameters

Table 10. operational parameters for the six test runs.

Location	Composting system	Test run	Biomass	Initial biomass weight		Duration of test run	Aeration		Power consumption		Man-power	
						Total	To reach 70°C for 1 hour	To reach 70°C for 1 hour	To reach 70°C for 1 hour	Total	For operation	For maintennance
				kg FW	kg DW	Hours	m^3	m^3 ton^{-1} FW	kWh	kWh	Hours	Hours
A, Fyn	Container system	1	Degassed fiber	15,3	4,047	113.5	12,075	789	6.4	16.0	4	2
A, Fyn	Container system	2	Degassed fiber	13,3	3,425	73.0	14,201	1,068	19.2	30.2	4	0
B, Bornholm	Silo system	1	Sludge+garden waste + ash	2,46	1,138	136.3	7,379	3,000	3.9	4.3	20	0
B, Bornholm	Silo system	2	Sludge+garden waste + ash	2,87	1,56	327.0	7,442	2,593	10.4	10.4	16	0
B, Bornholm	Silo system	1	Food waste + horse manure	2,9	1,53	162.8	4,706	1,623	4.3	6.1	16	0
B, Bornholm	Silo system	2	Food waste + horse manure	3,15	1,074	163.5	3,633	1,153	3.9	6.0	16	0

The process is rather time consuming. On an average 9 hours per ton DW is used. For the test runs on Bornholm, the time consumption for operation were 16-20 hours per test run. It was rather time consuming to weigh the quantity of the different biomasses for the biomass mixtures, especially since this was done in 4-7 separate batches per test run. For normal operation without this quantification, the time consumption for operation it expected to be approx. 8 hours per test run including loading and unloading the compost reactor.
On an average 5.5 kWh of electricity per ton DW was used in the process.

Operational Stability
The test proved that the BACESS Bio Fertilizer Production Unit BBFP-U had sufficient operational stability during the 6 separate runs with 3 different biomasses. However, the integrated air filter did not work and can therefore not be verified.
Particularly, the following issues shall be observed:

- Pressure drop should be monitored to prevent clogging and insufficient airflow
- Airflow should continue until temperature is down to close to ambient temperature to ensure an oxidated environment in the hole process and thereby minimising the risk of methane and hydrogen sulphide emissions.
- The use of man power need to be reduced in order to make a sustainable business
- High attention to reduce leaks in the system.
- A suitable air filter to reduce ammonia emission from the system have to be found.

5 ADDITIONAL INFORMATION, INCLUDING ADDITIONAL PARAMETERS[1]

Verified claims.

It is verified that the technology can increase the temperature to minimum 70°C for at least one hour.

With 6.9% N-Loss, a N-loss of maximum 10% of the total N, in the initial biomass, from the process was verified.

The total emission of CO2, CH4 and N2O adds up to 163 kg CO2-eq per ton of initial DW. The claim of less than 200 kg CO2 equivalents per ton dry matter of initial biomass is verified.

A mixture of 25% compost/sand for compost 1 and 2 had a mineral N fertilizer efficiency of 112%, what is more than the claimed 90% efficiency claimed.

Addition of 15% compost 1 or 2 have a significant protection against the negative effect of the two fungal diseases on growth of tomato plants.

Validity

This ETV Verification Statement is only valid for the specific verified product/technology and the tested category. The validity of this ETV Verification Statement is limited for as long as the product/technology stays unmodified.

ETA-Danmark can, however, at any time invalidate ETV Verification Statement if it is found to be misused or if significant modifications have been made to the product/technology that are estimated to have a negative effect on the environmental efficiency or operational stability. In regard to the latter ETV can require that a new ETV test should be performed.

Terms of Use

The use of this ETV Verification Statement must be in compliance with these terms:

- Bacess A/S must inform ETA-Danmark if any modifications are applied to the technology that can significantly influence the environmental efficiency and/or the operational stability.
- This verification cannot be considered an endorsement, approval, authorization or warranty of any kind, and the performance parameters provided cannot be extended to other applications or to other technologies.
- Bacess A/S agrees not to use this ETV Verification Statement, the test reports, or to refer to those for any other technology than the one specified in the statement.
- The ETV Verification Statement will be made available for public access at ETA-Danmark's website: https://www.etadanmark.dk
- All other information obtained or produced during the verification process is considered confidential and will not be made available for others than the part owning the intellectual property rights.
-

6 QUALITY ASSURANCE AND DEVIATIONS

Compared to the specific verification protocol and test plan, the following has been changed:

- The air filter for cleaning of the exhaust air was only used in the initial phase of test run 1 with degassed fiber. The flow through the air filter was insufficient and prevented sufficient aeration of the biomass in the composting chamber. Consequently, the measurement of emissions during composting was only measured directly after the composting chamber and after the air filter.

- Air flow was measured using fan wheel anemometers in combination with registered ventilator performance, as Lindab UltraLink system proved not applicable.

- In test run 2 with garden waste + sludge, the duration of the compost run exceeded the planned maximum of 10 days due to technical problems.

- The test runs were delayed due to issues with delivery of biomasses.

7 REFERENCES

Bougnum, B.P., Knapp, B.A., Francois, Z. & Insam, H. (2011). Possible Use of Wood Ash and Compost for Improving Acid Tropical Soil. In: Recycling of Biomass Ashes, pp. 87-105.

Dalsgaard, M. (2020). Potteforsøg hos gartneriet Økologihaven fra august til november 2020. Report, BACESS A/S. 5 pages.

Mehta, C.M., Palni, U., Franke-Whittle, I.H. & Sharma, A.K. (2014). Compost: Its role, mechanism and impact on reducing soil-borne plant diseases. Waste Management, 34, 607-622.

Miljøstyrelsen (2010). Anvendelse af affald til jordbrugsformål. Vejledning fra Miljøstyrelsen Nr. 1 2010. https://www2.mst.dk/udgiv/publikationer/2010/978-87-92668-73-8/pdf/978-87-92668-74-5.pdf

Retsinformation (2020). Bekendtgørelse om kvalitetskrav til miljømålinger. BEK nr 1770 af 03/12/2020. https://www.retsinformation.dk/eli/lta/2020/1770

Rongai et al. 2017. "Antifungal activity of pomegranate peel extract against Fusarium wilt of tomato". Eur. J. Plant Pathol. 2017, 147: 229-238.

Termorshuizen, A. & Alsanius, B. (2016). Hygienization Aspects of Composting. Chapter 5, p.63-69. In: Handbook for Composting and Compost Use in Organic Horticulture. Eds. Van der Wurff, A.W.G., Fuchs, J.G., Raviv, M., Termorshuizen, A.J. BioGreenhouse, COST Action FA 1105, www.biogreenhouse.org. ISBN: 978-94-6257-749-7. DOI: http://dx.doi.org/10.18174/375218

US EPA (1997). Innovative uses of compost. Disease control for plants and animals. Fact sheet by United States Environmental Agency. 4 pages. https://www.epa.gov/sites/production/files/2015-08/documents/disease.pdf

Zinati, G.M. (2005). Compost in the 20th century: A tool to control plant diseases in nursery and vegetable crops. HortTechnology, 15(1), 61-66.