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BENEFIT COST ANALYSIS OF ADOPTING A MODIFIED CASSAVA ATTRITION PEELING MACHINE IN MECHANIZED CASSAVA PROCESSING

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Abstract. This paper assessed the benefits of adopting a modified cassava attrition peeling machine in mechanised Cassava (*Manihot Esculenta*) processing. The parameters evaluated and compared between the modified cassava attrition peeling machine, existing attrition peeler and manual peeling technique include the specific energy consumption, peeling efficiency, flesh loss, throughput capacity, payback period and benefit cost ratio. The results showed that the improved machine has a payback period of one year and four months with Benefit Cost Ratio, BCR of 2.56. Significant improvements on its performance parameters was evident with 43% increase in peeling efficiency, 74.8% increase in throughput, 67% tuber flesh recovery, 12 % energy cost savings and 10.6% reduction in specific energy consumption over the existing attrition peeler.

Keywords*: Modified Cassava attrition peeling machine, payback period, benefit cost ratio, energy cost savings, performance parameter.*

INTRODUCTION

Cassava, *Manihot Esculenta,* is an annual crop cultivated in the tropical and subtropical regions for its roots high carbohydrate content as a major source of edible starchy food.

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It is utilized extensively for human and livestock consumption as well as for other industrial products such as starch and alcohol production (El-Sharkawy and Cock, 1987). Its roots in addition to being rich in starch contain calcium, phosphorus and vitamin C in significant traces of 16 mg /100 g, 27 mg/100 g and 20.6 mg /100 g respectively (Ravindran, 1992). Though poor in protein and other nutrients they are generally composed of 70 % moisture, 24 % starch, 2 % fibre, 1 % protein and 3 % other nutrient (CSIR 2017).

The commercial potential of cassava is currently under utilized in Nigeria, even though she is one of the largest producer in the world with approximately 45 million tones of tubers produced annually, accounting for 19 % of world production (Adekanye *et al*., 2013).

This is attributed to inadequate mechanization of the processing operation. Egbeocha *et al.* (2016) posited that the best form of cassava tuber preservation and the reduction of post-harvest losses has been its immediate processing into various shelf stable products. Several operations are involved in the cassava processing into various desired products, and these include peeling, washing, grating, boiling, parboiling, drying, milling, pressing, sieving, extrusion and frying. Before the cassava tuber is processed into any of its food and some of its non-food products, it must be peeled.

Peeling removes the cortex and the outer periderm layer adhering to it basically for product quality and reduction of cyanide content. For a root composed of 15 % peel with a total cyanide content of 950 mg/kg (weight basis) and 35 mg/kg in the flesh, 83 % of the total cyanide is removed by peeling (Bencini, 1991) which is acceptable and safe for consumption. Ideally, and especially in the food industry, the peel must be completely removed without removing the useful tuber flesh for safe consumption and better quality of the end products. This justifies the need for improvement in mechanisation of cassava processing with special interest in the peeling process.

However, cassava peeling operations which obviously is the first post harvest processing operation in an attempt to commercially mechanise it has been faced with the challenges of preoperational treatment, geometric and morphological disparities in addition to other varying tuber properties. Thus, it is difficult to design an economically viable cassava peeling machine that is capable of peeling all roots from various varieties and sources with minimal useful tuber flesh wastage. To bridge the gap created by inefficient and low output of manual peeling process, mechanical peeling broadly achieved by either knife peeling principle (use of knife-like parts as peeling tools) or abrasive/attrition principle (use of frictional surfaces to cause wear) became inevitable

Numerous attempts made in development of peeling technology (Ezekwe, 1979; Nwokedi, 1984; Odigboh, 1983a; IITA, 2011; Akintunde *et al*., 2005, Olukunle, 2005; Oluwole, 2013), have been adversely characterised by drudgery of pre- operational activities of trimming, sorting, soaking and grading of tubers prior to peeling operation to mitigate for the afore mentioned design challenges and this consequently increases the processing cost and time Abrasive/attrition peeling concept exploited in cassava peeling model developed by Projects Development Institute (PRODA) though erroneously criticised and under rated by some researchers (Adetan, 2002 and Olukunle, 2013) possesses great prospects in eliminating these preoperational activities.

Their perceived inefficiencies could be attributed to some obvious design shortcomings and inappropriate design conception adopted.

In order to address the issues associated with the mechanised cassava attrition peeling process, Edeh (2017) designed and developed a modified cassava attrition peeling machine (Figure 1.0) based on the attrition peeling concept with the introduction of breaker baffles, enhancement of inner peeling drum surface, introduction of egg shaped peeling balls which improved cassava peeling in quality and quantity, eliminated the drudgery of pre-operational treatment of trimming, slicing, sorting and grading of cassava tubers prior to peeling thereby reducing processing time and cost. Performance optimization of the developed modified cassava attrition peeling machine confirmed that the machine performs optimally with an efficiency of 88.7 %, throughput of 180kg/hr, flesh loss of 5.49 % and specific energy consumption of 58.4 kJ/kg at an optimal peeling drum speed, cassava moisture content, mass of loaded cassava, number of peeling balls, geometric mean diameter and peel thickness of 45 rpm, 85 % Wb, 82 kg, 110, 48 mm and 4.13 mm respectively (Edeh, 2017). The machine showed improved peeling time resulting in reduced cost of processing hence suitable for further economic analysis.

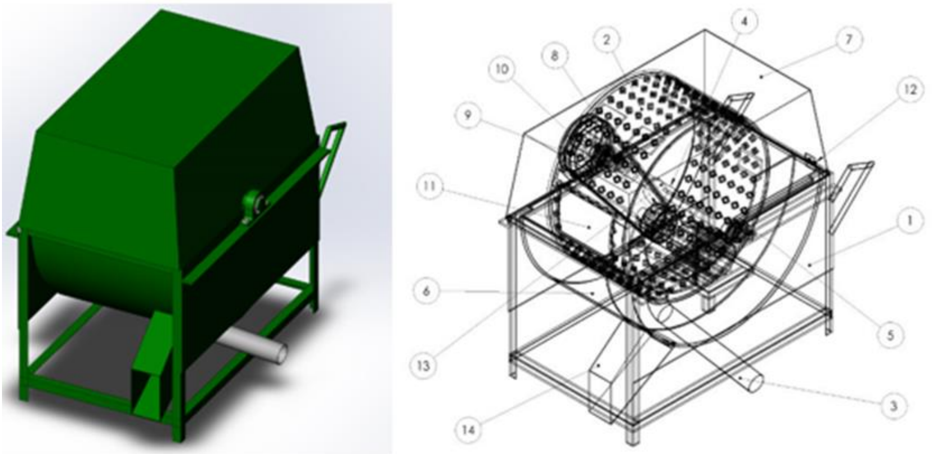

Figure 1. Modified Cassava Attrition Peeling Machine:1.Structural Frame, 2. Peeling drum, 3. Discharge pipe, 4. Shaft, 5. Bearing, 6. Water bath(trough) , 7. Covering hood, 8. Electric motor, 9.pulley, 10. Motor shaft, 11. Loading cover, 12. Hinges, 13.Bolt, 14. Discharge slit.

Despite the considerable improvement in the performance of the modified cassava attrition peeling machine, cassava processors and investors have remained sceptical in adopting this technology because most processors use initial capital (procurement) cost as the primary (and sometimes only) criteria for equipment selection (Oti and Lewachi, 2017) while most of the processors still rely on the manual peeling technique. Application of a benefit cost analysis will determine if an investment in this new peeling technology is profitable as well as provide a cost evaluation basis for comparing the modified cassava attrition peeling machine with existing peeling technology. Hence, in this study, the benefit cost analysis is used to explore the cost effectiveness and economic viability of adopting this modified cassava attrition peeling machine.

MATERIALS AND METHODS

Machine Description and Evaluation Parameters

The detailed diagram and photograph of the modified cassava attrition peeling machine with egg. shaped peeling balls designed and developed by Edeh, *2017* are shown in Figure 1 and Plate 1 respectively. The principle of operation of the modified cassava attrition peeling machine is achieved by attrition which constitute the use of metal surfaces of roughened inner peeling drum and egg shaped peeling balls to cause abrasion with consequent removal of softer cassava tuber surface (the peel). In operation, a known mass of cassava for which other relevant properties are determined and estimated numbers of peeling balls are loaded through the gate into the peeling drum. The machine is energized through the prime mover causing a rotational motion of the drum.

The egg. shaped peeling balls together with the embossed inner surface of the drum causes the wearing of the cassava peel. Being a batch process operation, the cylindrical peeling drums impacts rotational motion on the balls freely mixed with the cassava and consequently creating tumbling effect in the drum that gives random relative motion hence effecting peeling. Material removed from the surface of the cassava by abrasion, which has the form of flake and also tiny particles in pulpy matter, sinks through the perforations of the drum to the bottom of the housing trough serving as water bath and also prevents the clogging of the balls.

Plate 1: (a) Modified cassava attrition peeling machine *(b) Peeling Balls*

Performance test indicators which aid in the analysis of the economic viability of the modified machine include the peeling efficiency, flesh loss, throughput, and specific energy consumption. Flesh loss is the amount of starchy flesh removed alongside the peels during peeling. Peeling efficiency is the ratio of the total mass of peel by the machine to mass of manual peel (theoretical mass of peel) while its throughput is the total mass of cassava peeled and discharged by the machine per unit time.

Specific energy consumption of the machine is quantity of energy it used to peel a unit mass of cassava fed into it. The mathematical relationship used for computing the test indicators are shown in equations 1 – 4 given by (Agrawal, 1987; Nwankwojike et al., 2016; Edeh, 2017).

$$F_l = M_{c-}(m_{cp} + m_{pt}) \quad (1)$$

$$\eta_p = \frac{M_{Pc}}{M_{pr}+M_{pc}} \times \frac{100}{1} \quad (2)$$

$$TP = \frac{M_c}{t} \quad (3)$$

$$SE = \frac{Pt}{M_c} \quad (4)$$

Where F_l=Tuber flesh loss (%), η_p=peeling efficiency (%), TP= throughput, (kg/h), and SE = specific energy consumption (kJ/kg).

m_{cp} = mass of the peeled cassava(kg), m_{pt} = theoretical mass of peel, M_c = mass of the loaded cassava, M_{pc} = mass of peel (kg) collected through the peel outlet of machine and M_{pr} = mass of peel removed by hand after machine peeling (kg), t = Time taken (s). P = Power consumed by the electric motor in kW.

The benefits in adopting the improved cassava attrition peeling machine was also evaluated using the time taken to complete batch peeling process, amount charged for peeling in the various techniques, the average price per kg for peeling batch cassava mass, throughput capacity for the various batch mass of cassava and the total energy cost. Energy cost savings is evaluated using Equation (5).

$$ECS = \frac{TEC_{proda/Manual} - TEC_{MCAPM}}{TEC_{proda/Manual}} \times 100 \quad (5)$$

Where:

ECS = Energy cost savings,

TEC = Total Energy cost.

The Benefit Cost Ratio, BCR of the modified machine was evaluated using Equation (6) by Gerald and Marta (2009).

$$BCR = \frac{PVB}{PVC} \quad (6)$$

Where the Present Value Cost,

$$PVC = \sum_{t=1}^{T} \frac{B_t}{(1+r_i)^t} \quad (7)$$

And the Present Value Benefit,

$$PVB = \sum_{t=1}^{T} \frac{C_t}{(1+r_i)^t} \quad (8)$$

B_t and C_t are the respective benefits and costs in time t and r_i is interest rate = 13% (Daniel and Elisha, 2015).

RESULTS AND DISCUSSION

The improved machine charged ₦500 per 80 kg batch mass of cassava while the existing and manual peeler charged ₦500 per 60 kg and 20 kg batch mass respectively. The modified cassava attrition peeling machine (MCAPM) designed and fabricated using locally sourced material with egg shaped ball accessories and improved peeling surface features eliminated pre-operational treatment with 42.8% savings in processing time, 43% increase in peeling efficiency, 74.8% increase in throughput, 67% tuber flesh recovery and 10.6% reduction in specific energy consumption over the existing machine as shown in the performance graphs in Figure 2.

Since the peeling machines are powered electrically, the cost of generated electricity is taken into consideration to determine the energy cost of using the machines. Electrical cost from the national grid used to power the machines is at the rate of ₦30.93 per kWh while energy cost for the manual peeler was considered as his wages per batch mass of cassava.

The analysis as shown in Table 1 reveals a decrease in the total energy cost in using the improved cassava attrition peeling machine as compared to the existing version and manual peeling process. In addition to its increased throughput capacity, the improved cassava attrition peeling machine performed optimally with a 12% and 69% energy cost savings than the existing and manual peeling process.

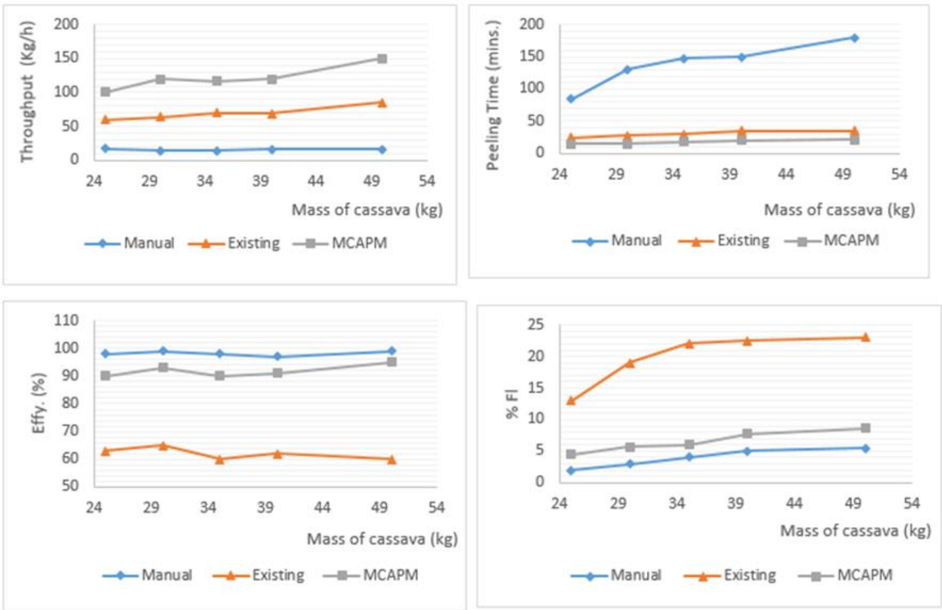

Figure 2. Performance Test Graphs

Table 1: Cost Evaluation

S/N	Manual peeling			Existing Machine			Improved Cassava Attrition Peeling Machine		
	Mass of cassava (kg)	Amount (₦)	Time taken (Mins.)	Mass of cassava (kg)	Amount (₦)	Time taken (Mins.)	Mass of cassava (kg)	Amount (₦)	Time taken (Mins.)
1	100	2500	300	100	833	45	100	625	25
2	200	5000	430	200	1666	65	200	1250	40
3	300	7500	560	300	2500	80	300	1875	65
4	400	10000	600	400	3333	120	400	2500	90
5	450	11250	750	450	3750	150	450	2812.5	110
6	500	12500	950	500	4166	185	500	3125	130
Average price (₦/kg)		25			8.33			6.25	
Average time taken (Min/kg)		1.84			0.33			0.23	
Throughput capacities (kg/h)		32.59			181.39			254.34	
Total energy cost (TEC)		8125			2795			2451	
Energy cost savings per kg (ECS)		69%			12%				

Payback and benefit cost ratio analysis

In the analysis of the payback period and cost benefit ratio of the existing (PRODA) and Modified cassava attrition peeling machines (Table 2), the following considerations were made.

1. The machines operate at 8 hours/day and 6 days/week, hence the machine operation time per year is 288 days/yr (2304 hrs/yr). If the maintenance time is taken as 24hrs/yr, thus the effective machine operation time is 2280 hrs/yr.
2. The existing PRODA machine utilizes a total of 3728.5W (≈ 3.73KW) for its operation. Thus energy consumed per year is 8504.4 KWh. while the modified cassava attrition peeling machine (MCAPM) utilizes a total of 2237.1W (≈ 2.23kW) for its operation. Thus its energy consumed per year is 5084 kWh and as stated earlier PHCN charges ₦30.93 per kWh.

This result reveal a payback period of one year and four months for the modified machine while the existing PRODA version has a payback period of three years and nine months. Thus, the amount invested in this project will be recovered within this length of time with an average yearly cash inflow of **₦** 414,420 from just peeling cassava tubers**.**

The Benefit Cost Ratio, BCR of the modified machine tabulated in Table 3 was evaluated as 2.56 using Equation (6). This implies that for every **₦**1 spent, a benefit of **₦**2.56 was realized. The investment is therefore acceptable.

Table 2: Payback period of the attrition machine.

NON Recurring costs and revenues	Modified machine		PRODA Version	
	Costs (₦)	Revenues(₦)	Costs (₦)	Revenues (₦)
1. Capital Investments				
Cost of machine	200,000.00		220,000.00	
Installation Cost	5,000.00		5,000.00	
2. Revenue				
Sales of equipment after useful period		68,000.00		80,000.00
Total	205,000.00	68,000.00	225,000.00	80,000.00
Recurring annual costs and revenues	Costs (₦)	Revenues (₦)	Costs (₦)	Revenues (₦)
1. Operational and Maintenance cost				
(a) Direct Costs				
Labour	120,000.00		120,000.00	
Material Cost	4,320.00		4,320.00	
(b) Indirect costs				
Maintenance	60,000.00		70,000.00	
Utilities (Power)	157,260.00		263,041.10	
Other cost	3,000.00		3,000.00	
2. Revenue				
Revenue		950,400.00		850,500.00
Total	344,580.00	950,400.00	460,361.10	850,500.00
Before Tax Net Cash Flow (BTCF) Analysis				
End of year	Modified Machine		PRODA Version	
0	205,000.00		225,000.00	
1	400,820.00		165,138.90	
2	400,820.00		165,138.90	
3	400,820.00		165,138.90	
4	400,820.00		165,138.90	
5	468,820.00	414,420.00	245,138.90	181,138.90
Payback period	Initial investment cost/average annual cash inflow			
		1.33		3.78

Table 3: Benefit-cost analysis of the modified cassava attrition peeling machine.

YR	Investment Cost (₦)	Operating Cost (₦)	Total Cost (₦)	Sales (₦)	Salvage value (₦)	Total Benefit (₦)	Present Value Benefit (₦)	Present Value Cost (₦)
0	135,000.00	344,580.00	479,580.00	950,400.00	-	950,400.00	950,400.00	479,580.00
1		344,580.00	344,580.00	950,400.00	-	950,400.00	841,061.95	304,938.05
2		344,580.00	344,580.00	950,400.00	-	950,400.00	744,302.61	269,856.68
3		344,580.00	344,580.00	950,400.00	-	950,400.00	658,674.87	238,811.22
4		344,580.00	344,580.00	950,400.00	-	950,400.00	582,898.12	211,337.37
5		344,580.00	344,580.00	950,400.00	68,000.00	1,018,400.00	552,746.72	187,024.22
	Total						4,330,084.27	1,691,547.55

CONCLUSION

The modified cassava attrition peeling machine eliminated pre-operational treatment with 42.8% savings in processing time, 12 % energy cost savings compared to the existing machine, 43% increase in peeling efficiency, 74.8% increase in throughput, 67% tuber flesh recovery and 10.6% reduction in specific energy consumption over existing machine.

Its benefit cost analysis showed that the improved machine has a payback period of one year and four months with Benefit Cost Ratio, BCR of 2.56 hence a worthwhile investment.

Since peeling constitutes the major bottle neck in the processing cassava, Government and other agencies should grant loan to farmer so that they can afford to adopt this important innovation immediately for mass processing of cassava products to meet the growing demand of the Nigeria industries and for export.

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ANALIZA TROŠKOVA PRIMENE MODIFIKOVANE MAŠINE ZA LJUŠTENJE KOD MEHANIZOVANE OBRADE CASAVE

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Sažetak: U ovom radu su ocenjene prednosti usvajanja primene modifikovane mašine za ljuštenje kod mehanizovane obrade kasave (*Manihot Esculenta*). Parametri koji se procenjuju i upoređuju između modifikovane mašine za piling -ljuštenje kasave, postojećeg alata za ljuštenje i tehnike ručnog ljuštenja uključuju: specifičnu potrošnju energije, efikasnost ljuštenja, gubitak mase, propusni kapacitet mašine, period otplate i procenu troškova koristi.

Rezultati pokazuju da poboljšana – modifikovana mašina ima rok vraćanja troškova od jedne godine i četiri meseca, a odnos koeficijenta koristi i troškova (BCR) od 2,56.

Značajna poboljšanja parametara performansi mašine bila su evidentna sa povećanjem efikasnosti ljuštenja do 43%, povećanje protoka zrna od 74,8%, protokom mase od 67%, sa uštedom troškova energije od 12% i smanjenja potrošnje specifične energije od 10,6% u odnosu na postojeći aparat-uređaj za ljuštenje

Ključne reči: Modifikovana mašina za piling-ljuštenje kasave, rok otplate, procena troškova I koristi, ušteda troškova energije, parametari performansi.

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