THE BATCH CARBONISATION OF COCONUT SHELL WITH WASTE HEAT RECOVERY

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1. INTRODUCTION

Technology developed by ODNRI for waste heat recovery during carbonisation of coconut shell has been succesfully adopted by the desiccated coconut industry in Sri Lanka. The initial development and design of the unit has been described elsewhere (Breag et al, 1984) and also the broader issues of the technology in relation to the Sri Lankan coconut industry have been examined (Breag et al. 1985). In the five year period since the first prototype trial was carried out, the Coconut Development Authority, Sri Lanka assisted by ODNRI, has disserninated knowledge of the technology and promoted manufacture of the equipment. At this time there are 15 units installed of the basic 8M3 capacity system and a prototype $16m^3$ capacity unit has been commissioned recently. The units are manufactured by a number of local companies and are now being supplied to mill owners on a purely commercial basis. This paper provides a cost benefit financial analysis for the standard $8m^3$ capacity unit using the data acquired from accumulated,operating experience.

2. PRODUCT DESCRIPTION

This unit enables the gases evolved during the carbonisation of coconut shell to be burnt. The heat generated by the combustion of the gases in a furnace/heat exchanger system can be used in associated processes in the coconut industry - such as drying, heating and sterilisation of coconut kernel and its products. It can be used to supply process heat in a wide range of other industries, but the viability in these cases will be site specific.

In addition it produces good quality charcoal suitable for the manufacture of gas phase activated carbon for which there is a great demand.

A small quantity of tar and pyroligneous acid is also produced; these may find application as timber preservatives.

3. RAW MATERIAL

Coconut shell from the desiccated and copra industries are used to produce both good quality charcoal and process heat.

4. PRODUCTION PROCESS

The process is basically the batch carbonisation of coconut shell in a specially-designed kiln. The gases evolved during the process are burnt in a furnace/heat exchanger systern to produce heat for processing.

In comparison with traditional charcoal-making, this process has the advantages of (a) virtually eliminating the obnoxious fumes and smoke evolved during carbonisation; (b) producing a higher yield of better quality charcoal; (c) enabling heat normally lost to the surrounding - approximately 50% of the gross heat content of the feedstock - to be used as process heat.

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5. EQUIPMENT

The unit is a vertical cylindrical metal kiln standing on three legs, 2 metres above a concrete plinth. The kiln is connected by a 20 cm diameter pipe to the furnace/heat exchanger system. The "kiln gases" and air are sucked into the furnace by a 4.5 kw fan located in the flue and the resultant gases of combustion are exhausted to the atmosphere via a heat exchanger and chimney. The exhaust gases are virtually smoke free.

6. PRODUCTION CAPACITY

The unit carbonises 1.5 tonnes of coconut shells in 10 to 11 hours and produces 0.4 - 0.5 tonnes of coconut shell charcoal. The heat recovered per run from the unit amounts to 9.75 GJ which is equivalent to approximately 230 litres of fuel oil. The complete cycle - loading carbonisation, cooling discharging and recharging the kiln - takes 24 hours. Based on 200 days of operation, the production capacity of the unit is approximately 100 tonnes of charcoal per year using 340 tonnes of cocunut shell feedstock.

7. ANNUAL OPERATING COSTS (200 OPERATING DAYS)

7.1	Raw materials		
	The coconut shells are given a value of		
	$ 18/tonne, 340 tonnes required per year	$	6,120
7.2	Energy and Water		
	Daily rate - 2.9 kw x 12 hrs @ $ 0.067/kwh = 33 kwh/day	$	466
	Annual electricity consumption is 6600 kwh		
	Water consumption is negligible		
7.3	Personnel		
	l Supervisor (30% of working time) @ $ l /day	$	200
	2 Skilled workers (full-time kiln operators) @ $ 2/day/person	$	800
	5 Unskilled workers @ $ 1.3 /day/person.	$	1.300
	1 Clerk (20% of time) @ $ l/day	$	200
	Social benefits (20% of total wages)	$	500
		$	3,000
7.4	Loading and Transporl		
	Transport of charcoal to port		
	(approx 80 miles / 128 km)	$	450
7.5	Brokerage Costs		
	2% of sales value plus l % sales tax		
	(selling charcoal at $ 100/tonne)	$	300
7.6	Maintenance and repairs		
	The annual costs of maintenance and repairs		
	are estimated at 10% of the costs of installed equipment.	$	650
7.7	Contingency Fund		
	An amount of 2.5% of production costs is		
	budgetted for contingencies.	$	279

7.8 Overheads
These would include 10% for depreciation of installed equipment and 14% interest on capital borrowed over 5 years, but are not included in cash flow.

7.9 Summary of production costs

• Raw materials		$	6,120
• Energy		$	466
• Personnel		$	3,000
• Transport & Brokerage		$	850
• Maintenance		$	650
*Insurance		$	65
*Contingency Fund		$	279
	Total	$	11,430

NB Figures based on Sri Lankan rupees converted to US dollars @ Rs 30 per US $ l.

8. Investments

8.1 Fixed Investment

a) Land 110 m^2		$	40
b) Building - 2 storage sheds 50 m^2 x $ 100/m^2 (Rs 50/ft^2)		$	1,500
c) Equipment (produced locally)	$	6,500	
d) Commissioning		$	300
	Total	$	8,340

8.2 Working Capital
Taken as two months of the cost production $ 1,850

8.3 Financing needs

• Fixed investments		$	8,340
• Working Capital		$	1,850
	Total	$	10,190

8.4 Residual value
For the 10th year of production this value is estimated as follows:

• Land		$	40
• Buildings		$	750
• Equipment		$	900
	Total	$	1,690

It is assumed that the working capital will be returned in its entirety.

9. REVENUE

8.1 Sales of charcoal $ 10,000
100 tonnes/annum at an av. price $ 100 tonne

10. COST SAVINGS

In deriving cost savings from introduction of the WHU it is necessary to make comparison with current practice. Existing fuelling can be by either oil or wood and the heat transfer mechanism can be either direct (without a heat exchanger) or indirect (with a heat exchanger). There is an energy loss assoclated with indirect beating; for oil and gas fuelling the energy efficiency is 80% whereas for wood fuelling it is 55%.

The cost savings through using the WHU have been evaluated for three alternative cases as follows:-

CASE 1. (a) Direct beating using gas from the WHU versus direct beating using oil and
(b) Indirect beating using gas from the WHU versus indirect beating using oil.

Both (a) and (b) result in a fuel oil saving of 230 litres/day. Therefore, the annual cost saving = 230 litres at $0.625 x 200 = $12,100

CASE II. Direct beating using gas from the WHU versus indirect beating using oil.

In this case the fuel oil saving = 230/0.8 litres/day = 287 litres/day. Therefore, the annual cost saving = 287 litres at $0.263 x 200 = $15,100

CASE III. Indirect beating using gas from the WHU versus indirect beating using wood.

In this case the heat supplied from the WHU of 9.75 GJ is equivalent to a wood fuel saving of 683 kgm/day (ie based on wood heat content of 20,750 kJ/kg then equivalent weight of

$$\text{Wood} = 9.75 \times 10^6 \times \frac{0.08}{0.55} \times \frac{1}{20{,}750} = 683 \text{ kg})$$

Therefore, the annual cost saving = 683 kg at $0.0325 x 200 = $4,400

11. RESULTS OF NPV ANALYSIS

In the analysis shown in Table 1 the value of fuel saved is included as a benefit. In the two cases where waste heat is substituted for oil, the savings are so great that a producer could afford to give the charcoal, away. Thus, the price of charcoal has no bearing on the investment. Where waste heat is substituted for woodfuel, the charcoal price is more critical, and at a 20% interest rate, the minimum price would be S 94/tonne.

The financial rate of return calculated for each of the three cases shows that ail three options are financially viable. The internal rates of return of cases l and 11 where oil heating is replaced have rates of return of 101% and 128% respectively. The payback period would be about 16 months and 12 months respectively. Installing a WHU to replace a wood-fired indirect systern is much less favourable and the financial rate of return of case III is only 27%. In this case the payback period would be around three years and nine months. The reason for this surprisingly low rate of return is the very low price of fuelwood in Sri Lanka, which does not reflect its true cost (ie the cost of producing an equivalent amount of wood). In other countries, where wood may be scarcer and its price higher, more fully taking account of its economic cost, the rate of return could be much more favourable. Ail cases assurne that the WHU operates at 75% capacity (150 rather than 200 days) during the first year.

12. REFERENCES

* Breag G R, Harker A P, Paddon A R, and Robinson A P (1984). The design, construction and operation of a unit for the carbonisation of coconut shell with recovery of waste heat. TDRI Report G182.

* Breag G R, Harker A P and Smith A (1985). A Case study of the TDRI carbonisation and waste heat recovery unit's techno-economic evaluation of the use of a prototype unit for the carbonisation of coconut shell in Sri Lanka. Tropical Science 25,165-167.

Table 1 Brake-even selling price of charcoal and financial rate of return

Year	Invest	Working Capital	Operate Costs	Total Cost	Svgs I	Svgs II	Svgs III	TC-SI	TC-SII	TC-SIII	Annual Prod h (t)	Sales $100/t	Cash Flow II
0	8,340			8,340				8,340	8,340	8,340			-8,340
1		1,850	8,573	10,423	9,075	11,325	3,300	1,348	-902	7,123	75	7,500	6,152
2			11,430	11,430	12,100	15,100	4,400	-670	-3,670	7,030	100	10,000	10,670
3			11,430	11,430	12,100	15,100	4,400	-670	-3,670	7,030	100	10,000	10,670
4			11,430	11,430	12,100	15,100	4,400	-670	-3,670	7,030	100	10,000	10,670
5			11,430	11,430	12,100	15,100	4,400	-670	-3,670	7,030	100	10,000	10,670
6			11,430	11,430	12,100	15,100	4,400	-670	-3,670	7,030	100	10,000	10,670
7			11,430	11,430	12,100	15,100	4,400	-670	-3,670	7,030	100	10,000	10,670
8			11,430	11,430	12,100	15,100	4,400	-670	-3,670	7,030	100	10,000	10,670
9			11,430	11,430	12,100	15,100	4,400	-670	-3,670	7,030	100	10,000	10,670
10	-1,690	-1,850	11,430	7,890	12,100	15,100	4,400	-4,210	-7,210	3,490	100	10,000	14,210
				Discount Rate:				5,857	-8,547	42,838	480.1	NVP:	42,157
			15%					6,641	-5,311	37,319	398.4	NVP:	33,200
					20%			7,564	-1,134	29,888	289.9	NVP:	21,428
					30%								
					Min selling price/tone ($)		15%	12.2	-17.8	89.2		IRR:	100.7%
							20%	16.7	-13.3	93.7			
							30%	26.1	-3.9	103.1			