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Anaerobic Digestion of Agro-Industrial Wastes:
Categories, Characteristics, Technologies, Emissions and Methane Production Potential

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Overview

- Background
- Agro-Industrial Waste Overview
  - Current Emissions and Waste Disposal Practices
  - Potential Methane Production
- Potentially Applicable Processes
- Project Development Issues
- Conclusions

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Background

- The Methane to Markets (M2M) Agriculture Subcommittee was created to promote anaerobic digestion (AD) to reduce methane emissions from livestock manure.
- In November 2008, the M2M Agriculture Subcommittee proposed to the Steering Committee that agro-industrial wastes be added to the scope of the Subcommittee's work.
- The Steering Committee supported this proposal, and the Subcommittee is now working to include agro-industrial waste.

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Agro-Industrial Waste Overview

- Agro-industrial wastes can be organized into the following categories:
  - Food processing wastes
  - Energy crops and biofuel production wastes
  - Crop residues

- These categories also contribute to the organic fraction of municipal solid waste which are also an emissions source

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Agro-Industrial Waste Overview
Disposal Practices

Sector	Region	% of Wastewater	
		Untreated Discharge	On-site Anaerobic Treatment
Meat, poultry, dairy, & fish processing	Africa	60	34
	Asia (except Japan)	70	22
	Eastern Europe	50	23
	Latin America	50	32
Fruit and vegetable processing	Africa	70	6
	Asia (except Japan)	70	5
	Eastern Europe	50	1
	Latin America	60	5
Alcohol, beer, wine, vegetable oil, sugar, and starch	Africa	60	17
	Asia (except Japan)	60	11
	Eastern Europe	20	8
	Latin America	20	13

From Doorn et al., 1997

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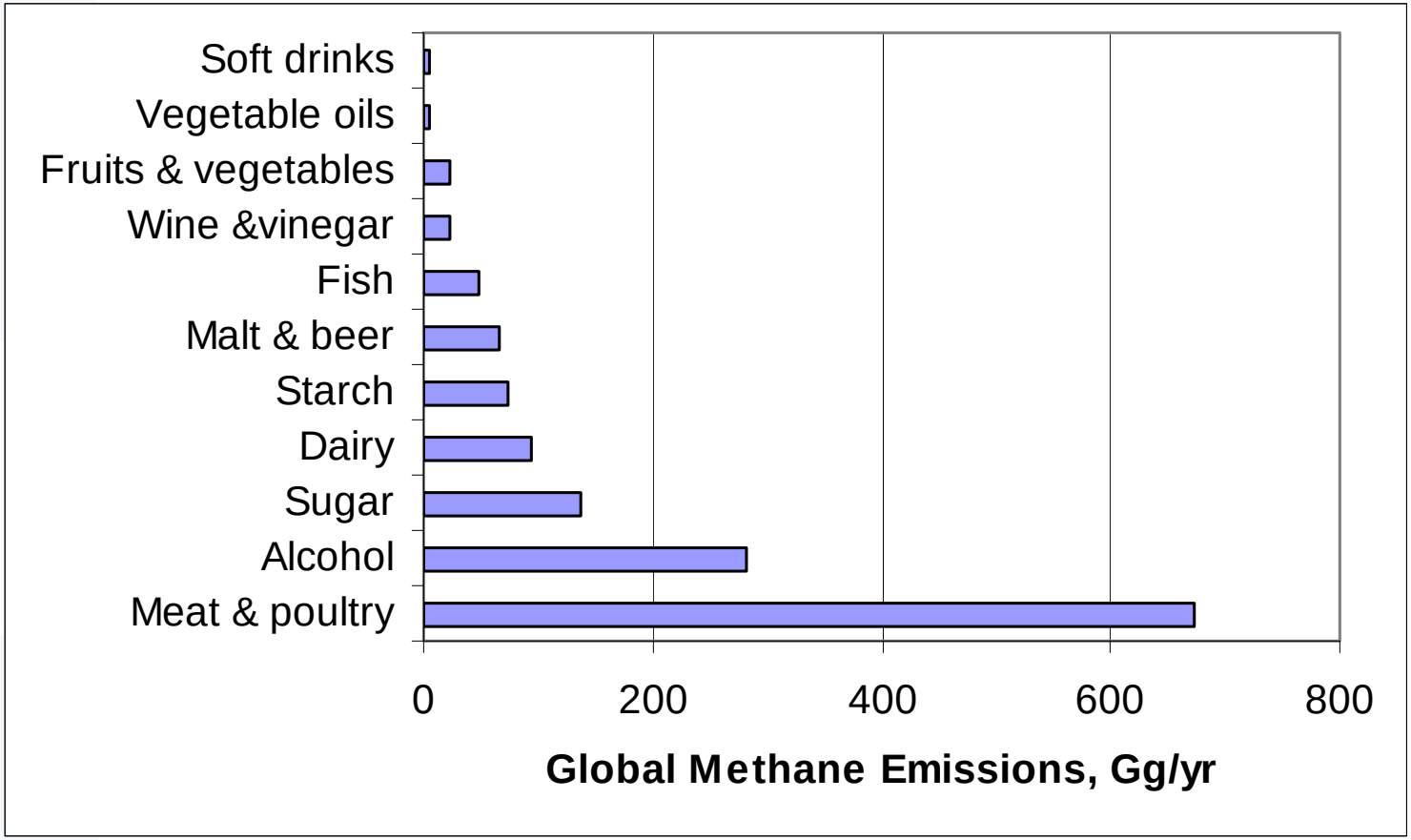
Agro-Industrial Waste Overview
Current Global CH_4 Emissions



From Doorn et al., 1997

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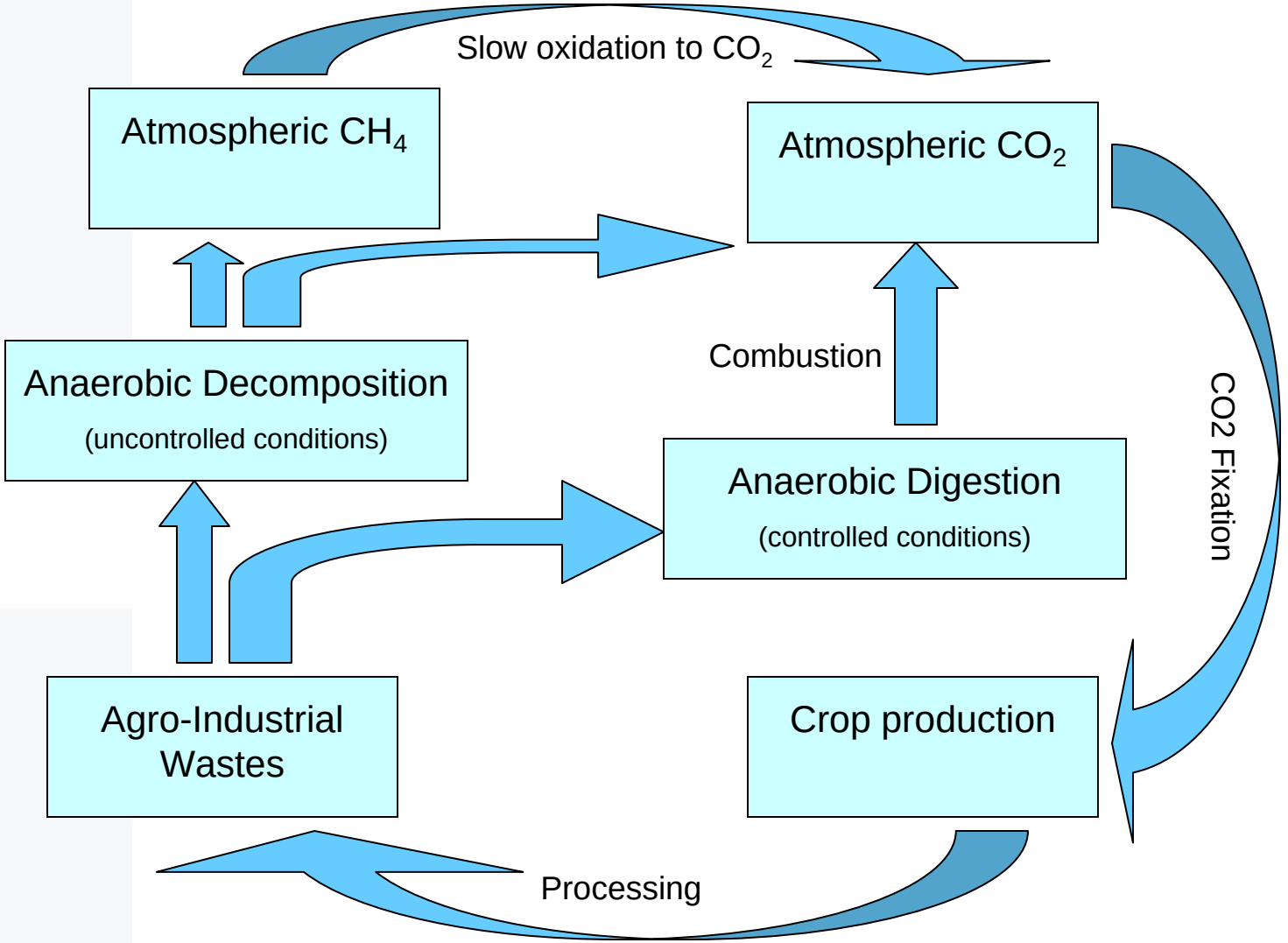
Agro-Industrial Waste Overview
Organic Carbon Cycling



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Agro-Industrial Waste Overview
Potential for AD

- The organic fraction of Agro-industrial wastes typically is more readily biodegradable than manure. Thus, greater reductions in biochemical oxygen demand (BOD), chemical oxygen demand (COD), and volatile solids (VS) during AD can be realized.

- The higher readily biodegradable fraction of agro-industrial wastes translates directly into higher methane production potential.

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Food Processing Wastes
Greatest Potential for AD

Of the 4 categories of agro-industrial wastes,food processing wastes have the greatest potential for methane production.

- Typically are high strength with BOD_5 concentrations of at least an order of magnitude higher than domestic wastewater.
- Storage or disposal practices may result in methane emissions or water quality impairment or both.
- AD could decrease methane emissions while simultaneously improve water quality, human health and provide a renewable source of energy.
- On-site use of the methane captured as a fuel generally is high.
- Use of AD as a pre-treatment process will reduce wastewater treatment costs and energy requirements

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Food Processing Wastes: Overview

- Food processing wastes vary greatly so they are difficult to characterize.
- The volumes and concentrations of the wastes vary based on industry, process, and location.
- These wastes may be placed into the following broad categories, which can be generalized as having similar characteristics:
  - Fats and oils
  - Proteins
  - Carbohydrates

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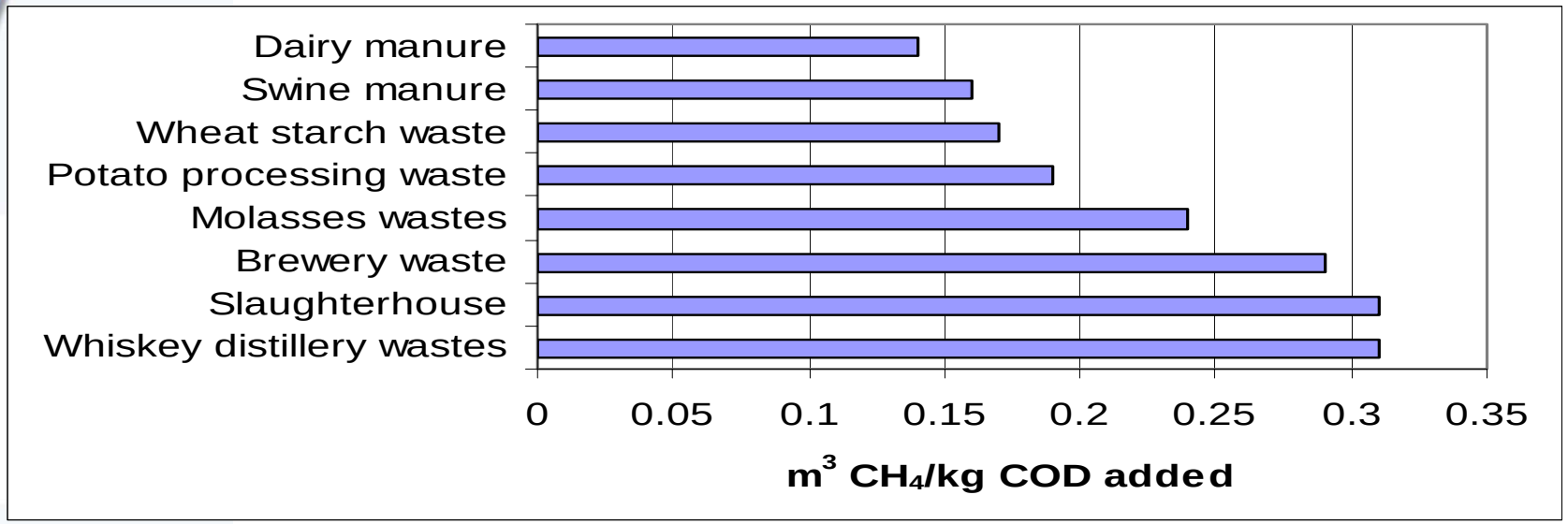
Agro-Industrial Waste Overview
Comparative Methane Yields



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Agro-Industrial Waste Overview
Carbon Chains Drive Methane Yields

- AD of the following food processing waste compounds may be represented with the simplified equations below.
  - Carbohydrates (sugars and starches)
    $C_6H_{12}O_6 + H_20 \rightarrow 3CO_2 + 3CH_4$
  - Proteins
    $C_{10}H_{20}O_6N_2 + 3H_20 \rightarrow 5.5CH_4 + 4.5CO_2 + 2NH_3$
  - Fats and oils (triglycerides)
    $C_{54}H_{106}O_6 + 28\ H_20 \rightarrow 40CH_4 + 17CO_2$

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Agro-Industrial Waste Overview
Controlling Methane Production Factors

- **Variables Affecting the Rate of Methane Production during Anaerobic Digestion**
  - Waste physical and chemical characteristics
    - Pickling, crusting, floating, solidification, settling, nutrient deficiencies
    - Livestock waste digesters are excellent buffers for chemical impacts on microbial populations
  - Volumetric loading rate or retention time, and
  - Temperature.

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Potentially Applicable Processes

- Suspended growth
  - Complete mix
  - Anaerobic contact
  - Anaerobic sequencing batch reactor

- Anaerobic sludge blanket
  - Upflow (USAB)
  - Baffled reactor (ABR)
  - Migrating blanket reactor (AMBR)

Potentially Applicable Processes (continued)

- Attached growth
  - Upflow packed bed
  - Upflow expanded bed
  - Upflow fluidized bed
  - Downflow

- Other processes
  - Covered lagoon

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Food Processing Wastes:
Examples of Utilization in the US

- Slaughterhouse wastewater (pork)
  - Smithfield Foods
- Milk processing wastewaters
  - Kraft Foods
- Winery wastewaters
  - Canandaigua Winery
- Brewery Wastes
  - Coors Beer

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Project Development Issues

- Availability of:
  - Institutional (national and local government) support
  - Technical Capacity
    - Design, Equipment, and Service
  - Capital for digester construction and biogas utilization
  - Reliable supply of waste or wastes without seasonal variation, and
  - Demand for captured methane as a fuel.

- Similar issues also impact deployment of livestock waste digesters

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Resource Assessments are Critical First Steps

- M2M supporting *Resource Assessments (RA's)* as strategic tool for country implementation plans and next steps
- RA's identify appropriate sectors for anaerobic digestion projects that:
  - Have sufficient scale to be economically viable,
  - Can realize significant value from the captured methane as a fuel, and
  - Have potential to significantly reduce methane emissions.
- M2M supporting RA development in a number of participating Latin and Asian countries

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Summary and Conclusions

- AD of agro-industrial wastes has the potential of:
  - Reducing methane emissions
  - Providing a renewable source of energy
  - Improving water quality and Human Health
- Food Processing wastes show the most potential for AD followed by wastes from biofuel production
- Technologies exist
  - Some wastes will require co-digestion with another waste such as livestock manure
- Resource Assessments are strategic tools to develop effective implementation plans
  - M2M supporting a number participating countries