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Design and Fabrication of Oil Palm Loose Fruit Collector

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Abstract

The loose fruit collection procedure gets more attention than the other processes since it offers the highest rate of oil extraction. The technique for collecting the loose fruits usually uses a hand and collects into the bucket but the workers need to bend over to collect loose fruit on the ground which can cause back pain. This project proposes a loose fruit collector with more ergonomic lightweight and easier to use. It begins with the analysis from the research and the survey regarding the problems faced by the workers and the specific design requirements of the respondents. To develop the collector's concept, the eight phases of George E. Dieter's engineering design process were followed, benchmarking existing market items and patents. SolidWorks software was used to identify and model the optimal concept and enable thorough engineering investigation, including static analysis. After extensive engineering calculations and simulations in SolidWorks, the final product design has overall dimensions of 500 x 432 x 825 mm for the basket and 320 x 96 x 1260 mm for the rake. The entire weight of the product, including fasteners, is 4 kg. It is anticipated that these creative collectors would greatly increase the effectiveness and simplicity of upholding Malaysia's ergonomic work culture.

1. Introduction

One of the most important elements in the process of harvesting and gathering oil palm fruits is loose fruit. Roughly 3-4% of the bunch weight is considered to be made up of uncollected loose fruits. In the past, gathering loose fruits was typically done by hand and placed in a bucket, plastic bag, or gunny [1]. Typically, loose fruit is collected by hand and gathered into a basket, as shown in the Fig 1, or into a plastic bag or gunny. In addition, there were additional possibilities such as the use of a scoop, planks, and rake [2]. The farmer must bend their body to gather loose fruit from the ground and move from tree to tree. Fruit collection typically takes up to 30% of the harvesting period [3]. This approach wastes time, disturbs the farmer, and harms their backs.

Fig 1 *Worker gather loose fruit using basket*

Manual effort is required for the collection of loose oil palm fruits; workers use rakes, scoops, bags, or gunnysacks as well as other instruments [4]. However, this manual method creates ergonomic problems, making it difficult for workers to bend over and pick fruits off the ground [5]. About 11.5% of Malaysian workers are affected by the significant occupational risks associated with working on oil palm plantations, which include musculoskeletal issues [6]. The worker is shown squatting to gather the loose fruit in Fig 2. Therefore, resolving these ergonomic issues is essential to protecting agricultural workers' health in Malaysia's oil palm sector.

Fig 2 *The worker squatting to collect the loose fruit*

Currently, loose fruits are gathered by hand or by raking. This approach requires a lot of work, takes a long time, and is exhausting. Throughout the workday, workers are required to stand and squat when collecting. This exercise, which purposely encourages poor posture, takes minimal time but is performed frequently daily [7].

The development of a practical and cost-effective mechanical loose fruit harvesting method is a primary objective for the oil palm industry. Enhancing the efficiency of picking loose fruit while minimizing expenses is crucial. The development of an affordable and efficient loose fruit-gathering method is still the fundamental objective of the oil palm industry. Due to various technological restrictions and constraints, the goal has not been accomplished through the development of multiple technologies [8]. Consideration such as functional, technical, ergonomics and user-friendly requirements have been taken in designing process in order to achieve the best collector.

Benchmarking all of your patent research and existing product systematically compares your methods to industry standards, providing you with comprehensive knowledge and competitive advantage in the design and innovation process. The patents discussed in Table 1 highlights a design concept of leaves collector. From this patents idea such as rake, basket or scoop have been taken as one of reference in searching idea for the collector design. To get information and specifications for the relevant machine, it is crucial to research and evaluate the products that are currently on the market. Based on the study, helps to come up with fresh concepts for designs and to enhance the functionality, look, and mechanisms of the current equipment.as shown in Table 2

Table 1 *Patents Search*

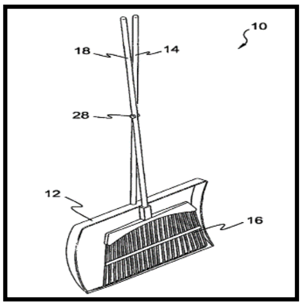
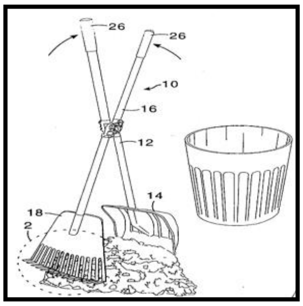
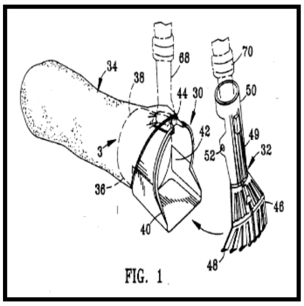
Patents Search		
Combination Rake and Shovel Tool (Patent No: 7,703,822 B1)	Raking and Pick-Up Tool (Patent No: 5,564,267)	Manual Scoop and Rake System for Collecting Leaves and Other Light Debris (Patent No: 5,498,046)
		

Table 2 *Benchmarking of the Commercial Product*

Product Name	Oil Palm Loose Fruit Rake and Basket	Oil Palm Loose Fruit Collector	Roller Picker Loose Fruit Collector
Figure	 		
Manufacture	Rake: SamleeM2222 Basket: BAJA MALAYSIA	LOGAMBOY	JomShop.Store
Dimension (cm)	Rake: (0.3 x 29.5) x 7.5 x 3.3 Basket: 50 x 26 x 20	Rake: 35 x 7.5 x 50.8 Compartment with ribs: 42 x 45 x 30	Head size: 32*19cm Telescopic pole size: 48-105cm
Price (RM)	Rake: 12.10 Basket: 14.00	96.00	89.00
Feature			
Weight (kg)	0.3	2	1.4

2. Methodology

By following George E. Dieter's method in designing this collector, there are three phases followed which is conceptual design, embodiment design and detailed design. Since this project need to fabricated the product one addition phase which is fabrication phase. In conceptual design, to establish Product Design Specification (PDS), the problem was described, ideas are generated through research and feedback, and concepts are assessed. Next, embodiment design phase optimizes dependability and manufacturability by refining the design using product architecture, configuration design, and parametric design. In detail design phase SolidWorks software is used to create comprehensive drawings that give all part specifications. Lastly will be fabrication phase where a prototype will be fabricated based on the design and it will test for functionality.

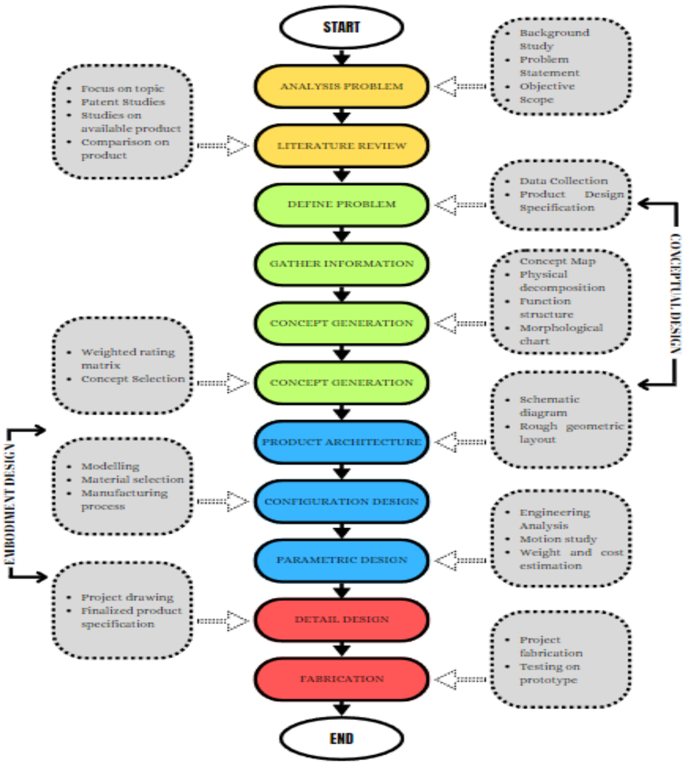


Fig 3 *Flowchart of the Design Process*

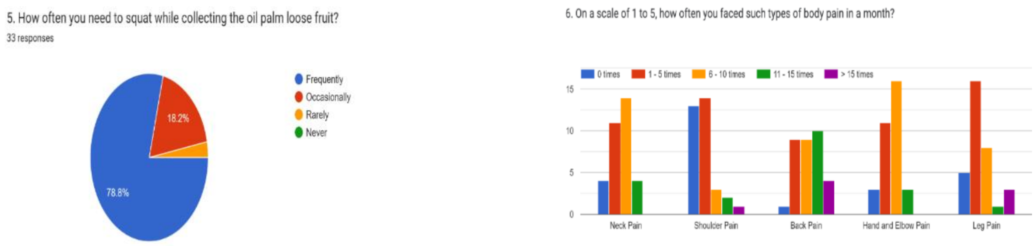
3. Results and Discussion

3.1 Identification of Needs

In this chapter, design process introduced by George E. Dieter is used as a guideline to all activities in design process. It consists of eight stages of design process except for information gathering where it done in literature review.

3.1.1 Google Form Analysis

A Survey through google form have been done in order to gather all the information needed. In the google form survey there are several parts and some of it asking how often their need to squat to collect loose fruit and what is the body pain often faced by them Respondents also asked about 11 customer requirements and respondents need to state which requirements are important in designing an Oil Palm Loose Fruit Collector. Table 3 shows customer requirements and the score.



(a) (b)

Fig 4 *Some data from the survey (a) Distribution of respondents based on how often they squatting (b) Distribution of respondents based on how often they faced such types of body pain in a month*

Table 3 *Customer Requirements and the Score*

No.	Customer Requirements	Score
1	User – friendly	5
2	Easy to collect loose fruit	5
3	Easy to separate sand, debris and rock	5
4	Portability	4
5	Good durability	5
6	Attractive appearance	3
7	Lightweight	5
8	Adjustable Holder	5
9	Comfortable handle grip	5
10	Safe to use	5
11	Affordable	4
Total		51

3.1.2 Product Design Specification (PDS)

The project specifications, including measurements, ergonomic and environmental considerations, aesthetics, and maintenance, are fully described in the Product Design Specification (PDS). It addresses the selected methodology, anticipated geological circumstances, and safety guidelines. The PDS acts as a condensed design task blueprint by outlining the design capabilities while leaving out implementation strategies.

Table 4 *Product Design Specification*

INTRODUCTION	
Title	Oil Palm Loose Fruit Collector
Design Problem	Less ergonomic collector
Special Features	Improving features of collector to make it more ergonomics for the user
CUSTOMER REQUIREMENTS	
Function	• Collector must be easy to used. • User can easily collect loose fruit. • User can easily separate sand and others.
Design	• Collector must be easy to carry. • Collector must have good durability. • Have an attractive appearance
Ergonomic	• Lightweight collector. • Collector have adjustable holder. • Collector have good handle grip.
Safety	• Less sharp edge for the collector. • The collector should not expose any danger to the user.

Cost	• Collector should affordable for the user.

3.2 Result of Conceptual Design phase

As seen in Fig 5 (a), physical decomposition is utilized to break down the product into smaller components to facilitate comprehension of the coupling's connection and achieve the largest function. In addition, as Fig 5 (b) illustrates, the relative functions of the components are displayed in Function Decomposition. A diagram produced using function decomposition is called a function structure. It illustrates the material, signal, and energy fluxes using a block diagram and three different arrow patterns. Next, Fig 6 shows the whole process flows for gathering the loose fruit.

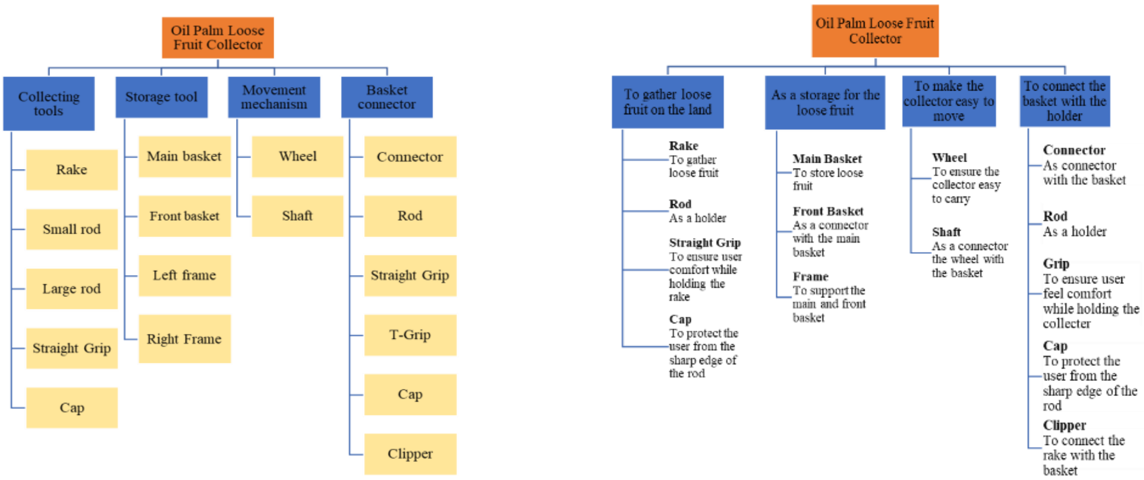


Fig 5 *(a) Physical Decomposition of Oil Palm Loose Fruit Collector (b) Function Decomposition of Oil Palm Loose Fruit Collector*

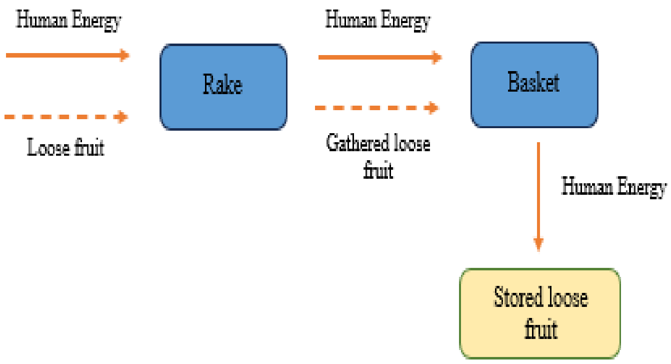


Fig 6 *Function Structure for Oil Palm Loose Fruit Collector*

Table 5 shows the selected concept design and the concept was selected based on morphological chart in order to identify which alternatives are suitable for the product. From the morphological chart there are three combinations have been made and one best combination will be chosen based on weighted rating matrix results.

After the best combination choose, three sketching ideas was made based on rake and scope concept and Fig 7 shows the best product sketching choose as a main idea to do the project design.

Table 5 *Selected Concept Design*

No.	Function	Combination 2
1.	To gather loose fruit	Plastic Basket
2.	Provide good grip for the user (basket)	T - Grip
	Provide good grip for the user (rake)	Straight Grip
3.	As a connector for the rod and the basket	Plastic

4.	To gather loose fruit on the land	Plastic
5.	To ensure any user suitable to use the rake	Adjustable Holder
6.	To move the basket	Rubber Wheel
7.	To ensure the shaft can withstand the load applied on the basket	Carbon Steel

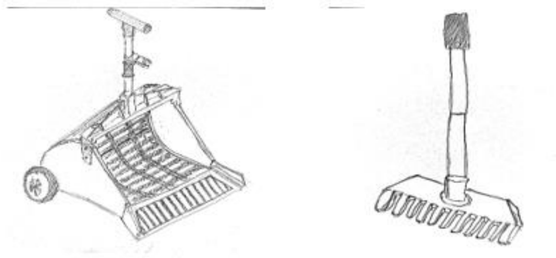


Fig 7 *Product sketching*

3.3 Embodiment Design Phase Results

In configuration design which is one of the phases in embodiment design, 3D Modelling was developed based on the previous concept selection by using computer-aided design software, SolidWorks. The components that had design using. SolidWorks are Basket, Rake, Frame, Grip, Rod, Cap, Connector, Shaft, Wheel, and Clipper. All components were combined to form a final product, Oil Palm Loose Fruit Collector. Fig 8 shows the final design of the product where all the components are assembled

While in parametric design, there are several steps need to be done including cost estimation and simulation of the product Cost estimation is important to ensure the right commitment of finance to a project development throughout their life cycle. In order to calculate the total of the material cost, we need to know cost for the standard part and the price per kilograms for each material that used for the project. Then multiply the price per kilogram for each material with the weight of its component. The Table 6 shows the total material cost.

Fig 8 *Final design product*

Table 6 *Total material cost*

Parts and Components	Material Cost
Standard Part	29.00
Each Component	198.19
Total	227.19

In simulation of the product there are four types of simulation will be analysed which are Von Mises Stress, Displacement, Strain and Factor of Safety. All this simulation will be analysed on three parts of the project which are the basket, rake and the shaft. There two types of material will test for each of the part to identify which material is the most suitable used for the parts. Table 7 shows the result comparison of static analysis for product design and Table 8 shows the result of static analysis based on selected material.

Table 7 *Result comparison of static analysis for product design*

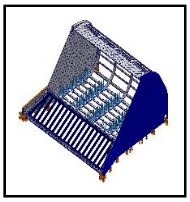
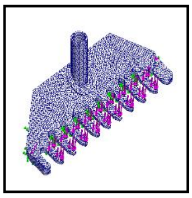
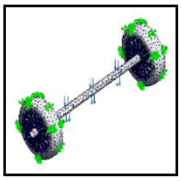
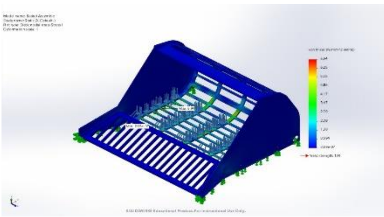
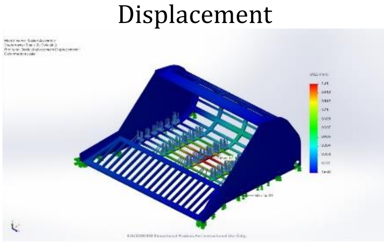
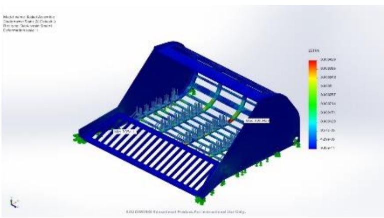
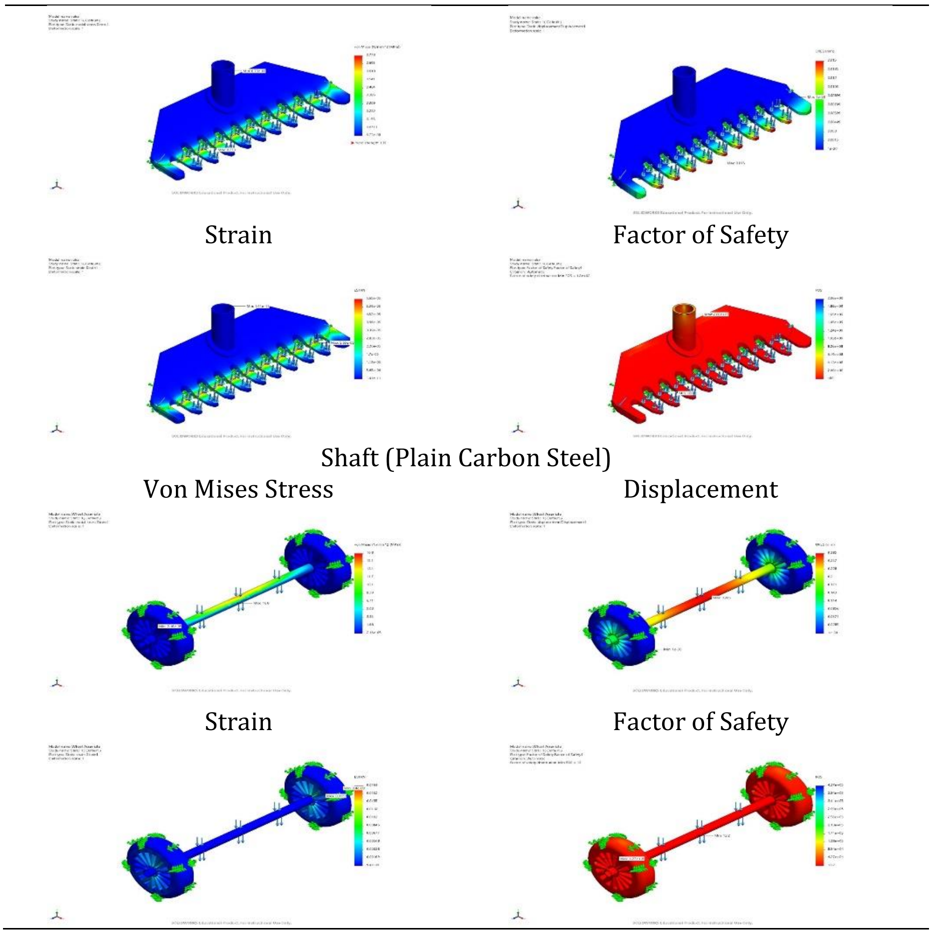
Parts	Simulation Material	Von Mises Stress (Mpa)	Displacement (mm)	Strain	Factor of Safety
Basket	Delrin 2700 NC010	7.63	4.43	0.00131	8.3
	Nylon 6/12	6.94	1.01	0.0000429	20
Rake	Delrin 2700 NC010	0.7692	0.04278	0.0000164	82
	Nylon 6/12	0.773	0.015	0.0000565	180
Shaft	Plain Carbon Steel	16.8	0.288	0.0169	13
	1060 Alloy	16.1	0.53	0.0228	1.7

Table 8 *The result of static analysis for product design based on selected material*

Basket (Nylon 6/10)	
Von Mises Stress	Displacement
	
Strain	Factor of Safety
	
Rake (Nylon 6/10)	
Von Mises Stress	Displacement



Based on the comparison above, material that will be chosen for the collector was Nylon 6/12 for basket and rake also Plain Carbon Steel for the shaft. This is because, based on the analysis we can see that Nylon 6/12 and Plain Carbon Steel give great output on the results of the simulation even the Von Mises Stress simulation give a little bit negative output for rake and shaft simulation.

3.4 Detail Design Phase Results

Detail design is the last phase of the entire design process. Product specification and detail engineering drawing are finalized in this phase before design release to manufacture. All the main information regarding the product was shown in Table 9.

Table 9 *The main information of the product specification*

Product Specification	Description
Collector Weight (KG)	4 KG (Including fasterner)
Dimension (mm)	500 x 432 x 825 (Basket)
	320 x 96 x 1260 (Rake)
Maximum load (KG)	10 KG
Price	RM350

3.5 Prototype Fabrication

After all product drawings and specifications are complete, the product is fabricated to test design functionality and determine if the prototype meets project goals. This prototype fabrication was done to see how the real product will look like. Materials used in the fabrication was taken from recycle material and not exactly the same like material used in the design process. Fig 9 shows the comparison of the prototype and the final design of the Oil Palm Loose Fruit collector.

(a) (b)

Fig. 9 *The comparison of the prototype and the final design of the collector (a) Prototype (b) Final Design*

3.5.1 Prototype testing

Prototype testing was done in order to see how it works based on its functionality. From this testing also we can know either objective of this project was achieved or not. Fig 10 (a) shows that the worker was testing on the prototype to collect the loose fruit. After finished collect the loose fruit, Fig 10 (b) shows the worker put the rake on the clipper and carries the prototype to another tree as shown in Fig 10 (c).

(a) (b) (c)

Fig. 10 *Prototype testing (a) The worker collecting loose fruit using the prototype (b) The worker put the rake on the clipper (c) The worker carries the prototype to another tree*

4. Conclusion

In conclusion, the Design and Fabrication Oil Palm Loose Fruit Collector was successfully completed according to the engineering design process introduced by George E. Dieter. Utilizing the knowledge gained throughout the academic year from the mechanical engineering course, the necessary calculations and analyses were effectively applied during the design process of this machine. Additionally, leveraging the latest design software, such as SolidWorks, allowed for the comprehensive completion of the machine design, including an excellent simulation video demonstrating the working principles of the machine. This greatly enhanced our understanding of the process and concept of the machine.

Furthermore, all the objectives of this project were achieved as the collector were more ergonomic and easier to use where the idea of making the adjustable holder can minimize the worker from frequently squat or bend their body also the innovation of the wheel and the clipper make the collector more portable and can be use in any types of terrain. This project also environment friendly which good for the sustainability of out landscape. Lastly, this collector east to maintain since the assembly of the product just use as fasteners.

Even the collector design and fabrication were completed, there are still some improvements that can be done where defects or potential failure in the design and fabrication process. A few recommendations for enhancing this collector include:

- Exploring the use of sustainable and lightweight materials in order to reduce costs and improve ergonomics

- Optimizing the weight distribution for better maneuverability.
- Improvise the design of the collector where parts can be easily removed, replaced or maintained.
- Collaborating with industry's stakeholders could provide valuable feedbacks and support for large-scale implementation to ensure the loose fruit collector continue to evolve and meet the needs of the palm oil sector.

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