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Activated carbon production from wastes: profitability index and product cost reduction method

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ABSTRACT

A previous paper on developing a national capability for the manufacture of activated carbon from agricultural waste by the same authors was considered. In the said paper, the process flow diagram for the manufacture of Granular Activated Carbon from three agricultural wastes namely coconut shell, oil-palm shells and sugarcane bagasse was provided and the plant's economic analysis done. The objectives of this study were to investigate selling price reducing options and profitability of the investment discussed. In the study, the profitability indexes for the overall plant projects for the three plants were found. The effect of equipment cost reduction on the total productive cost was also examined. For the steam activation of coconut shell, successive reduction by 10% in the overall equipment cost was found reduce the corresponding Product cost geometrically by values ranging from 2.44-1.22% for ten successive reductions. The profitability index was between 0.057 and 4.07% respectively for the 1st to the 11th year. The steam activation of sugarcane bagasse was different, successive reduction by 10% in the overall equipment cost reduce the corresponding Product cost also geometrically by values ranging from 2.85-3.69% (increasing with each reduction) also for 10 successive reductions. The profitability index was between 0.09 and 3.7% respectively for the 1st to the 11th year. And for the phosphoric activation of oil-palm shell, successive reduction by 10% in the overall equipment cost was found reduce the corresponding Product cost geometrically by values ranging from 4.58-2.88% (decreasing with each reduction as in steam activation of coconut shells). The profitability index was between -1.08 and 2.12% respectively for the 1st to the 11th year. In addition, an excel software to simulate the economic analysis previously done and output the key costs after the simulation.

Keyword:-Granular Activated carbon, coconut shell, oil-palm shell, sugarcane bagasse, profitability Index, Total product Cost, Total Equipment cost.

INTRODUCTION

Profitability is simply the measure of the amount of profit that can be obtained form a given situation (Holland *et al*, 1973). The profit goal of a company is to maximise income above the cost of the capital which must be invested to generate the income (Baasel, 1976). if the goal were to maximize profit, then any investment would be accepted which would give profit no matter how low the return or how great the cost. (Peters *et al*, 1958).

For a plant like the activated plant developed before, it is necessary to know how much profit can be obtained versus the cost involved. This will help investors in making decision as to where and how best to invest. In a plant like the activated carbon plant where the cost are relatively high, the rate of return, rather than the total amount of profit is a more important profitability factor in determining its suitability for investment.

Four methods are generally acceptable for profitability evaluation namely:

1. Rate of return on investment
2. Discounted cash flow based on full-life performance
3. Net present worth
4. Capitalised costs
5. Payout period.

The method used for his study is the rate of return on investment based on discounted cash flow but with the use of continuous interest compounding. The choice of this method is based on its taking into account the time value of money and is based on the amount on investment that in unreturned at the end of each year during the estimated life of the project (Park, *et al*, 1973). The rate of return by this method is equivalent to the maximum interest rate at which money can be borrowed to finance the project under condition where the net cash flow to the project over its useful life would be sufficient to pay all principal and interest accumulated on the outstanding principal. (Peters *et al*, 1958). This maximum interest rate is known as the discounted cash flow rate of return or profitability index.

Chilton Ng, Wayne Marshall, Ramu M. Rao, Rishipal R. Bansode, Jack N. Losso and Ralph J. Portier's "Granular Activated Carbons from Agricultural By-products: Process Description and Estimated Cost of Production" described a process for producing activated carbon from three agricultural process namely; steam activation of sugarcane bagasse, steam activation of pecan shells and phosphoric acid activation of pecan shells.

Odesola I.F and Daramola O.N developed a national capability for the manufacture of activation carbon from three agricultural wastes namely, coconut shells, oil-palm shells and sugarcane bagasse. They described the steam activation of coconut shell, steam activation of sugarcane of sugarcane bagasse, and phosphoric activation of oil-palm shells in which they also did the economic analysis of the process.

METHODS

Assumptions: The assumptions made for the analysis are as follows:

I. The project life is taken as the equipment life and is 11 years as given by Peter and Timmerrhaus in their book, Plant Design and Economics for Chemical Engineers for chemical processing equipment.
II. The annual depreciation used is the one evaluated in the considered project.
III. The salvage value of the combined plant equipment is taken as the 10% of the purchased equipment cost delivered.

a. Profitability Index

Peter and Timmerrhaus in their book used the rate of return on investment based on discounted cash flow with the use of continuous interest compounding method to compute the profitability index of a project (table 3, page 320). The method was reapplied for the plant but modified to suit the current situation. In the method, the cash position given was modified for the case of the project as:

Cash position at time n = present value of cash flow to project – present value of fixed capital investment + present value of terminal fixed capital investment, working capital investment and salvage value based on interest compounded continuously for n years – present value of working capital investment.

This can be written as:

Cash position at time n = (annual constant cash flow to project)(e^{rn}-1)/1 - fixed capital investment(e^{rn}) – working capital investment(e^{rn}) + (terminal fixed capital investment, working capital investment and salvage value)(1/ e^{rn}) ....equation 1

The values of the parameters needed to solve have already been calculated in the economic analysis of the plants in the previous work. This are excerpted given in the table below:

1. Steam activation of coconut shell:

Fixed capital investment	N727,080,590.40
Working capital investment	N109,062,088.60
Annual depreciation	N72,708,059.04
Annual qty. Produced	N1,500,000
Profit/unit	N40.255
Total annual profit	N60,383,050.24

2. Steam activation of sugarcane bagasse

Fixed capital investment	N809,906,578.00
Working capital investment	N121,485,986.70
Annual depreciation	N80,990,657.80
Annual qty. Produced	N582,000.00
Profit/unit	N108.454
Total annual profit	N62,559,398.56

3. Phosphoric acid activation of oil-palm shells

Fixed capital investment	N809,906,578.00
Working capital investment	N121,485,986.70
Annual depreciation	N80,990,657.80
Annual qty. Produced	N582,000.00
Profit/unit	N108.454
Total annual profit	N62,559,398.56

The table 1, table 3 and table 5 in appendix 1, 2 and 3 respectively contains this computations of this parameters with equation 1.

The profitability index is the r (nominal continuous interest rate) at which the right-hand-side of equation 1 is zero. To determine this value of r at the end of each year, Microsoft Office Excel 2007 Goal Seek function was used. These values are given in table 2, table 4 and table 6 of appendix 1, 2 and 3 respectively.

Graphs of cash position Vs time in years, and that of the profitability index Vs time in years for the three processes are given in figure 1 and 2, 3 and 4, and 5 and 6 of appendix 1, 2 and 3 respectively.

Simulation for the cost analysis of the activation of each of the materials: The prices of equipments used in the project are based on information from fabricators previous works. The fact that prospective investors could explore less expensive equipments of similar quality is not overlooked. For example some fabricators in Nigeria have proven their excellence in the fabrication of some of this equipment. Raw materials could also be sourced at a cheaper rate based on some factors that affects their prices. As a result of this, a simulation of the cost is provided (Excel file simulation.xlsm). The simulation was written with excel VBA and just prompt a user for prices of the variables used in the economic analysis calculation. When prices are entered and the simulate button in the form that appears is clicked, excel does the calculation and when the escape button is clicked excel provides for the user in a message box the total capital investment, the manufacturing cost, the total product cost and the selling price/Kg. Appendix i-H

Equipment cost variation with total productive cost: The total equipment cost delivered was varied with the total productive cost to investigate the effect of the former on the latter. This was carried out by reducing the total equipment cost delivered by 10% successively and simulating to calculate the total product cost. (table 7, 8 and 9, appendix 4-6). The resulting product costs were plotted versus the equipment costs(figure 7, 9 and 11, appendix 4-6). A bar chart of the percentage reduction in the total product costs with each 10% percent reduction in equipment costs were also plotted. Shown in figure 8, 10, and 12 of Appendix 4-6.

CONCLUSION: In this work, the profitability index of the proposed three projects was found. The rate of return by this method is equivalent to the maximum interest rate at which money can be borrowed to finance the project under condition where the net cash flow to the project over its useful life would be sufficient to pay all principal and interest accumulated on the outstanding principal. And so the result of the study shows that the maximum interest rate at which the money can be borrowed to finance the project for profitability for the steam activation of coconut shell is 4.7% to be paid at the 11^{th} year, 3.7% for the steam activation of sugarcane bagasse and 2.12% for the phosphoric acid activation of oil-palm shells all to be paid at the end of the useful life of the equipments. 11^{th} year as given by Peters, M., and Timmerhaus, K. For the equipment for chemical and allied processes.

For the three processes, reduction in the equipment costs reduces the total product cost with the percentage reduction increasing reducing at successive reductions for the steam activation of coconut shells and the phosphoric activation of oil-palm shell but reducing with increasing reductions for the steam activation of sugarcane bagasse.

The developed simulation program that allows the prospective investors enter costs into the calculation excel sheet for calculation is a good tool, in that it makes it possible and easier to even start cost savings strategies even before the project begins.

APPENDIX 1: STEAM ACTIVATION OF COCONUT SHELL

n	$1/e^{nr}$	capital investment and salvage value based on interest compounded continuously for each year	$(e^{nr}-1/r)$	Present value of cash flow to project(NOT INCLUDING DEPRECIATION)	DEPRECIATION	Present value of cash flow to project(INCLUDING DEPRECIATION)	e^{nr}	present value working-capital investment	present value of fixed capital investment	cash position at time t
1	0.961	816,597,311	1.0200	61,588,374	72,708,059	-11,119,684	1.040	113,444,909	756,299,396	- 64,266,679.
2	0.924	785,048,961	2.081	125,651,767	72,708,059	52,943,708	1.082	118,003,860	786,692,403	-66,703,593
3	0.889	754,719,446	3.185	192,289,643	72,708,059	119,581,584	1.126	122,746,019	818,306,797	-66,751,786
4	0.854	725,561,680	4.332	261,605,460	72,708,059	188,897,401	1.171	127,678,749	851,191,663	-64,411,330
5	0.821	697,530,392	5.527	333,706,836	72,708,059	260,998,777	1.218	132,809,708	885,398,056	-59,678,594
6	0.790	670,582,063	6.769	408,705,711	72,708,059	335,997,652	1.267	138,146,862	920,979,082	-52,546,229
7	0.759	644,674,853	8.061	486,718,527	72,708,059	414,010,468	1.318	143,698,497	957,989,985	-43,003,161
8	0.730	619,768,540	9.404	567,866,404	72,708,059	495,158,344	1.371	149,473,234	996,488,226	-31,034,575
9	0.702	595,824,455	10.802	652,275,327	72,708,059	579,567,268	1.426	155,480,036	1,036,533,575	-16,621,888
10	0.674	572,805,424	12.256	740,076,347	72,708,059	667,368,288	1.483	161,728,231	1,078,188,206	257,275
11	0.648	550,675,709	13.769	831,405,781.	72,708,059	758,697,722.	1.543	168,227,518	1,121,516,789	19,629,123

Table 1: Cash Position calculation table

YEAR OF PAYMENT	PROFIITABILITY INDEX
1	0.00057
2	0.0189
3	0.0255
4	0.0291
5	0.0316
6	0.0336
7	0.0353
8	0.0368
9	0.0381
10	0.0394
1	0.0407

Table 2: PROFITABILITY INDEX/YEAR

Appendix 1: continued

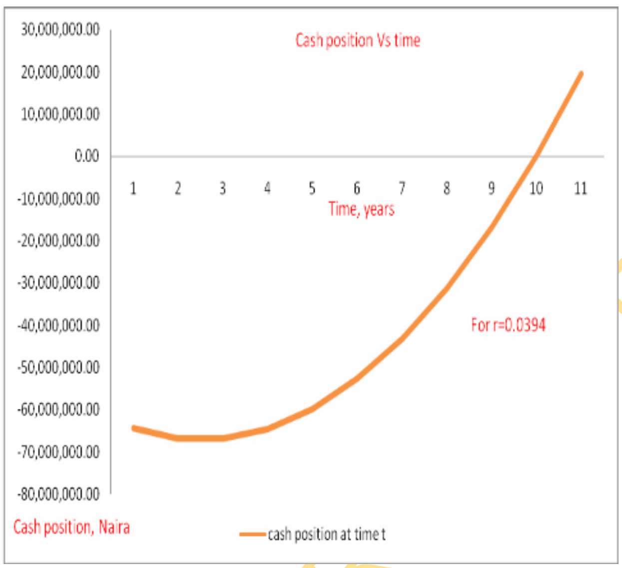

Fig 1: Graph of cash position Vs Time, for r=0.0394

Appendix 1: continued

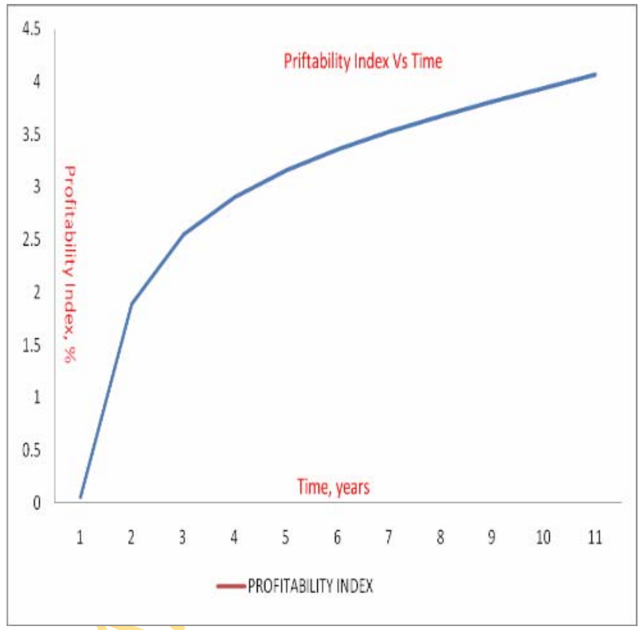

Fig 2: Graph of profitability Index Vs Time

APPENDIX 2: STEAM ACTIVATION OF SUGARCANE BAGASSE

n	$1/e^{nr}$	present value of fixed capital investment,working capita investment and salvage value based on interest compounded continuously for each year	$(e^{nr}-1/r)$	Present value of cash flow to project(NOT INCLUDING DEPRECIATION)	DEPRECIATION	Present value of cash flow to project(INCLUDING DEPRECIATION)	e^{nr}	present value working-capital investment	present value of fixed capital investment	cash position at time t
1	0.965	917,789,574	1.018	63,700,840	80,990,657	-17,289,817	1.037	125,945,987	839,639,915	-65,086,145
2	0.930	885,288,800	2.074	129,740,269	80,990,657	48,749,612	1.0747	130,569,723	870,464,825	-66,996,136
3	0.898	853,938,944	3.168	198,204,142	80,990,657	117,213,484	1.114	135,363,207	902,421,381	-66,632,159
4	0.866	823,699,249	4.303	269,181,465	80,990,657	188,190,807	1.155	140,332,669	935,551,127	-63,993,740
5	0.835	794,530,402	5.479	342,764,511	80,990,657	261,773,853	1.198	145,484,570	969,897,135	-59,077,450
6	0.806	766,394,483	6.699	419,048,942	80,990,657	338,058,284	1.241	150,825,608	1,005,504,056	-51,876,896
7	0.777	739,254,913	7.963	498,133,932	80,990,657	417,143,274	1.287	156,362,727	1,042,418,179	-42,382,718
8	0.750	713,076,410	9.273	580,122,294	80,990,657	499,131,637	1.334	162,103,124	1,080,687,497	-30,582,574
9	0.723	687,824,940	10.632	665,120,619	80,990,657	584,129,961	1.383	168,054,264	1,120,361,760	-16,461,121
10	0.697	663,467,676	12.040	753,239,406	80,990,657	672,248,748	1.434	174,223,881	1,161,492,546	-3
11	0.673	639,972,952	13.501	844,593,216	80,990,657	763,602,558	1.487	180,619,999	1,204,133,329	18,822,182

Table 3: Cash position calculation table for the steam activation of sugarcane bagasse

N, YEAR	PROFITABILITY INDEX
1	0.089
2	1.8
3	2.34
4	2.7
5	2.9
6	3.1
7	3.2
8	3.4
9	3.5
10	3.6
11	3.7

Table 4: Profitability Index per year for the steam activation of sugarcane bagasse

Appendix 2:: continued

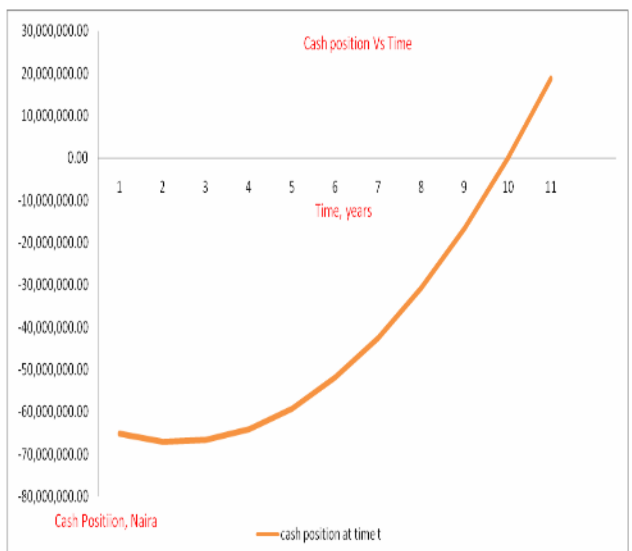

Figure 3: Graph of cash position Vs Time

Appendix 2: continued

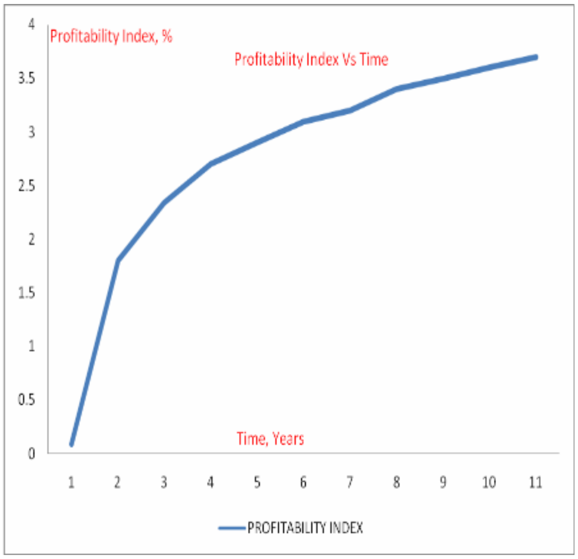

Fig 4: Profitability Index Vs Time

APPENDIX 3: PHOSPHORIC ACTIVATION OF OIL-PALM SHELLS

n	$1/e^{nr}$	present value of fixed capital investment,working capita investment and salvage value based on interest compounded continuously for each year	$(e^{nr}-1/r)$	Present value of cash flow to project(NOT INCLUDING DEPRECIATION)	DEPRECIATION	Present value of cash flow to project(INCLUDING DEPRECIATION)	e^{nr}	present value working-capital investment	present value of fixed capital investment	cash position at time t
1	0.980	1,124,402,974	1.010	49,586,830	97,705,605	-48,118,774	1.020854	149,614,807.06	997,432,047.04	-70,762,654.64
2	0.980	1,101,433,160	2.0419	100,207,564	97,705,605	2,501,959	1.042144	152,734,945.74	1,018,232,971.58	-67,032,797.54
3	0.940	1,078,932,585	3.095	151,884,379	97,705,605	54,178,774	1.063877	155,920,153.28	1,039,467,688.55	-62,276,482.36
4	0.921	1,056,891,661	4.170	204,638,262	97,705,605	106,932,657	1.086064	159,171,786.67	1,061,145,244.46	-56,492,712.41
5	0.902	1,035,300,999	5.267	258,493,143	97,705,605	160,787,537	1.108713	162,491,231.17	1,083,274,874.47	-49,677,568.38
6	0.884	1,014,151,401	6.387	313,470,074	97,705,605	215,764,469	1.131835	165,879,900.95	1,105,866,006.36	-41,830,036.69
7	0.866	993,433,857	7.531	369,594,811	97,705,605	271,889,206	1.155439	169,339,239.68	1,128,928,264.51	-32,944,440.63
8	0.848	973,139,540	8.699	426,888,479	97,705,605	329,182,873	1.179535	172,870,721.10	1,152,471,474.02	-23,019,781.05
9	0.831	953,259,804	9.89	485,378,734	97,705,605	387,673,128	1.204133	176,475,849.73	1,176,505,664.87	-12,048,581.17
10	0.814	933,786,181	11.11	545,086,773	97,705,605	447,381,168	1.229245	180,156,161.43	1,201,041,076.21	-29,887.56
11	0.797	914,710,374	12.35	606,042,238	97,705,605	508,336,633	1.25488	183,913,224.11	1,226,088,160.75	13,045,622.41

Table 5: cash position calculation table for the phosphoric activation of oil-palm shell

YEAR OF PAYMENT	REQUIRED INTEREST
1	-1.08546
2	0.555
3	1.12
4	1.41
5	1.61
6	1.74
7	1.84
8	1.93
9	1.999
10	2.064
11	2.122

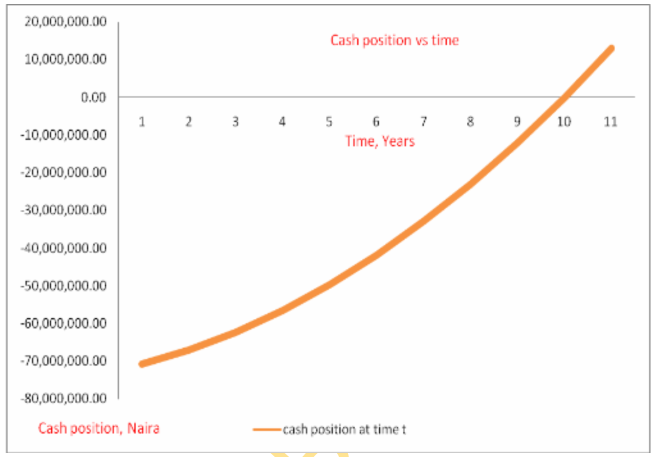

Figure 5: Graph of Cash position Vs Time

Table 6: profitability Index per year table

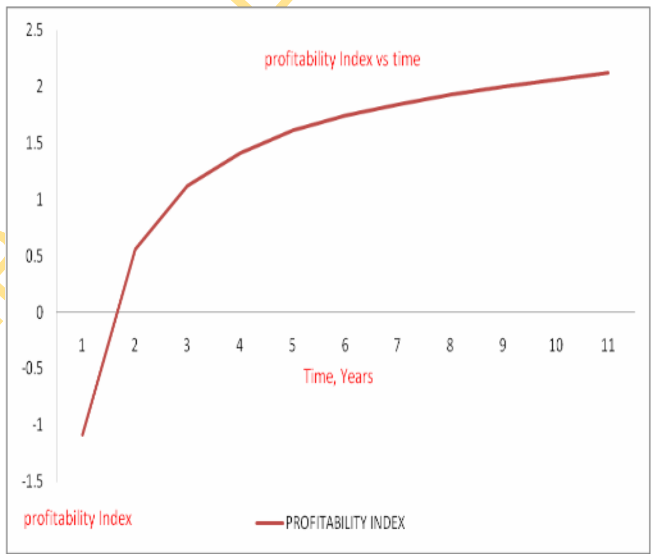

Fig 6: Graph of Profitability Index Vs Time

APPENDIX 4: STEAM ACTIVATION OF COCONUT SHELLS

Equipment cost	Total product cost	Reduction in Total product cost	Percentage reduction in total product cost for 10% successive reduction In equipment costs
1.33E+08	603,830,502.00		
1.19E+08	589,121,837.75	14,708,664.25	2.44
1.07E+08	575,884,039.57	13,237,798.18	2.25
9.67E+07	563,970,021.21	11,914,018.36	2.07
8.71E+07	553,247,404.69	10,722,616.52	1.90
7.84E+07	543,597,049.82	9,650,354.87	1.74
7.05E+07	534,911,703.44	8,685,346.38	1.60
6.35E+07	527,094,943.00	7,816,760.44	1.46
5.71E+07	520,059,834.30	7,035,108.70	1.33
5.14E+07	513,728,236.47	6,331,597.83	1.22

Table 7: Table showing % reduction in the total productive cost for each successive 10% reduction in equipment cost

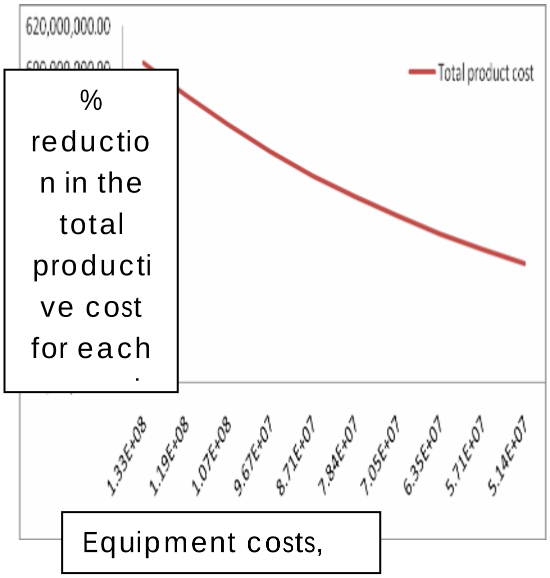

Fig 7: the graph of Total productive costs Vs equipment cost

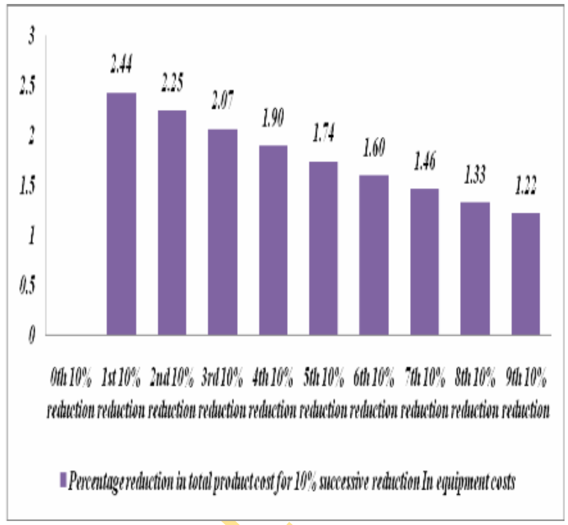

Fig 8: Bar chart showing % reduction in total product cost for 10% cost in equipment costs

Appendix 4 cotinued

APPENDIX 5: STEAM ACTIVATION OF SUGARCANE BAGASSE

Equipment cost	Total product cost	Reduction in Total product cost	Percentage reduction in total product cost for 10% successive reduction In equipment costs
2.01E+08	631203554.5		0
1.81E+08	613224862	17978692.45	2.85
1.61E+08	595246169.6	17978692.44	2.93
1.41E+08	577267477.1	17978692.45	3.02
1.21E+08	559288784.7	17978692.44	3.11
1.00E+08	541310092.2	17978692.45	3.21
8.04E+07	523331399.8	17978692.45	3.32
6.03E+07	505352707.3	17978692.44	3.44
4.02E+07	487374014.9	17978692.45	3.56
2.01E+07	469395322.5	17978692.44	3.69

Table 8: Table showing % reduction in the total productive cost for each successive 10% reduction in equipment cost

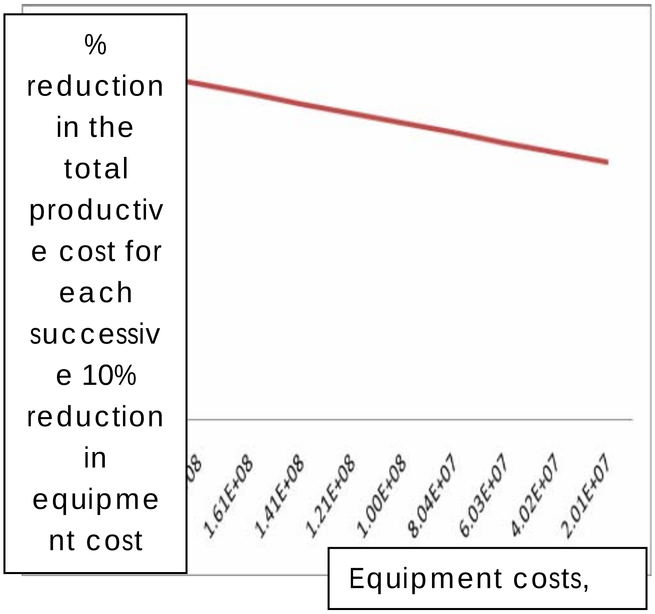

Fig 9: the graph of Total productive costs Vs equipment cost

APPENDIX 5; CONTINUED

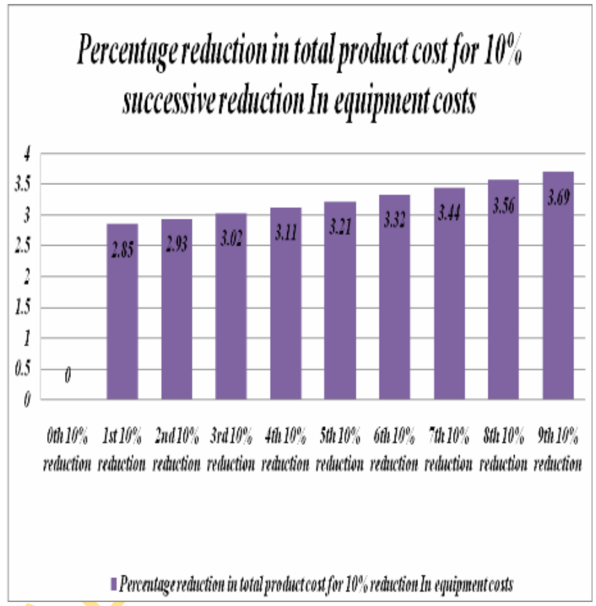

Fig 10: Bar chart showing % reduction in total product cost for 10% cost in equipment costs

APPENDIX 6: PHOSPHORIC ACID ACTIVATION OF SUGARCANE BAGASSE

Equipment cost	Total product cost	Reduction in product cost	Percentage reduction for 10% reduction In equipment costs
242,373,500.00	473,969,728.00		
218,136,150.00	452,280,572.44	21,689,155.56	4.58
196,322,535.00	432,760,331.85	19,520,240.59	4.32
176,690,181.50	415,192,025.84	17,568,306.01	4.06
159,021,163.40	399,380,639.96	15,811,385.88	3.81
143,119,047.10	385,150,392.65	14,230,247.31	3.56
128,807,142.40	372,343,170.05	12,807,222.60	3.33
115,926,428.20	360,816,669.74	11,526,500.31	3.10
104,333,785.40	350,442,819.44	10,373,850.30	2.88
93,900,406.86	341,106,354.19	9,336,465.25	2.66

Table 9: Table showing % reduction in the total productive cost for each successive 10% reduction in equipment cost

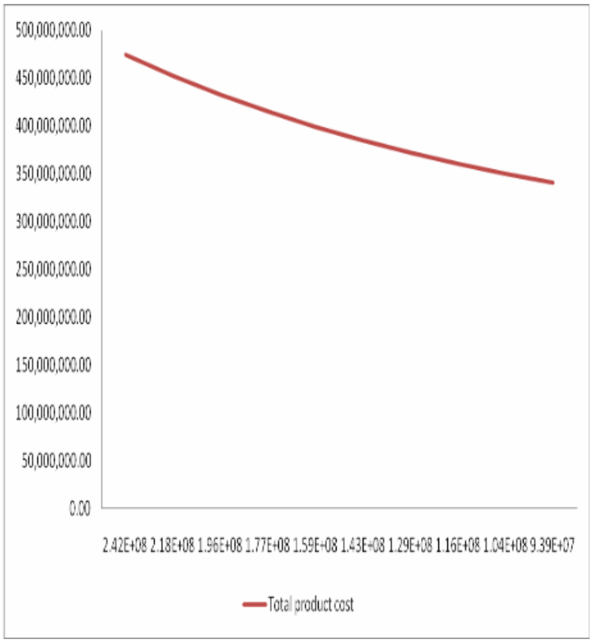

Fig 11: the graph of Total productive costs Vs equipment cost

APPENDIX 6: CONTINUED

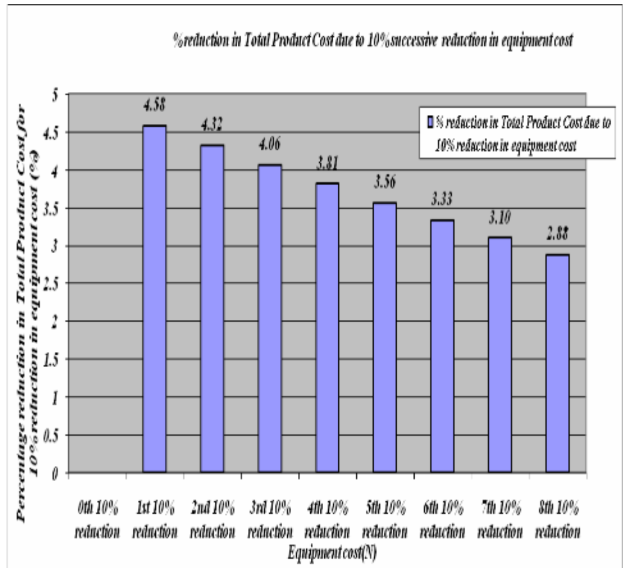

Fig 12: Bar chart showing % reduction in total product cost for 10% cost in equipment costs

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