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DESIGN OF A COST-EFFECTIVE LOOSE PALM OIL FRESH FRUIT COLLECTOR FOR SMALL-SCALE FARMERS

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Abstract:

This study investigates the enhancement of existing low-cost loose palm oil fresh fruit collectors. The aims are to design and fabricate simple, portable, cost-effective, and user-friendly collector for small-scale farmers, aiming to alleviate back pain and spinal issues among workers. To achieve this, a tool was developed by modifying the traditional spike-based loose palm oil fruit collector. Data were gathered from various research sources, then prototype was designed and developed, followed by a performance analysis of the newly designed collector. The results demonstrate that the new design is versatile, capable of gathering not only loose palm oil fresh fruits but also other types of fruits, thereby increasing its utility and value for farmers. Specifically, the new collector reduces the physical strain on workers by incorporating ergonomic features that minimize bending and lifting. This improvement is crucial for small-scale farmers who often lack access to advanced machinery and rely heavily on manual labor. The cost-effectiveness of the new design is another significant finding. By utilizing readily available materials and simple manufacturing processes, the new collector remains affordable for small-scale farmers, ensuring that it can be widely adopted without imposing a financial burden. This aspect is particularly important in developing regions where budget constraints often limit access to improved agricultural tools. The

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research underscores the importance of innovation in addressing the challenges faced by small-scale farmers and emphasizes the need for continued efforts to develop tools that improve agricultural practices. The findings of this study have the potential to drive further advancements in agricultural technology and improve the livelihoods of farmers in the palm oil industry.

Keywords:

Agricultural Tools, Small-Scale Farmers, Low-Cost, Palm Oil Fruit

Introduction

Palm oil represents one of the cornerstone crops of the global agricultural sector and is particularly significant in Malaysia, where it is primarily cultivated for its oil-rich fruits known for their multifunctionality. As the second-largest producer of palm oil globally, Malaysia has made substantial investments in various areas, including palm oil plantation management, research and development (R&D), and the training of skilled labor (Syahid et.al, 2025, Sarwani et.al, 2024 and Hussin et.al, 2023). The efficient harvesting of oil palm fruits plays a pivotal role in boosting palm oil production productivity and minimizing labor costs. To achieve this, employing appropriate tools and machinery is essential. However, the financial constraints faced by small-scale farmers often render the acquisition of expensive harvesting equipment infeasible. Addressing this challenge, the development and implementation of low-cost harvesting tools present a practical solution. Such tools can significantly alleviate labor demand, enhance harvesting efficiency, reduce the loss of loose fruits, and ultimately increase the profitability of palm oil farming activities, particularly for small-scale producers (Akendola et.al., 2025).

Malaysia has developed advanced and mature harvesting techniques for palm oil fruits. However, during the harvesting process, it is common for palm oil fruit bunches to fall from the trees and hit the ground, causing loose fruits to detach from their stalks and scatter. Notably, these loose fruits possess the highest oil content within the bunch, as they typically represent the most mature fruits (Ruswanto, et.al., 2020). Despite their economic value, these loose fruits are often left on the ground after the collection of fruit bunches. Under traditional harvesting methods, laborers are required to repeatedly bend and squat to manually gather loose fruits, which can lead to significant health issues such as back pain, spinal problems, and long-term injuries caused by improper posture (Pawitra et.al, 2021). Additionally, this practice reduces worker efficiency and slows the harvesting process.

Small-scale palm oil farmers face further challenges due to their inability to afford costly machinery and tools, which hinders their ability to balance operational costs with profitability. There are many tools and machinery that exist in the market that are high in cost especially those tools that have high collecting efficiency. Besides that, some of the tools are not ergonomic and safety, it may cause injury to the farmers if they handle improperly. By having wrong posture when picking up the loose fruits may cause spine problems and exoskeletal injury (Forest et al., 2024 and Saedin et al., 2025). Previous research mostly aimed to improve collecting efficiency while ignoring the ergonomic of the tools. However, none of the tools in the market perfectly suit the farmer, every tool has its own limitations and advantages. This is the reason why improved modified tools should be made. This study focuses on addressing these issues by designing and improving low-cost, user-friendly loose fruit collectors tailored

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specifically for small-scale farmers. The proposed collector utilizes a do-it-yourself (DIY) approach, incorporating primarily recyclable materials, making it an affordable and practical solution. By enhancing the efficiency and usability of these tools, the initiative aims to support small-scale farmers in increasing their productivity and reducing physical strain.

Existing Low-Cost Oil Palm Loose Fresh Fruits Collector Design

The benchmarking process was carried out to gain a comprehensive understanding of the existing designs and their practical applications. This study analysed five types of loose fruit collectors: the drum-based collector, spike collector, rolling-basket-based collector, raked-basket-based collector, and vacuum-based collector.

The drum-based collector operates on the principles of friction and strength to capture and gather loose palm oil fruits into a container (Saulia et.al, 2022). As the drum rotates, loose fruits become stuck on the spikes of the drum and are subsequently filtered into a basket at the front. This tool is highly effective for covering large areas with minimal manual effort, making it a valuable option for efficient collection. However, despite its advantages, the drum-based collector has notable limitations. It is large and costly, with a manufacturing process that requires precision machine cutting, making it structurally complex. Its considerable size also reduces its mobility, posing challenges for individuals with smaller body frames who may struggle to operate it efficiently.

The spike-based collector (Khalid et.al, 2021) comprises an iron plate, hollow aluminium, nails, springs, and Polyvinyl Chloride (PVC) components. While it is considered the least popular among the evaluated collectors, it has a unique working mechanism. When labourers press the collector onto the loose fruits on the ground, the fruits are impaled on the exposed nails. The operator then pushes a lower plate, which is connected to the PVC inside the hollow aluminium, to release the fruits from the nails. Although relatively effective and user-friendly, this design has significant drawbacks. The nails may damage the loose fruits, compromising their quality, and their exposed nature poses a safety hazard to labourers during use.

The rolling-based collector is a manual tool specifically designed for the collection of loose palm oil fruits. This tool operates on the principle of mechanical wheels rolling over loose fruits on the ground. Due to the elasticity of its cylindrical wire, the loose fruits are rolled inward and gathered within the mechanical wheels. The device features a long rod attached to an oval-shaped rolling wheel constructed from curved elastic wire. Its lightweight, compact, and straightforward design makes it a popular choice among labourers, as it is both user-friendly and easy to handle (Bakar et.al, 2022). However, a critical drawback of this design is its low durability. Prolonged use, particularly on rocky terrain, can lead to deformation and failure of the elastic wire upon impact with rocks. This impairs the smooth rolling motion and reduces the efficiency of the collection process (Navarro et.al, 2024).

The raked-basket collector is the most common and affordable tool currently available in the market for loose palm oil fruit collection. Widely favoured by farmers, this design is valued for its simplicity, lightweight structure, and ease of use. The tool consists of a long pole with a rake-shaped end and a scoop resembling a dustpan, designed with numerous gaps and holes. This setup enables the tool to collect loose fruits from the ground by dragging them into the scoop while filtering out small pebbles and sand through the gaps. The raked-basket collector operates on principles similar to those of a conventional sweeper and dustpan. However, this

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design is less effective on uneven ground or rough terrain, often leaving loose fruits behind. Additionally, its durability is compromised by the materials used in its construction, further limiting its reliability over time.

The vacuum-based collector represents a more advanced technological solution, leveraging the concept of suction cyclone technology (Aljawadi et.al, 2021). This machine is designed not only to collect loose palm oil fruits but also to separate the fruits from debris within a two-layer vacuum chamber, producing clean fruits at the base of the collection barrel. It is easy to operate and highly efficient, with the capacity to collect between 1200 kg and 1500 kg of loose fruits per day (Abd Rahim et.al., 2018 and Bakar et.al., 2022). An enhanced feature of this machinery is its barrel, which acts as a temporary storage unit. The barrel's contents can be periodically emptied into another container with a holding capacity of up to 500 kg, ensuring uninterrupted operation. These improvements make the vacuum-based collector a fast and convenient option for large-scale collection activities.

The benchmarking comparison, as summarized in Table 1, highlights key aspects: geometric design, the advantages and disadvantages of each collector type. Based on this comparison, the spike-based collector concept was selected for the prototype fabrication. This choice is attributed to its relatively low cost compared to other loose fruit collectors, making it an affordable option for small-scale palm oil field workers. Additionally, the spike-based collector is user-friendly and effective in gathering loose palm oil fruits, addressing the practical needs of its intended users. To optimize its functionality, modifications were made to the available design to address and overcome its identified limitations, ensuring improved performance and usability.

Table 1: Benchmarking Comparison

Criteria	Drum-based	Spike-based	Rolling-basket based	Raked-based	Vacuum-based
Geometry	Size: Adjustable Height:70 cm Mass: 34 kg	Size:Non-Adjustable Height: 80 cm-150 cm Mass: 4 kg	Size: Adjustable Height:120 cm-130 cm Mass: 1kg	Size: Adjustable Height:130 cm Mass: 2 kg	Size: Very Big Height: 150 cm Mass: 60 kg
Advantages	Very effective in collecting loose palm oil fruits, Does not require professional technician to handle, Stable and steady	Easy to be used Low Cost Fast and effective Suitable to all type of people, Save energy	Easy to use, Safety, Low Cost	Very low cost, Easy to use, Light and easy to store	Effective, Energy saving
Disadvantages	Too big and heavy, High	Danger and need	Not suitable for all type of	Not very effective,	Very high cost, Too big

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	cost compared to other design, Have hidden danger due to the exposed spike, Maintenance costs a lot, Not suitable for all type of land	to be caution, may cause damaged to the loose fruits	land, Easily deformations, Needs maintenance frequently, Sometimes stones and pebbles may stuck inside the roller, Require a lot of energy to roll in the loose fruits	Pebbles and rocks may be mixed with the loose fruit when collect, Easily deformations due to cheap materials, Non-durable	and heavy, Require technician to operates, Maintenance costs are high, Require electricity to operate

Methodology

This study was conducted through four primary stages: 1) Design Requirement, 2) Concept Generation, 3) Concept Selection, and 4) Prototype Fabrication. Each stage was meticulously planned and executed to ensure a systematic approach toward the development of a user-friendly and cost-effective tool for loose palm oil fruit collection. Table 2 below outlines the detailed design requirements, (Johnny et.al., 2024) which served as a foundation for the subsequent stages. Figure 1 illustrates the flowchart of the overall design and development process, demonstrating the systematic progression from the identification of requirements to the creation of the final prototype.

Table 2: Specific Design Requirements

Design Requirements	Criteria
Geometry	Size: Medium Height:50 cm-130 cm (considering human factor and ergonomics) Mass: 1 kg-5 kg
Material	Recycled/ Easily available for do-it-yourself purposes
Safety	Safe to use / Do not have hidden danger and easy to use (user friendly)
Operation	Able to collect the standard size of loose fruits: 1.5 cm-2.5 cm (Basyuni et.al, 2017)
Maintenance	1. Able to dissemble for maintenance 2. Parts can be found in market 3. Can be clean easily
Cost	1. Manufacturing cost: RM50-RM100 2. Market Price Range: RM100-RM150

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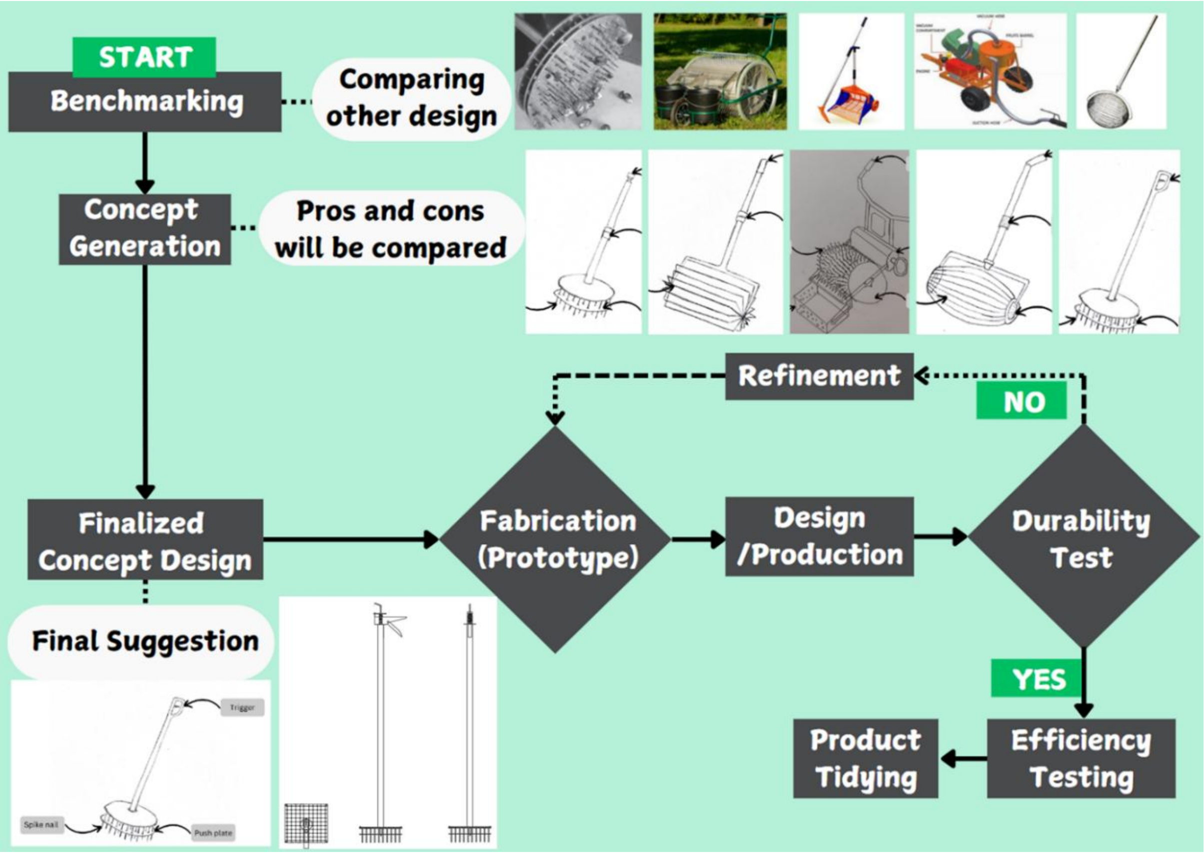

Figure 1: Flowchart of the Design Process

Result and Discussion

Concept Selection and Working Procedure

Based on the design requirements, five concepts were initially developed, of which the spike-based concept was ultimately selected due to its cost-effectiveness and suitability for small-scale palm oil operations. However, the original spike-based design presented significant safety concerns, particularly in the separation of palm oil fruits from the nails. The sharpness of the nails posed a risk of injury if mishandled, and the process of collecting loose fruits stuck between the nails was both cumbersome and potentially hazardous. To address these challenges, substantial modifications were made to improve the safety, efficiency, and usability of the design.

The modified spike-based concept incorporates a silicon gun mechanism at the top end of the pole, seamlessly integrated with a spring system and an internal metal concrete bar. The silicon gun is mechanically connected to the trigger and spring assembly within the iron pole, which facilitates a smoother and safer fruit removal process. The working principle involves welding the first iron plate to the iron pole, which houses the iron nails. The second iron plate, connected to the internal metal bar, moves in response to the trigger mechanism. When the trigger of the silicon gun is pressed, the metal bar inside the pole pushes the second plate forward, effectively dislodging the loose fruits from the nails. To reset the mechanism for subsequent use, the release plate at the spring assembly can be activated, allowing the second plate to return to its initial position. For this design, all materials used are metal because it requires a lot of welding and needs to make sure that the joint and the materials are strong enough to withstand the stress

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when collecting the loose fruits. L-shape iron bars are specifically used in strengthening the joint between the iron plate and the iron pole to increase its durability and prevent deformation when using.

The integration of a spring system and piston mechanism significantly improves operational safety and eliminates the manual handling of sharp nails. With the spring-assisted ejection system, farmers no longer need to invert the spikes to verify fruit removal, as the mechanism ensures complete dislodgment in a single action. Furthermore, this design prioritizes low-cost materials and energy-efficient operation while maintaining the ability to collect loose fruits of standard size. Other than that, the length of this design is moderate, and it is suitable and comfortable to be used by people of any height. The improvements ensure that the tool remains accessible to small-scale farmers while enhancing its functionality.

In terms of quality considerations, it is important to note that the minor damage caused by the nails does not compromise the oil content or quality of the harvested fruits, provided they are transported promptly to processing facilities within 24 hours, which aligns with handling and degradation studies of FFB during post-harvest processes, which also indicates that oil palm losses predominantly occur during the oil extraction phase (Sharif et.al, 2017). To further streamline the fabrication process and enhance the durability of the design, the clipping method was adopted for securing nails to the collection iron plate instead of the traditional welding process. This adjustment improves structural integrity while reducing production complexity and cost.

Finalized Design
Figure 2 shows the orthographic drawing of the final design. The height of the collector is about 127 cm and the weight is 3.38kg. For the size of the plate is 20.5cm x 20.5cm.

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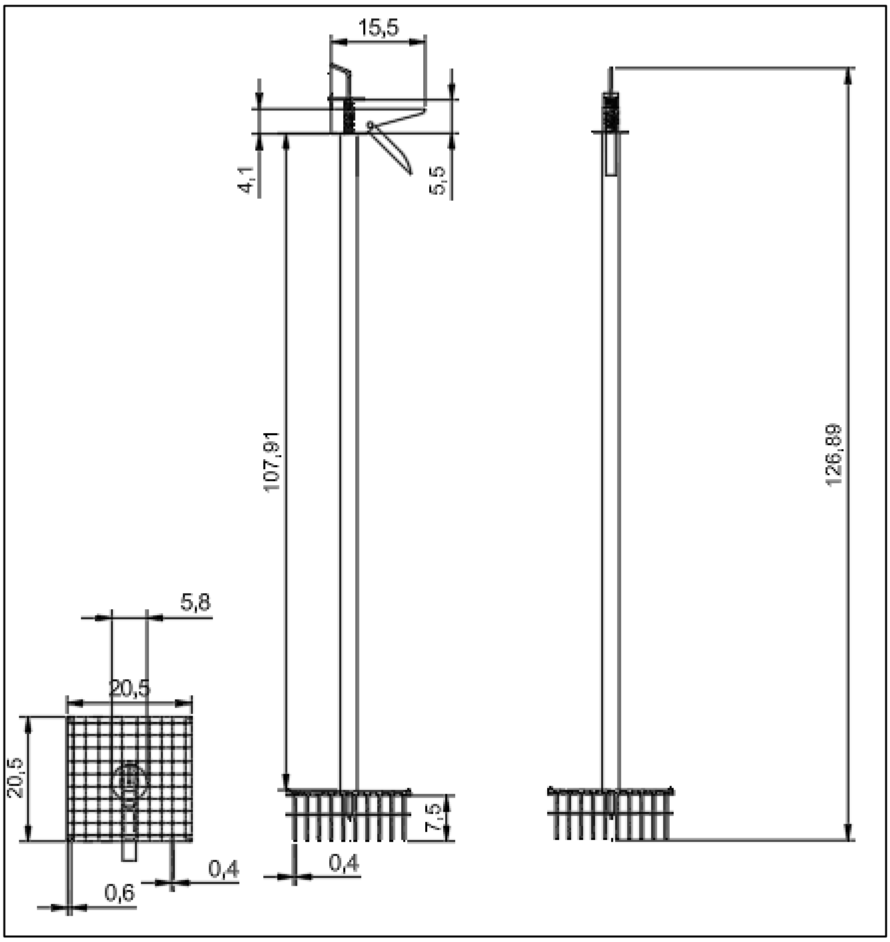

Figure 2: Orthographic Drawing of Final Design

Prototype Fabrication

Following the finalization of product drawings and technical specifications, the prototype was fabricated to assess its design functionality and ensure alignment with the project objectives. The fabrication phase served as a critical step in the development process, providing an opportunity to visualize and evaluate the final product in a real-world context. This stage also enabled iterative improvements to optimize performance and functionality.

The prototype was constructed using recycled and readily available materials, aligning with the project's goal of creating a cost-effective and sustainable tool for small-scale palm oil farmers. The use of recyclable materials not only reduced fabrication costs but also supported the objective of making the prototype accessible and replicable for its intended users.

Throughout the fabrication process, several improvements were implemented to address the challenges identified during the design and planning stages. These enhancements included modifications to the structural components, refinement of the trigger and spring mechanisms, and adjustments to the placement of critical elements to ensure ergonomic operation and ease of maintenance. Such iterative modifications were informed by preliminary testing and feedback, emphasizing usability, efficiency, and durability.

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Figure 3 illustrates the step-by-step improvement process carried out during the fabrication phase, showcasing the evolution from the initial design concept to the optimized prototype. Figure 4 displays the final prototype, highlighting the integration of the modified spike-based mechanism, spring system, and structural reinforcements. The fabricated prototype reflects the culmination of the design considerations and emphasizes the feasibility of producing a low-cost yet functional tool for the efficient collection of loose palm oil fruits.

Figure 3: Product Improvement Flow

Figure 4: Prototype of Spike-Based (Modified)

Prototype Testing

The prototype testing phase was conducted to evaluate the functionality and practicality of the low-cost oil palm loose fruit collector. This process aimed to ensure that the final design met

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its intended objectives of efficiency, user-friendliness, ergonomic, durability and reliability under operational conditions.

The test was separated into two parts: durability and efficiency. The durability test is conducted in the palm oil field based on the real situation and environment. he durability test evaluated whether the tool deformed under repeated testing. During early trials, structural failure occurred, indicating insufficient strength in the initial design. Reinforcement was subsequently applied to improve load-bearing capacity. Durability tests of the final prototype confirmed that the reinforced joints and use of L-shaped bars prevented deformation after repeated three stress cycles in palm oil fields. The tool maintained operational functionality across multiple trials, demonstrating structural reliability. This outcome is consistent with durability-focused evaluations of palm fruit collectors and the role of reinforcement in preventing structural failure under field impacts (Navarro et al., 2024). The results confirm that the design is durable and ergonomically suitable for small-scale farmers, reducing maintenance needs while ensuring operational comfort.

The testing procedure for the efficiency test involved the following steps: the trigger pin was initially activated by pushing it to retract the iron rod located at the back of the trigger mechanism. The head of the prototype was then pressed against the loose palm oil fruits scattered on the ground. The number of loose fruits collected during this action was recorded. To release the collected fruits from the spikes, the trigger was pressed again to engage the spring-loaded mechanism. Subsequently, any remaining fruits that were not successfully dislodged from the nails were recorded. This data provided insights into the efficiency of the design in collecting and ejecting the loose fruits effectively.

The results of the testing, as detailed in Table 3, revealed an average efficiency rate of 83.33%, calculated using Equation (1). This metric represents the ratio of the number of loose fruits (L.F) successfully collected and ejected to the total number of fruits targeted during testing. The high efficiency rate demonstrates that the modified spike-based design provides a reliable solution for loose fruit collection, particularly for small-scale palm oil operations. Furthermore, the consistent efficiency rate validates the reliability of the spring-assisted ejection system, which distributes internal pressure evenly along the plate, ensuring uniform fruit dislodgment and minimizing operator effort. These findings highlight the ergonomic suitability of the design, as the mechanism minimizes repetitive bending and grip force, thereby lowering musculoskeletal risk among small-scale farmers (Chahal, 2020; Mohd Tamrin et al., 2015).

The combination of durability and efficiency outcomes demonstrates that the modified spike-based collector is both structurally reliable and ergonomically suitable for small-scale farmers. By reducing repetitive bending and grip force, the design directly addresses common musculoskeletal issues in palm oil harvesting, while maintaining cost-effectiveness and ease of use.

$$Efficiency\ Rate = \frac{No.\ of\ L.F.\ Successfully\ Push\ Out}{No.\ of\ L.F.\ Collected} \times 100\% \qquad \textbf{Equation (1)}$$

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Table 3: The Results for Efficiency Tests

No.	No. of L.F Collected	No. of L.F Successfully Ejected	Efficiency Rate (%)
1.	9	8	88.8
2.	10	7	70
3.	11	9	81.8
4.	11	10	90.9
5.	12	10	83.3
6.	12	10	83.3
7.	8	6	75
8.	13	10	76.9
9.	12	10	83.3
10.	9	9	100
Average Efficiency Rate			**83.33**

Cost Distribution

The cost distribution for the prototype fabrication is detailed in Table 4, which includes an estimated breakdown of recycled and purchased materials. The total fabrication cost demonstrates that the modified spike-based collector falls within a reasonable price range compared to similar products currently available in the market. This indicates the design's competitiveness in terms of affordability, particularly for small-scale farmers.

A significant cost-saving aspect of this design lies in the use of recyclable materials, which greatly reduces manufacturing expenses. For example, iron plates and rods collected from workshops lowered the overall cost by nearly one-third compared to using new materials. Should these components be sourced directly by farmers, the overall expenditure could be further minimized. This aligns with the project's objective of promoting a do-it-yourself (DIY) fabrication concept, empowering farmers to construct and maintain the tools themselves with basic resources.

Beyond affordability, the analysis highlights that fabrication using recycled materials reduced total expenditure by approximately 30–40% compared to commercial alternatives. This validates the economic feasibility of decentralized, farmer-led production, ensuring accessibility for communities with limited financial means. Similar findings have been reported in studies of mechanisation adoption in small-scale oil palm plantations, where cost savings and accessibility are critical for farmer uptake (Ahmad et al., 2023; Ramli et al., 2021). Figure 5 illustrates the comparative affordability, confirming that recycled-material fabrication achieves significant cost savings while maintaining functionality.

Table 4: List of Materials and Cost

No.	Material	Quantity	Cost (RM)
1.	Mild steel pipe 2.5 × 0.06 (120 cm)	1	20.90
2.	Iron Nails (3 inch)	1.2 kg	8.00
3.	Silicon Caulking Gun	1	10.90
4.	Iron plate 25 × 25 (0.15 cm)	3	Recycled (collected from workshop with estimated price is RM14.40)

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5.	Iron rod 0.8 × 150 cm	1	Recycled (collected from workshop with estimated price is RM7.50)
6.	Bolt & Nut 2.0 cm	4	3.90
7.	Washers 0.5 cm	4	1.20
8.	Angle Bar	6	Recycled (collected from workshop with estimated price is RM10.50)
9.	Spray paint	1	7.00
10.	Bosch Cobalt Bit 0.48 cm	2	18.40

The comparison of the prototype's cost with market alternatives as shown in Figure 5 highlights its financial viability, emphasizing its capacity to deliver comparable functionality at a fraction of the cost. The analysis shows that the spike-based (modified) collector type can be priced at quite affordable range. The affordability of the design, coupled with its focus on user-friendliness and practicality, positions it as an ideal tool for small-scale palm oil field operations. This cost analysis underscores the prototype's potential to make a significant contribution toward improving harvesting efficiency while remaining economically sustainable for its target users.

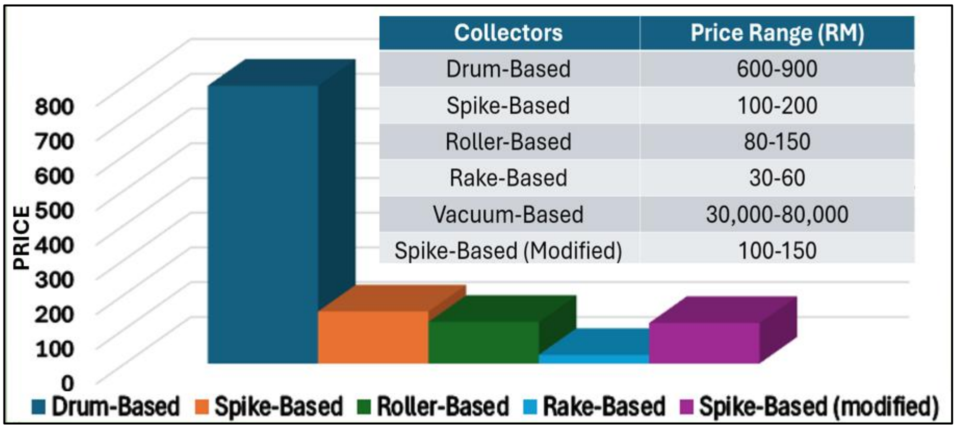

Figure 5: Price Comparison between Spike-Based (Modified) with Available Collectors in Market

Conclusion

The development of a low-cost palm oil loose fruit collector represents a critical advancement in addressing the challenges faced by small-scale and low-income farmers. By modifying the spike-based design with a spring-assisted ejection system and structural reinforcements, the prototype reduces musculoskeletal strain, improves safety, and maintains operational durability. Testing confirmed an average efficiency rate of 83.33%, validating the tool's reliability in real field conditions while remaining affordable using recycled materials.

Beyond technical performance, the innovation demonstrates strong industry relevance by providing farmers with an accessible alternative to costly machinery. Its affordability and DIY fabrication approach empower rural communities to sustain productivity without financial burden. In alignment with sustainability goals (SDG 1: No Poverty, SDG 8: Decent Work and Economic Growth, SDG 12: Responsible Consumption and Production), the design reduces material waste, enhances labor conditions, and promotes inclusive innovation. This highlights

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the potential for scalable, farmer-led solutions that strengthen rural livelihoods, improve harvesting efficiency, and contribute to more sustainable palm oil production systems. Future work should explore broader adoption across diverse plantation contexts and integration with emerging technologies to enhance long-term impact, while ensuring continued relevance to low-income farming communities.

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