Developing A Bio-gas based Carbon Neutral Engine Systems

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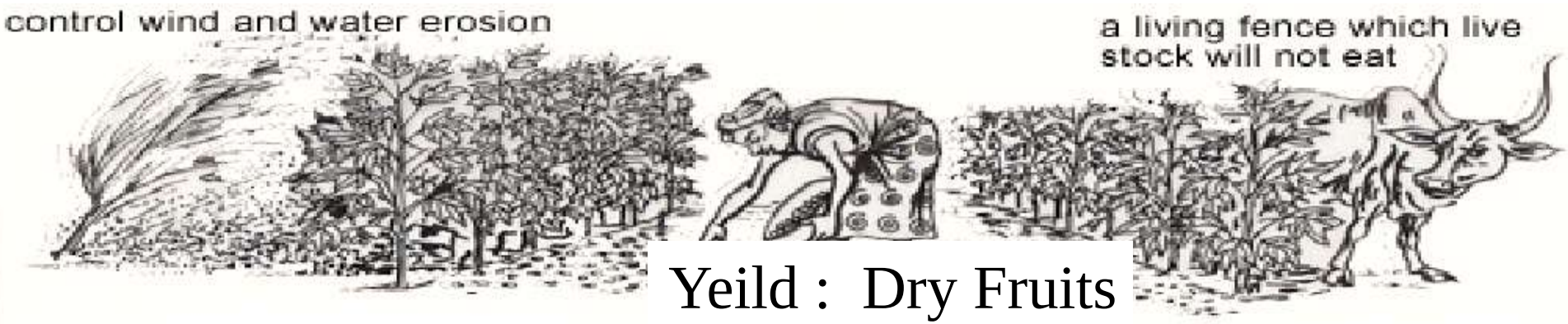
A Shift from Exploitation to Harvesting ….

Carbon Neutral Energy Systems

Bio-Diesel Seed Crops



Yeild : Dry Fruits

Shell : Woody bio-mass

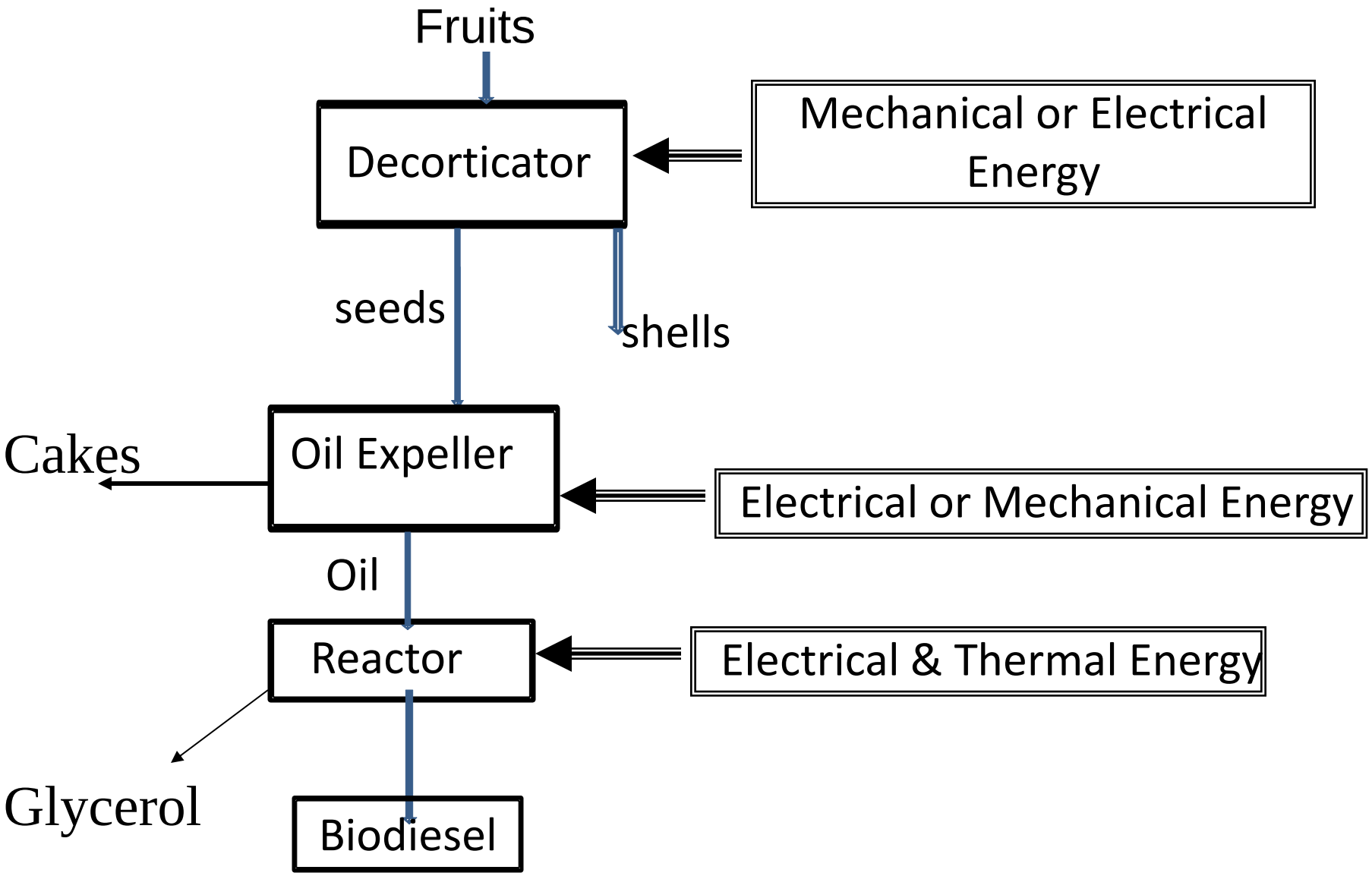
seeds

Bio-Diesel

Oil

Cake ~ 32% by mass

Energy Credits for Bio-Diesel Production



Pongamia Trees At IIT Delhi

Pongamia Collections

Mass Distribution of Pongamia Collections

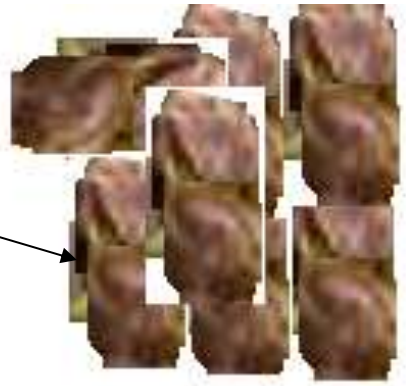
~50%

~50%

Mass Distribution of Jatropha Collections

~40%

~60%



Mass Distribution of Pongamia Seeds

~35%

~65%

Mass Distribution of Jatropha Seeds

~35%

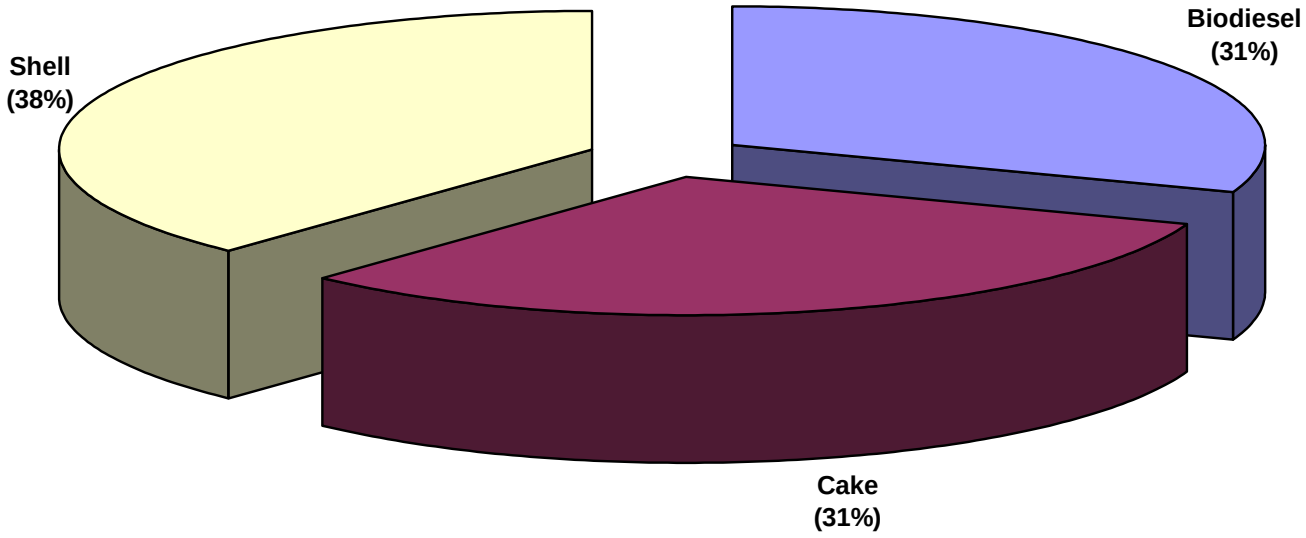
~65%

Energy Audit of Sub-Species of Oil Seed Collections : 1ton of Bio-Diesel

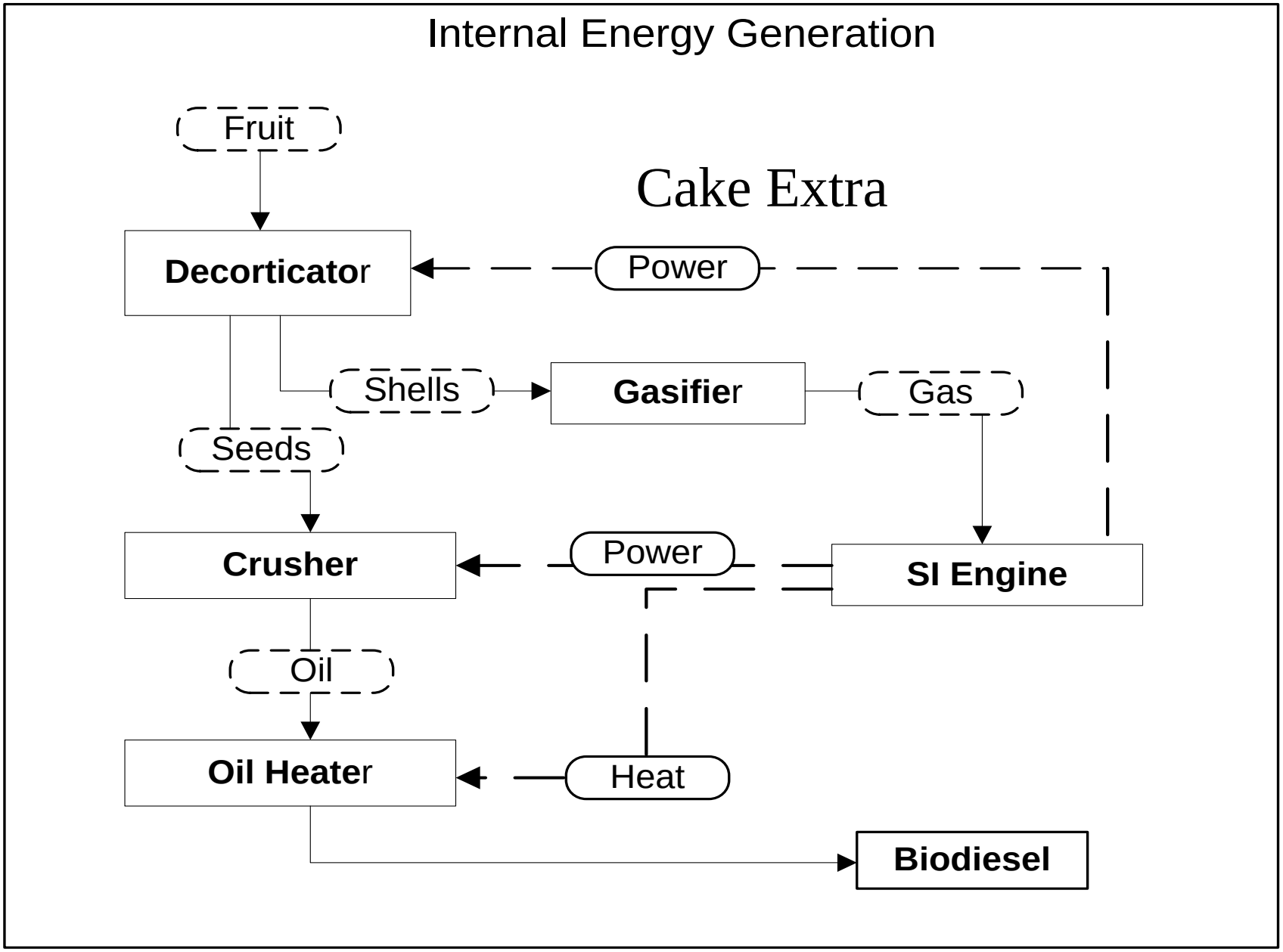
- Mass of produce: 6.3 tons.
- Mass of Bio Diesel: 1 ton.
- Mass of cake : 2.15 tons.
- Mass of Shells : 3.15 tons.
- Calorific value of Bio-diesel : 38 MJ/kg
- Calorific value of cake: 19 MJ/kg.
- Calorific value of shells: 15 MJ/kg.
- Total Energy value of Bio-diesel: 38 GJ
- Total Energy value of Cake: 40.8GJ
- Total Energy value of Shells: 47.25GJ

Energy content in sub species of pongamia fruit seed as biodiesel feedstock

Mass distribution of biodiesel and by produce:
Pongamia oil (17.5%); Cake (32.5%); Seed shell (50%)



Internal Re-Generation of Energy Credits



Cake -- to -- Bio-Fuels

- Indian Bio-diesel Mission
- Jatropha and pongamia oils seeds.
- Neither used as cattle feed nor as bio-manure.
- Annual production of toxic jatropha oil cake alone is estimated to be about 60, 000 tonnes.
- Non-availability of much scientific information on biomethanation of jatropha and pongamia oil seed cakes
- The oil cake could be a potential source of biogas production, to supplement the petroleum demand in substantial amount.

Biogas Generation from Non-Edible Oil Seed Cakes

Dry Pongamia Seed Cake

Seed Cakes soaked in water

Dry Jatropha Seed Cake

Proximate analysis of feed materials

Feed material	Physiochemical properties				
	Moisture content %	Oil content %	Total solids %	Volatile solids %	Non-volatile solids %
Cattle dung	81.6 (442.5 db)	Nil	18.4	14.4 (78.8 db)	21.2
Jatropha oil seed cake	07.5 (8.1 db)	8.3	92.5	86.4 (93.0 db)	07.0
Pongamia oil seed cake	10.5 (11.7 db)	7.2	89.5	85.3 (94.8 db)	05.2

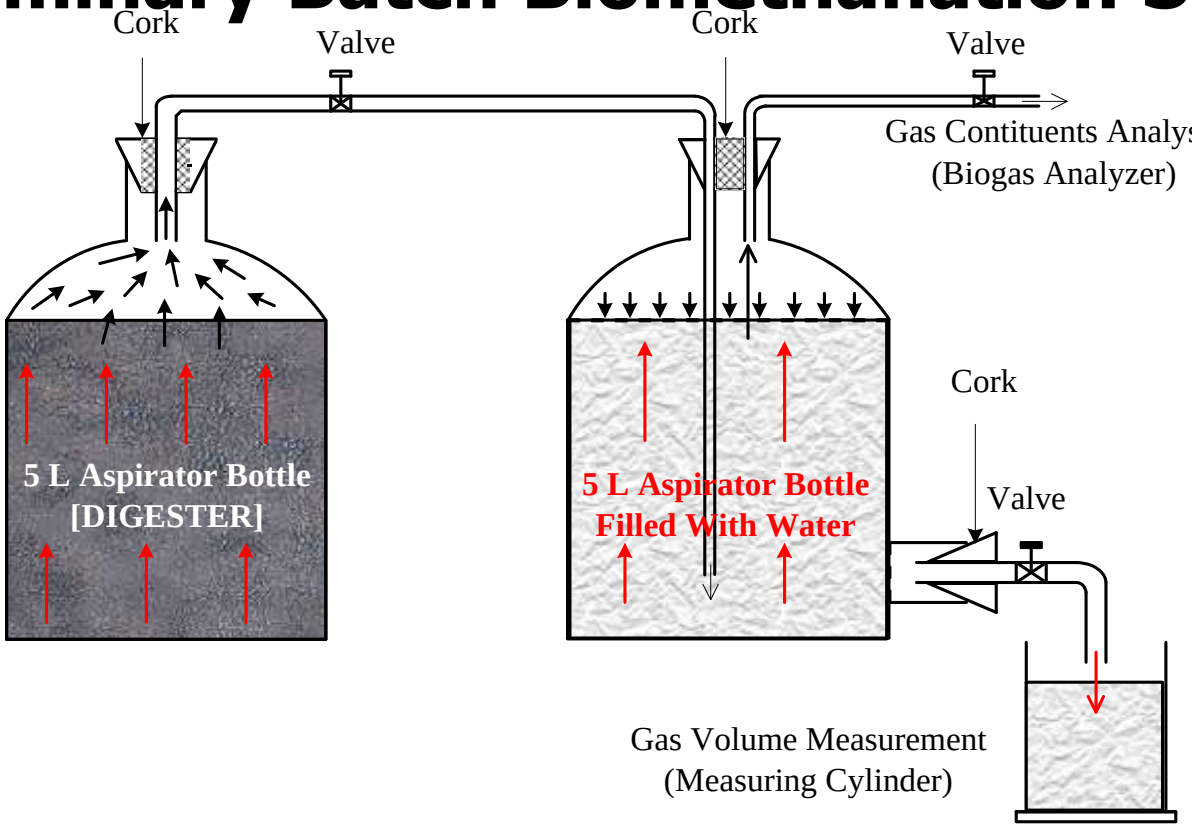
Ultimate Analysis and carbon-nitrogen ratio of feed materials

Sr. No.	Feed material	C (%)	H (%)	N (%)	C/N ratio
1	Cattle Dung	35.20	4.60	1.55	22.7
2	Jatropha oil seed cake	48.80	6.20	3.85	12.7
3	Pongamia oil seed cake	47.80	6.50	5.50	8.7

The study showed that these oil cake have more than six times higher volatile solids content than that of cattle dung.

Carbon and Hydrogen contents are also higher than cattle dung.

Preliminary Batch Biomethanation Study



Experimental setup for batch biomethanation study

Range of ambient temperature variation 24.5 to 35.1 °C

Range of substrate temperature variation 24 to 34.5 °C

Period of Experimental Study:15th March 2006 to 12th June 2006

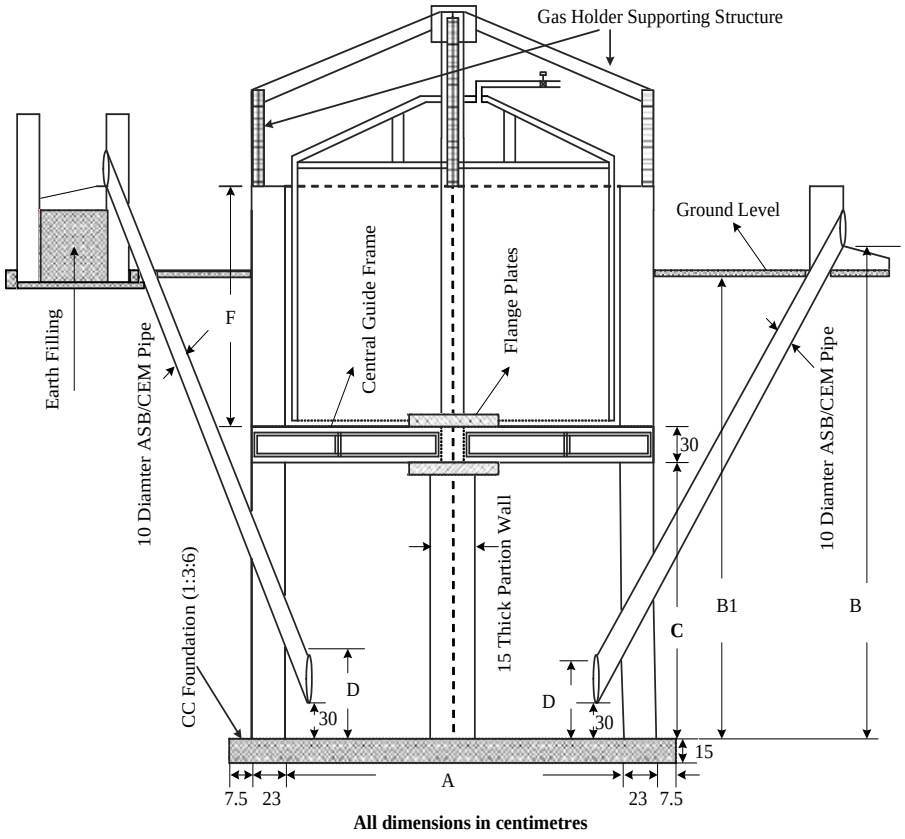
Experimental Setup used for Preliminary Batch Study

The Disheartening Results

- The maximum range of methane content in gas produced from biomethanation of jatropha and pongamia oil cake was found to vary from 25 to 30 % only.
- The quality of produced biogas was found very poor on oil cake substrates.
- HRT of 90 days!!!

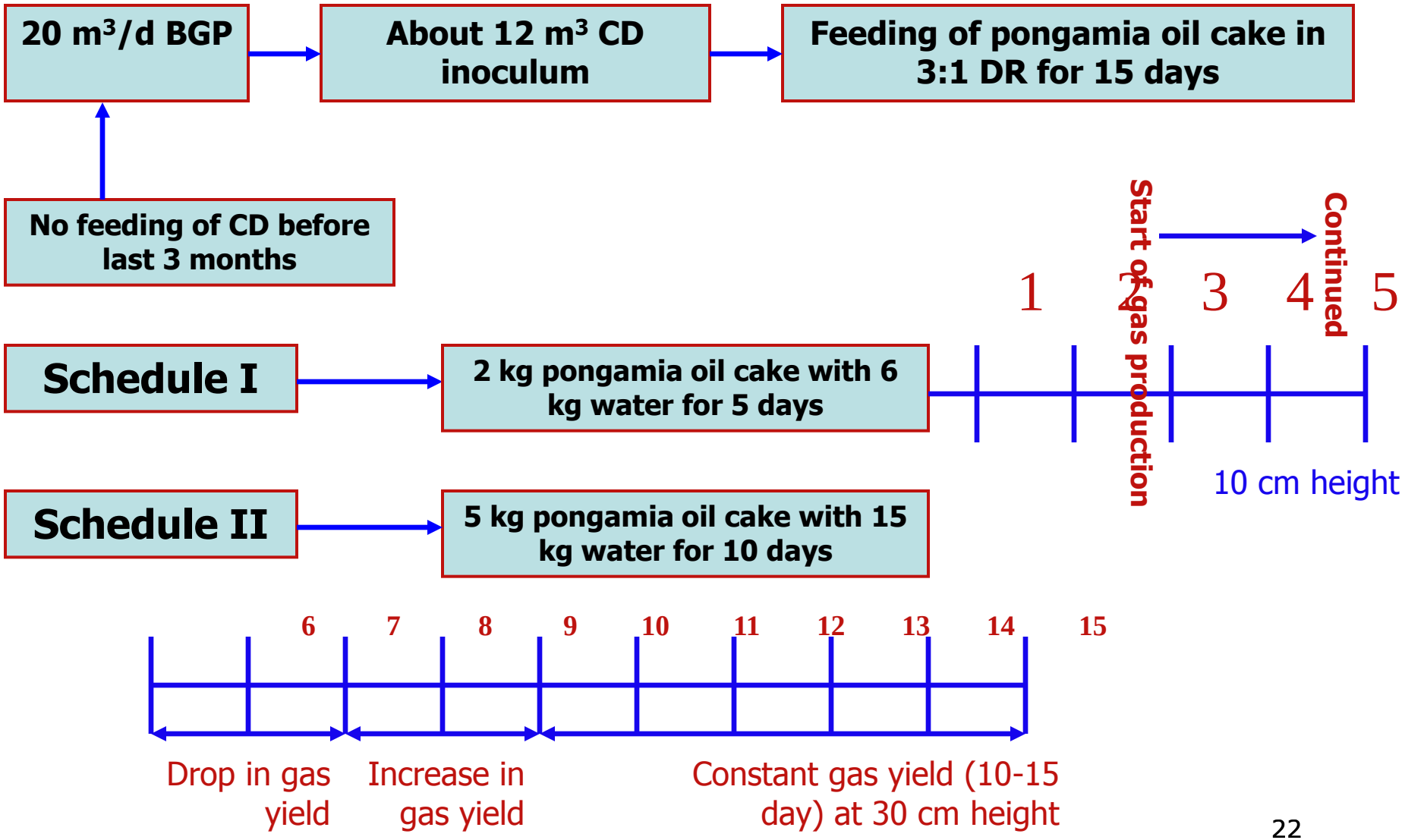
Conclusions from Characterization of Feed Materials and Preliminary Batch Biomethanation Study

- A major challenge in biomethanation of these oil cakes is lacking of inherent bacteria like cattle dung.
- Lack of these inherent bacteria demands a special attention for operation of digester with oil cake.
- Other major deficiency of cake is the presence of long chain free fatty acids, which are prone to destroy the population of bacteria.
- An appropriate amount of cattle dung with oil cake may stabilize the bacterial population.
- Low yield and very poor quality of biogas was observed during the preliminary batch biomethanation study.
- Thus the cattle dung inoculum were not encouraging.
- The substrates of jatropha and pongamia oil cakes might have created a sudden and drastic change in environment for the bacterial activity resulting in their inhibition. This shows that continuous drop in population of bacteria in the inoculum.
- This is due to effect of bacterial inhibition since the substrates were new for the bacteria present in the cattle dung inoculum.
- This proves that production of effective (special) inoculum in a small aspirator bottles with little amount of initial inoculum (taken from a cattle dung digester) is not feasible.



Biogas plant (20 m^3/d) capacity available at IIT Delhi

Development of Special Inoculum



A New Generation of Microbes

- The dung based bacteria evolved into a suitable strain in order to adopt to the environment offered by new substrates.

- This acclimatization is due to fact that, when the concentrations of inhibitory or toxic materials are slowly increased within the environment, many microorganisms can rearrange their metabolic resources, thus overcoming the metabolic block produced by the normally inhibitory or toxic material.
- *This study lead to a set of important developments, namely,*
  - *an effective inoculum as a pool of new microorganisms,*
  - *an optimal size of the inoculum and a mode of operation.*
- Sufficient time and controlled loading should be made available for this rearrangement to take place.

- The slurry of the biogas plant being fed with pongamia de-oil ed cake was used as inoculum for further studies.

BIOMETHANATION OF JATROPHA AND PONGAMIA OIL SEED CAKES AND STUDY OF REACTION KINETICS

Experimental phases of biomethanation process

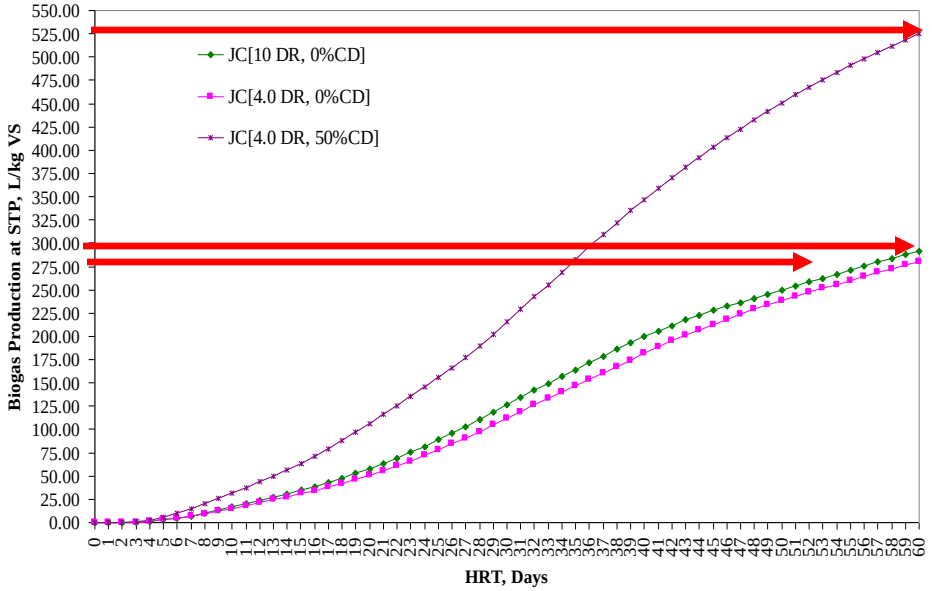
Phase	Phase description	Period of experimentation
I	Thorough experimentation on selected batch treatments (5 L digester capacity)	60 days HRT
II	Continuous feeding experimental investigation on selected treatments in digester of 300 litre capacity	30 days
III	Continuous feeding experimental investigation in floating drum biogas plant of 20 m3/d capacity	30 days

Thorough experimentation on selected batch treatments (5 L digester capacity)

Total solids and volatile solids concentration in the substrates under Phase I

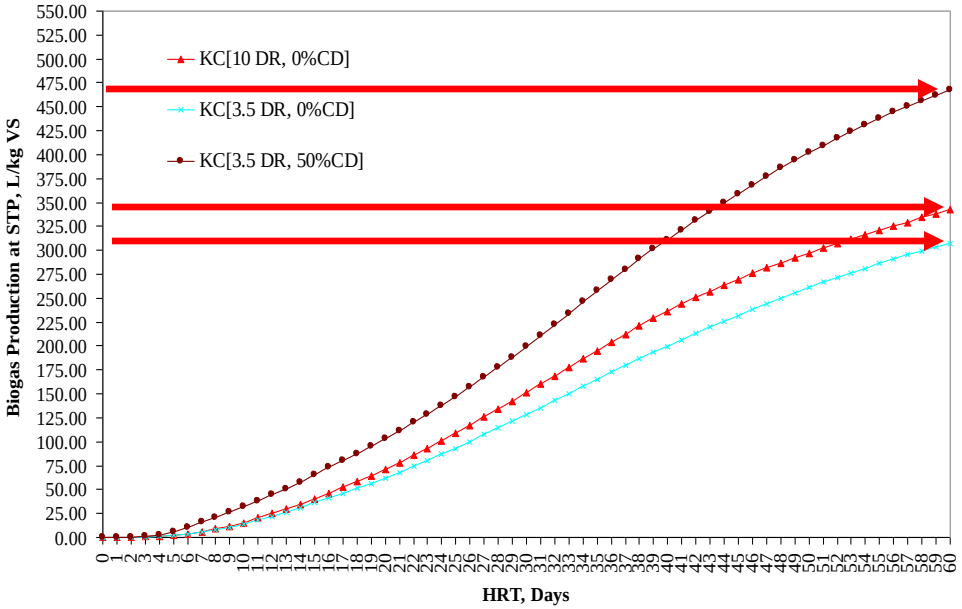
Sl. No.	Treatment	Substrate concentration			
		Total solids		Volatile solids	
		kg	%	kg	%
Jatropha oil seed cake substrates					
1	JC (4.0 DR, 0 % CD)	0.46	18.5	0.43	17.3
2	JC (4.0 DR, 50 % CD)	0.56	18.5	0.50	16.8
3	JC (10 DR, 0 % CD)	0.23	8.4	0.22	7.9
Pongamia oil seed cake substrates					
4	PC (3.5 DR, 0 % CD)	0.45	19.9	0.43	19.0
5	PC (3.5 DR, 50 % CD)	0.54	19.6	0.50	18.1
6	PC (10 DR, 0 % CD)	0.22	8.1	0.21	7.8

Cumulative biogas production yield based on volatile solids contents of the substrates



Jatropha Oil Cake Substrates

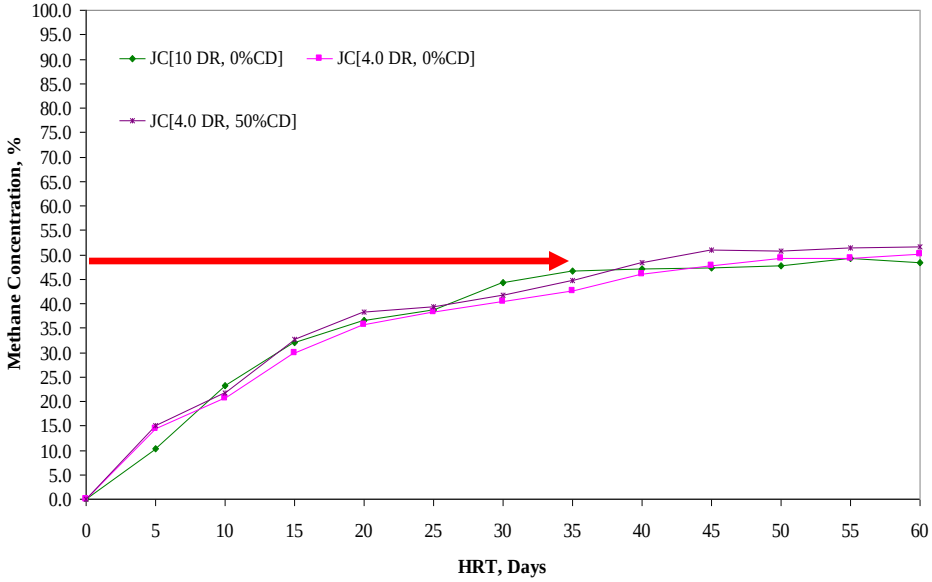
Pongamia Oil Cake Substrates



Range of ambient temperature variation 25.3 to 33.2 °C.

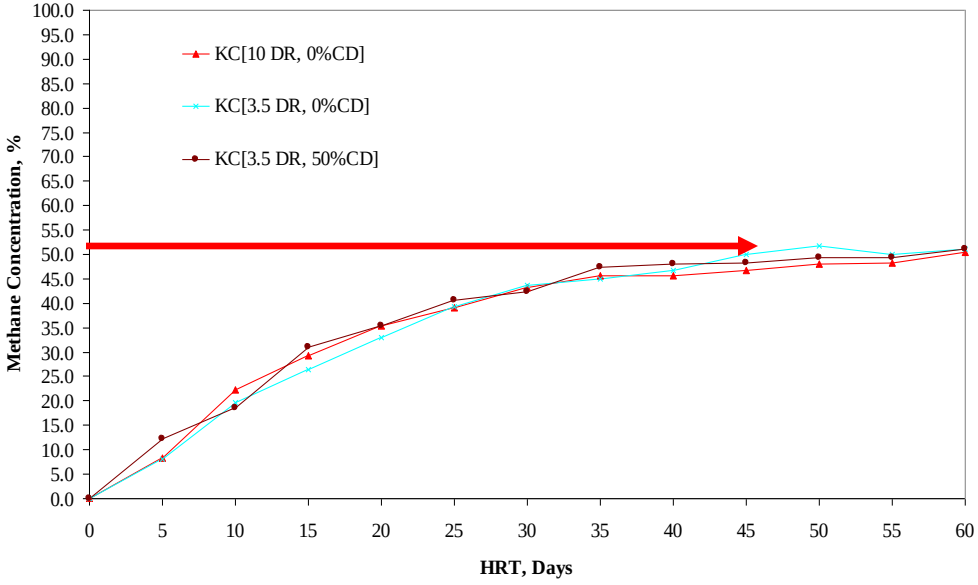
Range of substrate temperature variation 24.3 to 31.8 °C.

Variation of methane concentration in generated biogas

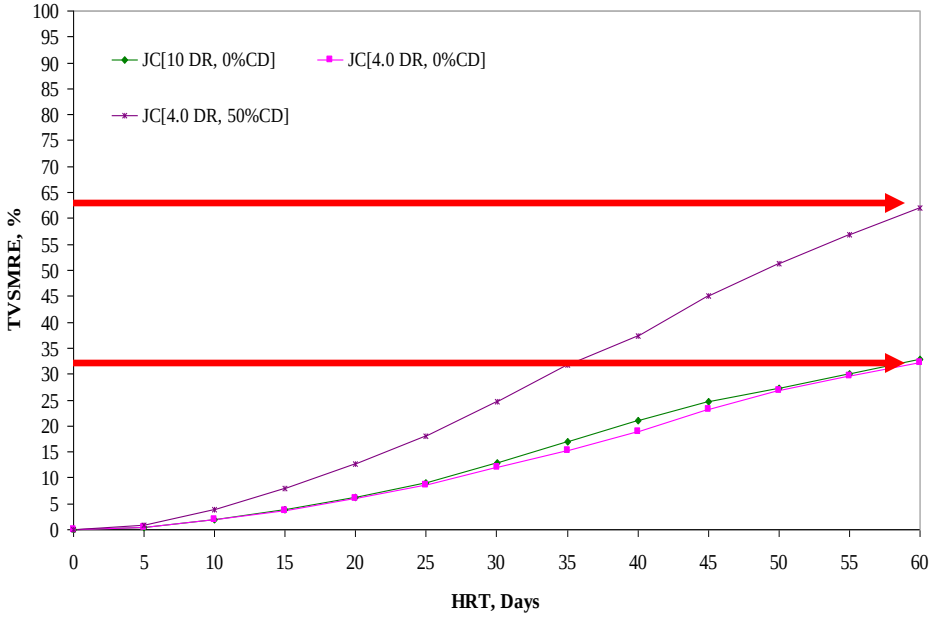


Jatropha Oil Cake Substrates

Pongamia Oil Cake Substrates

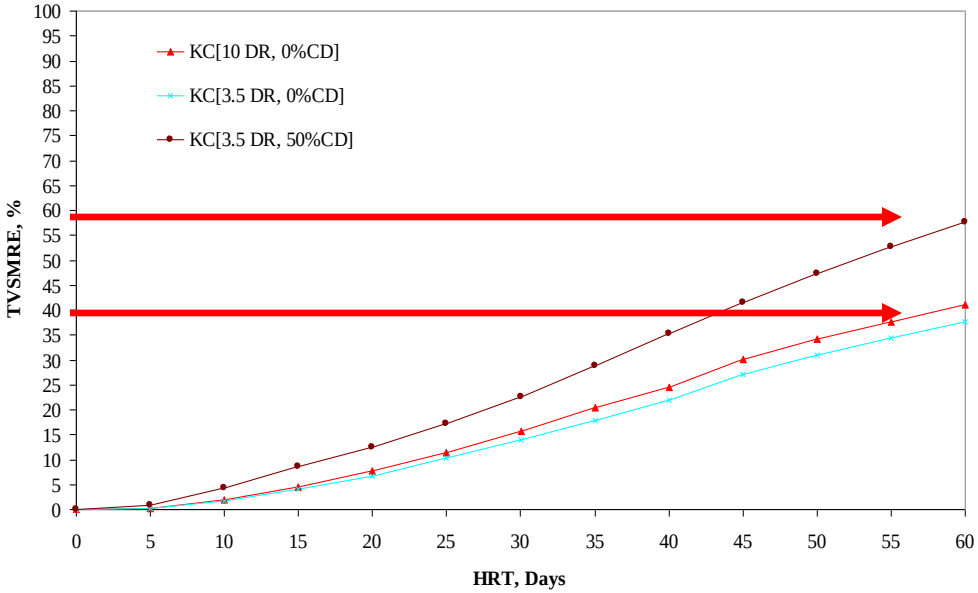


Variation of total volatile solid mass removal efficiencies of the substrates



Jatropha Oil Cake Substrates

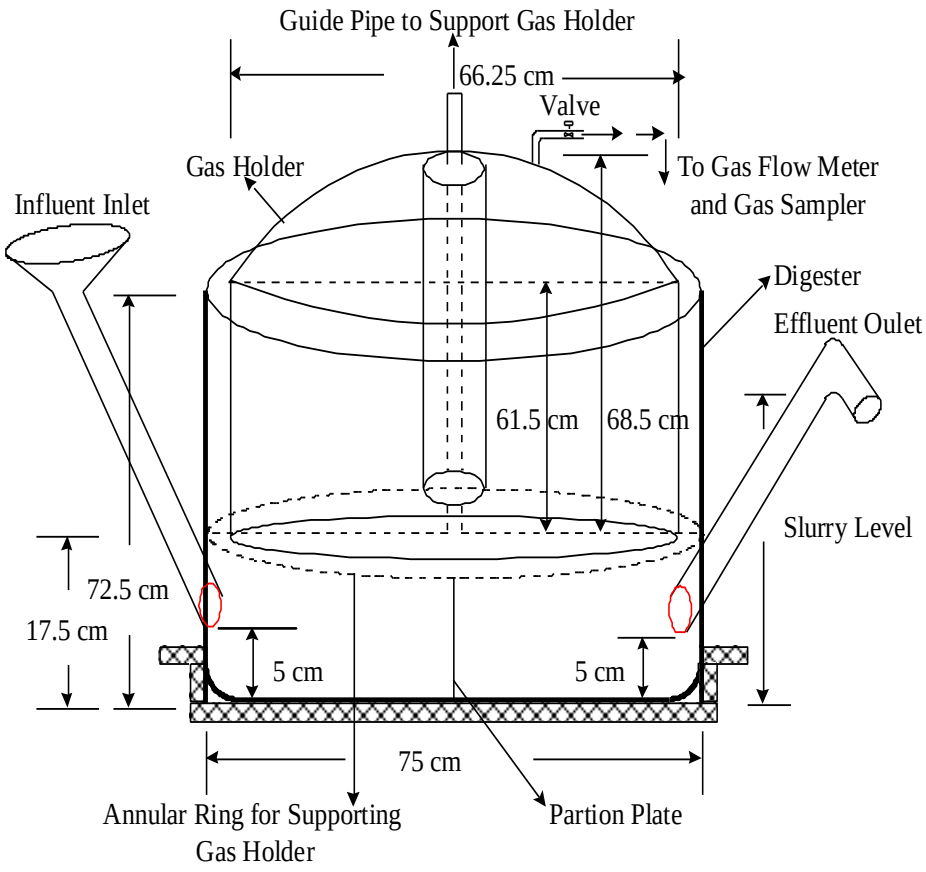
Pongamia Oil Cake Substrates



Specific Biogas Yield

Treatments	Phase- I	
	L/kg TS	L/kg VS
Jatropha oil cake substrates		
JC [10.0 DR, 0 % CD]	280.86	289.64
JC [4.0 DR, 0 % CD]	269.69	278.72
JC [4.0 DR, 50 % CD]	505.30	538.05
Pongamia oil cake substrates		
PC [10.0 DR, 0 % CD]	347.08	351.97
PC [3.5 DR, 0 % CD]	313.32	316.99
PC [3.5 DR, 50 % CD]	470.31	493.49

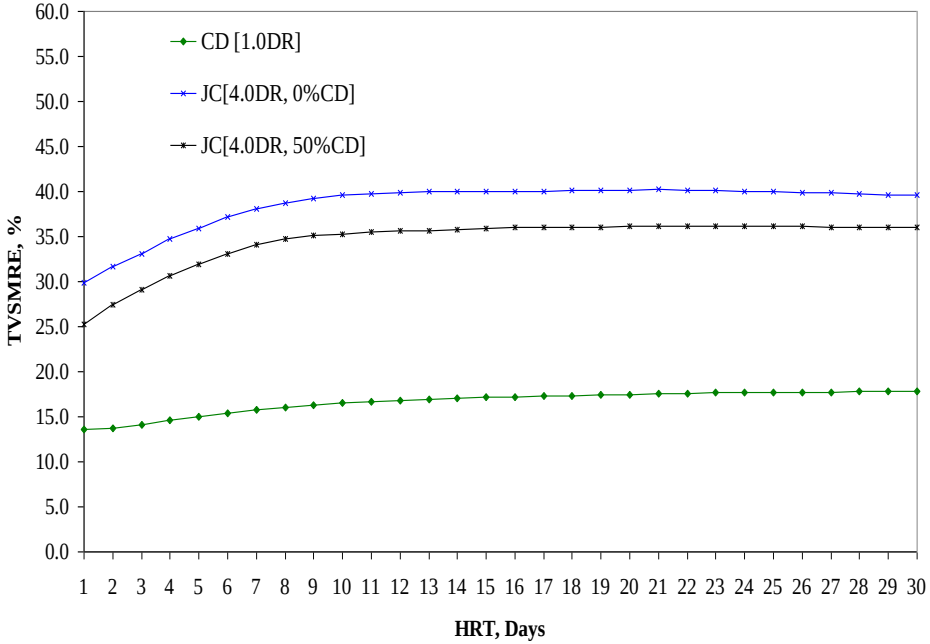
Continuous Feeding Experimental Investigation on Selected Treatments in Digester of 300 Litre Capacity



Total solids and volatile solids concentration in the substrates under Phase II

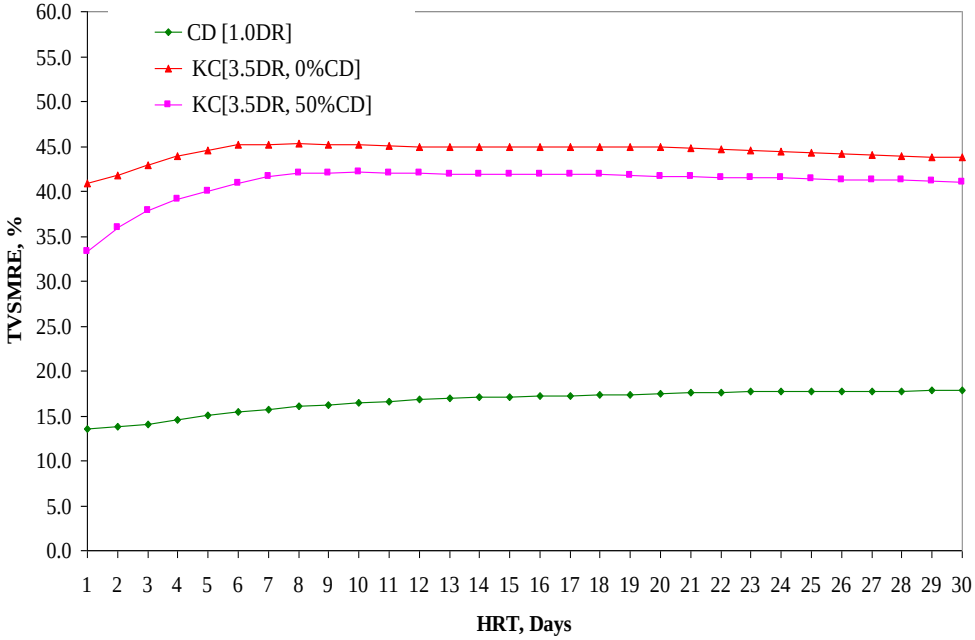
Sl. No.	Treatment	Substrate concentration of the daily feed material			
		Total solids		Volatile solids	
		kg/d	%	kg/d	%
1	CD [1.0 DR]	0.922	9.2	0.605	7.2
Jatropha oil seed cake substrates					
2	JC (4.0 DR, 0 % CD)	0.463	18.5	0.432	17.3
3	JC (4.0 DR, 50 % CD)	0.555	18.5	0.504	16.8
Pongamia oil seed cake substrates					
4	PC (3.5 DR, 0 % CD)	0.448	19.9	0.427	19.0
5	PC (3.5 DR, 50 % CD)	0.54	19.6	0.498	18.1

Variation of total volatile solid mass removal efficiencies of the substrates



Jatropha Oil Cake Substrates

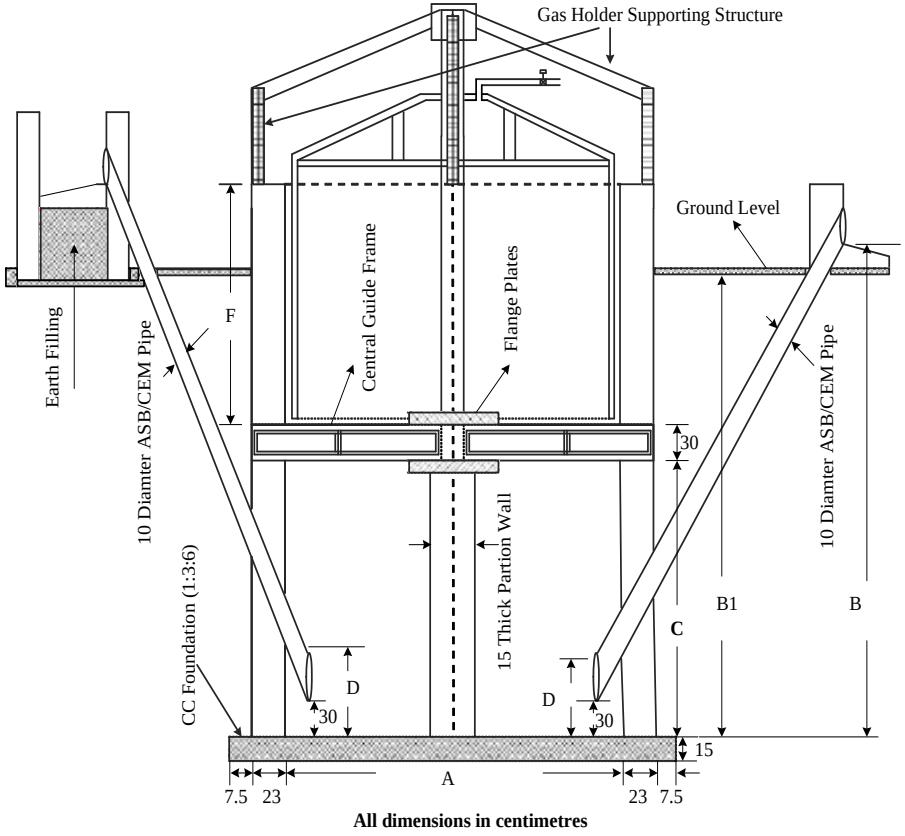
Pongamia Oil Cake Substrates



N, P & K Contents of Biogas Spent Slurry

Sl. No.	Treatment	N, %	P, %	K, %
1	CD [1.0 DR]	1.48	0.66	1.64
Jatropha oil cake biogas spent slurry				
2	JC (4.0 DR, 0 % CD)	3.60	2.20	1.72
3	JC (4.0 DR, 50 % CD)	3.30	2.10	1.69
Pongamia oil cake biogas spent slurry				
4	PC (3.5 DR, 0 % CD)	5.40	1.20	1.32
5	PC (3.5 DR, 50 % CD)	5.20	1.33	1.65

Continuous Feeding Experimental Investigation in Floating Drum Biogas Plant of 20 m3/d Capacity



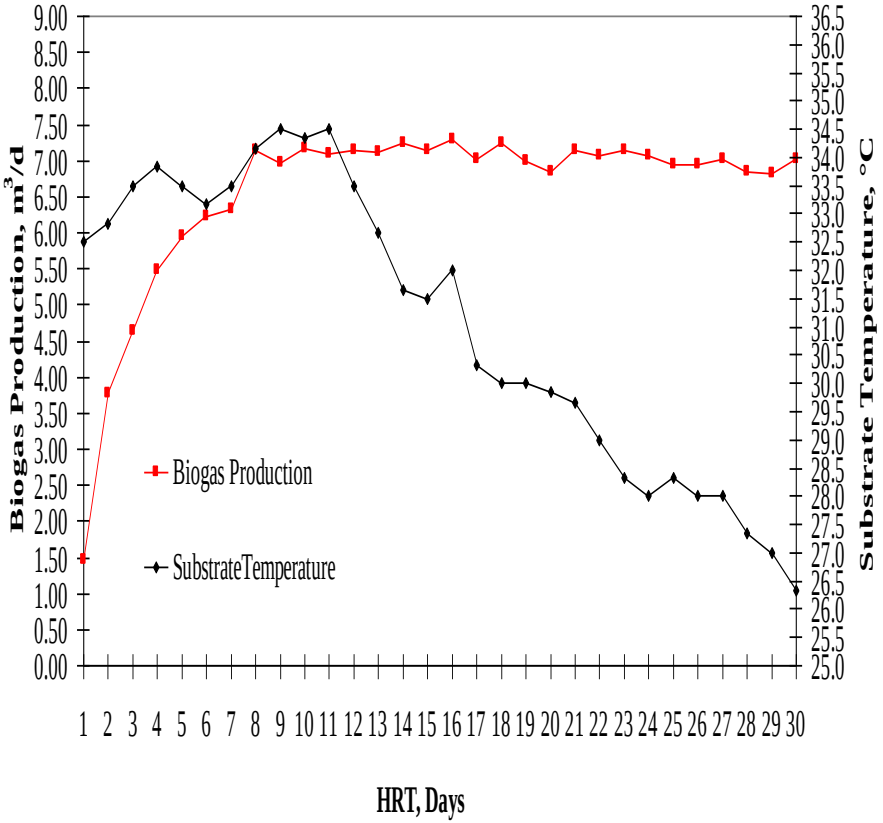
Biogas plant (20 m3/d) being fed with jatropha & pongamia oil seed cakes

Total solids and volatile solids concentration in the substrates

Sl. No.	Treatment	Substrate concentration of the daily feed material			
		Total solids		Volatile solids	
		kg/d	%	kg/d	%
Jatropha oil seed cake substrates					
1	JC (4.0 DR,0 % CD)	9.25	18.5	8.64	17.3
Pongamia oil seed cake substrates					
2	PC (3.5 DR,0 % CD)	8.95	19.9	8.53	19.0

Daily Biogas Production

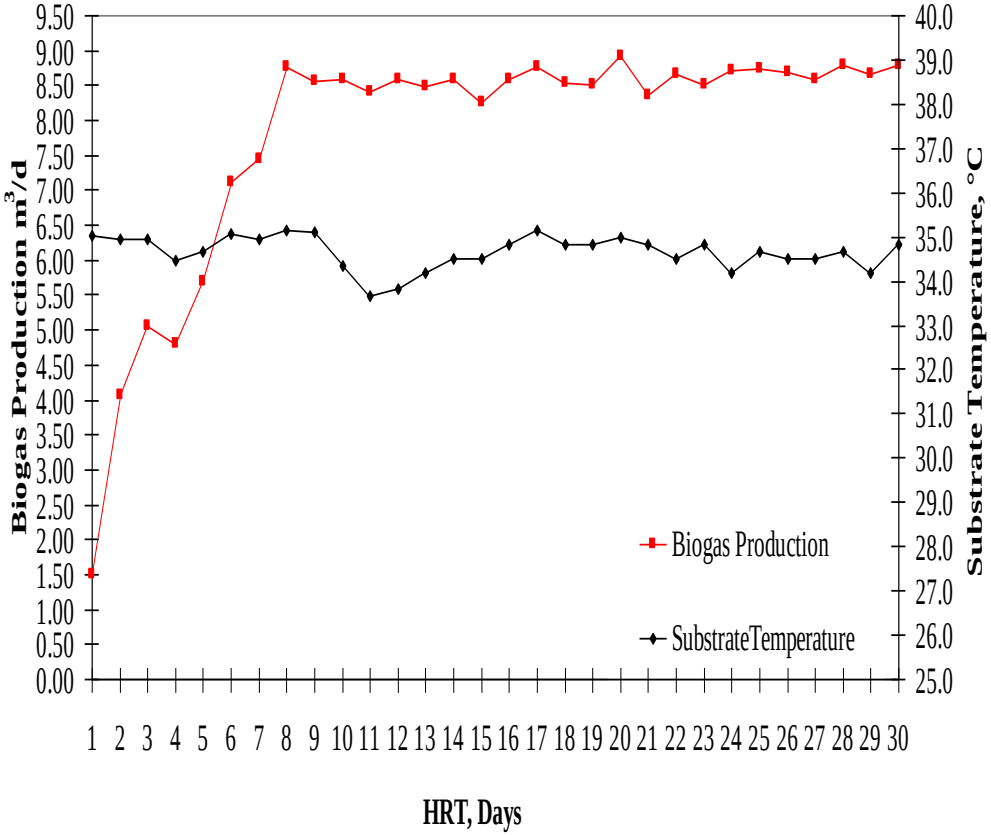
Range of ambient temperature variation 26 to 35 °C



Jatropha Oil Cake

JC [4.0 DR, 0 % CD]

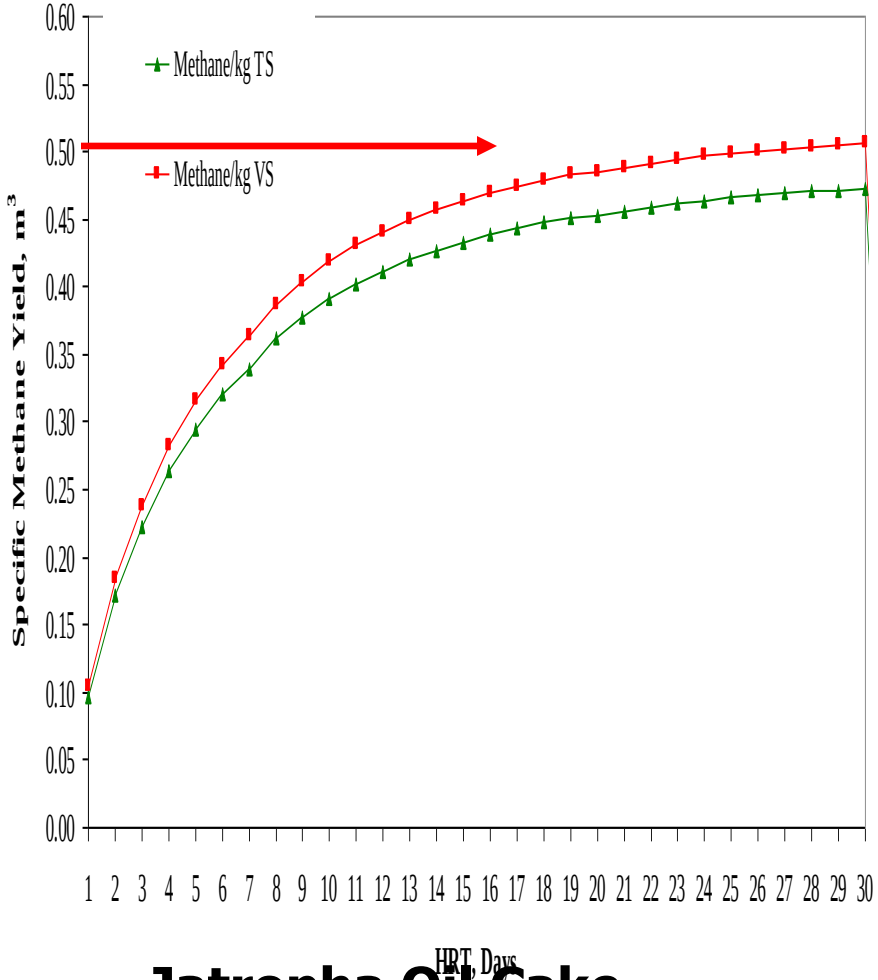
Range of ambient temperature variation 30.7 to 36.6 °C



Pongamia Oil Cake

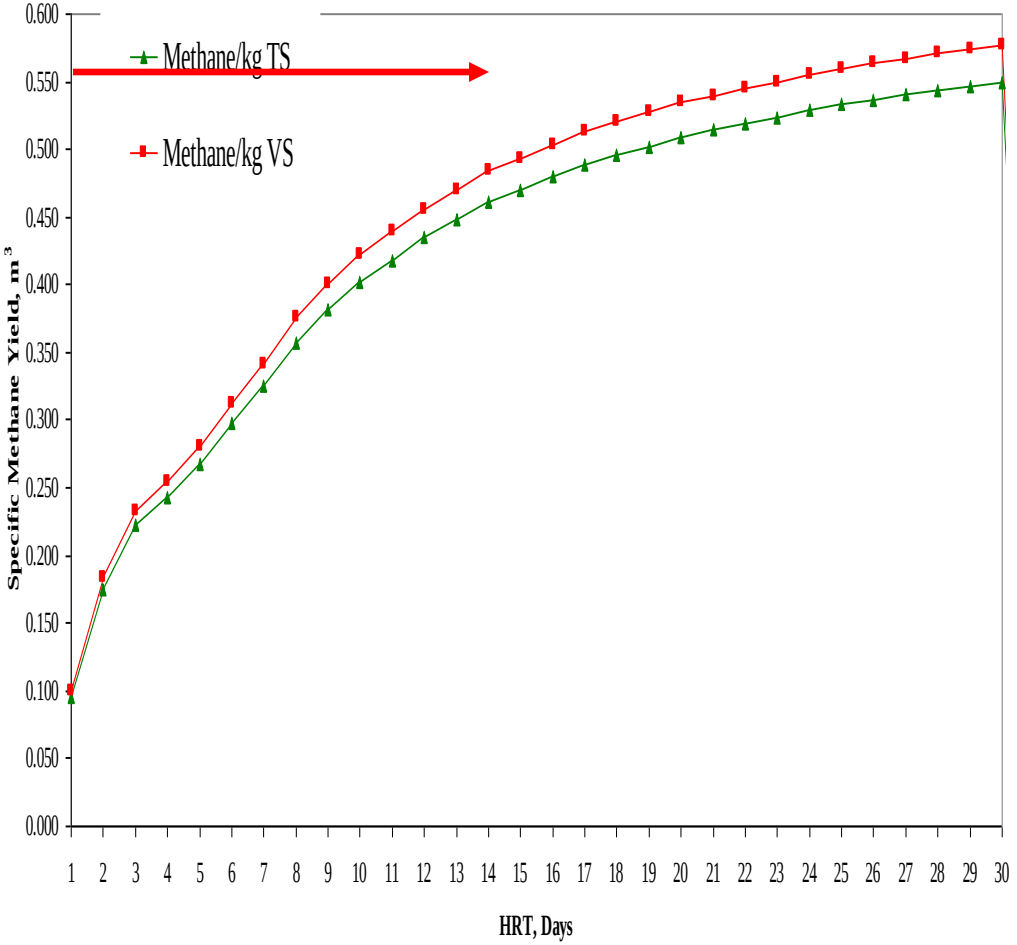
KC [3.5 DR, 0 % CD]

Specific Methane Yield



Jatropha Oil Cake

JC [4.0 DR, 0 % CD]



Pongamia Oil Cake

KC [3.5 DR, 0 % CD]

Specific Methane Yield: Phase II & III

Treatments	Phase- II		Phase- III	
	m^3/kg TS	m^3/kg VS	m^3/kg TS	m^3/kg VS
CD [1.0 DR]	0.055	0.070	NA	NA
Jatropha oil cake substrates				
JC [4.0 DR, 0 % CD]	0.172	0.184	0.394	0.422
JC [4.0 DR, 50 % CD]	0.152	0.167	NA	NA
Pongamia oil cake substrates				
PC [3.5 DR, 0 % CD]	0.203	0.213	0.427	0.448
PC [3.5 DR, 50 % CD]	0.181	0.196	NA	NA

The maximum and minimum values of methane and carbon dioxide were found to vary from 68.0 to 60.7 % and 32.7 to 29.0 % respectively. The average values of methane and carbon dioxide contents over 30 day of HRT were found as 66.6 % and 31.3 % respectively.

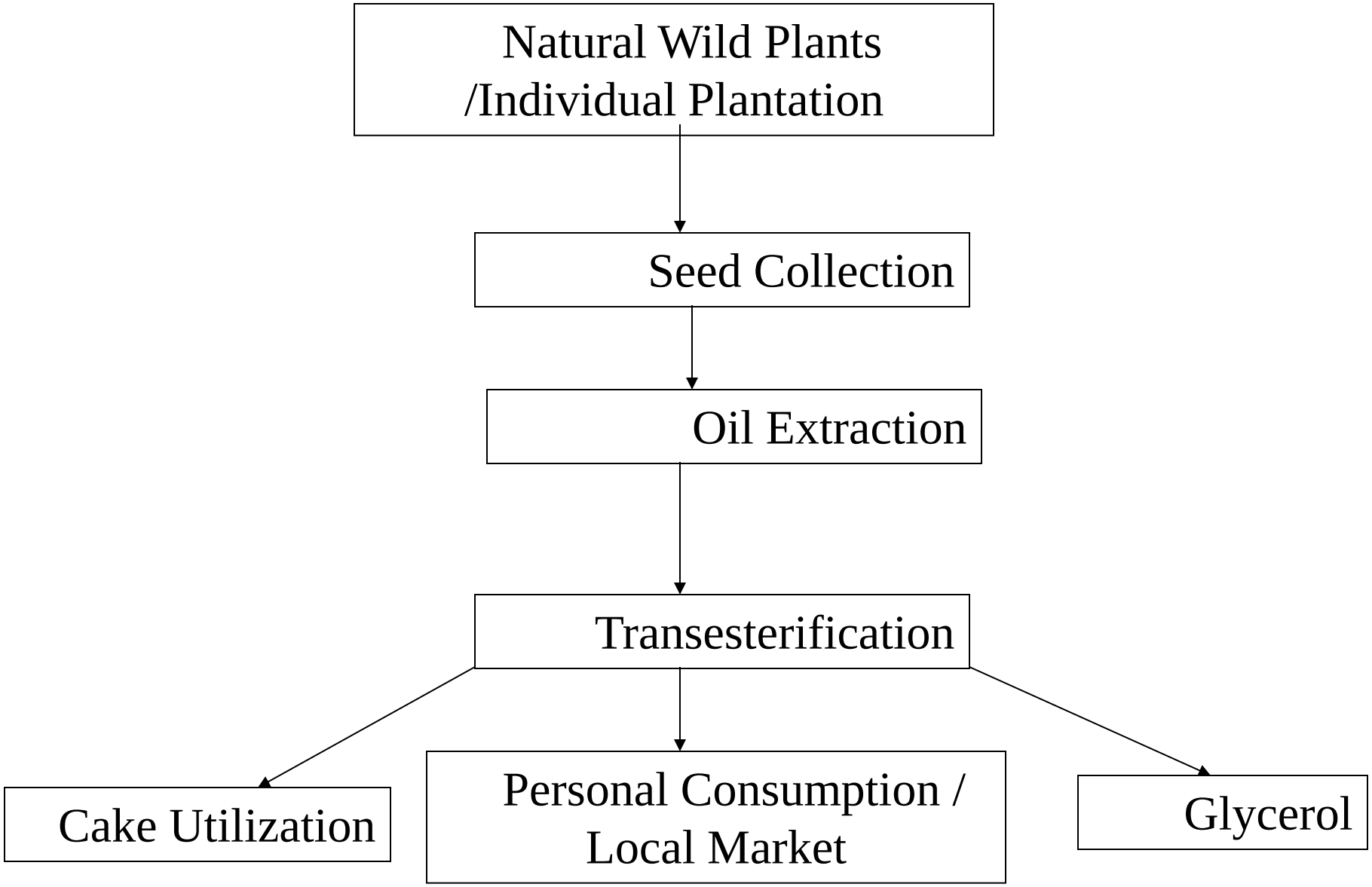
- Characterization of jatropha and pongamia oil cakes show that these oil cake have more than six times higher volatile solids content than that of cattle dung.

- Non-volatile solids content in jatropha oil cake is marginally higher than the pongamia oil cake.
- C/N ratio found to range from 8 to 12 for these two oil cakes which is comparatively too low in regard of cattle dung.

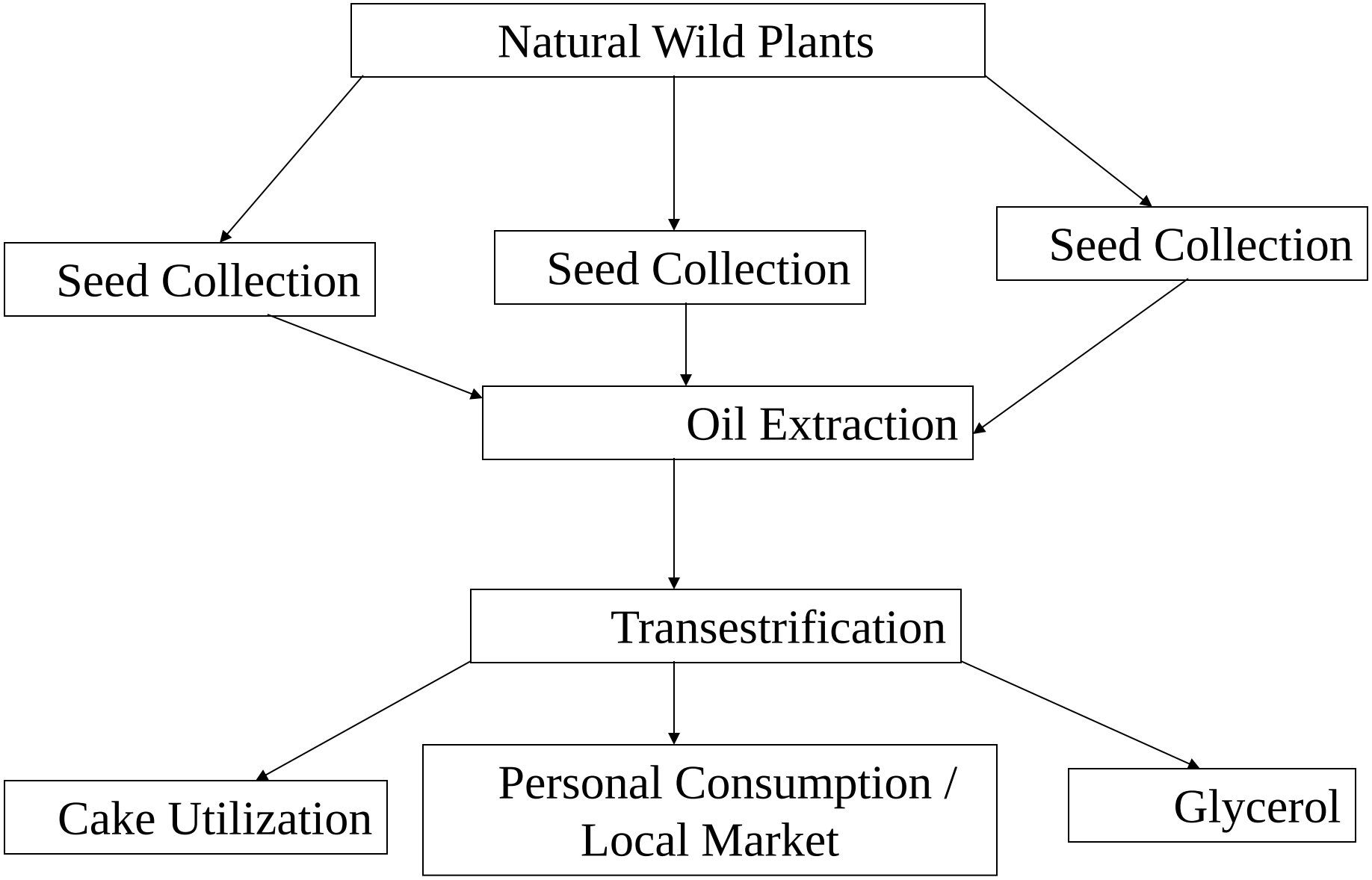
- Dilution ratio of 3:1 to 4:1(water: oil cake) is essential for maintaining proper flowabilty of biogas spent slurry inside the digester of biogas plant.

- It is necessary to develop a special inoculum for efficient digestion of jatropha and pongamia oil seed cakes substrates as the biomethanation process is inhibited if the substrates are seeded with normal inoculum.

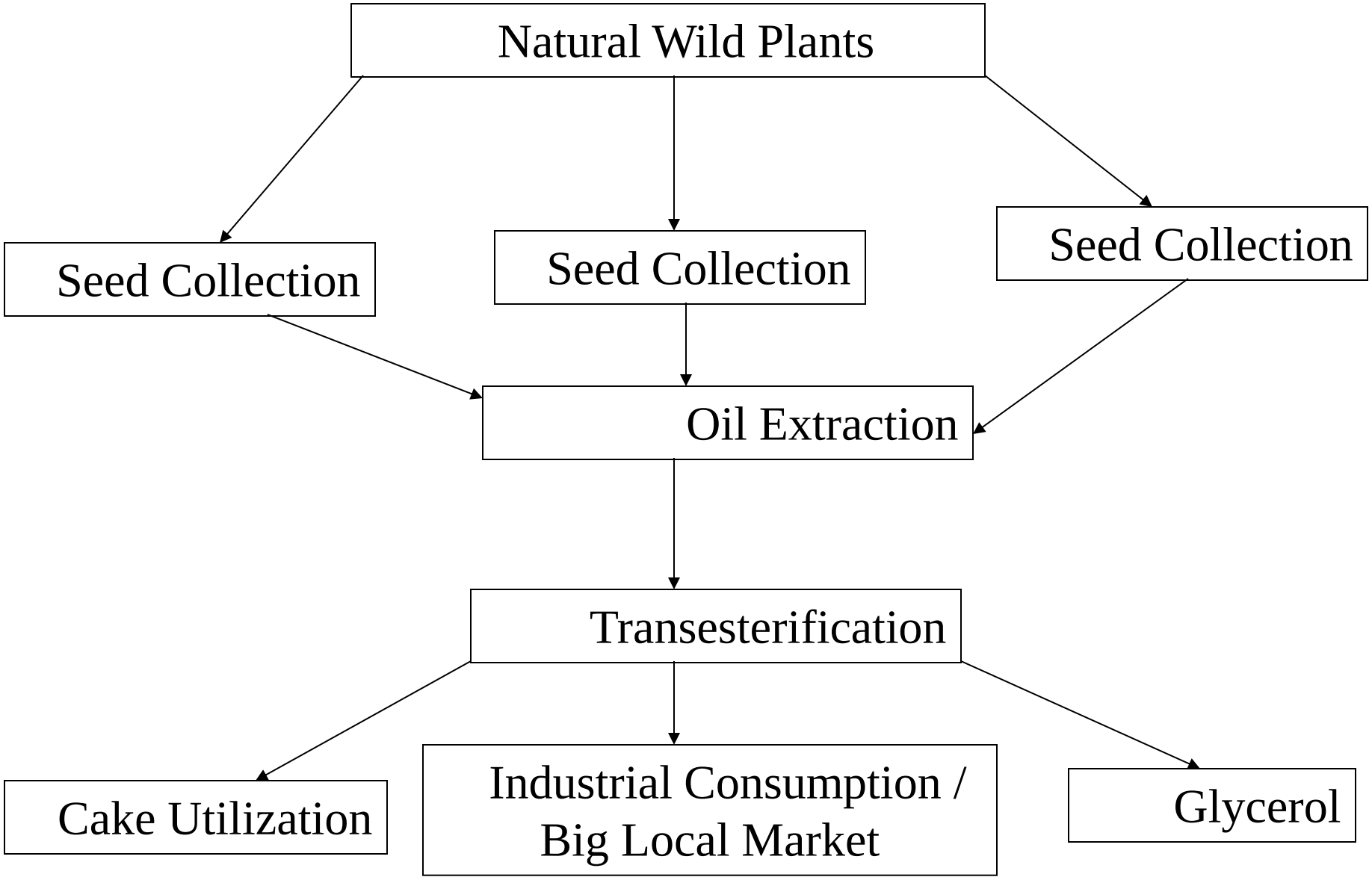
Micro Model


Natural Wild Plants
/Individual Plantation
Seed Collection
Oil Extraction
Transesterification
Cake Utilization
Personal Consumption /
Local Market
Glycerol

Simple Chain



Mini Model


Natural Wild Plants
Seed Collection
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Industrial Consumption / Big Local Market
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Let's work in coordination to Cultivation clean and green energy ....

THANK YOU

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