Industrial Biotechnology at University of Borås

Mohammad Taherzadeh
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“Swedish Centre for Resource Recovery”

Wastes and by-products
(Municipal, agricultural, forest, industries)

Social aspects

Thermal processes

Chemical processes

Biological processes

Material Recycling

Logistic optimization

Heat
Chill
Electricity

Chemicals
Diesel Gasoline

Feed
Biopolymers
Biogas Ethanol

Metals
Plastics
Papers
Glass

Sustainable Society

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“Swedish Centre for Resource Recovery”

- Research groups:
  - Biotechnology
  - Polymer technology
  - Energy
  - Social science
  - Civil engineering
  - Logistics
  - Physical chemistry
- Professors and researchers: ~20
- PhD students: ~ 30
- Laboratories equipment: ~ 3 million Euro

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MSc program in Resource Recovery

Industrial Biotechnology

Polymer Technology

Energy Engineering

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PhD program in Resource Recovery

A multidiciplinary PhD-program with specialities in:

- Biotechnology
- Polymer technology
- Energy technology
- Simulation technologies
- Social aspects

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Our vision:

Waste is a ”Resource”

but our knowledge is not enough to utilize it!

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Biotechnology group

- Seniors:
  - Mohammad Taherzadeh
  - Ilona Sarvari Horvath
  - Patrik Lennartsson
  - Akram Zamani
  - Päivi Ylitervo
- Postdocs:
  - Swarnima Agnihotri Kumar
  - Jorge Ferreira

- Current PhD students:
  - Ramkumar Nair
  - Mostafa Jabbari
  - Osagie Alex Osadolor
  - Regina Jijoho Patinvoh
  - Konstantinos Chandolias
  - Pedro Ferreira
  - Veronika Bátori
  - Amir Mahboobi
  - Lukitawesa
  - Rebecca Gmoser
  - Steven Wainaina

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Our graduated PhDs

1. Ria Millati, 2005
2. Keikhosro Karimi, 2005
3. Ronny Purwadi, 2006
4. Farid Talebnia, 2008
5. Mohammad Pourbafrani, 2010
6. Akram Zamani, 2010
7. **Azam Jeihanipour, 2011**
8. Patrik Lennartsson, 2012
9. **Gergely Forgacs, 2012**
10. **Supansa Youngsukkasem, 2012**
11. **Anna Teghammar, 2013**
12. Isroi, 2013
13. Johan Westman, 2014
14. **Solmaz Aslanzadeh, 2014**
15. Hamidreza Barghi, 2014
16. Päivi Ylitervo, 2014
17. Mofoluwake Ishola, 2014
18. **Rachma Wikandari, 2014**
19. **Maryam Mohseni Kabir, 2015**
20. **Julius Akinbomi, 2015**
21. **Karthik Rajendran, 2015**
22. Jorge Ferreira, 2015
23. **Jhosane Pagés Díaz, 2015**

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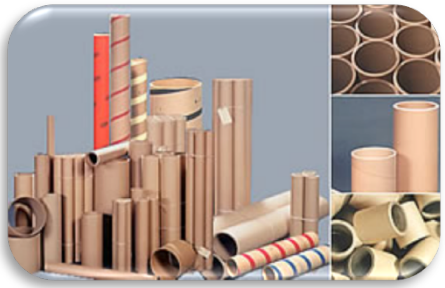
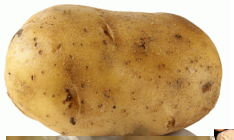
Challenging wastes = Research subjects







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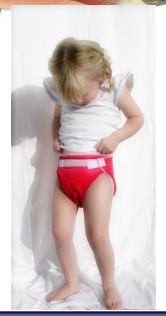
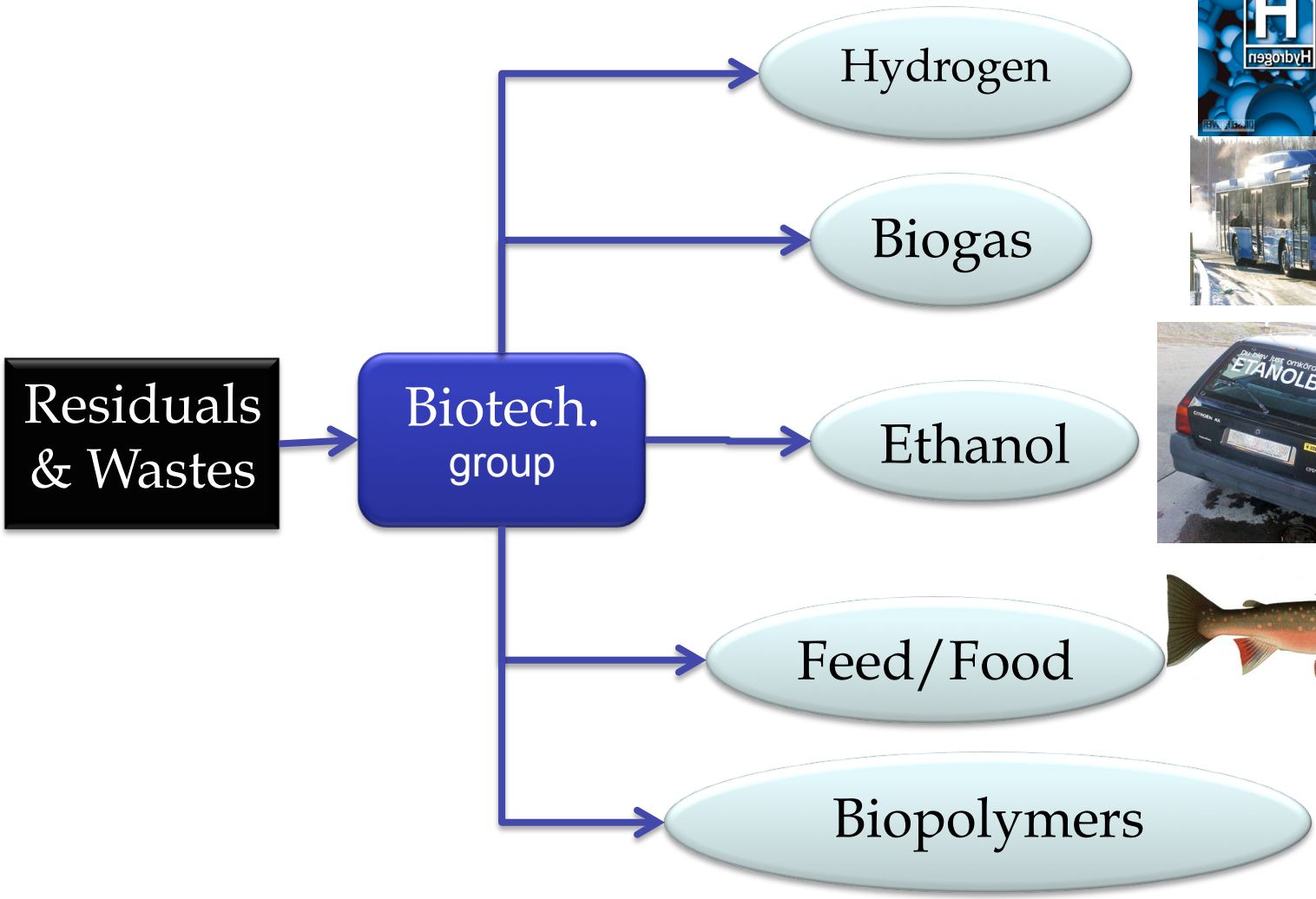
Our products!





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Research platforms

- MBR
- Syngas ferment.
- Rapid fermentation
- Co-digestion
- Textile reactors
- Pretreatment
- Process simulation

- 2nd generation ethanol
- Ethanol from wastes
- Process development
  - Pretreatment
  - Fermentation
  - MBR
- Integration 1 & 2nd generations ethanol
- BioPolyethylene

- Waste as raw materials
- Ethanol & Feed/ Food
- Biopolymers
- Process development
- Pellet formation
- Pigment

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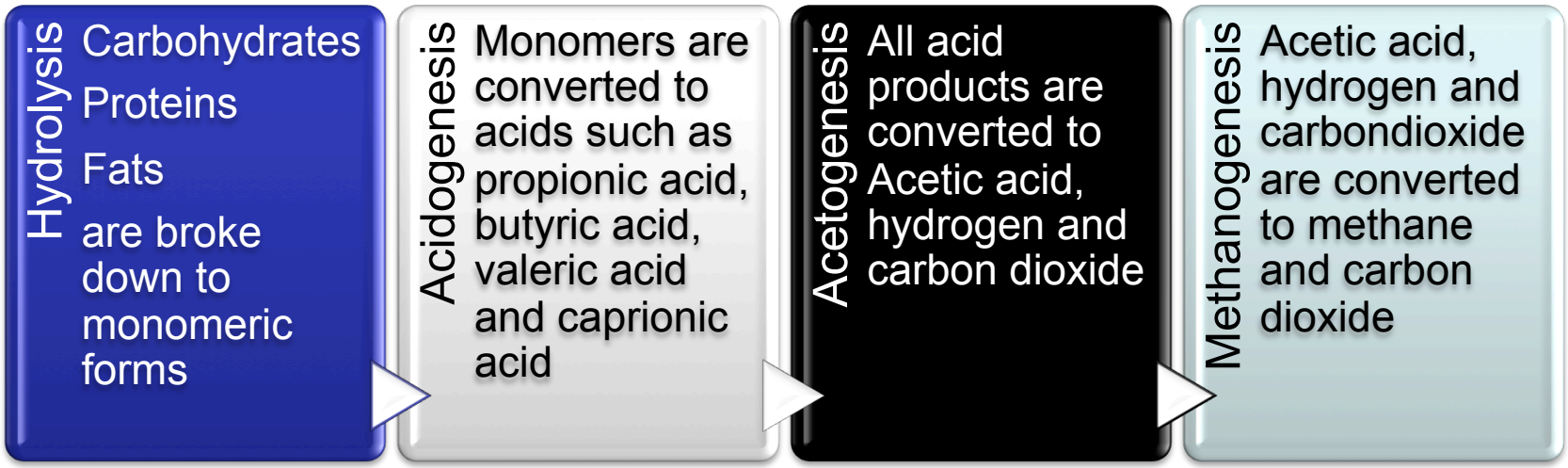
Biogas process



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Process Modeling Reactions…

A) Acetogenic reactions

1) OLEIC-AC + 15.2396 WATER + 0.2501 CO2 + 0.1701 NH3 --> 0.1701 C5H7NO2 + 8.6998 ACETI-AC + 14.4978 HYDROGEN
2) PROPI-01 + 0.06198 NH3 + 0.314336 WATER --> 0.06198 C5H7NO2 + 0.9345 ACETI-AC + 0.660412 METHANE + 0.160688 CO2 + 0.000552 HYDROGEN
3) ISOBU-01 + 0.0653 NH3 + 0.8038 WATER + 0.0006 HYDROGEN + 0.5543 CO2 --> 0.0653 C5H7NO2 + 1.8909 ACETI-AC + 0.446 METHANE
4) ISOVA-01 + 0.0653 NH3 + 0.5543 CO2 + 0.8044 WATER --> 0.0653 C5H7NO2 + 0.8912 ACETI-AC + PROPI-01 + 0.4454 METHANE + 0.0006 HYDROGEN
5) LINOLEIC + 15.356 WATER + 0.482 CO2 + 0.1701 NH3 --> 0.1701 C5H7NO2 + 9, 02 ACETI-AC + 10, 0723 HYDROGEN
6) PALM + 15.253 WATER + 0.482 CO2 + 0.1701 NH3 --> 0.1701 C5H7NO2 + 8, 4402 ACETI-AC + 14, 9748 HYDROGEN

B) Acidogen

1) DEXTROSE + 0.1115 NH3 --> 0.1115 C5H7NO2 + 0.744 ACETI-AC + 0.5 PROPI-01 + 0.4409 ISOBU-01 + 0.6909 CO2 + 1.0254 WATER
2) GLYCEROL + 0.4071 NH3 + 0.0291 CO2 + 5e-005 HYDROGEN --> 0.04071 C5H7NO2 + 0.94185 PROPI-01 + 1.09308 WATER

C) Amino Deg

1) GLYCINE + HYDROGEN --> ACETI-AC + NH3
2) THREONIN + HYDROGEN --> ACETI-AC + 0.5 ISOBU-01 + NH3
3) HISTIDIN + 4 WATER + 0.5 HYDROGEN --> FROMAMID + ACETI-AC + 0.5 ISOBU-0
4) ARGININE + 3 WATER + HYDROGEN --> 0.5 ACETI-AC + 0.5 PROPI-01 + 0.5 ISOVA-01 + 4 NH3 + CO2
5) PROLINE + WATER + HYDROGEN --> 0.5 ACETI-AC + 0.5 PROPI-01 + 0.5 ISOVA-0
6) METHIONI + 2 WATER --> PROPI-01 + CO2 + NH3 + HYDROGEN + CH4S
7) SERINE + WATER --> ACETI-AC + NH3 + CO2 + HYDROGEN
8) THREONIN + WATER --> PROPI-01 + NH3 + HYDROGEN + CO2
9) ASPARTIC + 2 WATER --> ACETI-AC + NH3 + 2 CO2 + 2 HYDROGEN
10) GLUTAMIC + WATER --> ACETI-AC + 0.5 ISOBU-01 + NH3 + CO2
11) GLUTAMIC + 2 WATER --> 2 ACETI-AC + NH3 + CO2 + HYDROGEN
12) HISTIDIN + 5 WATER --> FROMAMID + 2 ACETI-AC + 2 NH3 + CO2 + 0.5 HYDROGEN
13) ARGININE + 6 WATER --> 2 ACETI-AC + 4 NH3 + 2 CO2 + 3 HYDROGEN
14) LYSINE + 2 WATER --> ACETI-AC + ISOBU-01 + 2 NH3
15) LEUCINE + 2 WATER --> ISOVA-01 + NH3 + CO2 + 2 HYDROGEN
16) ISOLEUCI + 2 WATER --> ISOVA-01 + NH3 + CO2 + 2 HYDROGEN
17) VALINE + 2 WATER --> ISOBU-01 + NH3 + CO2 + 2 HYDROGEN
18) PHENYLAL + 2 WATER --> BENZENE + ACETI-AC + NH3 + CO2 + HYDROGEN
19) TYROSINE + 2 WATER --> PHENOL + ACETI-AC + NH3 + CO2 + HYDROGEN
20) TRYPTOPH + 2 WATER --> INDOLE + ACETI-AC + NH3 + CO2 + HYDROGEN
21) GLYCINE + 0.5 WATER --> 0.75 ACETI-AC + NH3 + 0.5 CO2
22) ALANINE + 2 WATER --> ACETI-AC + NH3 + CO2 + 2 HYDROGEN
23) CYSTEINE + 2 WATER --> ACETI-AC + NH3 + CO2 + 0.5 HYDROGEN + H2S

1) Starch + 7 Water → 7 Glucose
2) Cellulose + Water → Glucose
3) Hemicellulose + Water → 2,5 Acetic acid
4) Hemicellulose + Water → Xylose
5) Xylose → Furfural + 3. Water
6) Cellulose + water → 2. Ethanol + 2. CO2
7) 2. Ethanol + CO2 → 2. Acetic acid + Methane
8) Protein + 6. Water → 6.5 CO2 + 6.5 Methane + 3. NH3 + H2S
9) Keratin + 0,3337 Water → 0,045 Arginine + 0,048 Aspartic + 0,047 Threonine + 0,172 Serine +
0,074 Glutamic + 0,111 Proline + 0,25 Glycine + 0,047 Alanine + 0,067 Cysteine + 0,074 Valine +
0,07 leucine + 0,046 Isoleucine + 0,036 Phenyalanine
10) Triolein + 3. Water → Glycerol + 3. Oleic Acid
11) Tripalmtic + 3. Water → Glycerol + 3. Palmtic Acid
12) SN – Palmtio – Olein + 2. Water → Glycerol + Palmtic Acid + Oleic Acid
13) SN – Palmtio – Linolein + 2. Water → Glycerol + Palmtic Acid + Linoleic Acid

D) Methanogenic reactions

1) ACETI-AC + 0.022 NH3 --> 0.022 C5H7NO2 + 1,6 METHANE + 0.066 WATER + 0.67181 CO2
2) $CO_2 + 4\ H_2 \rightarrow CH_4 + 2H_2O$

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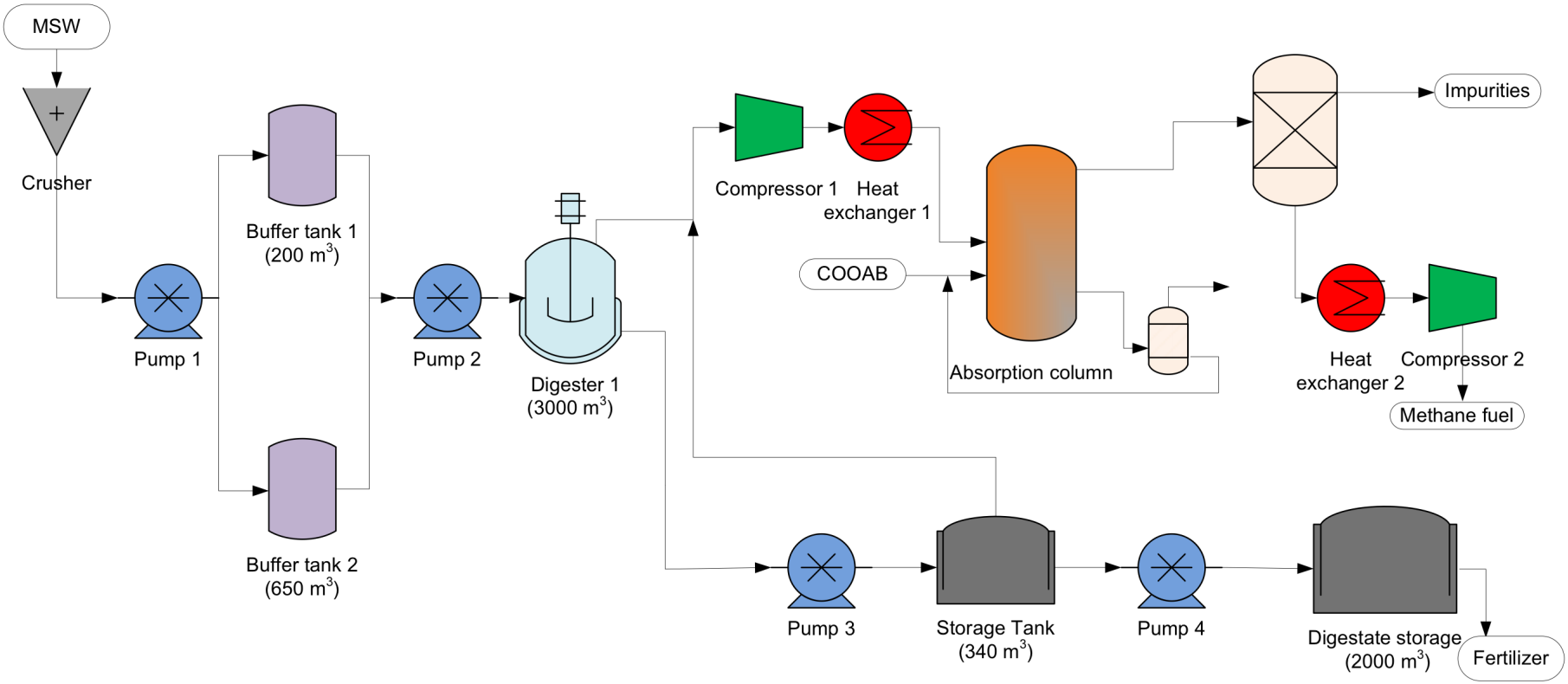
Process simulation (biogas & ethanol)



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Textile reactors for biogas & ethanol

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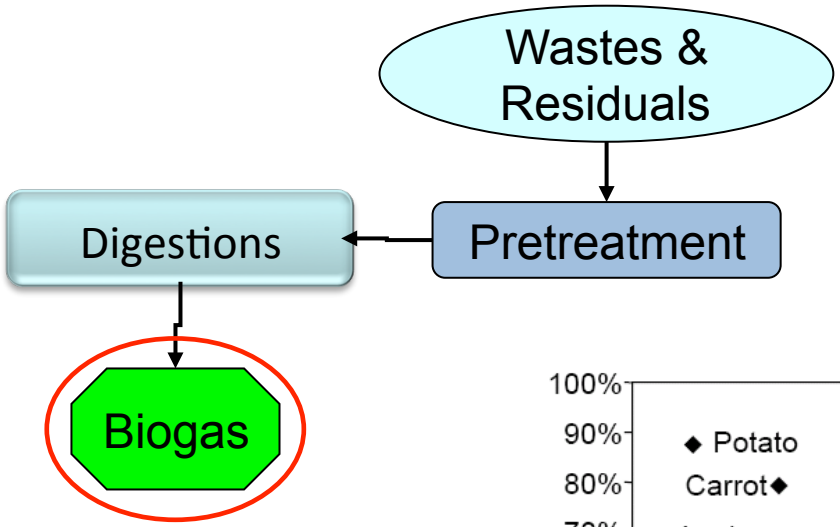
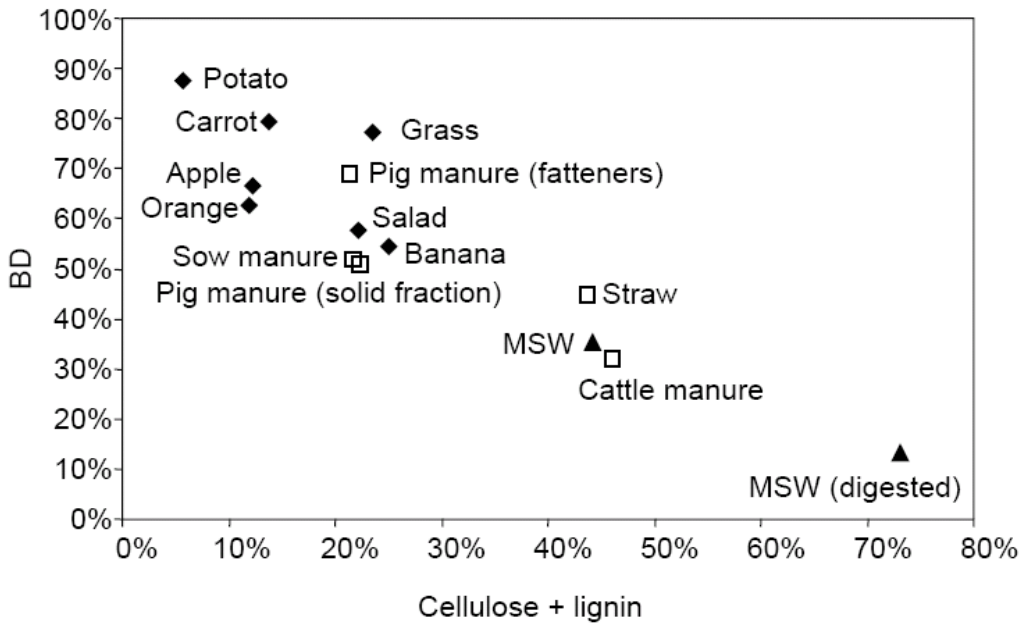
Improving digestion with pretreatment!





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Pretreatment of lignocelluloses and keratin-rich materials

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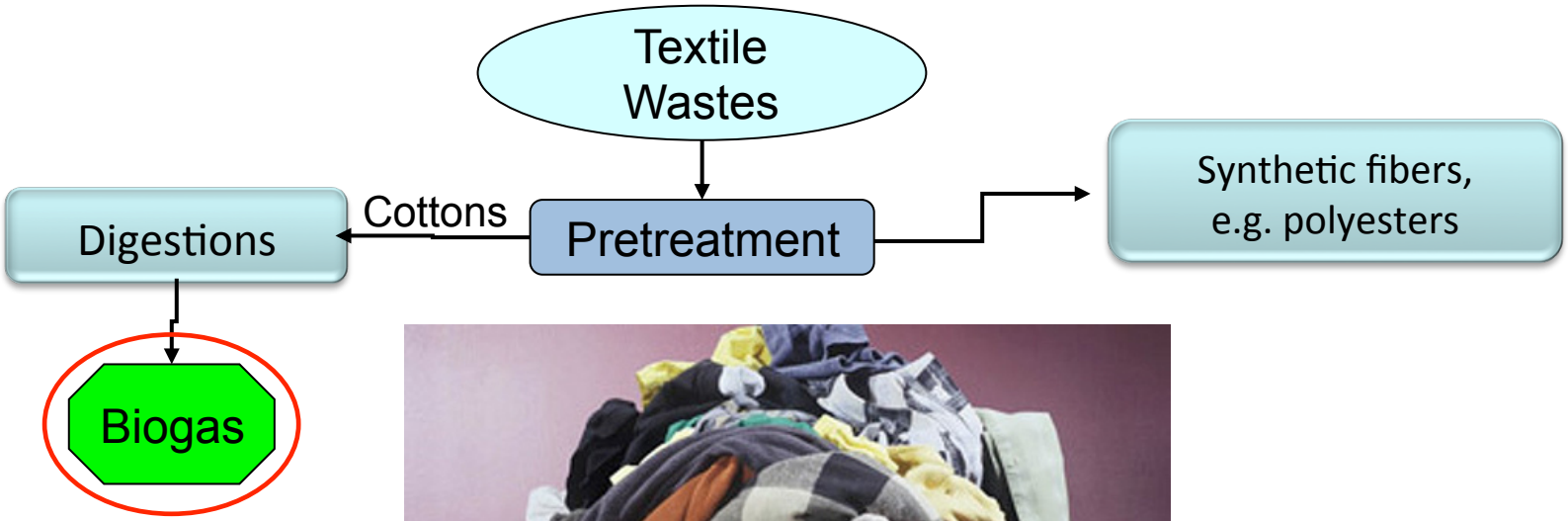
Separation of non-digestable wastes (e.g. fibers)!



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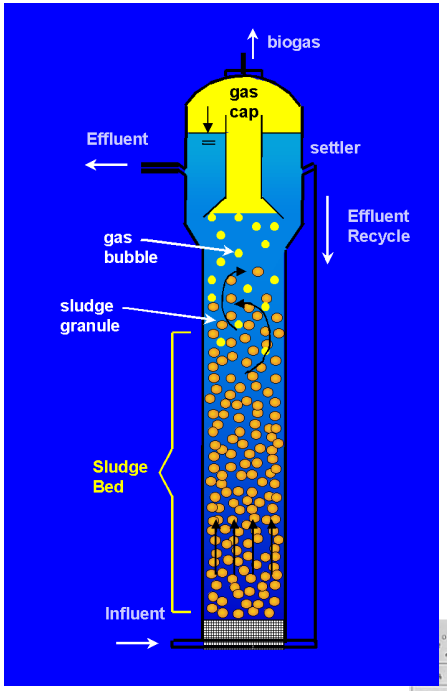
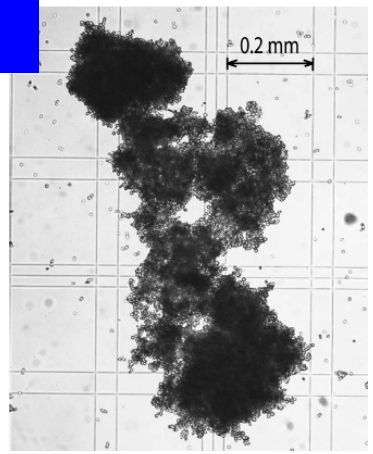
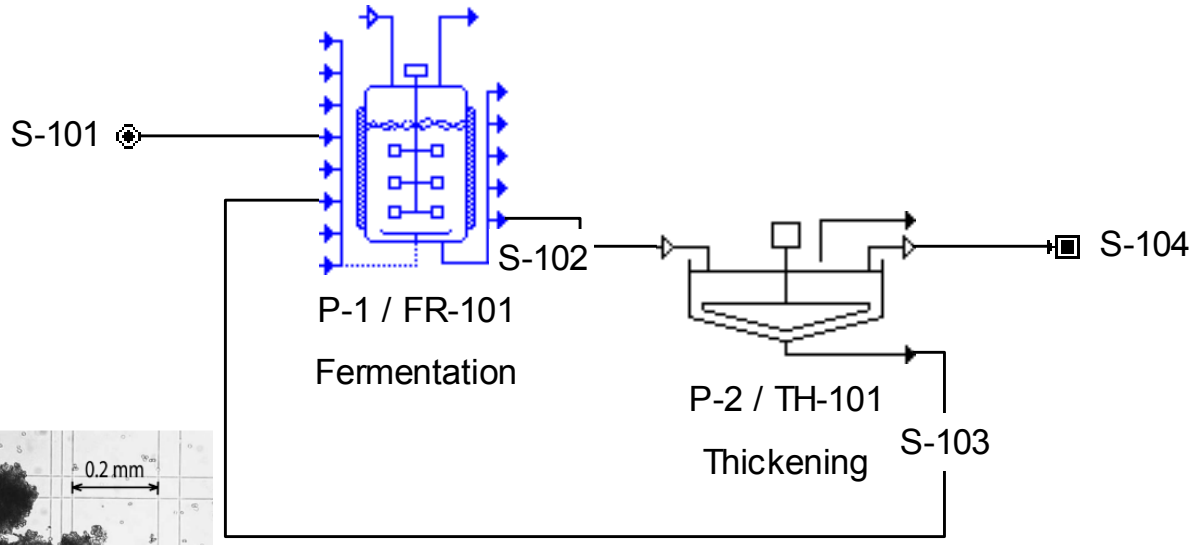
High cell density by flocs







Cell recycling

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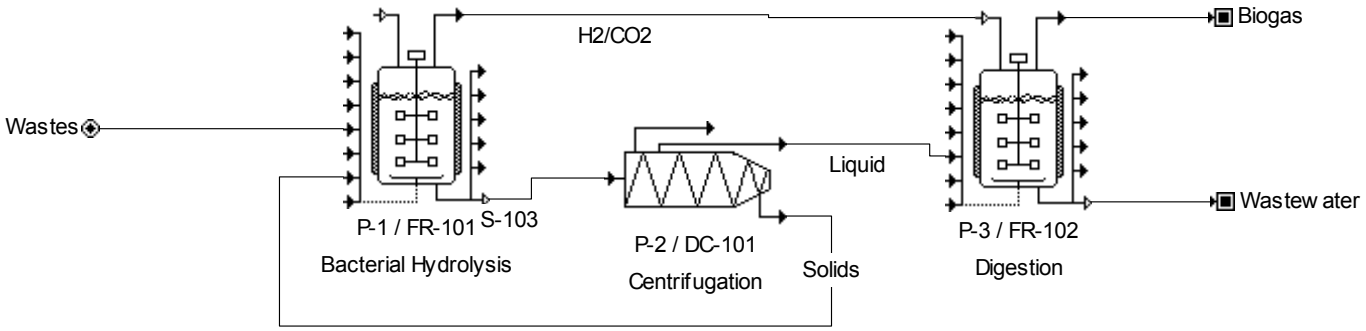
2-stage Digestion concept



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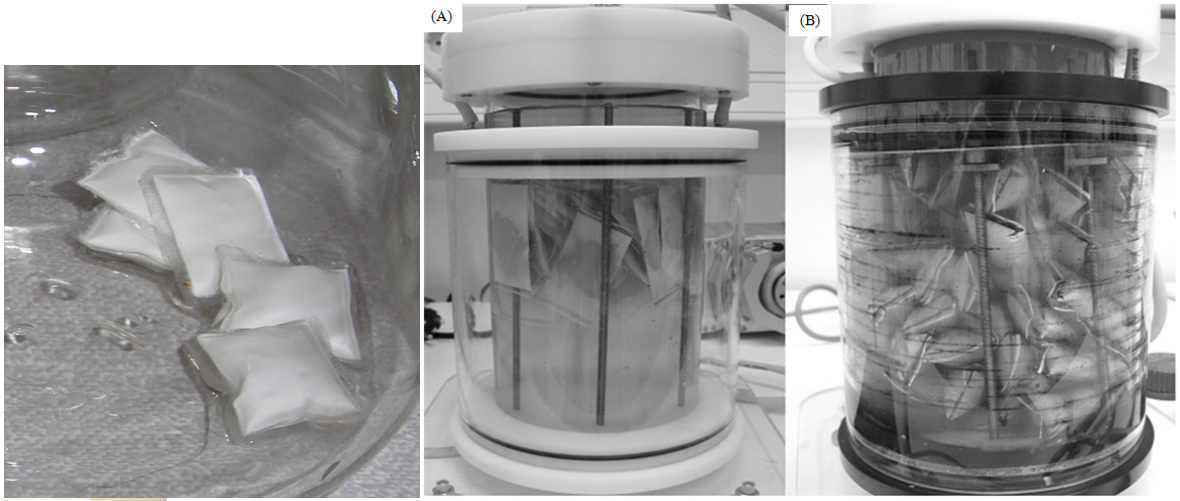
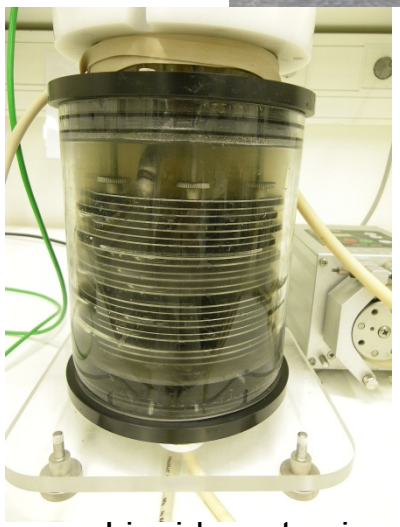
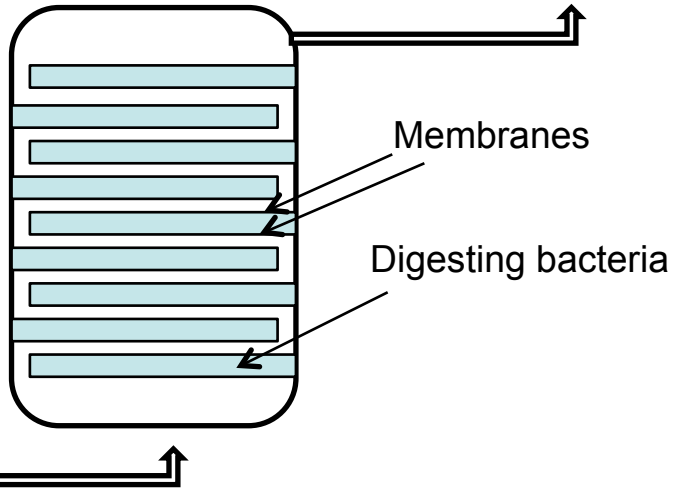
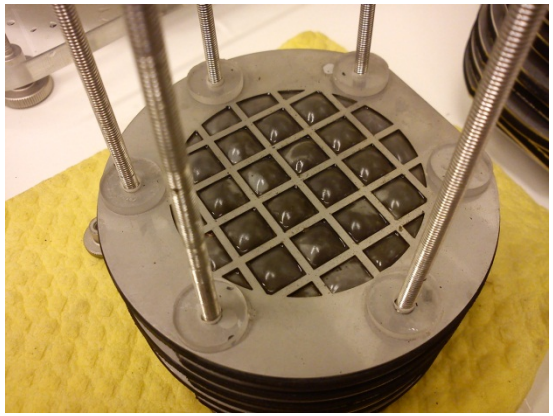
Biogas with encapsulated and membrane reactors









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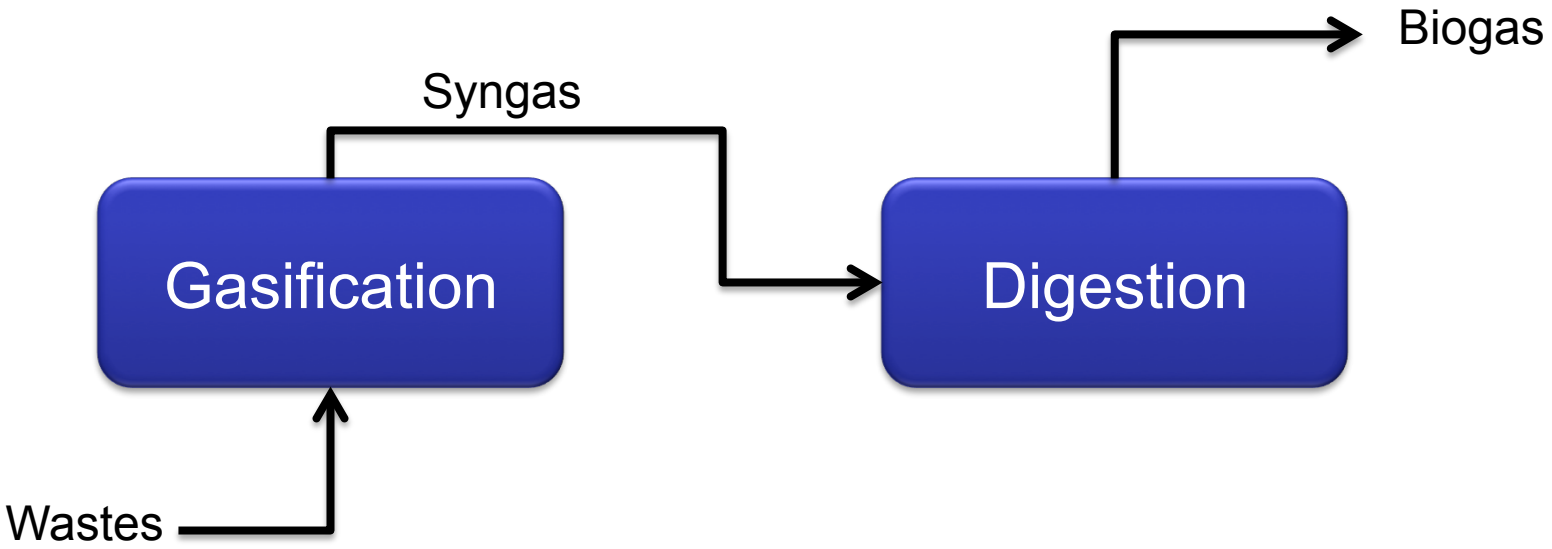
Biogas via gasification



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Effects of inhibitors on digestion: Fruit flavors

Flavor compounds	Fruit name
Hexanal	apple, grape Australian mango, orange, strawberry, plum, pear
E-2-hexenal	Apple, plum Australian mango, strawberry, cashew apple, peach
Nonanal	cashew apple, orange, strawberry, plum, peach
Acetaldehyde	Apple, strawberry
Benzaldehyde	Strawberry, peach
Octanal	Strawberry
Octanol	plum, orange , strawberry, grape
Hexanol	Apple, strawberry, peach, grape
Butanol	Apple, strawberry, pear
Benzyl alcohol	Peach
α-pinene	African atemoya, Tommy Atkins and Keit mango, Cuban atemoya, Venezuelan mango, plum orange, Brazilian mango, strawberry
Car-3-ene	cashew apple, Venezuelan mango, orange, Australian mango, Tommy Atkins and Keitt mango, Brazilian mango
Myrcene	orange, mango, Tommy Atkins and Keitt mango, Australian mango
Ethyl butanoate	Apple, strawberry, pear
Hexyl acetate	Strawberry, peach ,pear, grape
Ethyl acetate	Strawberry, pear, grape
Ethyl hexanoate	Strawberry, pear, grape
2-heptanone	Strawberry
3-hydroxy2-butanone	Pineapple
γ-octalactone	Peach
δ-octalactone	Peach
γ-dodecalactone	Peach
δ-dodecalactone	Peach

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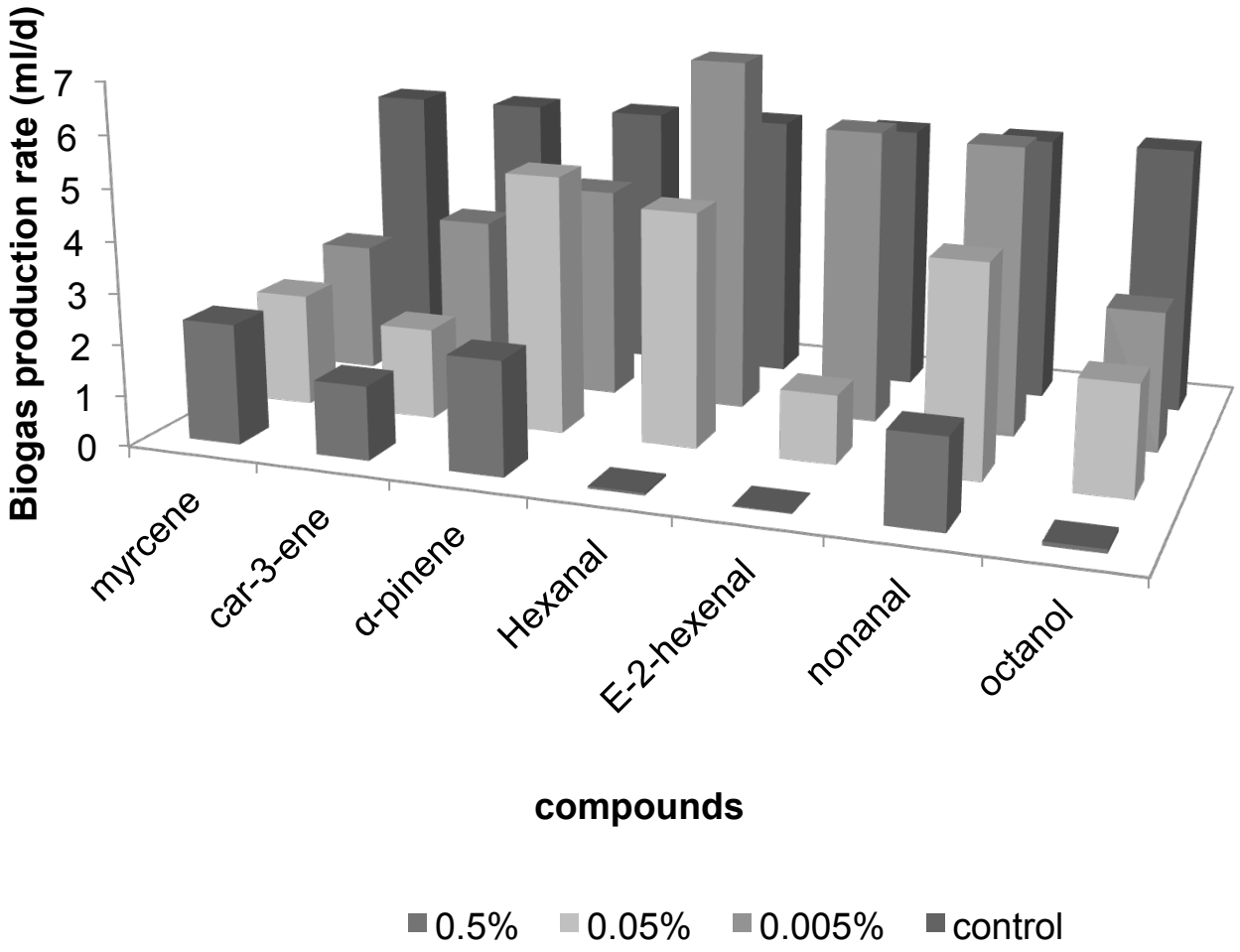

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Thank you!

Questions?

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