

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 ₂ O ₅	0.97
K ₂ O	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	$C_{15}H_{31}O_2COOH$	72
Proteins	C_4H_6ON	63
Carbohydrates	$C_6H_{12}O_6$	50





Model 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

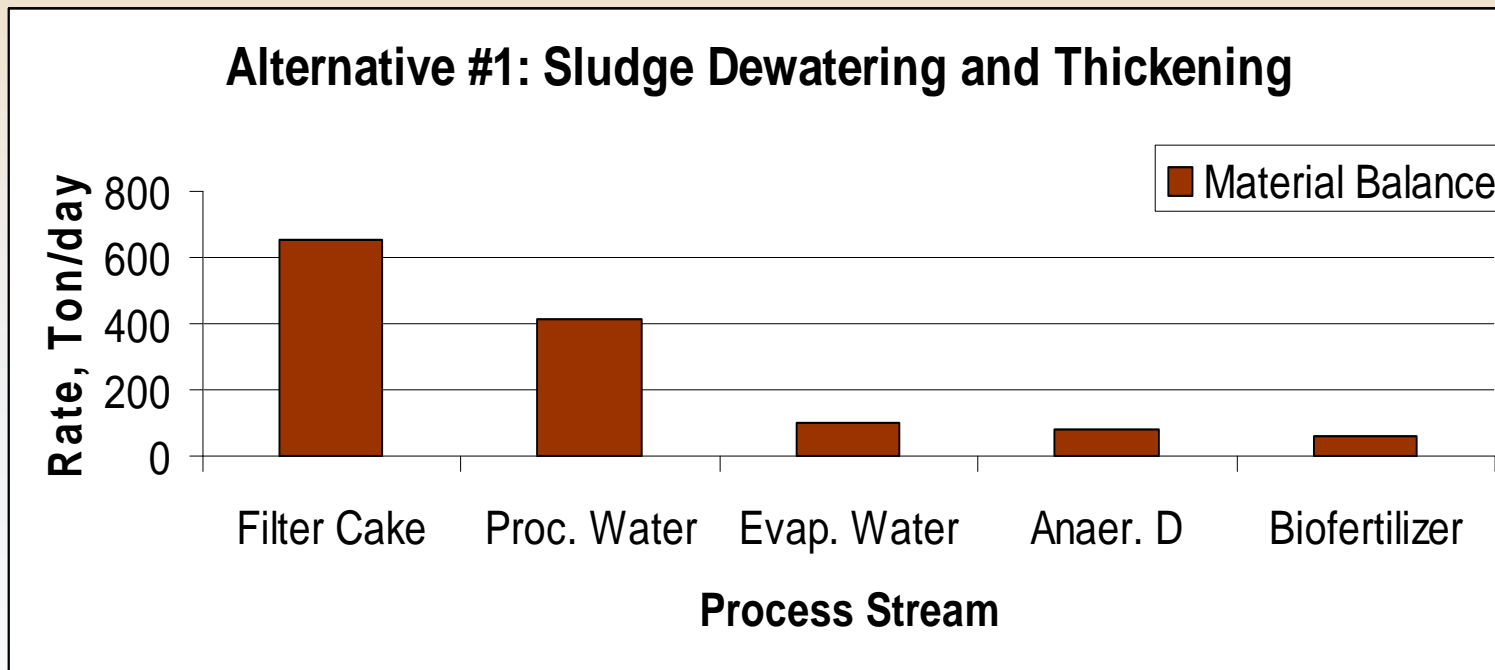
Alternative #1: Sludge Dewatering and Thickening

	Influent	Effluent	Percent of the Feed
Overall Material Balance			
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

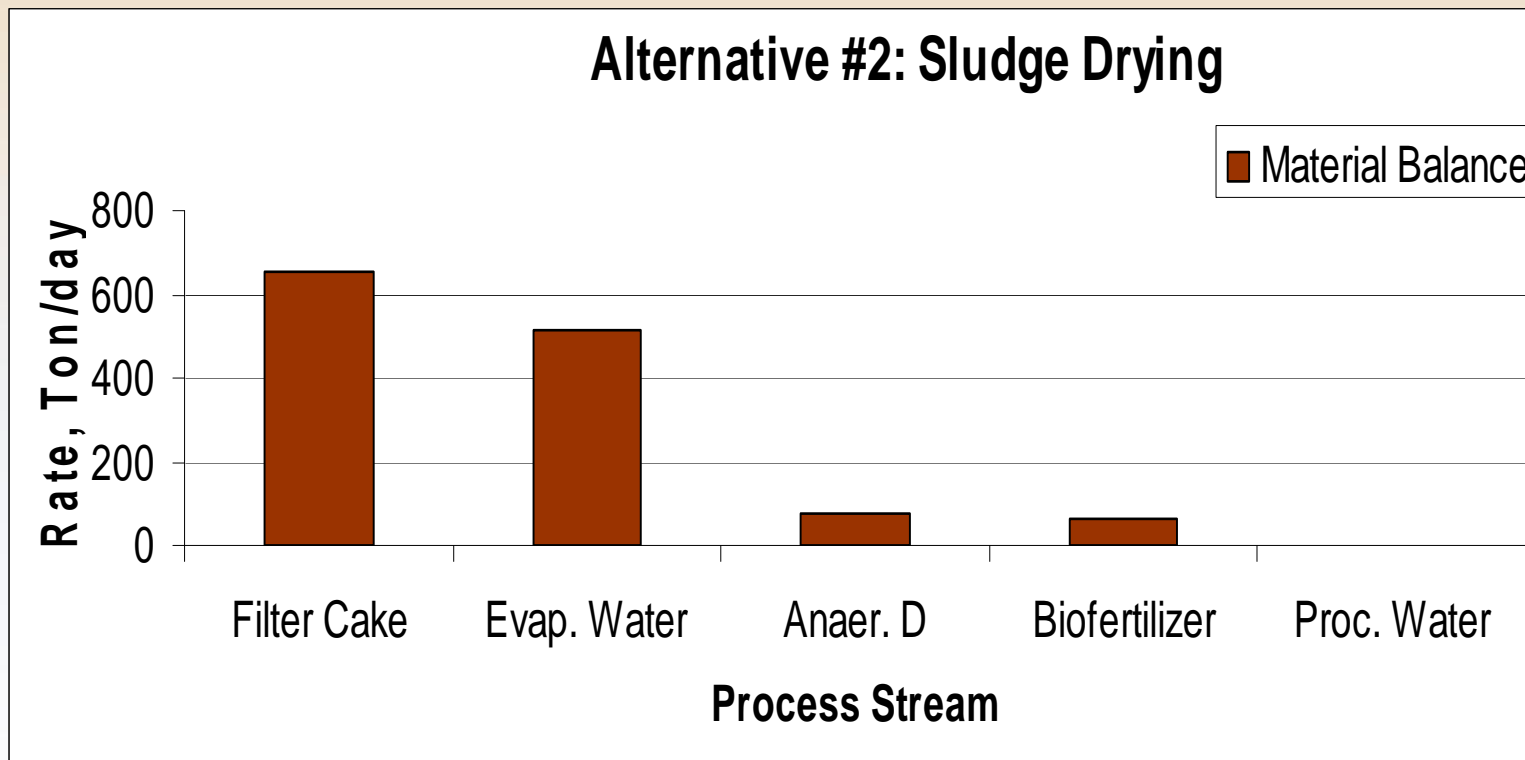
Alternative #2: Sludge Drying

	Influent	Effluent	Percent of the Feed
Overall Material Balance			
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

