BIOMASS PRETREATMENT
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Equipment overview:

Reactors for chemical pretreatment of biomass:
These reactors are suitable for acid (H₂SO₄, HCl...), alkaline (NaOH, ammonia...), sulfite, organosolv and other types of pretreatment
- Benchtop, 2 L (ATEX, glass lined, pressurized)
- 1 x 20 L (ATEX, Hastelloy, pressurized)
- 1 x 85 L (ATEX, stainless steel, pressurized)
- 1 x 500 L (ATEX, glass lined, pressurized)
- 1 x 1000 L (ATEX, glass lined, pressurized)
- 1 x 5400 L (ATEX, glass lined, pressurized)

Reactors for enzymatic hydrolysis of biomass:
- Lab scale hydrolysis
- 1 x 500 L
- 1 x 1000 L
- 2 x 4000 L
- 2 x 5000 L
- 4 x 8000 L
- 3 x 50 000 L
- And other intermediate scales

Reaction vessels for slurries with high solids contents

Auxiliary equipment:
- Milling
  - Dry milling: roller crusher, knife mill, hammer mill, cutting mill, pin disk mill
  - Wet milling: pulper (2000 L), inline mixer, inline colloid mixer
- Thermal treatment
  - Direct steam injection
  - Jet cooking with holding tube
- Dewatering and concentration equipment
  - Netsch filter press (cake volume 68 L)
  - Schenk filter press (cake volume 120 L)
  - Welders filter press (cake volume 352 L)
  - Welders ATEX filter press (cake volume 100 L)
  - Alfa Laval decanter centrifuge NX416 (3160 G, max 20 m³/h)

What we offer:
- Mechanical, thermal, physico-chemical and enzymatic pretreatment of biomass feedstocks
- Logistics and storage:
  - Truck (un)loading docks
  - Bulk solid biomass storage (55 t silo, 3x90 t bunkers)
  - Liquid storage (vessels up to 125 m³)
  - Dedicated areas for IBC storage
  - Chemicals storage
  - Refrigerated storage rooms, freeze and cool containers
- A wide spectrum of modular operation units
- Operation at various scale

Expertise:

Experience in treating the following lignocellulosic raw materials:
- Agro-industrial side streams: paper pulp, spent grains, bagasse, press cakes, stillage...
- Agronomic by-products: corn stover, corn cobs, husk, fiber, stems, leaves, verge grass...
- Dedicated energy crops: miscanthus, poplar...

For more information: please visit www.bbeu.org
For questions, please call +32 9 335 70 01 or contact BusDev@bbeu.org
EXPERTISE

BIOMASS PRETREATMENT  BIOCATALYSIS  FERMENTATION  GREEN CHEMISTRY  PRODUCT RECOVERY AND PURIFICATION

BIOCATALYSIS
BIOCATALYSIS

Equipment overview:

Process vessels for aqueous reactions:
- 3 x 300 L
- 1 x 1000 L
- 2 x 4000 L
- 2 x 5000 L
- 4 x 8000 L
- 3 x 50000 L

Process vessels for solvent-based reactions:
- 1 x 2 L [ATEX]
- 1 x 20 L [ATEX]
- 1 x 85 L [ATEX]
- 1 x 500 L [ATEX]
- 1 x 1000 L [ATEX]
- 1 x 5400 L [ATEX]

Reaction vessels for suspensions with high solids contents

Auxiliary equipment:
- Fermenters of different sizes to produce the biocatalyst [see fermentation brochure]
- A variety of downstream purification equipment to purify the product of interest from the reaction mixture [see product recovery and purification brochure]
- 4 x 30 000 L [ATEX, solvent]

What we offer:

- Scale-up and demonstration of biocatalytic processes
- Process development and optimization
- Custom manufacturing
- Single enzyme or whole cell biocatalyst systems
- Immobilization of enzymes and whole cells
- Aqueous and solvent based reactions
- Enzyme or whole cell biocatalyst production through bacterial, yeast or fungal fermentation
- Process design

Expertise:

BBEPP’s team of process and R&D engineers has built up a significant track record in production of biocatalysts and in biocatalytic conversions at lab and pilot scale. The team has demonstrated various aqueous and solvent based reactions at an industrially relevant scale.

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EXPERTISE

FERMENTATION

Equipment overview:

(A) Aerobic fermenters:
- batch, fed-batch, continuous
  - 4 x 1 L
  - 4 x 7 L
  - 2 x 10 L
  - 10 x 150 L
  - 2 x 1500 L
  - 1 x 4500 L
  - 2 x 15000 L

Anaerobic fermenters:
- 1 x 20 L (ATEX)
- 1 x 85 L (ATEX)
- 1 x 500 L (ATEX)
- 1 x 1000 L (ATEX)
- 1 x 5400 L (ATEX)

Gas fermenters, feed CO, CO₂, H₂, CH₄:
- 4 x 1 L (10 bar pressure)
- 1 x 10 L (ATEX, 5 bar pressure)
- Containerized mobile gas fermentation 100 L demo unit under construction

Auxiliary equipment:
- Analytical capabilities: HPLC, GC, fast bio-chemistry analyzer, off gas analysis and data logging
- Equipment for biomass separation: centrifuges, decanter, plate filters, filter press, membrane filtration
- Biomass pretreatment equipment for second generation bioproducts (see biomass pretreatment brochure)
- A variety of downstream processing equipment to recover and purify the product of interest from the fermentation broth (see product recovery and purification brochure)

What we offer:

- Scale-up and demonstration of fermentation processes
- Batch, fed-batch and continuous (with or without cell recycle) fermentations
- Experience with bacterial, yeast and fungal systems
- Optional: methanol dosage on all vessels
- Process development and optimization
- Custom manufacturing
- Examples of products: industrial enzymes, fine and bulk chemicals, biofuels, biochemicals, bioplastics, biosurfactants, biosolvents, nutraceuticals, food ingredients, bioflavours...

Expertise:

Our team combines over 100 years of fermentation experience. We can rely on fermentation experts with academic and industrial backgrounds and with track records in piloting. This combination makes our expertise unique.

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Equipment overview:

Glass lined, pressure proof, jacketed, agitated and corrosion resistant reactors, coupled to a condenser and vacuum pump.

Properties:
- Pressures up to 8 bar
- Temperatures up to 200°C
- Vacuum down to 20 mbara

Reactor volumes (ATEX):
- 1 x 500 mL (glass)
- 1 x 2 L (glass)
- 1 x 20 L (Hastelloy)
- 1 x 85 L (stainless steel)
- 1 x 500 L (glass lined)
- 1 x 1000 L (glass lined)
- 1 x 5400 L (glass lined)

Auxiliary equipment (ATEX):
- Disc stack centrifuge GEA: Liquid-Liquid or 3 phase separator, ca. 12000 RCF, ca. 1 m³/h
- Filter dryer 1900 L for solvent extraction, (pre-coat) filtration and solids drying
- Chamber filter press: cake vol. 100 L; max. 7.7 m² filtration area; cake squeezing
- Basket centrifuge for crystal separation: 40 kg; 1700 rpm
- Karr column (6 L/h) for counter current liquid-liquid extraction
- Dead-end plate- and frame filters
- Bag filters
- Columns for ion exchange, adsorption chromatography or activated carbon treatment
  - Bench scale glass columns: 300 mL
  - Glass columns: 3 x 5 L resin max. 1 bar
  - Fiberglass columns: 3 x 30 L resin; max. 16 bar
  - Fiberglass columns: 4 x 300 L; 4 x 1 m³; 1 x 1.3 m³; 4 x 1.9 m³; 2 x 3 m³ resin; max. 10 bar

What we offer:

ATEX compliant installation and expertise for chemical processes:
- Solvent evaporation and condensation
- Zoning of the operational area to ATEX zone 2
- Explosion protection on all electrical equipment: ExII2G T3
- N₂ inertisation and blanketing
- Pressure proof from -1 to 8 bar

Types of processes:
- Chemical synthesis reactions
- Chemical conversion reactions
- Chemical hydrolysis
- Extractions
- Flocculation

Expertise:

ATEX zoning challenges the possibilities and freedom of operation. However, our team of experienced engineers and operators can always find a safe and workable approach. Our team is ready to bring your product to the next scale.

Examples:
- Functionalisation of biopolymers and oligosaccharides
- Esterification of fatty acids
- Synthesis of oleochemicals
- Chemical synthesis of biosurfactants

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PRODUCT RECOVERY AND PURIFICATION
EXPERTISE

The equipment overview below gives an idea of the variety of modular unit operations we have available to perform your purification and product recovery processes. However, this list is not complete. If you are looking for specific equipment not listed below, do not hesitate to contact us.

**Equipment overview:**

**High speed disc stack centrifuges (60 L/h to 3 m³/h):**
- Solid-Liquid separators (ca. 7000 RCF)
  1. GEA: max. 60 L/h
  2. Alfa Laval: max. 100 L/h
  3. GEA: max. 500 L/h
  4. Alfa Laval: max. 3 m³/h
- Liquid-Liquid or 3 phase separator (ca. 12000 RCF)
  5. GEA: ATEX; ca. 1 m³/h

**Decanter centrifuges (ca. 3000 RCF):**
1. Alfa Laval: max. 500 L/h
2. Alfa Laval: max. 3 m³/h

**Basket centrifuges for crystal separation:**
1. Pilot unit: 10 kg; 1850 rpm
2. ATEX pilot unit: 40 kg; 1700 rpm
3. Heinkel inverting filter centrifuge: 52 L; 1940 rpm

**Cross flow membrane filtration (MF, UF, NF):**
- Flat sheet pilot unit: testing of several membranes in parallel; max. 2 m²
- Spiral wound filtration (MF, UF, NF)
  1. MF, UF Bench scale unit: ca. 0.23 m²
  2. MF, UF unit: Single 3.8-inch membrane unit; max. 5.7 m²
  3. MF, UF unit: Twelve 3.8-inch membranes; max. 70 m²
  4. MF, UF unit: Nine 6.3 – inch membranes; max. 5 bar; max. 150 m²
  5. MF, UF, NF, RO unit: six 8 – inch membranes; max. 40 bar; max. 180 m²
- Ceramic filtration
  1. MF, UF Bench scale unit: max. 0.032 m²
  2. MF, UF Single unit 1 or 3 membranes: 0.2 or 0.6 m²
  3. MF, UF pilot unit: 55 membranes x 0.2 m² = 11 m²
  4. MF, UF pilot unit: 110 membranes x 0.2 m² = 22 m²
  5. MF industrial unit (0.5 µm): 288 m²
- Hollow fiber filtration (MF, UF)
  1. MF, UF Bench scale unit: 0.037 m²
  2. MF, UF pilot unit: 10 and 500 kDa; max. 12.4 m²
  3. MF, UF pilot unit: 150 kDa; max. 50 m²

**Dead end filtration:**
- Chamber filter presses:
  1. Bench scale unit: cake volume 1.44 L; max. 822 cm² filtration area
  2. Pilot unit: cake volume 68 L; max. 2.5 m² filtration area
  3. Pilot unit: cake volume 120 L; max. 6.5 m² filtration area
  4. Large pilot unit: cake volume 352 L; max. 35 m² filtration area; cake squeezing
  5. Large pilot unit ATEX: cake vol. 100 L; max. 7.7 m² filtration area; cake squeezing

PRODUCT RECOVERY AND PURIFICATION
• Filter dryer 1900 L for solvent extraction, (pre-coat) filtration and solids drying
• Plate and frame units with cardboard filters
• Candle filters
• Rotary vacuum drum filter RVDF (3 m²)
• See “Basket centrifuges for crystal separation”

Ion exchange and adsorption:
Columns for ion exchange, adsorption chromatography or activated carbon treatment
• Bench scale glass columns: 300 mL
• Glass columns: 3 x 5 L resin; max. 1 bar
• Fiberglass columns: 3 x 30 L resin; max. 16 bar
• Fiberglass columns: 4 x 300 L; 4 x 1 m³; 1 x 1.3 m³; 4 x 1.9 m³; 2 x 3 m³ resin; max. 10 bar

Crystallization:
• Benchtop reactors 500 mL and 2 L for cooling- and/or evaporation crystallization
• Various reactors from 20 L to 5.4 m³ (several ATEX) for cooling- and/or evaporation crystallization
• Continuous cooling crystallization unit 50 L
• Crystallization line up to 1000 t/y equipped with crystallizer 4 m³, inverting filter basket centrifuge, rotary louvre dryer

Evaporation:
• Wiped film evaporators, 2 kg/h and 150 kg/h
• Spinning cone evaporator, up to 50 kg/h
• Falling film three-effect evaporator, 5 t/h
• Batch evaporation reactors for both water and solvent based distillation

Extraction ATEX:
• Filter dryer 1900 L for solvent extraction, (pre-coat) filtration and solids drying
• Karr column (6 L/h) for counter current liquid-liquid extraction
• Glass lined reactors, 500 L, 1000 L and 5400 L for solid-liquid and liquid-liquid extractions
• Phase separation with disc stack centrifuge; max. 2 m³/h

Chromatography:
• GRACE bench scale preparative chromatography unit
• Columns up to 500 L for batch chromatography

Drying:
• Louvre crystal dryer ca. 4 kg/h water evaporation
• Vacuum tray dryer, 300 L filling volume
• Filter dryer, 1900 L (ATEX)
• Drying oven, 2000 L
• Spray dryer, 1 kg/h water evaporation
• Spray dryer, 15 kg/h water evaporation
• Lyophilizer, 8 kg water evaporation per drying cycle
• Access to external freeze- and spray drying facilities

Various:
• Multipurpose temperature-controlled process tanks up to 8000 L
• Storage and process buffer tanks up to 50 m³
• Solvent tanks ATEX 4 x 30 m³
• High pressure homogenizer, cell disruptor (10 L/h; max 1200 bar)
• High pressure homogenizer, cell disruptor (850 L/h; max 1200 bar)
• Access to a wide range of rental equipment

What we offer:
• Expertise in development, scale-up and demonstration of product recovery and purification processes
• A broad range of processing equipment for aqueous and solvent based applications
• Flexibility in setting up dedicated process lines
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