13th International Symposium on Waste Management Zagreb 2014

Zagreb, 6th and 7th November 2014

APPLICATION OF INTEGRATED TECHNOLOGIES FOR WASTE MINIMIZATION, ENERGY SAVING AND GREENHOUSE GASES EMISSION REDUCTION IN AGRO-FOOD SECTOR

Andrea Hublin EKONERG - Energy and Environmental Protection Institute, Zagreb

Mirjana Čurlin University of Zagreb, Faculty of Food Technology and Biotechnology, Zagreb

Content

- agro-food waste management
- integrated technologies for waste minimization, energy saving and GHG emission reduction
- fermentation processes - production of biofuel
- optimization and development of integrated processes - effective utilization of resources and waste - zero emissions
- energy production and waste treatment in a less costly way
- environmentally-friendly technologies (EU targets 20/20/20)

Agro-food waste management

- needs for renewable energy generation and diversion of organic residuals from landfills to reduce the GHG emissions and other environmental impacts
  - ✓ bioconversion of agro-food waste to energy
- choice of method - based on maximum safety, minimum environmental impact, and valorisation of the waste and final recycling of the end products
  - ✓ anaerobic digestion (AD) technologies
  - ✓ membrane technology

Waste minimization

- Sustainable Waste Management Act (Official Gazette No. 94/13) - objectives of the waste hierarchy: (a) prevention; (b) preparing for re-use; (c) recycling; (d) other recovery, e.g. energy recovery; (e) disposal
- strategies in agro-food industry: (i) end of pipe abatement, (ii) reduction at source, (iii) zero-point discharge

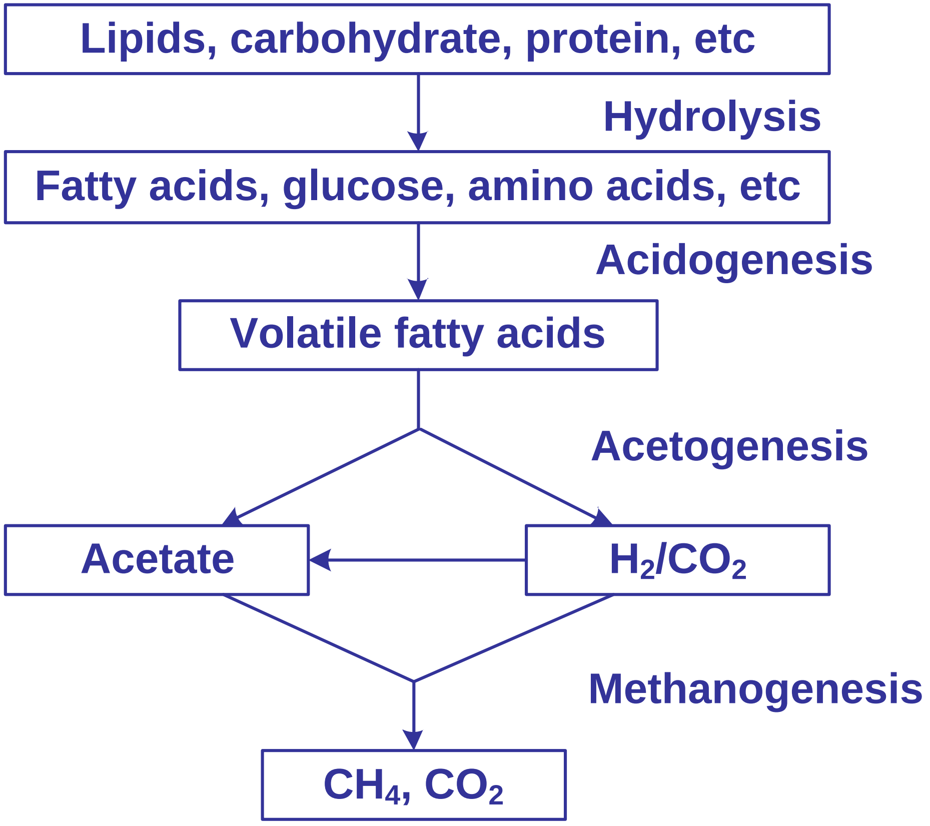
✓ recovery and re-use of by product and wastes as raw material

Bioconversion of agro-food waste

- material and energy recovery of biodegradable organic waste
  - ✓ cost and ecological acceptability
- AD technologies - bioconversion in terms of ethanol, hydrogen (H_2), methane (CH_4), biodiesel
  - ✓ in addition to biogas, a nutrient-rich digestate is produced - fertilizer or soil conditioner
- membrane processes - separated substances are recoverable in a chemically unchanged form
  - ✓ easily re-used

Anaerobic digestion of agro-food waste

- hydrolysis, acidogenesis, acetogenesis, methanogenesis[1]



[1] Zhang et al.: Reviewing the anaerobic digestion of food waste for biogas production; Renewable and Sustainable Energy Reviews 38 (2014) 383-392

Anaerobic co-digestion (AcoD) of agro-food waste

Improving biogas production and CH_4 yield[2]

Substrate	Co-substrate	Biogas production rate (l/d)	CH_4 yield (l/kg VS*)	Comments
Cattle excreta	Olive mill waste	1.10	179	The co-digestion system produced 337% higher biogas than that of excreta alone.
Cattle manure	Agricultural waste and energy crops	2.70	620	Significant increase in biogas production from the co-digestion was observed.
Fruit and vegetable waste	Abattoir wastewater	2.53	611	The addition of abattoir wastewater to the feedstock increased biogas yield up to 51.5%.
Pig manure	Fish and bio-diesel waste	16.4	620	Highest biogas production rate was obtained by a mixture of wastes.
Potato waste	Sugar beet waste	1.63	680	Co-digestion improved CH_4 yield up to 62% compared to the digestion of potato waste alone.
Primary sludge	Fruit and vegetable waste	4.40	600	Co-digestion produced more biogas as compared to primary sludge alone.
Slaughterhouse waste	Municipal solid waste	8.60	500	Biogas yield of the co-digestion systems doubled that of the slaughter house waste digestion system.

* VS: Volatile solids

[2] Khalid et al.: The anaerobic digestion of solid organic waste; Waste Management 31 (2011) 1737-1744

Anaerobic bioreactor configuration

- batch reactors
- one stage continuously fed system
- two or multi-stage continuously fed system

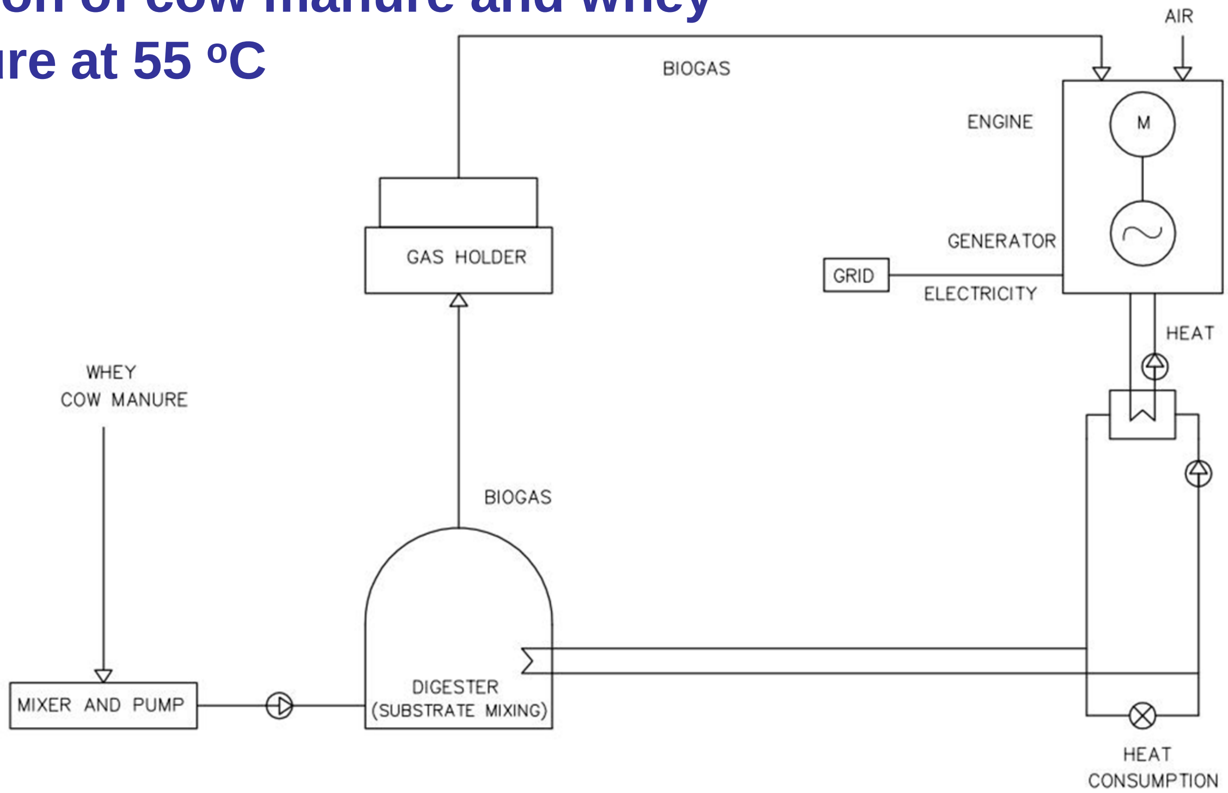
- integrated processes for treatment of livestock waste
  - ✓ anaerobic bioreactor for biogas production
  - ✓ different type of reactors for the treatment of the liquid stream produced from anaerobic digestion - sequencing batch reactor and membrane bioreactor

Biogas production from agro-food waste

- European Union - the electricity generation from biogas in 2012 reached 46.3 TWh (growth rate of 22.2%)
  - ✓ 64.9% was from cogeneration plants
- Germany - the primary biogas energy output in 2012 reached 6.4 Mtoe (electricity generation rose 28.6% year-on-year to reach 27.2 TWh by the end of 2012)
  - ✓ the number of biogas plants reached 9,200 in 2013 (including 107 units producing biomethane)
- Croatia (2014) - eleven biogas plants for agro-industrial wastes (total installed power of 11.135 MW) are connected to the power grid
  - ✓ nine biogas plants (total installed power of 7.544 MW) have signed power purchase agreements with the Croatian Energy Market Operator (HROTE)

Assumed full-scale biogas power plant

- **300 kW power and 510 kW heat unit[3]**
  - ✓ excrement of 450 livestock units is treated in the batch reactor
  - ✓ co-digestion of cow manure and whey
  - ✓ temperature at 55 ºC



[3] Hublin et al.: Utilization of biogas produced by anaerobic digestion of agro-industrial waste: Energy, economic and environmental effects; Waste Management & Research 32 (2014) 626-633

Techno-economic aspects of biogas production from agro-industrial waste (1)

Mass and energy balance of the biogas power plant

INITIAL MIXTURE		
Cow manure	t y^{-1}	4,860
Whey	t y^{-1}	540
Total initial mixture	t y^{-1}	5,400
BIOGAS PRODUCTION		
Lower heating value of biogas	kWh m^{-3}	6.4
Produced biogas	m^3 y^{-1}	869,400
Produced methane	m^3 y^{-1}	686,830
Energy value of biogas	kWh y^{-1}	5,554,500
DIGESTATE		
Total digestate	t y^{-1}	4,590
ELECTRICITY		
Electrical power	kW	300
Supplied electricity to the power grid	kWh y^{-1}	2,160,000
HEAT		
Heat power	kW	510
Delivered heat	kWh y^{-1}	2,448,000
ANNUAL EFFICIENCY		
Annual efficiency (min 50%)	%	83

Techno-economic aspects of biogas production from agro-industrial waste (2)

Economic analysis of the investment project

COSTS		
Capital cost	€	2,250,000
Operating and maintenance cost	€ y^{-1}	252,500
REVENUES		
Electricity delivered	€ y^{-1}	445,766
Heat delivered	€ y^{-1}	58,752
PROFITABILITY		
NET PRESENT VALUE		
Twelve years effectuation period	€	87,861
Fifteen years effectuation period	€	183,047
Twenty years effectuation period	€	-214,343
INTERNAL RATE OF RETURN		
Twelve years effectuation period	%	6.6
Fifteen years effectuation period	%	7.1
Twenty years effectuation period	%	4.2
PAYBACK PERIOD OF INVESTMENT		
Payback period	y	9.9

Ecological aspects of biogas production from agro-industrial waste

- direct reduction of carbon dioxide (CO_2) emissions - assumption that coal is used for the production of power/heat in a power plant
  - ✓ the use of biogas for the equivalent amount of generated energy directly reduces emissions by about 1.7 ktonnes CO_2 kWh^{-1} y^{-1}
  - ✓ the use of biogas for the equivalent amount of heat generation directly reduces emissions by about 1.8 ktonnes CO_2 kWh^{-1} y^{-1}
- indirect reduction of methane (CH_4) emissions (reducing the amount of waste entering landfills) - assuming that one tonne of biodegradable waste (67% of degradable organic carbon) within the period of 20 years emitted 0.05 tonne of CH_4
  - ✓ the use of 5,400 tonne y^{-1} of biodegradable waste could reduce emissions by 0.27 ktonnes CH_4 corresponding to 5.7 ktonnes CO_2-eq y^{-1}

Conclusion

- AD technologies can solve two complex problems
  - ✓ efficient conversion from biodegradable organic waste to electricity/heat production
  - ✓ efficient treatment of agro-food waste
- profitability of the plant is enabled by the benefits from the sale of electric energy at favourable prices
- positive ecological effects
  - ✓ direct reduction of CO_2 emissions
  - ✓ indirect reduction of CH_4 emissions
- achievement of EU targets 20/20/20

Thank you for your attention

Dr. Andrea Hublin
EKONERG - Energy and Environmental Protection Institute
Atmospheric Protection and Climate Change Department
Koranska 5, HR-10000 Zagreb
tel: +385 1 6000 134
fax: +385 1 6171 560
e-mail: andrea.hublin@ekonerg.hr
www.ekonerg.hr