Production of Bioenergy Using Filter Cake Mud in Sugar Cane Mill Factories

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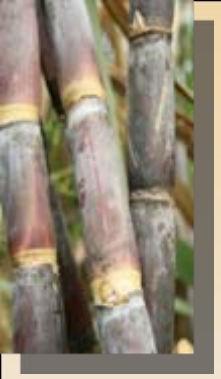
Objectives

- Evaluation of the bioenergy-producing capability of filter cake mud
- Improving the energy balance of the sugar mill
- Improving productivity of the sugar mill
- Evaluation of the mathematical kinetic model for anaerobic digestion
  - Digester size
  - Gas production potential
  - Byproducts

Advantages of Anaerobic Digestion

- Methane is a useful renewable fuel
- High degree of waste stabilization
- Low production of waste biological sludge
- Low nutrient requirements
- No oxygen requirements
- Reduce greenhouse gas emission
- Control of unpleasant odors

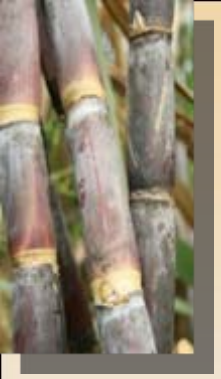


Anaerobic Digestion Fundamentals

- Anaerobic digestion is a complex biological process that uses microorganisms to break down organic material to carbon dioxide and methane
  - Complex wastes are broken down in 3 basic steps :
    - **Enzymatic Hydrolysis**
      Conversion of higher to lower molecular weight (LMW) material.
    - **Acid fermentation (Bacterial)**
      Conversion of LMW into fatty acids.
    - **Methanogenesis (Bacterial)**
      Conversion of fatty acids into methane and carbon dioxide.

Feed Analysis for Anaerobic Digestion

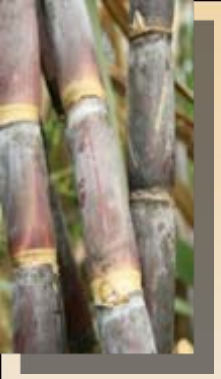
- Total Solids (TS)
- Total Dissolved Solids (TDS)
- Chemical Oxygen Demand (COD)
- Biological Oxygen Demand (BOD)
- Fixed Solids (Ash and Mineral Content)
- Crude Protein
- pH
- Temperature



Filter Cake Composition (Wet)

Compound Name	%
Sucrose	3.00
Wax and Fats	3.00
Fiber	6.50
Nitrogen	1.00
P_2O_5	0.97
K_2O	0.09
CaO	0.94
Ash	4.50
Moisture	80.00
Total	100.00

Source: Paturau, J.M., By-Products of the Cane Sugar Industry, an Introduction to their Industrial Utilization, 1982, Page 151, Elsevier, New York, USA.



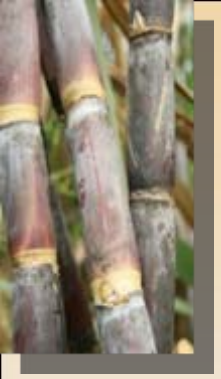
Filter Cake Composition (Dry)

Material Type	**Composition %**
Organics	70
Ash & Mineral	30

Filter Cake Composition

Parameter	Feed Concentration	
	mg/Kg	%
Total Solids	200,040	20.0
COD	157,025	15.7
BOD	84,042	8.4
Ash and Minerals	60,188	6.0
Moisture	800,000	80.0

Source: Carmen Baez-Smith's Personal Notes



Kinetic Model for Filter Cake

- Based on the Monod growth-kinetic equation for anaerobic digestion in a plug- flow digester with recycle (Equation 1)

$$\frac{1}{\theta} = \frac{Yk\,(S_o - S)}{(S_o - S) + (1+\alpha)K_s\,ln(\frac{S_i}{S})} - k_d$$

Equation 1

•Where

θ = Solids retention time, days

S_o = Influent concentration

S = Effluent concentration

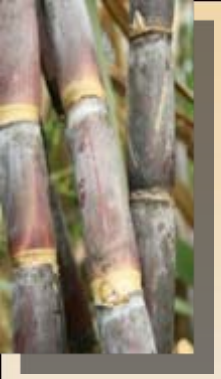
Y = maximum yield coefficient, defined as the ratio of the mass of cells formed to the mass of substrate consumed

K_s = Half-velocity constant, mass/unit volume

α = Recycle ratio

S_i = Influent concentration to reactor after dilution with recycle flow

K_d = Endogenous decay coefficient, day^{-1}

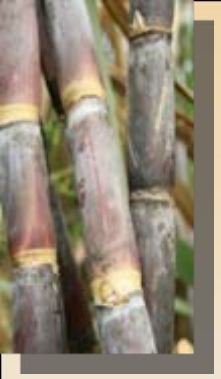


Anaerobic Digestion evaluation

Model Results

Solids Retention Time = 20 Days

Parameter	Value
Cane Grinding Rate, Ton/day	10,000
Filter Cake Production, Ton/day	655
Filter Cake COD, mg/Kg	157,025
Effluent COD, mg/Kg	23,554
Digester Volume, ft^3	392,957
Digester Volume, m^3	11,126
Volume of methane produced, ft^3/day	885,602
Volume of Methane Produced, m^3/day	25,081
Volume of gas produced, ft^3/day	1,581,432
Volume of gas produced, $meter^3$/day	44,776
Power Generation, MegaWatts	5.2



Correlation
Biological Solids (Cell Material)

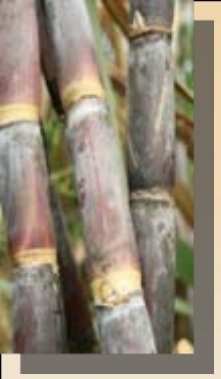
Solids Retention Time = 20 Days	Lb of Biological Solids Production/Lb of BOD
Filter Cake Mud	**0.044**
Fatty Acids*	0.035
Proteins*	0.065
Carbohydrates*	0.150

* Perry L. MacCarty, Anaerobic Waste Treatment Fundamentals, Part I, Public Works, Vol 95, 9, 1964.

Correlation
Gas Productivity

Gas Production Rates	Calculated	Reported *
COD Loading Rate, Lb COD/ft^3 day	0.52	0.10 - 0.30
COD Loading Rate, kg COD/m^3 day	8.39	1.6 - 4.8
Methane Yield, m^3/Kg COD added	0.27	0.13
Methane Yield, m^3/Kg BOD added	0.50	0.36
Gas Productivity, ft^3/lb COD Destroyed	9.04	12 - 18
Gas Productivity, m^3/Kg COD Destroyed	0.56	0.75 - 1.12

Sources: 1) *Ghos, S, T. Liu and K. Fukushi, Anaerobic Biodegradation of Toluene in a Plug-Flow Reactor, University of Utah, Salt Lake City, UT.
2) Metcalf & Eddy, Wastewater Engineering. Treatment, Disposal and Reuse, Third Ed. 1991, New York, NY



Theoretical Methane Content of Biogas

Substrate	**Chemical Composition**	**Methane % of Total Gas**
Fats	$C_{15}H_{31}OCOOH$	72
Proteins	C_4H_6ON	63
Carbohydrates	$C_6H_{12}O_6$	50

Model Assumptions

Assumptions	
Parameter	Value
Filter Cake COD, mg/Kg	157,025
Filter Cake Total Solids, mg/Kg	200,040
Efficiency of Waste Utilization (E), %	85%
Yield coefficient (Y), mg cells/mg COD	0.05
Maximum Rate of Substrate Utilization per Unit Mass of Microorganisms, k, $days^{-1}$	2
Recycle Ratio,	0.5
Temperature, ˚F	122
Endogenous Coefficient (K_d), day^{-1}	0.05
Half Velocity Constant, K_s, mg/L COD	40
Filter Cake Specific Gravity	1.07
Power Process Efficiency, %	80%
Methane % in Gas Produced, %	56%
Digester Methane Gas Heating Value, Btu/ft^3	600

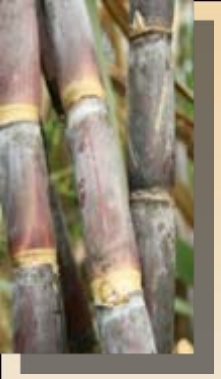
Overall Material Balance

- Two alternatives will be presented depending on the post-anaerobic digestion sludge treatment:
  - Alternative #1 will separate the sludge after anaerobic digestion into process water and a thicker sludge, which subsequently is dried to produce biofertilizer
  - Alternative #2 will just dry the sludge after anaerobic digestion to produce biofertilizer

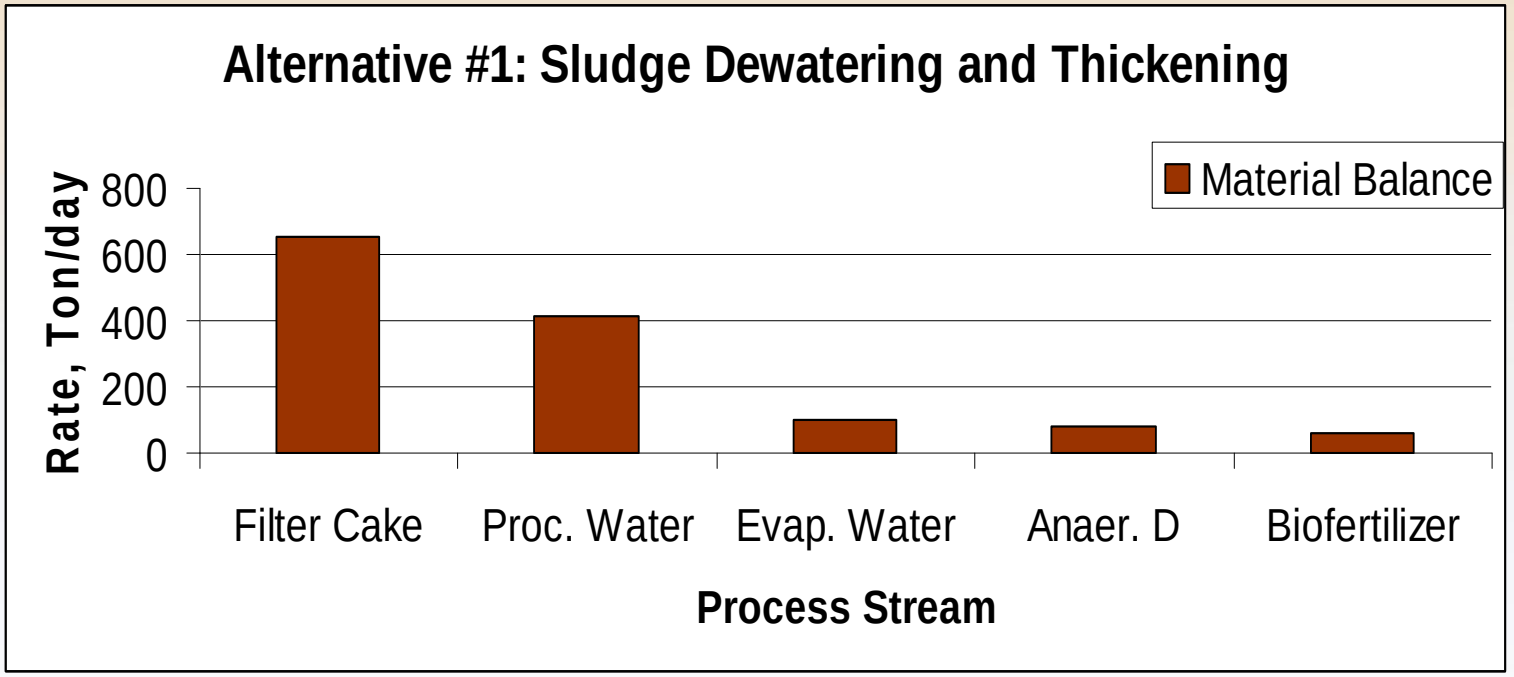
Overall Material Balance

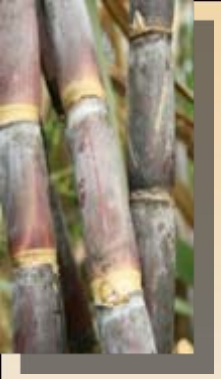
Alternative #1: Sludge Dewatering and Thickening

Overall Material Balance	Influent	Effluent	Percent of the Feed
Filter Cake Feed, Ton/day	655		
Bioconversion by Anaerobic Digestion, Ton/day		78	12%
Total Process Water Produced, Ton/day		414	63%
Total Water Evaporated (by Drying), ton/day		103	16%
Total Biofertilizer, Ton/day		60	9%
Total		655	100%



Overall Material Balance



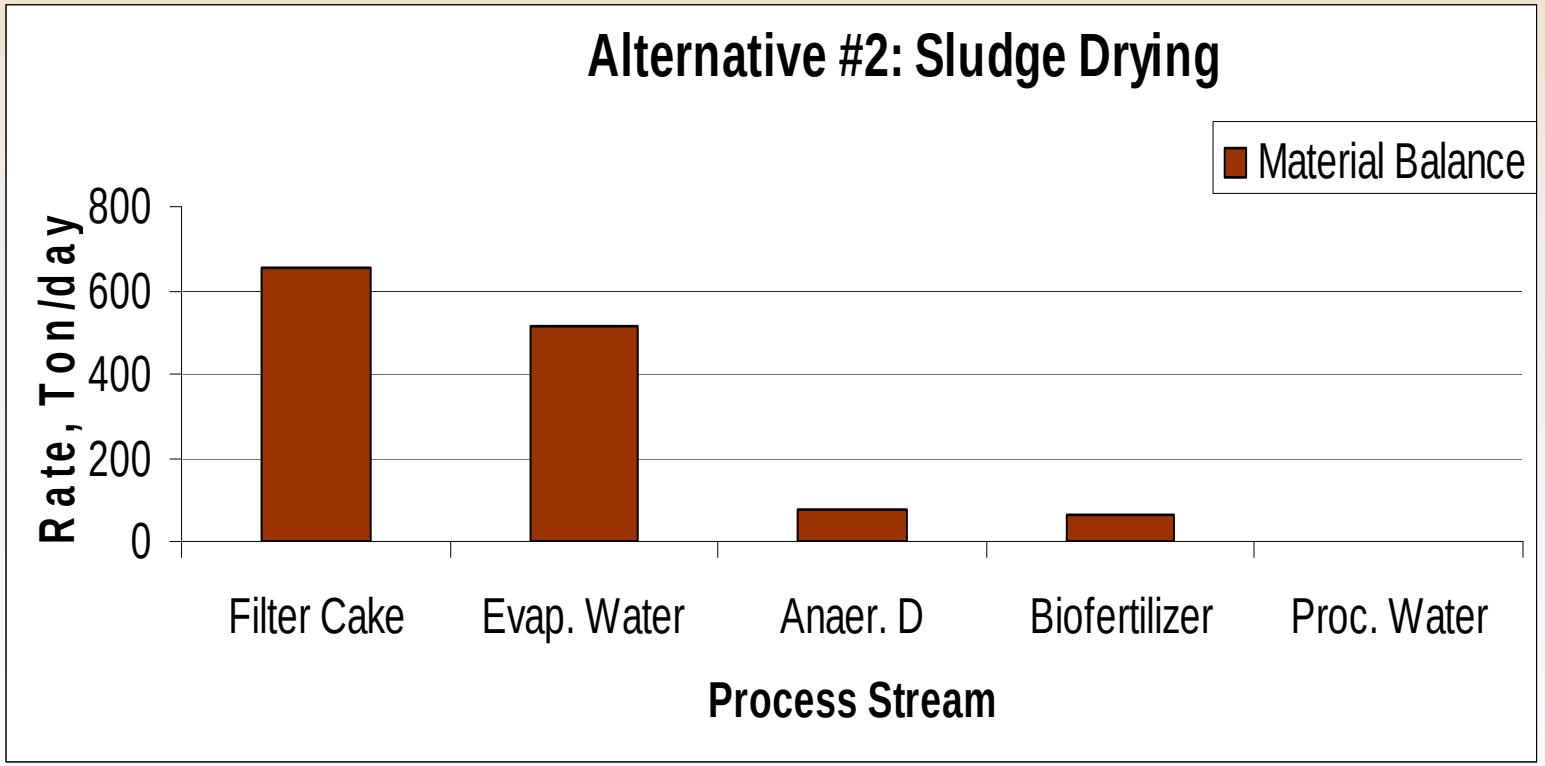


Overall Material Balance

Alternative #2: Sludge Drying

Overall Material Balance	Influent	Effluent	Percent of the Feed
Filter Cake Feed, Ton/day	655		
Bioconversion by Anaerobic Digestion, Ton/day		78	12%
Total Process Water Produced, Ton/day		0	0%
Total Water Evaporated (by Drying), ton/day		515	79%
Total Biofertilizer, Ton/day		62	10%
Total		655	100%

Overall Material Balance

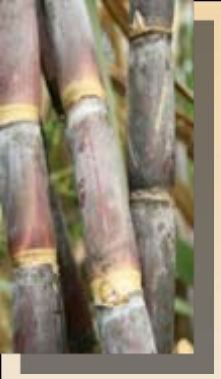


Conclusions

- Data seems to indicate that the kinetic model developed is adequate to quantify filter cake (FC) mud anaerobic digestion
- Enzymatic pretreatment of the FC increase the conversion capacity by at least 50%
- Applied research is needed to field-verify the results

Conclusions

- Data seems to indicate that anaerobic digestion (AD) of filter cake is an attractive alternative for an otherwise underappreciated byproduct of sugar cane mills
- AD has the potential of increasing productivity and portfolio diversity in the sugar mill operations



Thank You