Comparative Exploration of Mechanized Systems for Palm Broom Production

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Abstract: Performance and economic capabilities of two distinct mechanized systems for processing brooms from coconut and oil palm leaflets were surveyed in this study to determine the best technology to advance/adopt for commercialization. The systems are abrasive roller and knife edge aided peeling based machines while peeling efficiency, processing time/throughput, payback period and benefit cost ratio constitute the parameters weighed. Results revealed the knife edge based peeling systems as most viable even though the abrasion process based system performs with high throughput. This because it’s peeling efficiency of 96% is above the minimum acceptable rate of 95% and that of the abrasion process system (94%) is less. This, implies 5% scraps/reworks associated with abrasive aided peeling system which amount to post peeling operation of sorting. The high cost of production induced by this post peeling operation is obvious from the high payback period and low benefit cost ratio of this system compared the knife edged aided process.

The payback and benefit cost rating of knife edge aided system amounts to 0.8 and 2.45 respectively while 1.69 and 1.76 constitutes the respective ratings of abrasion process based machines.

In addition, the knife edge aided processing system peels both fresh and dry palm leaflets while the abrasion peeling system handles dry leaflets only. Hence, adoption of knife edge aided peeling process is recommended for advancing broom production from palm leaflets.

Key words: Abrasive, broom bristle, knife edge, machine, palm leaf, peeling

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INTRODUCTION

Broom is a bound organic or synthetic bristle basically used for sweeping floors and some auxiliary ornamental, political and religious purposes [1, 2]. Organic broom bristles from oil and coconut palm leaflets are common in Nigeria due to their effective dirt, dust and wears absorption and moisture-resistant features as well as abundance of these palms in this region [3, 4]. Bristle production from the palm leaf involves peeling or scraping off the leaf’s blade from its petiole (stalk) using sharp knife edged objects (such as knife and razor) or abrasives [5, 6]. The separated stalk constitutes the broom bristles. This separation process can be by manual or mechanized operations. The campaign for phasing out manual palm leaflets peeling due its high drudgery and risk features is not receiving adequate attention expected despite the successful development of mechanized systems for producing broom from the palms by [3, 7, 8, 9]. This is because of the palm broom processors’ problem of choosing among the two distinct mechanisms of abrasive and knife edge aided peeling process based on which the machines were developed. The innovation of [3] peels off the lamina from the midrib of dry oil palm leaflets by abrasion when its rotating abrasive-covered drum rubs the leaflet against a half pipe whose internal surface have been lined with abrasive as shown in Fig. 1. The leaf blade debris falls off through the mesh chute while the bristles are collected in a trough with their ‘head’ in a chuck.

Although this machine performed efficiently, binding the bristles into a handy broom still necessitated a manual effort that quelled its adoption commercially by stakeholders. Hence its improvement by integrating bristles tying/weaving units to it by [9] as shown in Fig. 2. The tying unit consists of a strapping pin attached to the chuck which holds and winds the rope around the broom bristles under the spring tension and recoil spool comprising a rope, recoil spring and a reel/spool.

The midrib separation machine (Fig. 3) developed by [7] peels coconut leaflets. It consists of vertical placed batch of one spiked and two non-spiked rollers which rotates in opposite direction to scrap off the blades of the leaflets fed into it. The need for both fresh and dry palm leaflets peeling mechanism led [8] to develop a knife edged aided peeling module which was later integrated to a tethering machine for processing broom from coconut and oil palm leaflets as shown in Fig. 4. This integrated peeling-tethering machine consisting a set of rollers, palm leaflets inlet, stripper and tethering unit. The rollers feed the leaf to the stripping a mild steel blade which peels the leaf blade off from its stalk before ejecting the sticks into the tethering unit for tying by electromechanical means.

Although, records indicated successful performance of these innovative peeling mechanisms for broom bristle production from palm leaflets, their mass production is still pending due to non-organization of their techno-economic viability data for effective comparison.

Hence, the dominance of manual peeling in this sector and ever increasing scarcity of brooms made from coconut and oil palm leaflets in our markets [8]. Since, adequate comparative knowledge of technical and economic viability of alternate innovations is vital for their adoption for both specific and general applications, this study presents the comparison of abrasion and knife edge peeling based coconut and oil palm broom processing systems.
Fig. 1. Palm frond broom peeling machine. [3].

Fig. 2. Oil palm broom processing machine. [9].
This study involves comparative viability assessment of the two distinct machines for producing brooms from coconut and oil palm leaflets from the records of [3, 7, 8, 9, 10, 11]. This is to determine the best for advancement. The systems parameters weighed include peeling efficiency, processing time/throughput, payback period and benefit cost ratio of the recent developed coconut and oil palm broom processing innovations. Throughput ($TP$) of each system constitutes the total number of palm leaflets it processed per unit time while the peeling efficiency ($\eta$) entails percentage ratio of the well processed broom bristles and number of palm leaflets processed within a given time expressed mathematically as follows [9].
The investment decision pointers of benefit cost ratio (BCR) and payback period ($P_b$) applied to assess the economic viabilities of the broom processing machines were determined from Equations (3) and (4) based useful life of five years and prevailing economic indicators/market prices of materials in Abia State of Nigeria between from 2014 to 2021. The decision criteria include that the payback period of each machine must be less than five years while the peeling efficiency and benefit cost ratio must be greater than 95% and 1 respectively for its acceptance.

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TP (\text{brooms/h}) = \frac{n}{t} \\
\eta(\%) = \frac{n-n_s}{n} \times 100 \\
P_b = \frac{C_i}{B_n} \\
BCR = \frac{PV_B}{PV_C}
\]

Where:
$n$ is the quantity of palm leaflets processed while $n_s$ constitutes defectives (which consists of those that the lamina were not properly removed and/or broken ones) while $C_i, B_n, PV_B$ and $PV_C$ constitute the initial investment cost and average annual net benefit (cash inflow), present values of benefits and costs of the machine.

RESULTS AND DISCUSSION

The results of this investigation shown in Table 1 revealed the knife edge aided peeling process adopted by [8] in developing broom processing machine as most viable even though the abrasive aided processing systems performed with high throughput. This because it’s peeling efficiency of 96% is above the minimum acceptable rate of 95% and that of the abrasion process system (94%) is less. This, implies 5% scraps/reworks associated with abrasive aided peeling system which amount to post peeling operation of sorting. The high cost of production induced by this post peeling operation is obvious from the high payback period and low benefit cost ratio of this system compared the knife edged aided process. The high cost of production induced by this post peeling operation is obvious from the high payback period and low benefit cost ratio of this system compared the knife edged aided process. Furthermore, the knife edge aided processing system peels both fresh and dry palm leaflets while the abrasion peeling system handles dry leaflets only. Hence, the knife edge aided peeling process based broom processing machine is apt for advancing broom production from palm leaflets.
Table 1. Comparative analysis of mechanized palm broom processing systems

| Evaluation parameters | Abrasive roller peeling based system | Knife edge peeling based system |
|------------------------|-------------------------------------|---------------------------------|
| Peeling efficiency (%) | 94.00                               | 96.00                           |
| Throughput (Kg/h)      | 6311.00                             | 2016.00                         |
| Payback period         | 1.69                                | 0.80                            |
| Benefit cost ratio     | 1.76                                | 2.45                            |
| Nature of Leaf processed | Dry                                | All                             |

**CONCLUSIONS**

The study revealed that broom processing machine developed based on knife edge aided peeling mechanism is most viable for advancing broom production from palm leaflets. This because of its high peeling efficiency and benefit cost ratio as well as low payback period ratings over abrasion based peeling systems. Hence, its general adoption and mass production is highly recommended to reduce drudgery and waste of palm leaflets in this country as well as scarcity of coconut and oil palm brooms.

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Apstrakt: U ovoj studiji ispitane su performanse i ekonomske mogućnosti dva različita mehanizovana sistema za izradu osnove metli (pogledati https://www.researchgate.net/publication/303805658) od listova (ogranača) kokosovog oraha i uljane palme. Tako bi se odredila najbolja tehnologija za unapređenje/usvajanje proizvodnje za komercijalnu namenu. Ovi sistem odabran za ljuštenje su mašine za ljuštenje sa abrazivnim metalnim rotirajućim valjcima i noževima sa sečivom. Efi kasmnost ljuštenja, vreme/protok biljne mase u toku obrade, period vraćanja mase, odnos troškova i koristi predstavljaju merene parametre. Rezultati istraživanja pokazuju da su sistemi za ljuštenje zasnovani na oštrici noža lako izvodljiviji, iako je ovaj sistem zasnovan na procesu abrazivnog delovanja valjka on radi sa velikim učinkom. To je zato što je efikasnost ljuštenja od 96%, iznad minimalne prihvatljive stope od 95%. Efi kasmnost sistema kod procesa abrazivnog delovanja valjka je manja (94%). Ovo podrazumeva pojavu 5% otpada u preradi koji su povezani sa sistemom za ljuštenje sa abrazivnim delovanjem valjka, što može da predstavlja i izdvojenu operaciju sortiranja nakon ljuštenja. Visoki troškovi proizvodnje izazvani operacijom ljuštenja su očigledni zbog dugog perioda vraćanja materijala i niskog odnosa troškova i koristi ovog sistema u poređenju sa procesom rada sa noževima na bubnju. Ocena korisnog dejstva kod sistema sa sečivima noža iznosi 0,8 i 2,45, dok vrednosti 1,69 i 1,76 predstavljaju odgovarajuće ocene mašina zasnovanih na procesu abrazivnog delovanja valjaka.
Pored toga, sistem za obradu sa ivicom noža ljušti sveže i suve listove palmi, dok sistem za ljuštenje pomoću abrazivnog delovanja valjaka obrađuje (odstranjuje) samo suve delove biljke palme. Stoga se preporučuje u ovom ispitivanju usvajanje procesa ljuštenja uz pomoć oštrica noža za unapređenje efikasnosti proizvodnje metli od ogranaka palme.

**Ključne reči:** abrazija, osnov metle, ivica noža, mašina, palmin list, ljuštenje.