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Design and Performance Evaluation of a DC-Powered Semi-Automatic Trolley for Oil Palm Loose Fruit Collection

Zoel Fachri[1], Rizki Faulianur[2], Zuhdi Eka Wara[3], Hibatul Muyassar[4], Irfa Hudaya Ekawati[5]

[1,2,3,4,5] Program Studi Mekatronika, Politeknik Aceh
Jl. Politeknik Aceh, Pango Raya, Banda Aceh 23119
[1]zoel@politeknikaceh.ac.id, [2] rizki@politeknikaceh.ac.id,
[3] eka2023@mhs.politeknikaceh.ac.id, [4] irfa2023@mhs.politeknikaceh.ac.id,
[5] hibatul2023@mhs.politeknikaceh.ac.id

ABSTRACT

Manual collection of oil palm loose fruits requires labor and may cause operator fatigue, thereby reducing harvesting efficiency. This study aimed to design and evaluate a DC-powered semi-automatic trolley for oil palm loose fruit collection. The system integrates a rotary sweeper, belt conveyor, and blower driven by DC motors and controlled through a simple ON/OFF circuit. Tests were conducted at a constant operating voltage of 12 V using loads of 2, 5, 7, and 10 kg. The evaluated parameters included operating time, current consumption, power requirement, and system stability. The results showed that the system processed loads from 2 to 10 kg under stable operating conditions. Increasing the load from 2 to 10 kg increased the operating time by 87.1%, from 6.2 to 11.6 s, while the power requirement increased by only 20%, from 54 to 64.8 W. The integrated mechanism enabled continuous collection, conveying, and cleaning of loose fruits while reducing manual labor and operator fatigue. Therefore, the developed trolley offers a practical and ergonomic solution for improving loose fruit collection in oil palm plantations.

Keywords: *Oil palm loose fruit, semi-automatic trolley, DC motor, belt conveyor, sweeper system, energy efficiency*

ABSTRAK

Pengumpulan brondolan kelapa sawit secara manual membutuhkan tenaga kerja besar, memerlukan waktu relatif lama, dan dapat menyebabkan kelelahan operator sehingga menurunkan efisiensi kegiatan panen. Penelitian ini bertujuan merancang dan mengevaluasi kinerja troli semiotomatis bertenaga arus searah untuk mendukung proses pengumpulan brondolan kelapa sawit. Sistem yang dikembangkan mengintegrasikan penyapu rotari, konveyor sabuk, dan blower yang digerakkan motor DC serta dikendalikan melalui rangkaian ON/OFF sederhana. Pengujian dilakukan pada tegangan operasi tetap 12 V dengan variasi beban 2, 5, 7, dan 10 kg. Parameter pengujian meliputi waktu operasi, konsumsi arus, kebutuhan daya, dan kestabilan sistem. Hasil pengujian menunjukkan bahwa sistem mampu memproses beban 2–10 kg secara stabil. Peningkatan beban dari 2 kg menjadi 10 kg menyebabkan waktu operasi meningkat sebesar 87,1%, yaitu dari 6,2 detik menjadi 11,6 detik, sedangkan kebutuhan daya hanya meningkat sebesar 20%, yaitu dari 54 W menjadi 64,8 W. Integrasi ketiga mekanisme tersebut memungkinkan proses pengumpulan, pemindahan, dan pembersihan brondolan berlangsung secara berkelanjutan sekaligus mengurangi pekerjaan manual dan kelelahan operator. Troli ini berpotensi menjadi solusi praktis dan ergonomis untuk meningkatkan efektivitas pengumpulan brondolan.

Kata kunci: *Brondolan kelapa sawit, troli semiotomatis, motor arus searah (DC), konveyor sabuk, sistem penyapu, efisiensi energi.*

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1. PENDAHULUAN

Oil palm *(Elaeis guineensis Jacq)* is one of Indonesia's primary plantation commodities, with strong development prospects from upstream to downstream sectors. Investment in the oil palm industry remains promising, while global demand for palm-derived products such as crude palm oil (CPO), palm kernel oil (PKO), margarine, butter, soap, and glycerol continues to increase. In Indonesia, oil palm plantations dominate as the most economically valuable crop per hectare compared to other vegetable oil sources, with an annual economic growth rate of 5.05% according to BPS data [1].

The high demand for palm oil products has driven both the government and private sector to improve production comprehensively. This includes efforts to enhance both the quantity and quality of oil palm yields through interventions across various operational sectors. In the oil palm industry, technical and managerial aspects of harvesting play a crucial role. These include harvest planning, maturity criteria determination, and efficient loose fruit collection techniques. Special attention to these aspects is essential to improve productivity and the quality of harvested fruits (Jufri and Chairudin, 2023).

A common problem in smallholder plantations is the loss of oil palm loose fruits during the harvesting process. Loose fruits refer to detached fruitlets that fall from the bunch. For smallholder farmers, these loose fruits carry high economic value due to their weight and rich oil content, thus increasing the selling value [3], [4]. Loose fruits are often scattered across various areas such as the harvesting circle, beneath fronds, in dead inter-rows, on carrying paths, frond piles, ditches, field collection points, access roads, trucks, tractors, and loading ramps [5].

Unfortunately, these loose fruits are often neglected due to worker fatigue during harvesting activities, leading to significant post-harvest losses and even becoming potential weeds in plantation areas [6].

Figure 1. Oil Palm Loose Fruits in Plantation Areas

Currently, the collection of loose fruits is still performed manually, typically requiring workers to squat or bend down, which is ergonomically inefficient.

To address this issue, this study proposes the development of a mechanized loose fruit collection system to improve operational efficiency and reduce harvest losses. The aim of this research is to design an automated oil palm loose fruit collector equipped with a lift-type conveyor system and a DC-powered blower. The objectives include designing a robust mechanical structure, integrating the belt conveyor and blower system, and developing an automatic control unit. It is expected that this tool will increase collection efficiency by at least 50% compared to manual methods. The research methodology involves literature review, mechanical design, system integration, development of control automation, and prototype testing.

1. Conveyor

Conveyors are mass transportation equipment used to move production materials from one location to another, with the main types including belt conveyors, screw conveyors, and roller conveyors [7]. These systems are widely applied across various industries such as agriculture, packaging, automotive, and food processing, playing a crucial role in material transportation and handling systems and agricultural automation

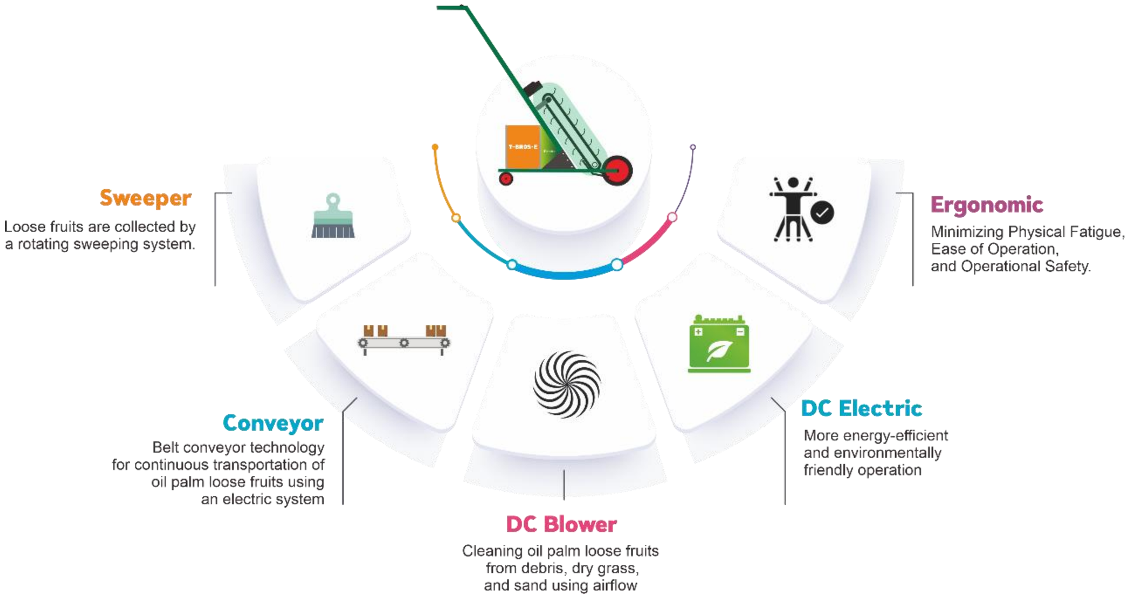


Figure 2. Electric Oil Palm Loose Fruit Collection System Application

sorting processes [8]. In particular, belt conveyors utilize a continuous belt to transport solid materials, including individual.

In particular, belt conveyors utilize a continuous belt to transport solid materials, including individual and bulk loads, either horizontally or with limited inclination, with system selection depending on capacity, material characteristics, and transportation conditions (Dhiya' Ushofa et al., 2022).

2. Motor DC

Direct current (DC) motors are electrical machines that convert direct current electrical energy into mechanical energy in the form of rotational motion and have been widely utilized for over a century in various technological applications. Owing to their simple construction, high starting torque, and ease of speed control through supply voltage variation, DC motors are extensively applied in small-scale electromechanical systems, enabling flexible and efficient regulation of rotational speed. These advantages make DC motors particularly suitable for material applications, where stable performance and good energy efficiency under varying load conditions are required[9], [10]

Structurally, a DC motor consists of a stationary part (stator) that generates a magnetic field through its field windings and a rotating part (rotor or armature) that moves within this magnetic field. The stator remains fixed, while the rotor and its armature windings rotate, separated by an air gap that allows smooth and contact-free motion [11].

II. METHODOLOGY

This research method aims to design an oil palm loose fruit collection device using a belt conveyor system and a blower for automatic cleaning, based on DC electrical technology. The following are the steps to be carried out in this research.

1. Problem Identification

The first stage of this research involves analyzing the availability of existing oil palm loose fruit collection technologies, evaluating constraints in manual cleaning processes, and assessing the performance of current collection tools to obtain a comprehensive understanding of the existing conditions.

2. Literature Review

This stage reviews existing oil palm loose fruit collection technologies to evaluate their advantages and limitations, examines belt conveyor and blower systems in

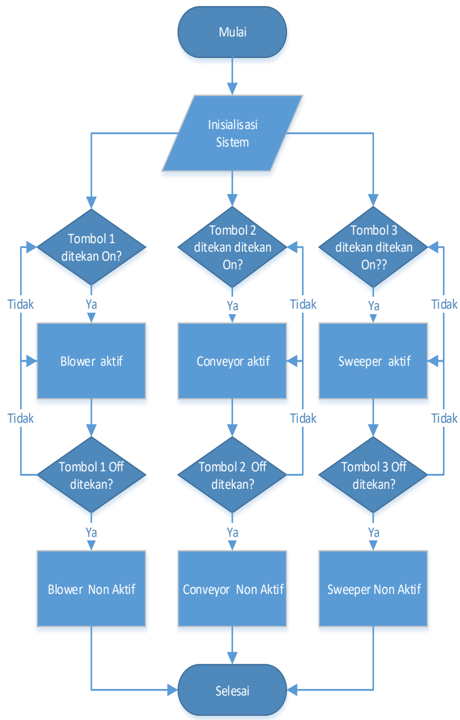


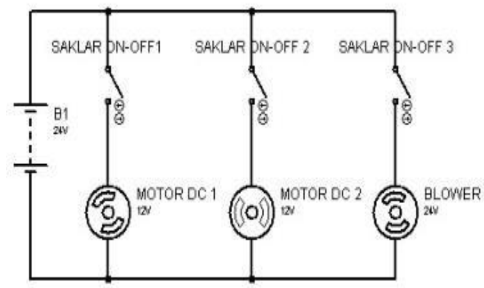
Figure 3. Flowchart of the Oil Palm Loose Fruit Collection Trolley System

Figure 3 illustrates the workflow and control system of the electric oil palm loose fruit collection device. The system is initialized and operated through ON/OFF buttons that independently control the blower, relation to the collection process, and explores the application of DC electrical technology to support automation.

3. System Design

At this stage, the main system design of the oil palm loose fruit collection device is developed by integrating several mechanical and electronic components, including
a sweeper, belt conveyor, and blower system, which function to guide, lift, and separate loose fruits from impurities such as leaves and soil. This process is illustrated in Figure 2. Sweeper, and belt conveyor for cleaning, collecting, and transporting loose fruits. The operation ends when all components are deactivated.

The integration of a DC electrical system



with three ON/OFF control buttons enables independent activation of the device components, allowing the system to operate automatically and efficiently using a 12 V power supply. This control configuration enhances operational flexibility, reliability, and energy efficiency, as shown in Figure 4.

Figure 4. DC Electrical System Circuit of the Oil Palm Loose Fruit Collection Trolley

In the trolley system, the oil palm loose fruit collection device is designed with a base frame measuring 50 cm × 40 cm to support the sweeper and steel scoop with dimensions of 20 cm in length and 15 cm in width. These dimensions were selected to ensure structural stability, mechanical reliability, and ergonomic operation by reducing operator fatigue during use. Subsequently, a belt conveyor system with a length of 60 cm and a width of 10 cm, along with a blower unit, was mounted on a support column inclined at 45 degrees to enhance material transfer efficiency, operational reliability, and user comfort, as shown in Figure 5 and 6.

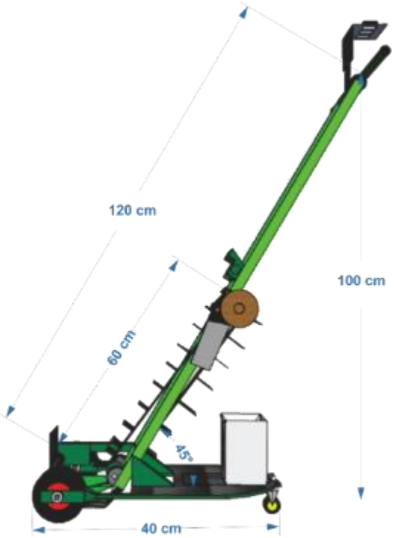


Figure 5. Side view of trolley design

Figure 6. Front view of trolley design

III. RESULTS AND DISCUSSION

The results of the design and fabrication process of the oil palm loose fruit collection device are presented in Figure 6. The prototype successfully integrates the sweeper, belt conveyor, blower, and DC electrical control system into a single trolley unit. The device is capable of collecting, transporting, and cleaning loose fruits continuously.

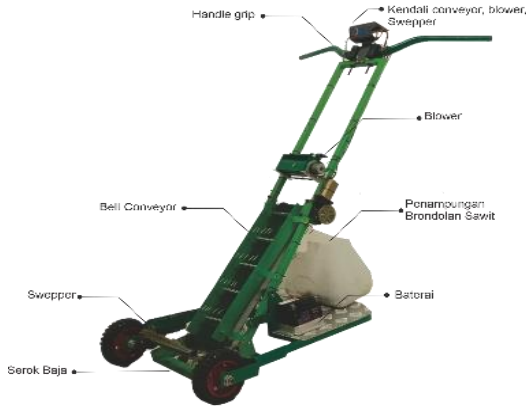


Figure 7. Prototype of an Electric Trolley for Oil Palm Loose Fruit Collection

The sweeper performance test was conducted using a brush with a width of 20 cm and a length of 10 cm, featuring three active sweeping sides. The sweeper operates through a rotational mechanism driven by a DC motor. This rotational motion enables continuous and uniform sweeping of oil palm loose fruits, thereby improving the effectiveness of collecting the fruits from the ground and directing them toward the conveyor system.

Table 1. Effective Performance of the Sweeper under Voltage Variations

Voltage (V)	Current (A)	Motor Speed (RPM)	Sweeping Time per Cycle (s)	Sweeping Performance
6	2,1	40	6,5	Less effective
9	3	65	4,8	Moderate
12	4,2	90	3,6	Effective
18	5,8	130	2,4	Very effective
24	7,5	170	1,8	Highly effective

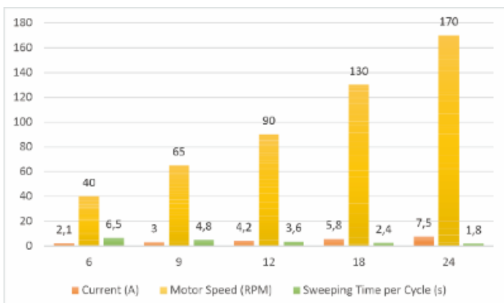


Figure 8. Effective Performance of the Sweeper under

Voltage Variations

An increase in the supply voltage of the DC motor leads to higher sweeper rotational speed and a shorter sweeping time. At low voltage levels, the sweeper performance remains limited, resulting in less effective loose fruit collection. The effective operating voltage range is 12–18 V, where the sweeper operates stably with relatively short sweeping time and good collection efficiency. At higher voltage levels, although the sweeping process becomes faster, increased current consumption must be controlled to maintain energy efficiency and overall system reliability.

Conveyor testing evaluated the performance of a DC motor–driven loose fruit transportation system by measuring rotational speed, transportation time over a 60 cm length, and current consumption under identical operating conditions.

Increasing the supply voltage raises the conveyor rotational speed and shortens transportation time. Effective and stable operation is achieved at 12–18 V, providing a balance between performance and current consumption, while higher voltages increase speed but reduce energy efficiency.

The overall performance test was conducted to evaluate the effectiveness and energy efficiency of the oil palm loose fruit collecting system operating at a constant supply voltage of 12 V under varying load conditions of 2 kg, 5 kg, 7 kg, and 10 kg. The evaluation focused on measuring total operation time, electrical current consumption, and power usage to assess the system's capability in handling different loads.

Table 2. Effective erformance of the Conveyor under Voltage Variations

Voltage (V)	Current (A)	Speed (RPM)	Trans port Time (s)	Performance
6	2,5	35	7,2	Less effective
9	3,6	60	5,4	Moderate
12	4,8	85	3,9	Effective
18	6,3	120	2,6	Very effective
24	7,9	155	2	Highly effective

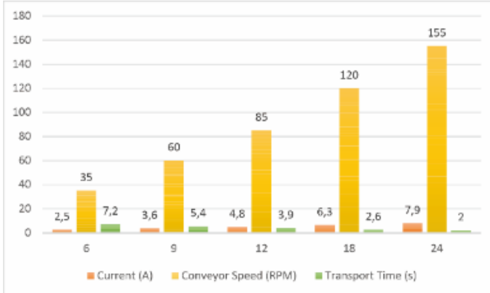


Figure 9. Effective Performance of the Conveyor under Voltage Variations

The results indicate that the system operates stably and efficiently at lower to medium loads, with a gradual increase in operation time and power consumption as the load increases.

This behavior demonstrates that the 12 V operating condition provides a balanced performance between effective loose fruit collection and efficient energy utilization, making it suitable for continuous and practical field operation.

Table 3. Overall Performance Test at 12 V Operation

Load (kg)	Total Operation Time (s)	Current Consumption (A)	Power Consumption (W)
2	6,2	4,5	54
5	7,8	4,8	57,6
7	9,4	5,1	61,2
10	11,6	5,4	64,8

IV. CONCLUSION

The experimental results demonstrate that the developed oil palm loose fruit collecting trolley operates reliably and stably at a constant supply voltage of 12 V under varying load conditions of 2 kg, 5 kg, 7 kg, and 10 kg. The integrated system, consisting of a sweeper, belt conveyor, blower, and DC electrical control system, successfully performs continuous collecting, conveying, and cleaning of loose fruits with consistent performance as the load increases.

Although power consumption and operating time increase proportionally with higher loads, the system maintains good electrical stability and mechanical reliability, achieving a balanced trade-off between energy efficiency, operational effectiveness, and user comfort. Overall, the proposed system shows strong potential as an efficient, ergonomic, and practical solution to enhance productivity and reduce reliance on manual loose fruit collection in oil palm plantations.

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