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**BELISSIMA Contract No. 19297/05/NL/SFe**  
**WP80.321 Demonstration test plan**  
**Waste Preparation Unit**

Organization Approval Loop :

Issue Date	Issue	Prepared by (visa):	Checked by (visa):	Approved by (visa):
18/10/2010	1	H. De Wever  Date : 24/10/10	H. Eslander  Date : 24/10/10	H. De Wever  Date : 24/10/10

Customer Approval :

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28/10/2010	1	B. Lamaze 

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## 1. Scope

Within Phase 1 of the BELISSIMA contract, a Waste Preparation Unit has been designed and assembled. Its hardware will be tested through this demonstration test plan.

## 2. Reference and applicable documents

### 2.1 *Applicable documents*

AD1 19071/05/NL/CP Memorandum of Understanding between MELiSSA partners  
Test plan template

### 2.2 *Reference documents*

RD1 TN80.241 Recommended design and integration strategy. Detailed design Waste Preparation Unit and Compartment I

## 3. Acronyms

WPU	Waste Preparation Unit
FAT	Factory Acceptance Testing
SAT	Site Acceptance Testing





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## 4. Test items

### 4.1 description

The aim of the WPU is to produce a homogeneously mixed feed for compartment I of the BELISSIMA loop. This feed will be prepared from frozen beet and lettuce, toilet paper, wheat straw, frozen urine and fecal material. The frozen beet and lettuce will be previously reduced in size in an off-line hygienic kitchen cutter (Robot Coupe, vertical cutter R30, 3 cutting blades with milled edges). The wheat straw is ground separately with two grinders from Retsch (step 1: Cutting mill SM100 at 8 mm, step 2: UltraCentrifugal Mill ZM200 with 2 mm sieve, step 3: UltraCentrifugal Mill ZM200 with 1.5 mm sieve) and sieved at 2 mm. The frozen urine and fecal material will be added directly into the WPU tank. The suspension is then diluted to the desired concentration through the addition of tap water. While the waste is circulated in a loop, further particle size reduction is achieved through an in-line pump shear pump. A sight-glass in the recirculation line allows to evaluate the mixing process.

The feed preparation unit will be cleaned after each use. To this end, an additional tank is provided from which flush water + cleaning agent can be pumped through the whole system, through a nozzles at the top of the main tank.

The final P&ID of the Waste Preparation Unit is shown in Figure 1.

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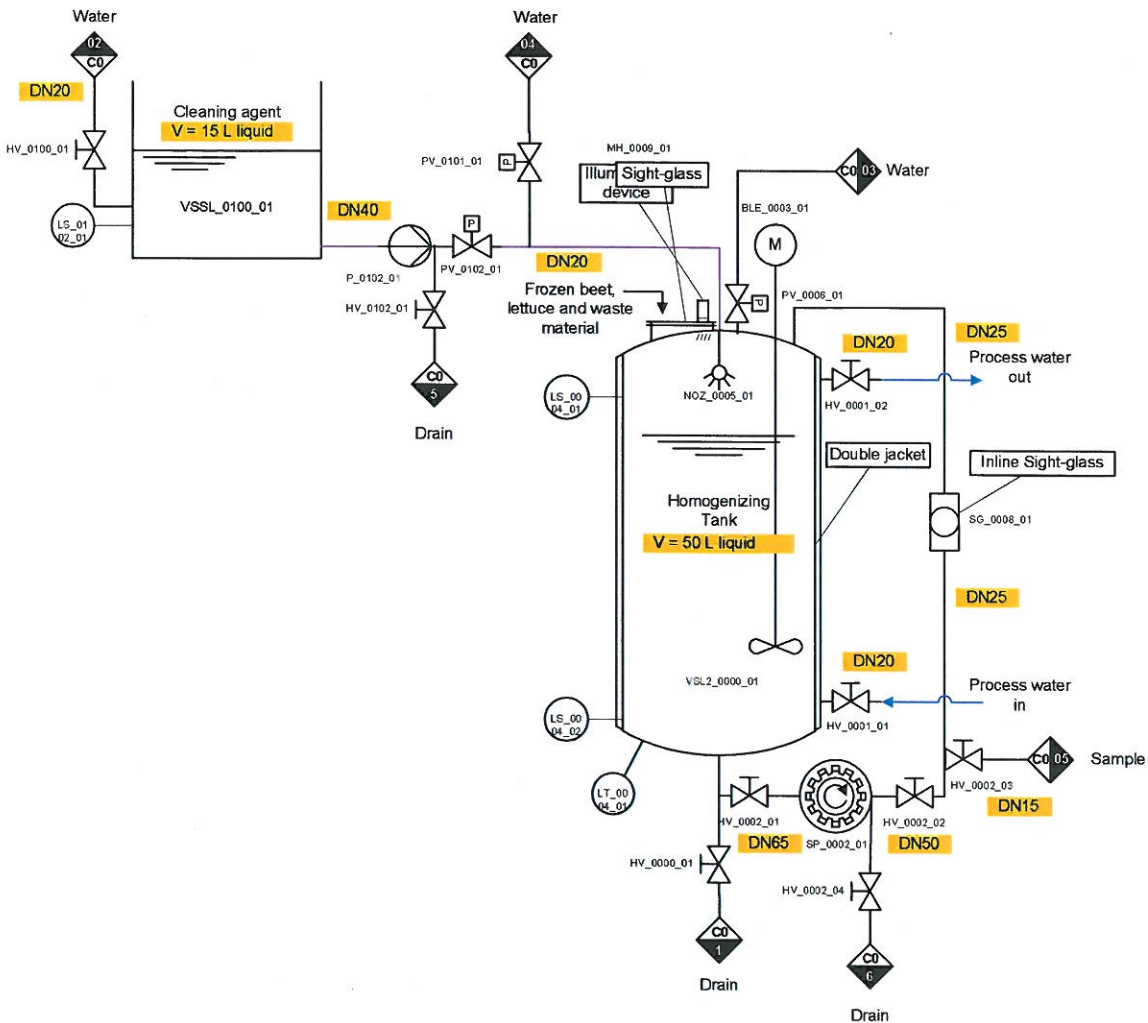


Figure 1. Final P&ID of the Waste Preparation Unit.

A component list is provided in Table 1.



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**Table 1: Component list Waste preparation Unit.**

Tag	Purpose - Description	Supplier	Ref. / order n°
VSL2_0000_01 BLE_0003_01	Mam tank, double jacket, SS316L, inside Ra < 0,8 µm, total volume 70 l, working volume 50 l Removable top with sight glass, illumination device, opening for waste material addition and spare hygienic port. Equipped with spray ball and mechanically coupled stirrer with seal containment chamber at variable frequency. Equipped with sanitary connections to instrumentation and devices for easy cleaning.	Packo  PRG: <a href="http://www.prg-gmbh.de">www.prg-gmbh.de</a>	Stirrer: R100La-4SW VITO, with frequency drive
VSSL_0100_01 SP_0002_01	Cleaning tank, SS316L, inside Ra < 0,8 µm, 15 l Shear pump	Packo Fristam <a href="http://www.fristam.de">www.fristam.de</a>	FSPE 3522/145 A, rotor 145 mm, 11 kW, Cr-Ni-Mo steel 1.4404, with frequency drive
P_0102_01	Centrifugal pump with mechanical coupling	Packo	FP2 32-125 112 O-130 M08S33SES
NOZ_0005_01	Sprayball, SS316L	Alfa Laval	Toffejorg SaniMicro Rotary Spray Head, SaniMicro 360 CLIP-ON
MH_0009_01	Manhole, SS316L, Ra < 0,8 µm, and light	Papenmeier	Glass DIN 8902, light USL03
SG_0008_01	Sight glass	AWH	1", SS316L
LS_0004_01	Level switch (foam detection)	E+H <a href="http://www.endress.com">www.endress.com</a>	Liquiphant M FTL 50H 1"-1"1/2, Tri-Clamp process connection
LS_0004_02	Level switch	E+H	Liquiphant T FTL 20H 1"-1"1/2, Tri-Clamp process connection
LT_0004_01	Level transmitter	E+H	CERABAR S PMP75, Tri-Clamp process connection
LS_0102_01	Level switch	E+H	Liquiphant T FTL 20H 1"-1"1/2, Tri-Clamp process connection
HV_0000_01	Sanitary 2-way ball valve, drain buffer tank	TVC	70T 2"1/2, Tri-Clamp process connection.
HV_0002_01	Sanitary 2-way ball valve, before shear pump	TVC	70T 2"1/2, Tri-Clamp process connection.
HV_0002_02	Sanitary 2-way ball valve, after shear pump	TVC	70T 2", Tri-Clamp process connection.
PV_0102_01	Powered 2-way diaphragm valve, after centrifugal	KSB	SISTO-B DN20, Tri-Clamp process connection





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Tag	Purpose - Description	Supplier	Ref. / order n°
PV_0006_01	pump Powered 2-way diaphragm valve, inlet water to main tank	KSB	SISTO-B DN25, Tri-Clamp process connection
HV_0002_03	2-way diaphragm valve, valve to sample	KSB	SISTO-B DN15, Tri-Clamp process connection
HV_0001_01	Sanitary 2-way ball valve, inlet double jacket	TVC	70T 3/4", Tri-Clamp process connection
HV_0001_02	Sanitary 2-way ball valve, inlet double jacket	TVC	70T 3/4", Tri-Clamp process connection
PV_0101_01	Powered 2-way diaphragm valve, inlet water to sprayball	KSB	SISTO-B DN20, Tri-Clamp process connection
HV_0100_01	Sanitary 2-way ball valve, inlet water to cleaning tank	TVC	70T 3/4", Tri-Clamp process connection
HV_0102_01	Sanitary 2-way ball valve, drain after centrifugal pump	TVC	70T 3/4", Tri-Clamp process connection
HV_0002_04	Sanitary 2-way ball valve, drain after shear pump	TVC	70T 3/4", Tri-Clamp process connection



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#### **4.2 hazards induced by test item and safety measures to be taken**

Fecal material and urine as well as the final feed mixture with fecal material or urine should be handled according to Class II Biosafety instructions. Personal protective means will be used (mouth masks, gloves, ..).

Feed mixture with fecal material: aerosol formation should be avoided. On the open vent a single use filter (Pall, Kleenpak Capsule Filter, Emflon filter KA1PFRP1, 0.2 µm) will be mounted.

Spreading of potentially hazardous feed waste material:

- Before filling the homogenization tank, the operator has to check whether the drain and sample hand valves are closed.
- Opening the manhole will stop the shear pump immediately.
- During cleaning, opening the manhole will stop the cleaning pump and sprayball immediately.
- Inlet and outlet openings of agitator flange should be closed by connecting them with tubing.

Pressure buildup

- the unit should not operate at a pressure above 0.5 bar. An open vent is always required.
- Before starting the shear pump, the operator has to check whether the hand valves before and after the pump are in the open position.

Chemical hazards with cleaning agents: use of appropriate personnel protective equipment

#### **4.3 instructions for operation**

An operating manual was provided by Packo and is provided in Appendix 1.

The instructions for operation are as follows:

- check that the installation is empty
- all pumps and stirrers shall be stopped
- check that the connections at the pumps are properly tightened after the last tests or cleanings
- an air filter shall be mounted on the open vent
- check that air filter is not clogged to avoid operation at a pressure above 0.5 bar
- check that the agitator flanges are closed/connected with tubing to avoid spreading of waste material through the openings
- all waste materials are added by hand
- avoid operating the stirrer for longer periods when there is no water in the homogenization tank

#### **4.4 instructions for maintenance**

- check for the absence of leaks



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- if there are leaks, tighten the connections or replace the gaskets in the Triclamp connections, the sensors, or the manhole lid
- make sure that mechanical stirrer flange is flushed by spraying with water

## 5. Test strategy

### 5.1 Objectives of the tests

To demonstrate the hardware with real feed material

### 5.2 Applicable requirements

- The WPU shall be liquid tight.
- The stirrer and pumps should induce homogeneous mixing of the substrate.
- The waste materials should be reduced to a size of 2 mm in the final waste suspension.
- The low and high level switches switch in response to low or high liquid levels.
- The level switch in the homogenization tank (LS\_0004\_01) switches when foam occurs.
- The level transmitter measures the correct liquid volume.
- The level transmitter produces a stable signal.
- Control actions result in correct responses of components.
- The unit can easily be cleaned.

### 5.3 Approach followed

This test plan with its test protocols is developed based on a failure analysis.

### 5.4 Features to be tested

- Homogeneity of mixing of the real waste suspension
- Size reduction of real waste suspension to 2 mm
- Response of the high level switch to foam occurrence
- Correctness of level transmitter measurement
- Cleaning of the unit.

### 5.5 Features not to be tested

The main tank of the WPU contains a double jacket, in case temperature control would need to be implemented in the future. As this feature is not installed, temperature control is not tested.

### 5.6 Success/failure criteria

	Success/failure criteria	Related instrumentation
1	Homogeneity of mixing: dry weight and particle size variation between samples should be below 5% and 10% respectively	Stirrer, pump
2	Size reduction down to 2 mm: compliance should be 95%	Stirrer, pump
3	Foam: the high level switch switches in contact with foam	High level switch
4	Cleaning of the unit: the turbidity and conductivity after cleaning should be those of RO water within a range of 10%	Nozzle, pumps, valves





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## 5.7 Test sequence (Test phases/test cycles)

- Preparation of waste materials
  - 2.7 kg wet weight of frozen red beet (organically grown) is left to thaw for a few hours in the hygienic kitchen cutter (Robot Coupe vertical cutter R30)
  - 4.3 kg of wet weight frozen lettuce (organically grown) and 36 g of toilet paper (ecological brand, 100% recycled fibres) are added to the red beet
  - The mixture is cut for several minutes in the vertical cutter until a near homogeneous mixture is obtained.
  - The organically grown wheat straw (215 g) is cut to 15 cm pieces, then ground in 3 steps (Retsch cutting mill SM100 for raw grinding at 8 and 2 mm), Retsch ultracentrifugal mill ZM200 for thin grinding at 1.5 mm).
  - Fecal material (180 g wet weight) and urine (3 l) are left to thaw for 1 hour.
- Checking the homogeneity of mixing and size reduction of the waste mixture (consisting of only vegetables and toilet paper) to 2 mm at a total working volume of 40 l
  - The proper amounts of size reduced waste materials are added to the homogenizing tank of the WPU
  - Water is added to the desired final volume of 40 l and the corresponding reading of the level transmitter checked
  - The stirrer is switched on at an average speed to avoid vortex creation and to limit foam formation
  - The shear pump is switched on at a low speed, which is then gradually increased in a few minutes up to an optimal speed not creating excessive foam formation. The shear pump is left to operate at this optimum for 10-15 min.
  - 3 times 250 ml samples are taken during this period to
    - determine the variability in dry weight content (expected value 16 g/l)
    - check visually the homogeneity
    - determine the remaining fraction > 2 mm
  - During operation of the unit, the response of the high level switch to foam formation will be checked visually. If necessary, the speed of the stirrer and of the shear pump will be further increased to induce foam formation and the response of the level switch.
  - The shear pump and stirrer are stopped.
  - After at least 0.5 h of settling, 2 extra 250 ml samples are taken from the drain to determine the fraction > 2 mm.
  - The stirrer is switched on again.
  - The unit is emptied, its total content sieved over an industrial sieve at 2 mm, equipped with beads. The stirrer is stopped when the liquid level drops below it.
  - All waste material is collected and frozen at -20°C.
- Cleaning of the WPU (see also supplier manual, section cleaning cycle)
  - Prerinse of tank
    - The cleaning tank is filled with 15 l of tap water





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- The cleaning pump is activated and the water distributed through the nozzle into the homogenization tank
  - The mixer is started
  - Liquid is collected through the drain and collected for waste disposal according to biosafety rules
  - The sequence is repeated until most of the remaining waste material is removed
- Prerinse of shear pump
  - The cleaning tank is filled with 15 l of tap water
  - The cleaning pump is activated and the water distributed through the nozzle into the homogenization tank
  - When the liquid is transferred into the tank, the shear pump is started
  - Sampling valve is opened and then closed again
  - The pump is stopped and liquid collected through the drain
- Rinse of tank and shear pump
  - The cleaning tank is filled with 15 l of RO water
  - The cleaning pump is activated and the water distributed through the nozzle into the homogenization tank
  - When the liquid is transferred into the tank, the shear pump is started
  - The diptube from the recirculating line of the shear pump is turned 180° by hand, left for 10 s, then turned back to ensure cleaning over 360°.
  - A sample is taken for turbidity and conductivity measurement.
- Cleanliness is then checked visually by opening the tank, and disassembling the shear pump
- Rinse agitator flange: a water hose is connected to the agitator flange inlet and water drained through the outlet
- Checking the homogeneity of mixing and size reduction of the waste mixture (consisting of the final composition including fecal material and urine) to 2 mm at a total working volume of 40 l:
  - as described above
  - expected dry weight: 21 g/l
- Cleaning of the WPU: as described above for prerinsing of tank and shear pump, then followed by
  - Rinse of tank and shear pump
    - The cleaning tank is filled with 15 l of tap water
    - The cleaning pump is activated and the water distributed through the nozzle into the homogenization tank
    - When the liquid is transferred into the tank, the shear pump is started
    - The diptube from the recirculating line of the shear pump is turned 180° by hand, left for 10 s, then turned back to ensure cleaning over 360°.
    - The sequence is repeated with 1% hypochlorite solution, which is circulated for 15 min through the unit



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- Postrinse tank: similar to the prerinse, the tank is rinsed first with tap water then with RO water until the turbidity and conductivity of the cleaning solution is in the range of RO water
- Postrinse pump: similar to the prerinse, the tank and pump are rinsed first with tap water then with RO water until the turbidity and conductivity of the cleaning solution is in the range of RO water
- Cleanliness is then checked visually by opening the tank, and disassembling the shear pump
- Rinse agitator flange: a water hose is connected to the agitator flange inlet and water drained through the outlet.

## 5.8 Test deliverables

Demonstration test report - Demonstration test results

## 6. Data collection plan – Sampling plan

### 6.1 Uncertainty acceptance level

For the dry weight measurements, the target is 1.6 or 2.1% dry weight with a deviation below 10%.

For the 2 mm size requirement, the fraction > 2 mm should be less than 5%.

For homogeneity of mixture, deviations on dry weight between samples should be below 5%, and those on particle sizes below 10%.

Turbidity and conductivity measures of final cleaning solutions should be those of RO water  $\pm 10\%$ .

### 6.2 Measurement plan

- Preparation of waste materials: weighing of required quantities of the different waste materials
- Checking homogeneity of mixing and 2 mm size reduction
  - Take replicate samples for dry weight determinations
  - Take samples through sampling valve and after settling through drain
  - Sieve total wet mixture over industrial sieve at 2 mm
- Cleaning of the WPU: conductivity and turbidity measurements to monitor rinsing (of hypochlorite solution)

### 6.3 Sampling techniques

Direct collection of suspensions through sample valve or drain.

### 6.4 Sample size, frequency, locations

Waste material is sampled at volumes between 250 and 500 ml.

For preparation of 1 batch, 5 samples are taken through the sampling valve or the drain.



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## 6.5 Analyses

- Dry weight determination: a known amount of sample is dried at 105°C overnight and weighed
- Particle size: laser diffractometry up to 3 mm size
- Wet sieving
  - The total waste mixture is sieved over a 2 mm industrial sieve with beads
  - The remaining material is collected with distilled water and dried at 105°C to constant weight
- Conductivity and turbidity: measurement with portable

## 7. Resources specification for the tests

### 7.1 Personnel : staff qualification and training needs

Engineering personnel will perform tests after consultation of the manual.

### 7.2 Hardware : instruments, specific part, hardware for software operation

WPU skid as assembled by Packo including electrical cabinet and Jumo dTRON 304/308/316 Compact Controller with program function.

### 7.3 Software : verification of software, backup needs

Not applicable.

### 7.4 Facilities : environmental needs, test conditions, interfaces needs, utilities needs

Interfaces: connection to tap water, tubing for draining

Utilities: tap water, pressurized air (6 bar), electricity (3x380VAC, 32A), drain

## 8. Responsibilities

### 8.1 Management team

Preparation test plan, supervision tests, review test results, reporting.

### 8.2 Testing team

Test execution and annotation test protocols.

### 8.3 Testing support team

Test performance and recording: Helmut Elslander, Silvia Vangeel

Reporting: Helmut Elslander





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Test Phase	Author	Checked by	Approved by	Approved by customer
Demonstration testing	H. Elslander	H. De Wever	H. De Wever	B. Lamaze

## 9. Schedule

Tests and reporting to be finalized by mid October 2010.

## 10. Risks and contingencies

NA.

## 11. Procedure for review and status reporting

### 11.1 Reporting of status for a test

The test sequence is performed as described in 5.7 by VITO personnel.  
At the end of the tests, the final status (pass/fail) is decided in agreement with ESA.

### 11.2 Deviations and non conformances

In case the test sequence cannot be performed as planned or the results are not conform the expectations, a deviation is opened and appended to the test record.  
The deviation is discussed between VITO and ESA to decide on how to address it.  
In any case, all deviations will be discussed before a decision is taken on the status for the test.

### 11.3 Test readiness review

To be organized as a meeting when all relevant documentation has been supplied to ESA.

### 11.4 Test acceptance review

To be organized when all functional and demonstration tests have been performed.





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### 11.5 Records

	<b>BELISSIMA Waste Preparation Unit</b>	
	<b>Test record sheet: Demonstration tests: Checking homogeneity and size reduction for vegetables mixture</b>	Test code: T_001 Version: 01 Date: /2010 Page:

<b>Responsible person</b>	
<b>Applicable test plan and protocols</b>	

Action	Expected result	Remarks	Result (C/NC)	Deviation
Lettuce, beet and straw are pretreated, mixed with water, then recirculated while stirrer is switched on	Dry weight is 16 g/l with a deviation below 10%  Fraction > 2 mm is less than 5%  Deviations between replicate samples are below 5%  Level switch LS_0004_01 responds to foam occurrence			
If no foam was observed, stirrer BLE_0003_01 speed and frequency of pump SP_0002_01 are increased to induce foam formation	Level switch LS_0004_01 responds to foam occurrence			

<b>Test result (pass/fail)</b>		<b>Number of deviations:</b>		
<b>Test executed by</b>		<b>Date</b>	<b>Signature</b>	
<b>Reviewed by</b>		<b>Date</b>	<b>Signature</b>	



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	<b>BELISSIMA Waste Preparation Unit</b>	
	<b>Test record sheet: Demonstration tests: Cleaning after test with vegetable mixture</b>	Test code: T_002 Version: 01 Date: /2010 Page:

<b>Responsible person</b>	
<b>Applicable test plan and protocols</b>	

Action	Expected result	Remarks	Result (C/NC)	Deviation
Prerinse and rinse steps are performed	Unit (tank, pump, backside diptube) is visually clean  Turbidity and conductivity are similar to those of RO water with a maximal deviation of 10%			

Test result (pass/fail)		Number of deviations:	
Test executed by	Date	Signature	
Reviewed by	Date	Signature	

Deviation Number	Deviation:	Criticality
	Corrective action:	Responsible / Due date
	Corrective action performed and checked: Ref. of retests	Checked/ approved by / Closing date



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	<b>BELISSIMA Waste Preparation Unit</b>	
	<b>Test record sheet: Demonstration tests: Checking homogeneity and size reduction for real waste mixture</b>	Test code: T_003 Version: 01 Date: /2010 Page:

<b>Responsible person</b>	
<b>Applicable test plan and protocols</b>	

Action	Expected result	Remarks	Result (C/NC)	Deviation
Lettuce, beet, straw, fecal material, urine, toilet paper are pretreated, mixed with water, then recirculated while stirrer is switched on	Dry weight is 21 g/l Fraction > 2 mm is less than 5% Deviations between replicate samples are below 5% Level switch LS_0004_01 responds to foam occurrence			
If no foam was observed, stirrer BLE_0003_01 speed and frequency of pump SP_0002_01 are increased to induce foam formation	Level switch LS_0004_01 responds to foam occurrence			

<b>Test result (pass/fail)</b>		<b>Number of deviations:</b>		
<b>Test executed by</b>		<b>Date</b>		<b>Signature</b>
<b>Reviewed by</b>		<b>Date</b>		<b>Signature</b>





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	<b>BELISSIMA Waste Preparation Unit</b>	
	<b>Test record sheet: Demonstration tests: Cleaning after test with real waste mixture</b>	Test code: T_004 Version: 01 Date: /2010 Page:

<b>Responsible person</b>	
<b>Applicable test plan and protocols</b>	

Action	Expected result	Remarks	Result (C/NC)	Deviation
Prerinse and rinse and postrinse steps are performed	Turbidity of RO water = Conductivity of RO water =  Turbidity of rinsing solution drops to RO water value during postrinse  Conductivity of rinsing solution drops to RO water value during postrinse  Unit (tank, pump, backside diptube) is visually clean			

Test result (pass/fail)		Number of deviations:		
Test executed by		Date	Signature	
Reviewed by		Date	Signature	





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Deviation Number	Deviation:		Criticality
	Corrective action:	Responsible	Due date
	Corrective action performed and checked: Ref. of retests	Checked/ approved by	Closing date



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**Appendix 1 – Manual and documentation Packo**

Provided on CD-ROM