Developments in construction and commercial use of gasifiers for renewable energy from fibrous crop residues in Cambodia

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Introduction

- 85% population are farmers based on rice, animal, vegetable, crops, fish
- GDP 571$/year, 2007
- 35% under poverty line

Access to electricity

- 20% access to electricity (0.35-0.90$/kwh)
- 2020, 100% access to electricity including battery utilization
- 2030, 70% access to grid electricity (hydro, biomass, solar)

Opportunities for renewable energy

- Suitable waste products available (Agricultural byproducts and other sources of biomass)
- Biomass utilization is promoted in Cambodia
- Saving expenditure on fuel
- Contributing to climate change mitigation

Flow diagram for integrated use of cassava for food, feed and fuel

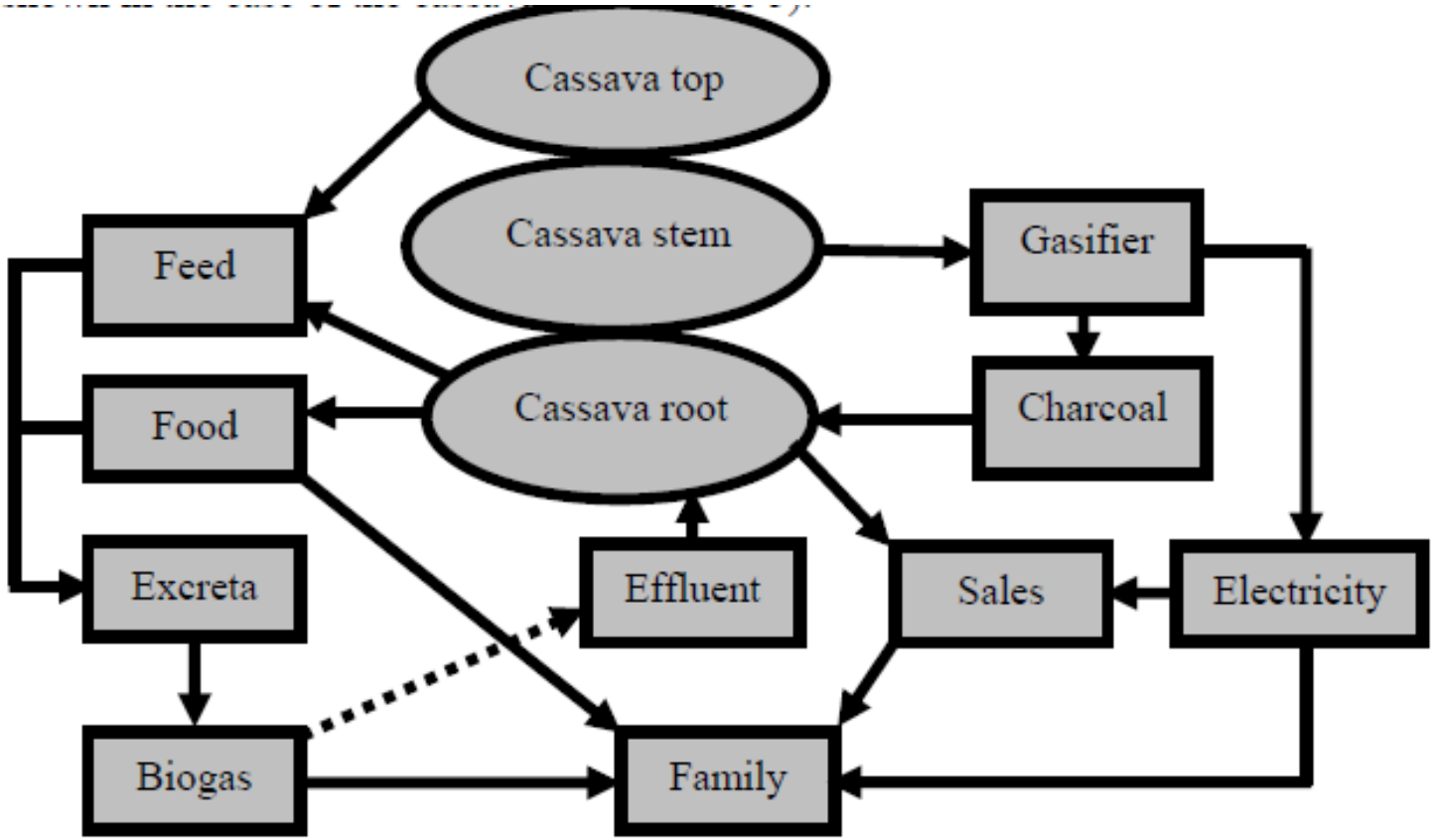


Figure 5: Flow diagram for the integrated use of the cassava crop for human food, animal feed and energy

$$C_6H_{12}O_6 + H_2O + O_2 \rightarrow CO + H_2 + CO_2$$

Ligno-cellulose + water + air → carbon monoxide + hydrogen + carbon dioxide

$$C + CO_2\uparrow \rightleftharpoons 2\,CO\uparrow$$

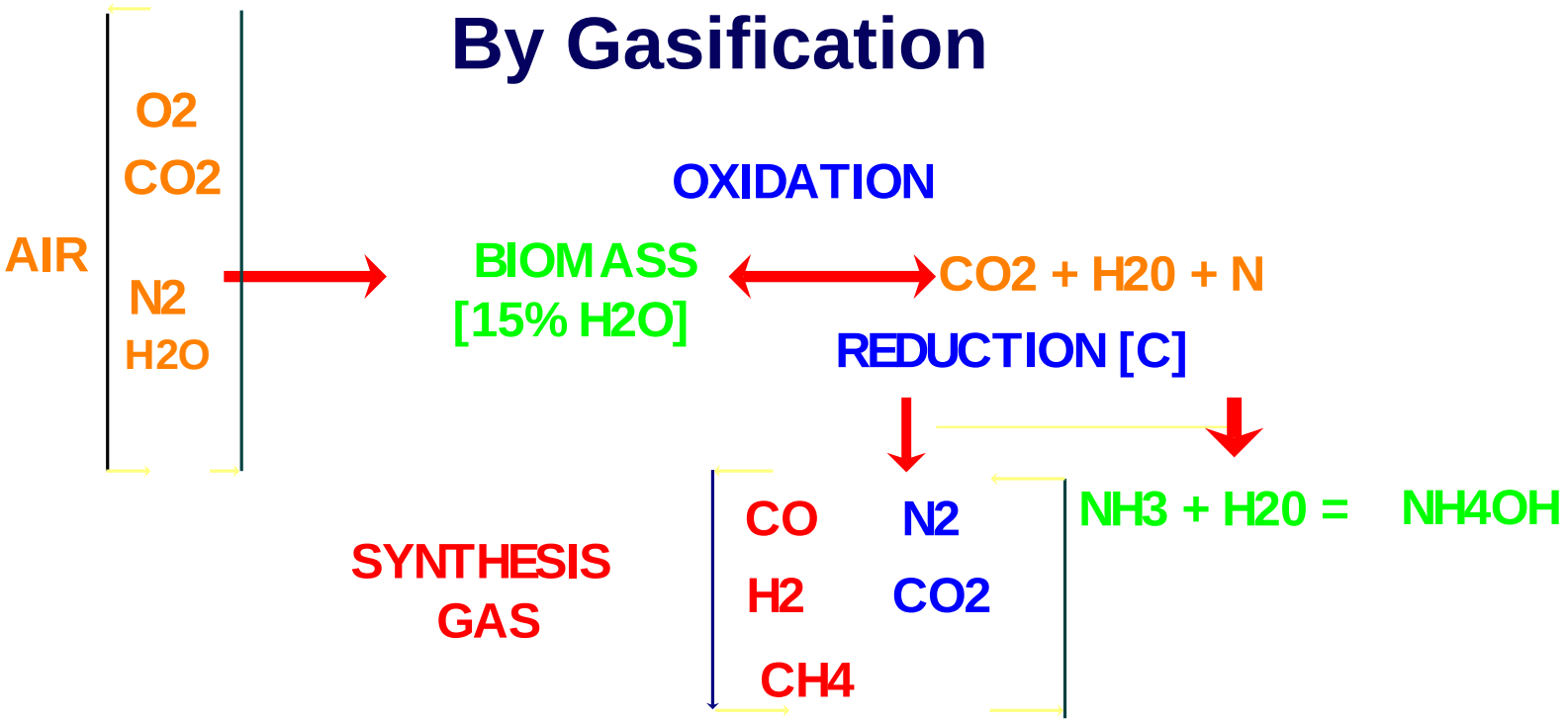
$$C + H_2O\uparrow \rightleftharpoons CO\uparrow + H_2\uparrow$$

$$C + H_2\uparrow \rightleftharpoons CH_4\uparrow$$

Figure 4: The chemical reactions occurring inside the gasifier

Biomass as source of fuel and chemical substrates

By Gasification



3kg Biomass --> 7m3 synthesis gas = 1 litre diesel oil

1.2 kg Biomass DM = 1 KWh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The four treatments were different sources of fibrous biomass:

- Cassava woody stem (CWS) [Figure 1]
- Mulberry stem (MS) [Figure 3]
- Branches from the ornamental tree *Cassia stamea* (CS) [Figure 5]
- Coconut husk (CH) [Figure 7]

Photo 2a: Chopped dried stems of cassava

Photo 2b: The cassava crop ready for harvesting of the roots

Photo 3a: Chopped dried stems of mulberry

Photo 3b: Mulberry grown primarily as a forage for feeding to goats

Photo 5a: Chopped husks of coconut

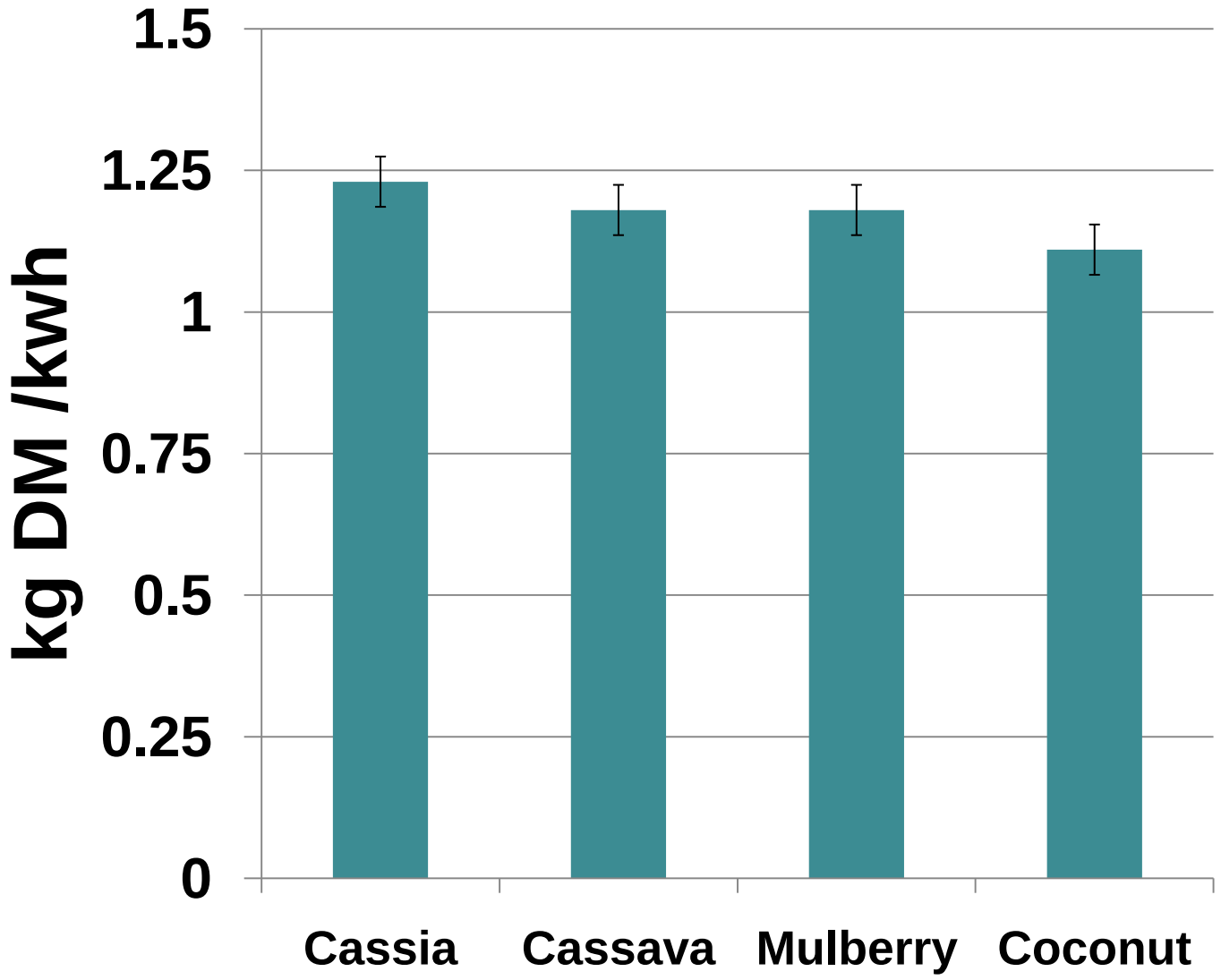
Photo 5b: Coconut fruit cultivation

Table 1: Mean values for gasifier characteristics using coconut shells-husks, cassava stems, mulberry stems and branches of *Cassia stamea* as feedstock

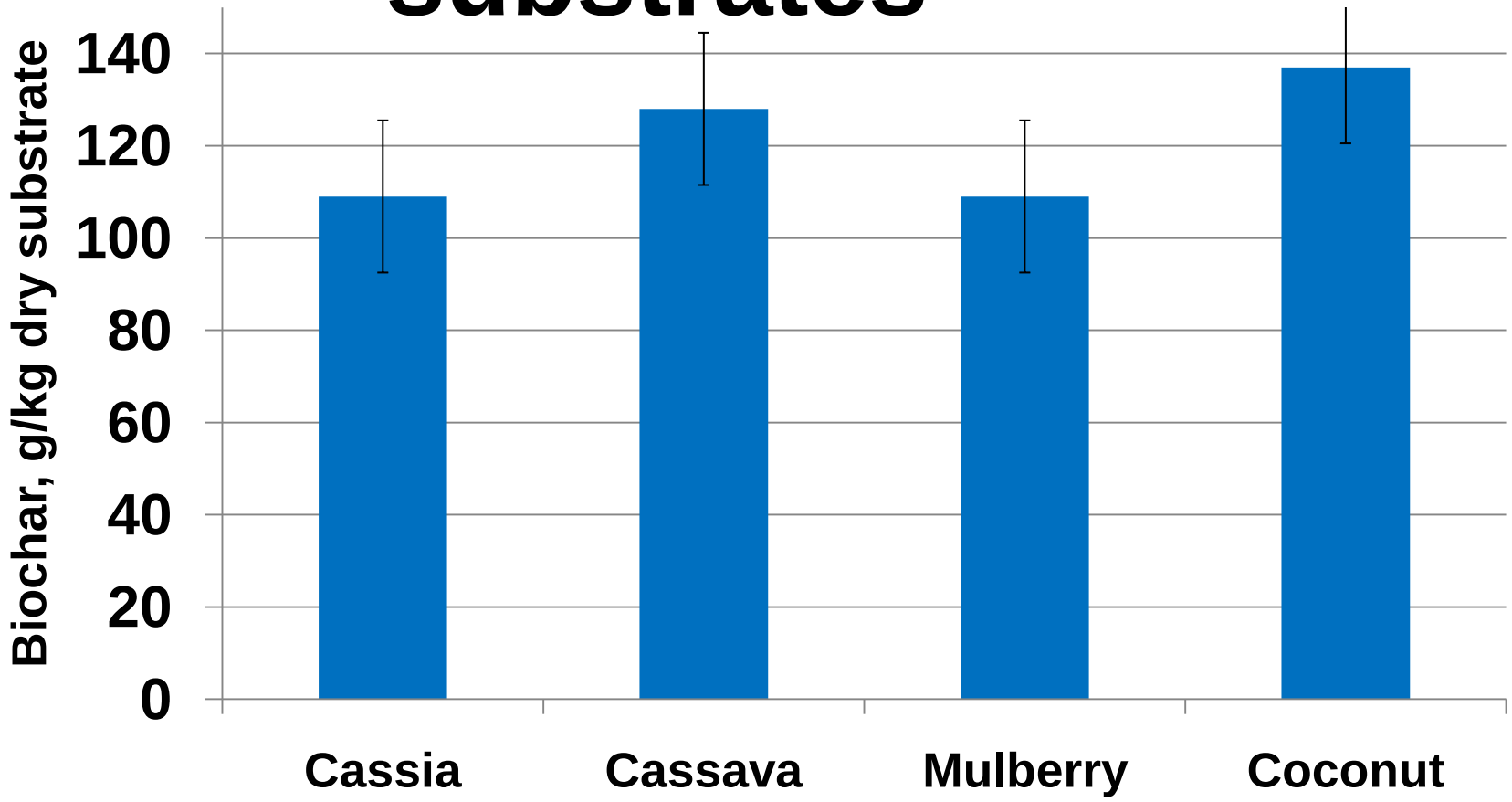
	Cassia	Cassava	Mulberry	Coconut	SEM	Prob.
Biomass DM, kg/test						
Initial	36.7	32.3	33.7	34.4	1.3	0.21
Final	4.93	1.90	0.00	3.07	2.19	0.49
Consumption	36.9	35.1	40.0	36.4	2.9	0.69
Moisture, %	14.0	13.3	15.7	14.0	1.4	0.69
Density, g/litre	348a	97.0c	273b	128c	10.4	0.001
Duration, hr	3.91	3.67	4.09	4.02	0.328	0.810
Output, kwh	27.4	25.7	28.7	28.2	2.29	0.810
Conversion*	1.23	1.18	1.18	1.11	0.044	0.42
Yield, kwh/kg DM biomass	0.813	0.848	0.850	0.903	0.032	0.400
Efficiency#	0.187	0.204	0.204	0.217	0.0082	0.170
Char, g/kg biomass DM	109	128	109	137	16.5	0.58

** kg dry biomass/kwh; # Assumes 15 MJ/kg biomass DM and 3.6 MJ/kwh of electricity*
abc Means in the same row without common letter are different at P<0.95

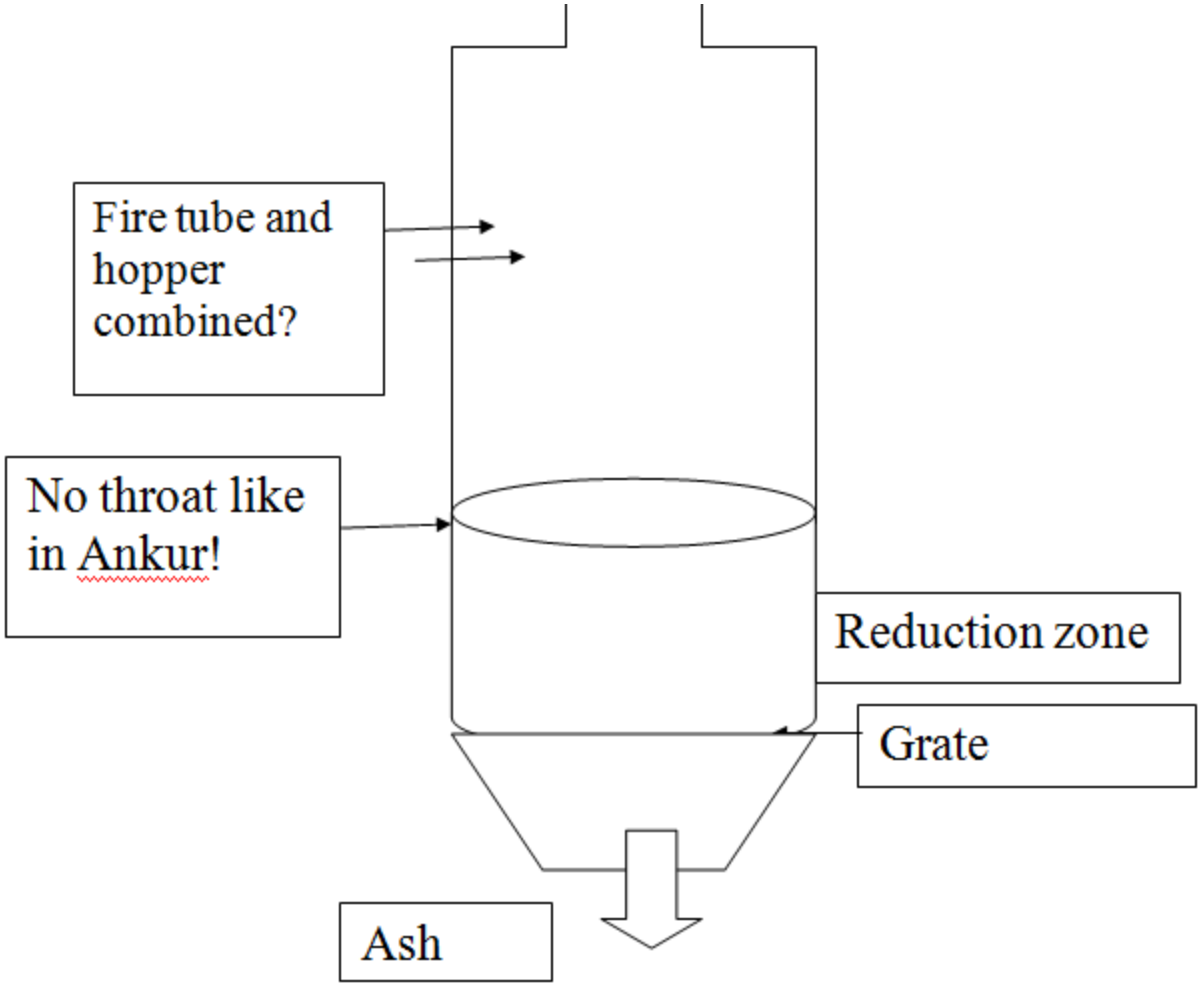
Conversion of dry biomass to electricity with different substrates



Conversion of dry biomass to biochar with different substrates

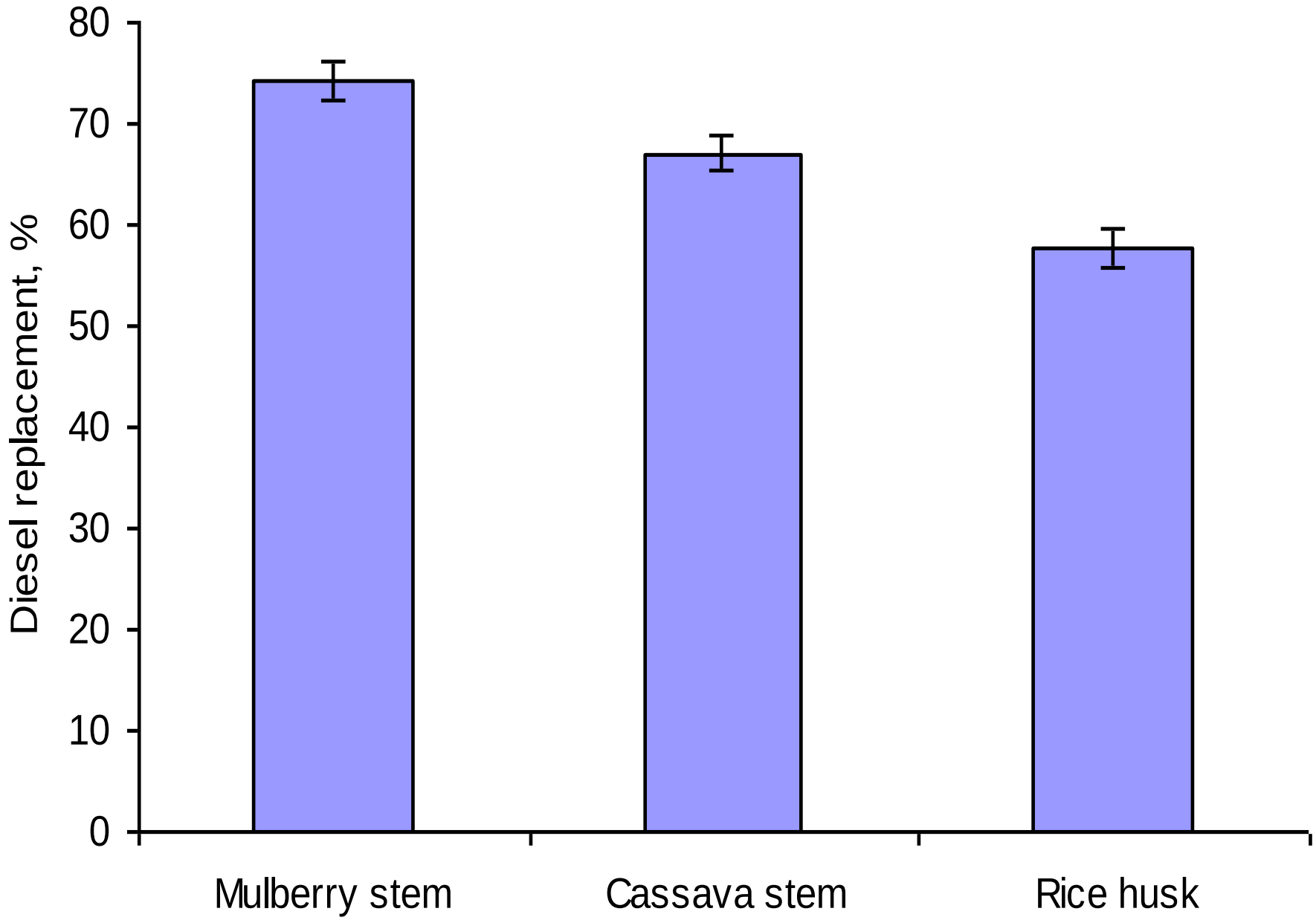


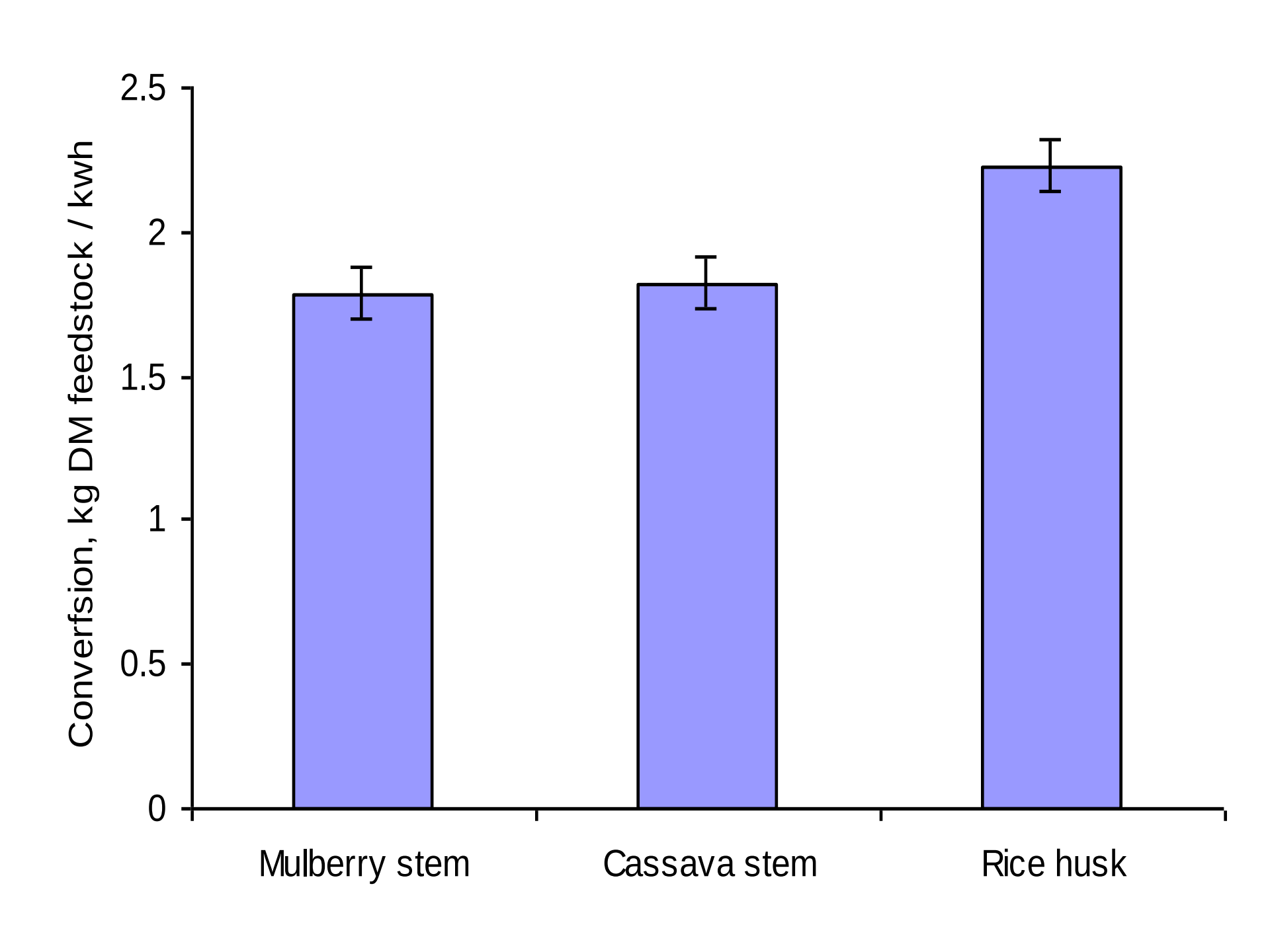
Local construction of gasifier in Cambodia

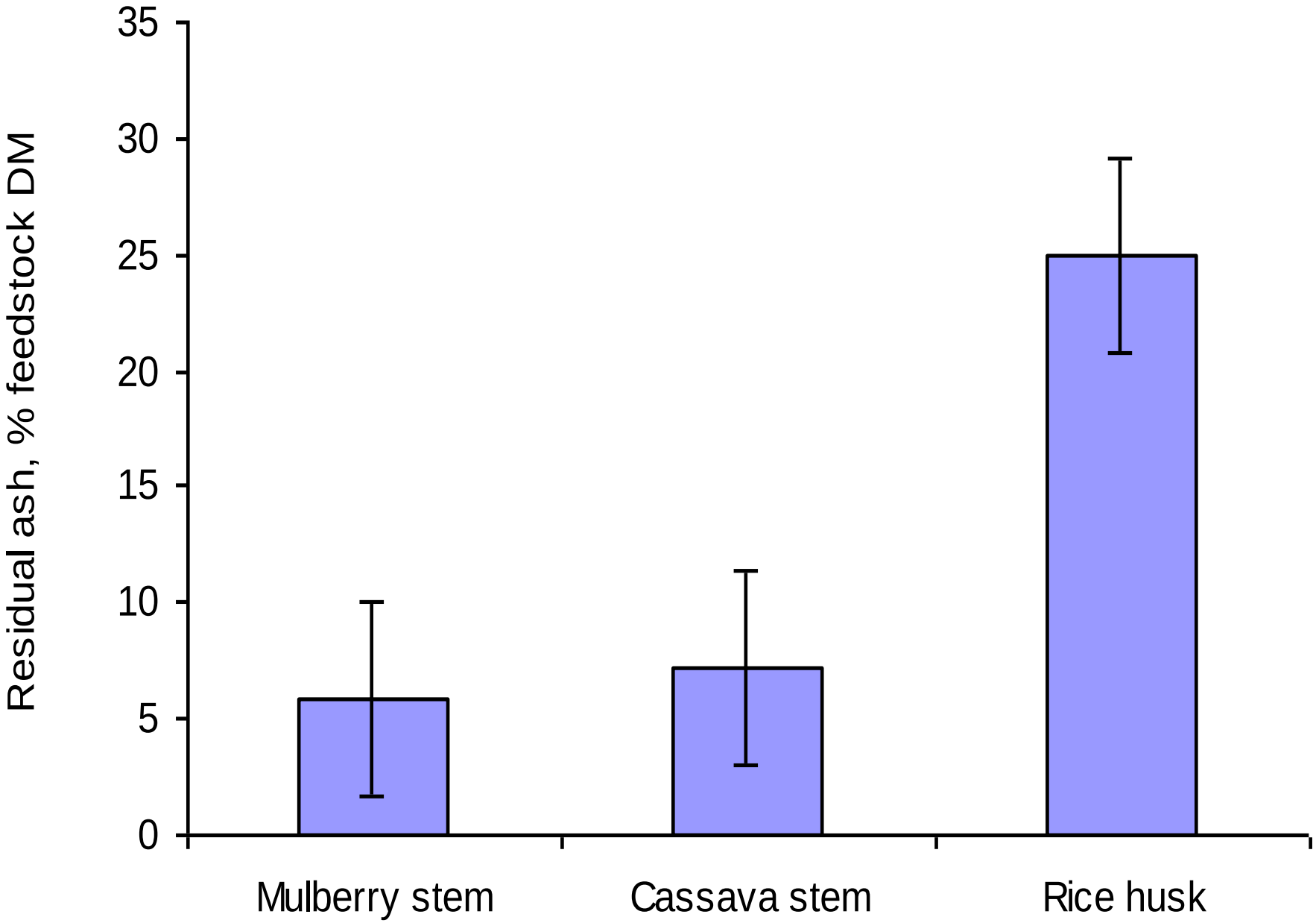


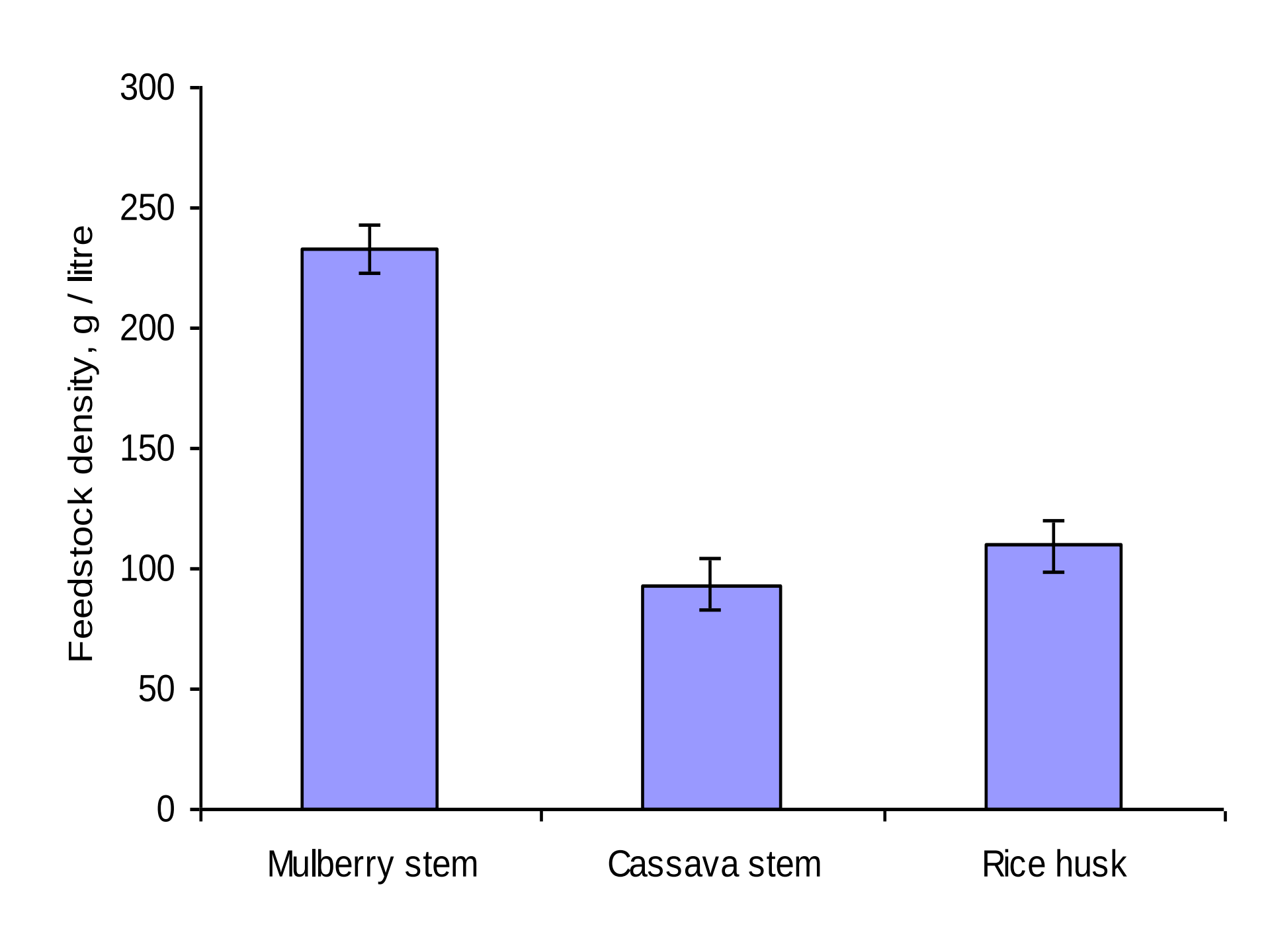
Three feedstocks using diesel engine in dual-fuel mode

- Mulberry stems
- Cassava stems
- Rice husks


Diesel replacement, %
80
70
60
50
40
30
20
10
0
Mulberry stem
Cassava stem
Rice husk


Converfsion, kg DM feedstock / kwh
2.5
2
1.5
1
0.5
0
Mulberry stem
Cassava stem
Rice husk


Residual ash, % feedstock DM
35
30
25
20
15
10
5
0
Mulberry stem
Cassava stem
Rice husk


300
250
200
150
100
50
0
Feedstock density, g / litre
Mulberry stem
Cassava stem
Rice husk

Gasifier Development in Cambodia

- 1 built by farmer in Battambang province
- 3 rice husk gasifier imported from Malaysia (electricity in rice mill)
- Local construction of gasifiers in Banteay Meanchey province, and Phnom Penh city (3 a month)
  - Capacity 100 to 250 KVA

Conclusion

- Fibrous woody biomass and agricultural by-product are efficient and effective source of feedstock in gasification
- Operating with diesel engines in dual-fuel mode can save much money spending on diesel
- Local construction of gasifiers directed at saving fuel in rice mills

Thank you very much for attention