Original Article

Palm Kernel Pickers: Proposed Tool Designs and their Simulation based on Ergonomic Risk Assessment

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Article history

Received 28/02/2024
Accepted (Panel 1) 15/05/2024

ABSTRACT: *This study addressed ergonomic challenges in Malaysia's palm oil industry, particularly its ergonomic risks. The paper examined the manual collection of palm kernels during the oil pressing process. Initial and advanced ergonomic risk assessment (ERA) was employed. The Rapid Entire Body Assessment (REBA) method was applied to assess worker's postures during kernel collection. This study determined that the posture risk is of greater concern than other ergonomic risk factors since the score for posture was 9, exceeding the threshold of 6. The paper proposed two palm kernel picker designs. SolidWorks simulation software, which facilitates the visualisation of a product for fabrication, was applied to develop 3D models of the proposed tools. Finite element analysis (FEA) was used to analyse the proportionally scaled models. Use of the proposed kernel pickers is expected to reduce worker's risk and improve their posture at work. Designs A and B were both simulated using FEA. Tool design A had an efficient design but only one ergonomic aspect, while design B had three ergonomic design aspects, including a curved handle, adjustable tool stick, and a net basket for efficient kernel accumulation. The success of the simulation suggests that we should proceed to the fabrication phase. We suggest that both palm kernel pickers be fabricated to allow comparison between designs and with conventional methods. The project aims to contribute to the sustainability and efficiency of Malaysia's crucial palm oil sector by enhancing the safety and well-being of labourers involved in palm kernel collection.*

Keywords: *Ergonomic Risk Assessment, FEA Simulation, Palm Oil Mill, Kernel, REBA, SolidWorks*

1.0 INTRODUCTION

The oil palm is one of the most important plantations in Malaysia's agricultural economy. Oil palm plantations play an important role in maintaining the biodiversity of Malaysia's food chain and are among the largest rain catchment areas. In 2022, the total oil palm planted area was recorded as 5.67 million hectares, a decrease of 1.1% from 5.74 million hectares in the previous year (Khayriyyah et al., 2021). Palm kernel oil is more expensive than palm oil. In general, palm kernels have a higher nutrient and oil content than the fruit. Owing to a lack of technology, these recently dropped decisions were poor, causing these palm kernels to be damaged and bad (Khayriyyah et al., 2021). Ergonomics is crucial for palm mill workers who work daily from 8–5 p.m., 8 h per day, in every shift. However, owing to the limited technology in this industry, the agricultural field has been unable to attract younger generations of workers (FFTC Agricultural Policy Platform, 2024). It is essential to ensure that workers maintain good posture, have low levels of fatigue, and a comfortable work environment. This paper assessed the ergonomic risk of the posture of palm mill workers using the Rapid Entire Body Assessment (REBA) tool. The aim of this study was to propose designs for palm kernel pickers. Poor ergonomic hand tool design contributes to biomechanical stress and increases the long-term risk of cumulative trauma, carpal tunnel syndrome disorders, injuries, and musculoskeletal disorders (MSDs).The designed kernel pickers are expected to reduce workers' risks and improve their posture at work. The proposed palm kernel picker designs aim to reduce movement and prevent worsening of the body posture. Many workers take nonergonomic activities in factories and mills for granted, leading to long-term risks. Awareness of ergonomic risk factors (ERF) needs to be increased among workers, especially those involved in difficult manual handling activities.

2.0 LITERATURE REVIEW

This section discusses ergonomic concepts and previous studies on palm oil processing, focusing on body posture analysis and methods of maintaining correct posture using the REBA method. The paper discusses the finalisation of a palm kernel picker project, highlighting its benefits, limitations, and previous studies on oil palm mill tools.

2.1 Palm Oil Extraction Process

The oil palm milling process produces various products, including cooking oil, palm kernel shells, fibre, and vegetable oil. The oil is used in the food, cosmetic, and biofuel industries. The mill is also involved in the production of starch, vegetable fats, and oils. Unlike other seed processing methods, the palm oil milling process includes stages such as receiving, sterilising, threshing, digesting, pressing of palm fruit, crude oil clarification, and palm kernel recovery. This method is both cost-effective and environmentally friendly. To ensure the quality of the extracted palm oil, fresh palm fruit bunches must be processed within 2 days of harvesting. Subsequently, the fruit is sterilised at high temperatures to soften and kill bacteria, increase the moisture content, and facilitate fruit separation. Threshing and screening are performed to separate the palm fruit from the bunches. The palm fruit is then transported to a digester, where it is combined and boiled to separate the pulp and nuts. A twin-screw hydraulic palm oil presser is used to extract crude palm oil, thereby increasing the production efficiency. The 'dry' method, which uses a mechanical press, and the 'wet' method, which uses hot water to melt the oil, are the two methods used to extract the oil from the digested material. By applying mechanical pressure to the digested pulp, the 'dry' method extracts oil from a mixture of oil, moisture, fibre, and nuts. Oil squeezing has three levels: slow, normal, and high. Fig. 1 illustrates the palm oil extraction process.

2.2 Ergonomics

Ergonomics involves the design of jobs to suit workers, thereby enhancing their safety and efficiency. The implementation of ergonomic solutions can improve worker comfort and productivity. This is vital because the musculoskeletal system is affected by factors such as awkward posture, extreme temperature, and repetitive movement, which can lead to symptoms such as fatigue, discomfort, and musculoskeletal disorders. According to a previous article, ergonomics and human factors apply the knowledge of human abilities to design systems, organisations, jobs, machines, tools, and consumer products for safe and efficient use. Ergonomic applications have evolved with advances in knowledge and research on global human challenges. Ergonomics makes workers' lives easier and safer, and contributes to improved sleep quality. Prioritising safety as a value rather than merely a priority is crucial for preventing injuries, retaining positive company outcomes, and avoiding worker compensation claims. Hagberg et al. (1995) distinguished between ergonomic and human factors in the workplace by focusing on how work affects employees and risk factors. However, ergonomics focuses on designs that minimise human error. Risk factors include actions or conditions that increase the likelihood of musculoskeletal injury. However, it is difficult to determine the link between exposure to risk factors and musculoskeletal injury. Ergonomic risk factors include repetitive awkward postures, forceful motion, direct pressure, vibration, extreme temperatures, noise, and work stress.

Awkward posture refers to body positions that deviate significantly from a neutral stance during work, making the muscles less efficient and requiring more effort. Examples include twisting, bending, reaching, pulling, or lifting, as well as working with the hands above the head or in positions where the neck or back is bent by >30° without support (Yale Environment Health and Safety, 2018). The finding of this study, that there is a high awareness of awkward posture, is promising. This awareness could be the foundation for creating programs or health-promoting strategies to address awkward posture and repetitive motion, which contribute to musculoskeletal disorders. Physical factors such as prolonged standing, sitting, and uncomfortable posture are linked to musculoskeletal disorders, especially among females (60.7%) and rural dwellers (56.7%).

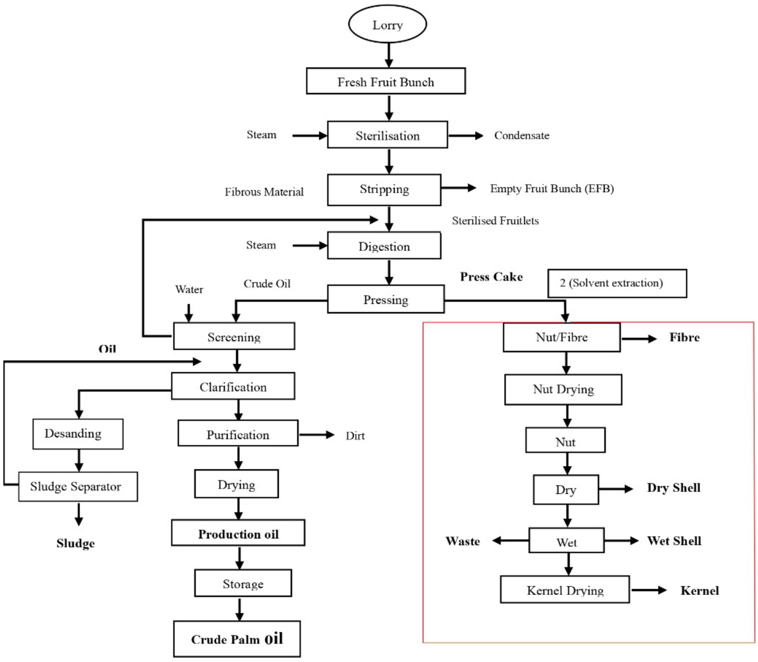

Figure 1: The Palm Oil Extraction Process

2.3 Ergonomic Risk Factors (ERF)

According to Hagberg et al. (1995), the terms “ergonomics” and “human factors” are used interchangeably in the workplace. Both describe the workers’ interactions with job demands. The distinction is that ergonomics focuses on how work affects workers, whereas human factors focus on designs that reduce the possibility of human error. By addressing traditional and environmental risk factors, workers can be kept injury free (Bongers et al., 2002). The risk factors include actions or conditions that increase the likelihood of musculoskeletal injury. The literature on applied ergonomics recognises a small set of common physical risk factors across many occupations and work settings. The relationship between exposure to risk factors and the risk of musculoskeletal injury is difficult to define. Although physical risk factors are important first-line risk factors, other plausible factors such as organisational and psychosocial factors may cause disorders or indirectly influence the effects of physical risk factors (Hagberg et al., 1995).

Ergonomic risk factors are workplace situations that cause body wear and tear, and can result in injury. Examples include repetition, awkward posture, forceful motion, stationary position, direct pressure, vibration, extreme temperatures, noise, and work stress. Awkward posture refers to body positions that deviate significantly from the neutral posture while performing work activities. When a worker assumes an awkward posture, the muscles work less efficiently and must exert more force to complete the task.

Work tasks with high-force loads require greater muscle effort, leading to fatigue and MSDs. The amount of physical effort required to perform a task, such as heavy lifting, or maintain control of equipment or tools, is referred to as force. The amount of force required is determined by the type of grip, object weight, body posture, activity type, and task duration. Forceful motion places great strain on the muscles, tendons, ligaments, and joints. Increasing force necessitates increased body demands, such as increased muscle motion, as well as other physiological changes required to sustain the increased effort. Prolonged or recurring activities of this type can cause not only fatigue but also MSDs if there is insufficient time for rest or recovery (Leffers, 2013).

Vibration is also an ergonomic risk factor, because when a specific body part meets a vibrating object, such as a powered hand tool, exposure to local vibration occurs. Whole-body vibration exposure can occur while standing or sitting in/on vibrating environments/objects, such as when driving heavy-duty vehicles or operating large machinery (Yale Environmental Health & Safety, 2018). According to Benos (2020), a review of ergonomics in agriculture found that machines used in agriculture with driving seats appear to be associated with painful lower back disorders, whereas handheld machines appear to be associated with upper extremity disorders. Whole-body vibration (WBV) and hand-arm transmitted vibration (HATV) are the primary causes of such disorders. However, personal characteristics, awkward posture, mechanical shock, and seat discomfort are also recognised causes of MSDs. Current ergonomic interventions are primarily aimed at reducing vibrations and improving operator comfort. Nonetheless, more collaborative efforts among physicians, ergonomists, engineers, and manufacturers are required to develop new ergonomic technologies and raise worker awareness regarding the risk factors involved.

Repeatedly performing the same motions places strain on the muscles and tendons. The severity of the risk is determined by the frequency with which the action is repeated, speed of movement, number of muscles involved, and the required force. Fatigue and muscle-tendon strain can accumulate if motions are repeated frequently within a few seconds and for long periods, such as an 8-h shift. The tendons and muscles frequently recover from the effects of stretching or forceful exertion if sufficient time is allowed between them. When awkward postures and forceful exertions are involved, the effects of repetitive motion on the performance of the same work activities are exacerbated. The risk factors for repetitive actions can also vary depending on the body area and specific actions being performed (HSE, 2019).

According to BostonTec (2021), static posture is the condition of remaining in the same posture or position for extended periods, typically while working. It has the potential to reduce blood flow and damage the muscles. Furthermore, a static posture can have an impact on the nerves, ligaments, blood vessels, and tendons. It is an ergonomic risk factor that may contribute to the development of MSDs. Static posture, whether sitting or standing for a long time, accompanied by repetitive movement, can cause soreness and fatigue. Furthermore, the back, shoulders, neck, legs, and wrists can experience stiffness and discomfort depending on the posture, work duration, and exertion level.

Contact stress is caused by contact between soft body tissue and a hard or sharp object, such as workstation edges, tools, machinery, products, or the floor. Contact abrasions most commonly affect the soft tissues on the fingers, palms, forearms, thighs, buttocks, shins, and feet. This contact may result in pressure being applied to a small area of the body such as the wrist or forearm, which can restrict blood flow, tendon and muscle movement, and nerve function.

Contact stress can cause MSDs when the tendons, nerves, or blood vessels in vulnerable areas are compressed. It can limit tendon movement, requiring more effort and potentially resulting in tendon and surrounding tissue inflammation. Contact stress, which causes a sharp push into deeper tissues, can reduce the blood flow and cause early muscle fatigue. The Occupational Safety and Health Administration (OSHA) Computer Workstations Etools document (2003) defines contact stress as internal stress caused by stretching or bending a tendon, nerve, or blood vessel around a bone or tendon. External contact stress occurs when a part of the body rubs against a workstation component such as a chair seat pan or desk edge. Consequently, nerves may be irritated or blood vessels constricted. According to published research, contact stress is a fairly well-identified risk factor for medium to heavy, repetitive, and manual job tasks, but there is little convincing evidence that it is a significant risk factor for computer users.

People in systems interact with their surroundings, and environmental ergonomics is concerned with how they interact with their surroundings from an ergonomic standpoint. Although many studies of human responses to the environment (light, noise, heat, cold, etc.) have been conducted over hundreds of years, it is only with the development of ergonomics as a discipline that the unique features of environmental ergonomics are beginning to emerge. Examples include societies and conferences on specific aspects of the environment such as noise, lighting, and vibrations (Mazalan & Shafie, 2021). The International Organisation for Standardisation (ISO) and European Standards Organisation (CEN) have made significant contributions to environmental ergonomics. However, the existence of established standards committees on noise, vibration, lighting, and other areas has slowed progress because they frequently take a product- or manufacturer-oriented perspective that is not human-centred and does not lend itself to an integrated ergonomics approach. However, this is not a static position, and it is being increasingly recognised that people experience whole environments, and that ergonomic methods are necessary for effective practical application (Parsons, 1995).

The palm oil industry contributes to global oil and fat production. Indonesia and Malaysia are the two largest palm oil producers worldwide. This industry involves over a million people; however, little information is available regarding the health and safety of their jobs. MSD risk variables are assessed using assessments, observations, video analyses, and electromyography measurements. MSD are caused by the method of activity and incorrect posture. MSDs affect muscles, joints, tendons, ligaments, and nerves. They may develop over time or occur suddenly owing to overload. Lifting heavy items; bending; reaching overhead; pushing and pulling heavy loads; working in awkward body postures; and repetitively performing the same or similar tasks can expose workers to risk factors. Exposure to these MSD risk factors increases the risk of injury in workers (HSE, 2019). Based on a study by the World Health Organisation, according to a recent analysis of the Global Burden of Disease (GBD) 2019 data, approximately 1.71 billion people worldwide are affected by musculoskeletal conditions such as low back pain, neck pain, fractures, other injuries, osteoarthritis, amputation, and rheumatoid arthritis (Cieza et al., 2021).

Although the prevalence of musculoskeletal conditions varies with age and diagnosis, individuals of all ages are affected. High-income countries are the most affected in terms of the number of people (441 million). While the prevalence of musculoskeletal conditions increases with age, younger people are more frequently affected during their prime-earning years. Because MSDs affect the muscles, joints, tendons, ligaments, bones, and nerves, their effects include tendinitis, carpal tunnel syndrome, osteoarthritis, rheumatoid arthritis (RA), fibromyalgia, and bone fracture. The severity of MSDs varies. In some cases, it can cause pain and discomfort, and interfere with daily activities. Early detection and treatment can help reduce symptoms and improve overall prognosis. Symptoms of MSDs include recurrent pain, stiff joints, swelling, and dull aches. They can also affect major areas of the musculoskeletal system, including the neck, shoulders, wrists, back, hips, legs, knees, and feet. Patients with MSDs may have a limited range of motion or difficulty completing routine tasks in the workplace (Morrison, 2018).

2.4 Kinovea Software to Measure Body Angles

Kinovea is a free computer-based two-dimensional motion analysis software that measures kinematic parameters in videos without using markers. It has been used to analyse running or vertical jumping in athletes and a strong correlation exists between Kinovea interrater reliability and the initial contact phase during running. The software has also been used to examine the range of motion of the cervical spine in the sagittal plane and determine the kinematics of the wrist joint. Parra et al. (2018) explored the use of two tools for oil palm harvesting and pruning: the sickle and the Malaysian pole. The sickle was used for palms taller than 4 m, whereas the Malaysian pole was a chisel for palms shorter than 4 m. While advances in this field have focused on productivity, motorised tools have been proposed to reduce task duration. However, these machines increase the momentum that workers must consider because of the length of the handle and the manoeuvring required to cut down bunches. Biomechanical stress was measured by observing the corporal positions of the workers while using each tool. The angles between the limbs and corporal planes were measured using a free-body diagram.

In another study (Mathew et al., 2017), this software was used to investigate the ankle, knee, and hip joint angles in older adults at various stages of the gait cycle. Kinematic asymmetries in the participants' gait patterns were cited by the authors as restrictions on hip extension. Therefore, the literature supports the use of Kinovea software in both sports and clinical settings. Therefore, a preliminary study of reliability and validity was conducted. Fernández-González et al. (2020) assessed the inter- and intra-rater reliability of Kinovea when registering the hip, knee, and ankle angles during the initial contact phase of walking, and investigated the agreement by comparing the angles obtained using Kinovea with those obtained using a three-dimensional motion capture system. It showed that Kinovea Software is suitable for the measurement of body angles for body posture assessment.

2.5 The Rapid Entire Body Assessment (REBA)

The REBA, a systematic process used to evaluate and analyse ergonomic risks associated with various work tasks, is an alternative to Kinovea. It is frequently used in occupational health and safety to evaluate workstation ergonomics and to identify potential areas for improvement. The REBA is a tool for assessing the risk of MSDs associated with specific job tasks. It is a whole-body screening tool that assesses biomechanical and postural loading of the body using a systematic procedure, while allowing for multiple assessments per task or job. The advantages of this tool are that it is simple, quick, and requires little equipment. The REBA evaluates the entire body and can be used to evaluate any task (Morrison, 2018), however, it can only assess one posture at a time, and may exclude high-risk aspects of the task. Joshi and Deepthi (2020) conducted an analysis of the REBA and found that it considers all body parts, loads handled, and coupling types, making it the simplest and most widely used method. However, it is less helpful for assessing manual material-handling tasks. Deepthi's research highlights the popularity of REBA owing to its ease of use and speed, and its use in various sectors to determine relative risk levels for tasks. Table 1 summarises previous research using tools related to the Rapid Upper Limb Assessment ((RULA) and REBA.

Table 1: Previous Research Works Using Tools Related

No	Author/s	Title	Method	Findings
1	Fazi *et al.,* (2019)	Risks assessment at automotive manufacturing company and ergonomic working condition	• RULA	Automotive industry management faces hazards in assembly lines and to workers owing to inappropriate tasks and unsafe workplaces. Research using interviews, observation, videotaping. and RULA identified occupational risks and recommended ergonomic working conditions.
2	Mohamaddan *et al.,* (2021)	Investigation of oil palm harvesting tools design and technique on work-related musculoskeletal disorders of the upper body.	• RULA • CATIA software	The study identified work-related musculoskeletal disorders (WMSDs) in harvesters' shoulders and trunks, indicating the need for immediate tool changes (RULA score = 7).
3	Wibowo and Mawadati, (2021)	The analysis of employees' work posture by using REBA and RULA.	• RULA • REBA	The study examines employees' work posture using the REBA and RULA, by calculating angles on the back, neck, and leg. Results show a RULA score of 7 and REBA score of 11. Immediate improvement is recommended to prevent injuries owing to incorrect posture.
4	Saulia *et al.,* (2022)	Postural analysis in design evaluation of oil palm loose fruit collector machine.	• REBA	A roller-shaped machine with elastic spikes clamped loose oil palm fruit, thereby increasing productivity and workplace safety on farms. The angles of the neck, torso, legs, upper arms, forearms, and wrists were measured and the machine scored 2–5 on the REBA scale.
5	Sulaimana *et al.*, (2023)	Design of harvesting tool using ergonomic approach for musculoskeletal discomfort prevention in low-cost farming system: A case study of Korean melon (Cucumis melo var. Makuwa).	• RULA • OWAS	The study revealed manual harvesting by labourers. Korean melons at lower levels created work-related MSD risks. The harvesting process involved cutting, collecting, lifting, and moving, with OWAS and RULA scores of 4 and 7, respectively.

RULA: Rapid Upper Limb Assessment; REBA: Rapid Entire Body Assessment; MSD: musculoskeletal disorders; OWAS: Ovako Working Analysis System

2.6 SolidWorks Software

The improved, ergonomically designed tools for palm kernel pickers were sketched in SolidWorks (Dassault Systèmes, Waltham, MA, USA), an effective computer-aided modelling application. SolidWorks was used to design the mechanical structures from start to finish. Software, such as Finite Element Analysis (FEA) software, was initially used for project management and simulation, as well as for planning, visual ideation, modelling, feasibility assessment, prototyping, and feasibility assessment. SolidWorks software was then used to create mechanical, electrical, and software components, using static structural analysis, which is a type of FEA. This type of FEA analyses proportionally scaled models. The test maintains that any structure that is sound on a small scale can handle the same interactions and produce the same results as a full-scale structure. It is a static simulation that uses and develops stress data, as well as the Von Mises stress and safety factor. Von Mises stress analysis is an essential tool in FEA simulation, helping identify and resolve structural issues, improving worker comfort and usability, and assessing the structural integrity and potential failure of materials under various loading conditions. The data were analysed and compared in terms of ergonomics and material quality (Parra et al., 2018).

Several ergonomically designed tools have been created to improve the working conditions of palm oil mill workers in the plantation industry. Numerous studies have been conducted on ergonomic cutting tools for the harvesting of bunches of oil palm fruit. One study designed an oil-palm fruit collector. A study conducted by Parra et al. (2018) designed a fruit-palm bunch-cutting tool system for harvesting. Harvesting and pruning were performed using two different tools, both of which had a long handle attached to a blade. The effectiveness of the tool varied depending on the blade shape. The sickle was used for palms taller than 4 m, whereas the Malaysian pole was a chisel used for palms shorter than 4 m. Advances have been made in this field, but they have prioritised productivity over user health. The use of motorised tools has been proposed to reduce task duration. However, these machines result in an increase in the momentum that the worker's bodies must endure. Therefore, the purpose of this study was to compare the stress on the lower back when cutting fruit bunches using a traditional tool and a new cutting tool proposed using a biomechanical analysis simulated by JACK Siemens. The tools were evaluated at three different levels: 1) when the operator was carrying the tool, designated as 0°; 2) when the operator raised the tool to 70°; and 3) when the operator began to pull on the tool, designated as 70° + force. Fig. 2 shows the new oil palm cutting tool system, and Fig.3 shows the different levels of measurement.

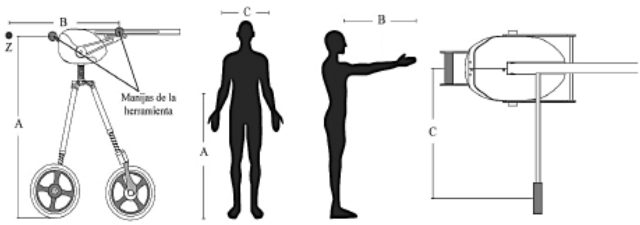

Figure 2: New Oil Palm Cutting Tool (Parra et al., 2018)

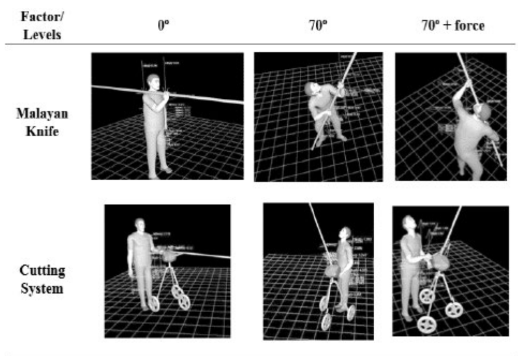

Figure 3: The Different Levels for Each Measurement (Parra *et al.,* 2018)

Saulia et al. (2022) conducted a postural analysis for the design evaluation of a loose oil palm fruit-collection machine. Loose fruit scattered on the ground must also be collected. However, this activity is considered less productive and time-consuming, and causes several problems, such as fatigue and a variety of symptoms related to unsafe working posture. The worker manually picks up and collects loose oil palm fruit that are scattered on the ground and is required to maintain a high-intensity, bent posture. This activity should be evaluated in the workplace because it is a key ergonomic risk indicator.

This study developed an ergonomic machine in the form of a roller equipped with elastic spikes on its entire surface. This unit applied the principles of elasticity and strength to clamp loose oil palm fruit and collect them in a container. The machine was designed for use on farms, to increase productivity and ensure workplace safety. Fig. 4 shows the loose oil palm fruit collector.

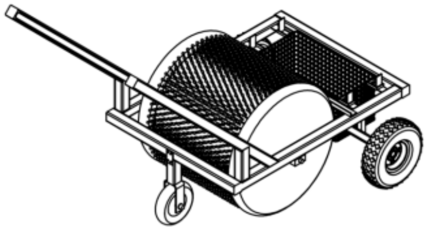

Figure 4: Loose Oil Palm Fruit Collector (Saulia *et al.*, 2022)

Ergonomic compatibility with users was also considered during the design and manufacture of the loose oil palm fruit-collector. Working posture and vision, which are important human factors, were incorporated into the machine's design analysis. This project used the RULA to analyse posture when using the loose oil palm fruit-collector and CATIA software (Dassault Systèmes, Waltham, MA, USA) for machine design. The purpose of this project was to determine the level of risk of the working posture during loose fruit collection using a loose oil palm fruit-collector called the ERBRON-C. A REBA evaluation of prototype users was performed to ensure design compatibility. In this project, the actual process of collecting oil palm leaves with ERBRON-C had a REBA score of 2–5, indicating a low-to-moderate risk level; therefore, the posture assessment at the design stage differed little.

3.0 METHODOLOGY

This section describes the research methodology used to answer the research question, and to describe the research approach, primary data collection process for secondary research, data analysis tools used, and limitations of the adopted research method. Fig. 5 shows the conceptual design methodologies applied to the palm kernel pickers. According to Eby (2022), the project design cycle consists of seven steps: situation analysis, design process, submission and approval, implementation and monitoring, appraisal, final evaluation, and implementation and monitoring. This study is currently in stage 2 and the design process is based on situational analysis. This study is still at an early stage of the design cycle and requires approval from experts and end users. The paper began with the identification of problems, data collection, and analysis, with project planning being crucial for efficient and accurate results. Fig. 6 shows the study flowchart.

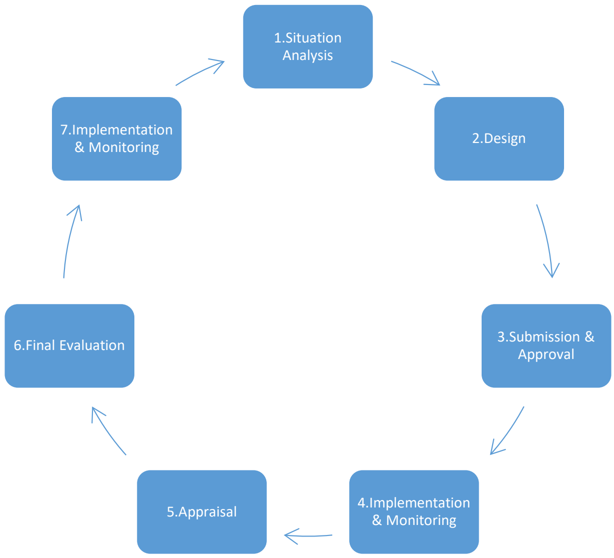

Figure 5: Project Design Cycle Diagram (Eby, 2022)

3.1 Kinovea Software

Kinovea is software that analyses angles and body motion in videos or pictures. This helps identify the correct posture angle in worker photos before using the REBA. The software can accurately measure distances of up to 5 m and angles of 45–90°, with a 90° angle recommended for optimal results. This project used Kinovea's goniometer tool to measure the angles of body segments during specific tasks or movements, aligning with REBA's principle of assessing posture and joint angles to evaluate ergonomic risk. By visually inspecting and measuring these angles, users can compare them with the ergonomic guidelines and reference values in the REBA to determine the potential risk levels associated with specific body postures or movement patterns.

3.2 Initial Ergonomic Risk Assessment (ERA)

The initial ERA is the first step in planning and carrying out an ergonomic workplace evaluation. An initial ERA is a tool used to systematically evaluate and capture potential ergonomic hazards in the workplace. It aids in the identification of areas of concern and provides a structured approach for the management of ergonomic risk. Table 2 presents the initial ERA.

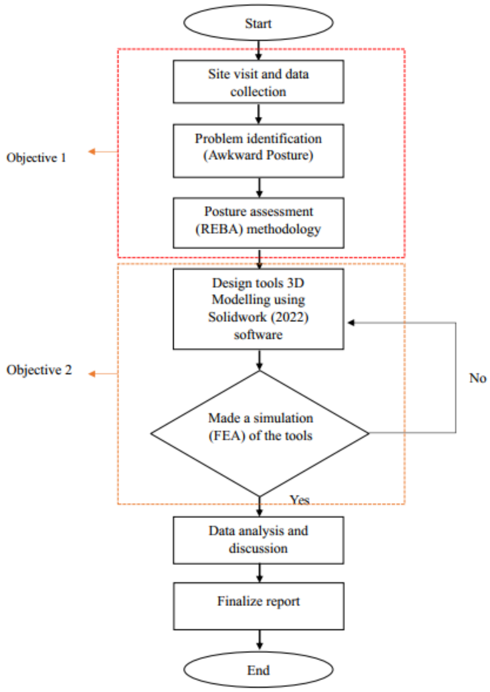

Figure 6: Study Flowchart

Table 2: Initial ERA Form

Risk factors	Total Score	Minimum requirement for advanced ERA	Result of Initial ERA	Pain or Discomfort due to Risk Factors determined in Musculoskeletal Assessment		Need Advanced ERA? (Yes/No)
Awkward Postures	13	⩾ 6	**9**	If YES, please tick (√) which part of the body (Yes/No)		**Yes**
				Neck	/	
Static and Sustained Work Posture	3	⩾ 1	0	Shoulder	/	No
				Upper back	/	
				Upper arm	/	
Forceful exertion	1	1	0	Lower back	/	No
Repetition Motion	5	⩾ 1	0	Forearm	/	No
				Wrist	/	
				Hand	/	
Vibration	4	⩾ 1	0	Hip/buttocks	-	No
				Thigh	/	
				Knee	-	
Lighting	1	1	**1**	Lower leg	/	**Yes**
Temperature	1	1	0	Feet	-	No
Ventilation	1	1	0			No

Noise	2	⩾ 1	0	No

ERA: Ergonomic risk assessment

3.3 Rapid Entire Body Assessment (REBA)

The REBA is an ergonomic assessment tool that uses a worksheet to evaluate whole-body postural MSD and job task risks. It assesses posture, forceful exertions, movement type, repetition, and coupling, and requires no advanced ergonomic training or expensive equipment. The tool assigns scores to the wrists, forearms, elbows, and shoulders. The worksheet is divided into Parts A and B. Fig. 7 shows the REBA worksheet used in this study.

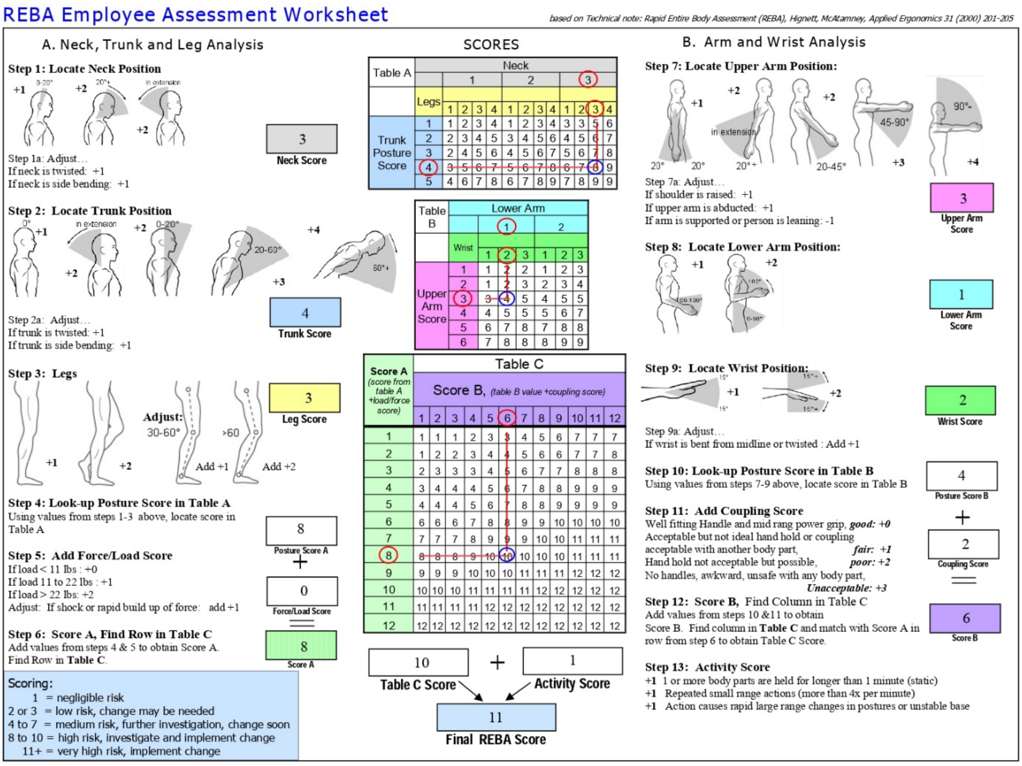

Figure 7: REBA Worksheet

3.4 SolidWorks

This project used SolidWorks simulation software to improve the ergonomic tool design. Two ergonomic tool designs were proposed, and FEA simulations were performed to simulate them. The simulation data were compared to determine the most suitable tool for the task.

3.5 Finite Element Analysis (FEA)

Static structural analysis, a type of FEA, was used to analyse the proportionally scaled models. The test maintains that any structure that is sound on a small scale can produce the same results as a full-scale structure. The results were simulated using FEA of the two proposed design tools. This static simulation uses and develops stress data, as well as the Von Mises stress and safety factor. The data were analysed and compared in terms of ergonomics and material quality.

4.0 DATA ANALYSIS AND RESULTS

4.1 Site Visit Observation

Kilang ABC Sdn Bhd, located in a forest surrounded by oil palms, is a raw materials industry that falls under the Department of Corporate Relations, Malaysia. Observations and meetings with assistant engineers revealed that the mill had multiple sections dedicated to palm oil processing. The project focused on the pressing section, and on workers' performance of their duties.

4.2 Ergonomic Issues

4.2.1 Awkward Posture

The project analysed the posture of workers in the pressing machine section at Kilang Kelapa Sawit ABC Sdn Bhd. The observations revealed awkward postures and the use of inappropriate tools, particularly for the collection of scattered kernels. The REBA method was employed to assess the ergonomic risks associated with upper-extremity MSDs. Fig. 8 shows an image of a worker's awkward posture at the workstation.

Figure 8: Awkward Posture of the Worker

The results indicated a medium-to-high risk level, especially in palm mills where workers faced challenges in efficient kernel collection. The analysis considered various body regions such as the neck, trunk, legs, arms, and wrists. Specific angles and movements were evaluated by assigning a score to each region. The combined score indicated a high risk in neck, trunk, and leg analyses, as well as in upper arm, lower arm, and wrist analyses. The ergonomic assessment highlighted issues such as neck angles exceeding 20°, forward and twisted trunk positions, and leg bending. The final posture score suggested a critical situation requiring ergonomic tools to prevent MSDs. The analysis culminated in a REBA score of 11, indicating a severe level of risk, prompting the recommendation of appropriate design tools to mitigate MSD risks.

4.3 Proposed Design

Owing to the lack of modern and suitable tools to speed up the cleaning process, kernels are collected slowly. This project developed ergonomically designed tools to ensure that workers collected kernels in good posture, which would decrease the risk of MSDs.

4.3.1 Proposed Tool Design A

This project showcases two tools developed to improve productivity in the fruit-harvesting industry. The Fruit Roller Picker, with a trigger in the hand, reduces time and improves ergonomics. Manufacturers play a role in disseminating information and training workers, thus ensuring a better user experience. Fig. 9 shows tool design A.

Figure 9: 3-Diagram of Tool Design A

4.3.2 Proposed Tool Design B

Tool design B has an ergonomic handle and a basket for the collection of rolling palm kernels. The stick can be adjusted to fit the height and working posture of the user. This tool allows workers to collect excess palm kernels without removing the oil palm seeds. The tool collects 1–2 kg each time and the process can be repeated without affecting ergonomics. Despite its limited size, it maintains the worker's posture for an extended period despite the tool's limited number of data points. Fig. 10 shows tool design B.

Figure 10: 3-Diagram of Tool Design B

4.4 SolidWorks

4.4.1 Finite Element Analysis (FEA)

The project used SolidWorks, 3D CAD software with a FEA module, and SolidWorks Simulation to simulate and analyse the structural behaviour of the components in tool designs A and B, focusing on the stress values and displacement.

For tool design A, simulations were conducted on the trigger and roller picker components. Under a 100N load, the trigger showed Von Mises stress values and a safety factor of 2.000. The roller picker, subjected to a 10N load, exhibited deformation with stress values ranging from 0.000–344.819 MPa and a safety factor ranging from 1.196–2.000.

Tool design B components, including the basket net, holder, and assembly, underwent simulations with a 100N load. The results indicated the stress values, safety factors, and displacement. A simulation of the basket net with a 30N force yielded stress values of 0.000–0.202 MPa and a safety factor of 2.000. The results suggest that improvements in materials, geometry, and force minimisation would enhance the analysed values. The simulations provided valuable insights into the structural integrity and performance of the designed components under the specified conditions. Fig. 11 and 12 show the trigger and roller picker, respectively, of the FEA simulation of tool design A. Fig. 13–15 show the handle, cover, and basket net, respectively, of the FEA simulation of tool design B.

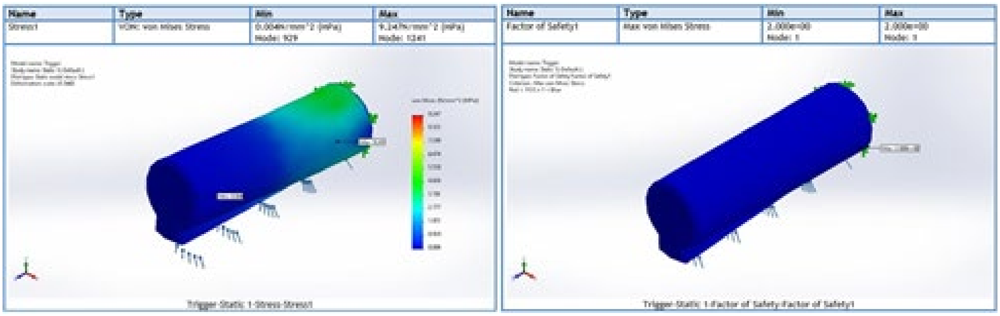

Figure 11: Trigger

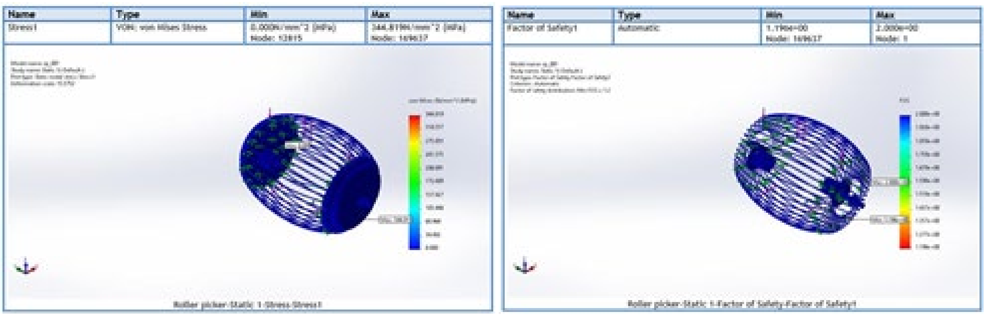

Figure 12: Roller Picker

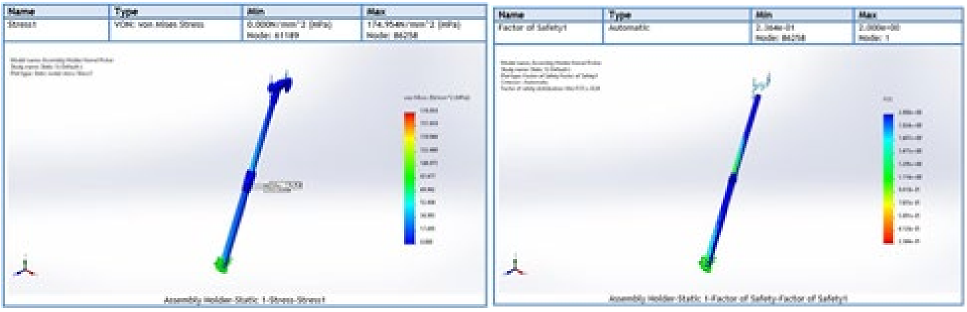

Figure 13: Handle

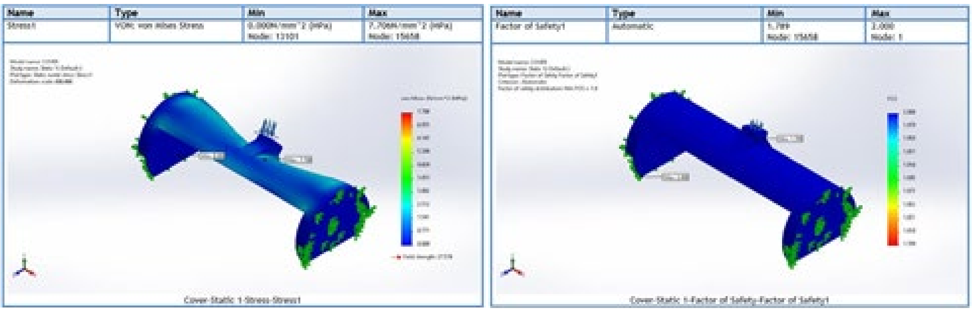

Figure 14: Cover

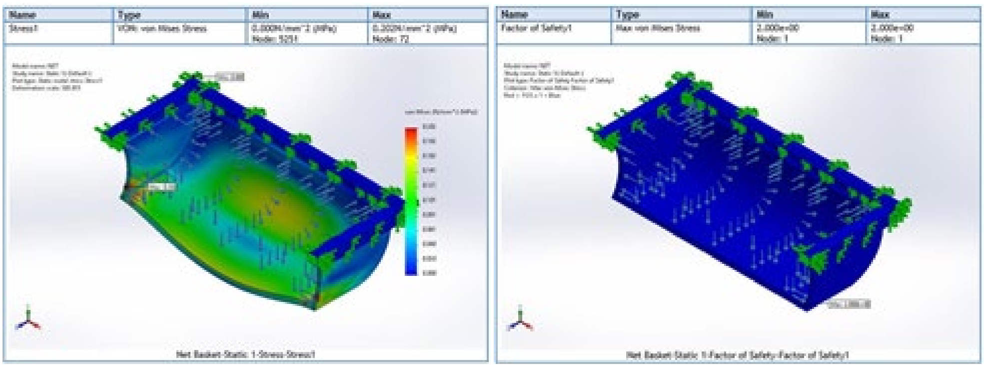

Figure 15: Basket Net

4.5 Comparison of Tool Designs A and B

4.5.1 Ergonomics

Ergonomics is the design of tools and systems that enhance human well-being and system performance. Key aspects included the assessment of handle design, weight, grip surface, controls, adjustable features, visibility, lighting, worker interface, anthropometrics, and safety features, using FEA.

4.5.2 Material Quality

Material quality is crucial in industries such as manufacturing, construction, and electronics because it affects their performance, durability, and suitability for specific applications. Von Mises stress is influenced by the material used, and an ergonomic design must be used to ensure structural integrity and worker safety. Two ergonomic tool designs were used: A, which was based on Von Mises stress data and the safety factor, and B, which used FEA for key components. Tool design A used 1060 alloy and acrylonitrile butadiene styrene polycarbonate (ABS PC), which is influenced by the application, design requirements, and manufacturing processes. Table 3 presents a comparison of tool designs A and B.

Table 3: Comparison of Tool Designs A and B

No	Type	FEA/Others	Tool Design A	Tool Design B
1	Ergonomics	Von Mises Stress & Safety Factor	The project used FEA to determine the force applied when pressing the trigger of the assembly roller picker. FEA analysis was used for parts that made contact with the body, such as armrests, and for the worker's body posture. The trigger was found to exceed the yield strength limit of 62 MPa, indicating a safe level. Tool design A was found to be safe due to its safety factor of 2.	FEA analysis was used to assess the worker's body posture with respect to the assembly handle, cover, and basket net parts. The analysis ensured that the yield strength was not exceeded by the forces placed on the tool, ensuring that the basket net's Von Mises tension value did not exceed the yield strength. The study found that the force applied to the parts affecting hand and body posture were at a good level, indicating durability. It was determined that damaged basket mesh could increase the probability of dropped kernels during carrying or emptying. The tool was considered to be safe with a maximum safety factor value of 2
		Others	This tool had a perfect weight distribution and mass balance, which are important factors in providing comfort to workers. Tool design A was light, easy to use, and could be carried anywhere.	The kernel picker tool emphasized user safety and comfort with an adjustable design to prevent bad posture and a secure handle to reduce the risk of injury. A cover closed the brush for user convenience, while the sack-shaped basket net prevented kernel spills. It was suitable for long-term agricultural use. The ergonomic design minimised physical stress during repetitive tasks, promoting worker well-being. Durable materials in the basket net extended equipment life, reducing replacement needs, and the strong yet flexible mesh ensured natural body movement during kernel collection in agricultural settings.
2	Material Quality	Von Mises Stress & Safety Factor	The material used on this tool was analysed in terms of Von Mises stress and safety factor. Two force-based components of tool design A, the roller picker and trigger, were simulated to prevent cracking or breaking. The roller picker had a Von Mises stress value ranging from 0.000–344.819 MPa, with a modulus of elasticity greater than the maximum stress value. This indicates that the elasticity level did not exceed the limit that would cause the component to rupture. The trigger also had a Von Mises stress range and a modulus of elasticity greater than the maximum stress value, ensuring that the tool components will not rupture or be easily damaged. The safety factors for both components indicated their safety.	This tool also underwent analysis of the material used. Three components of tool design B were simulated: the holder, cover, and basket net. The stress values of the three parts analysed were found to be below the yield strength of the material. The safety factors were also within the safe range.
		ABS PC	The trigger is constructed using ABS PC material that provides a good balance of toughness, impact resistance, and heat resistance. The cost of ABS PC can vary depending on factors such as the ABS PC ratio	ABS PC is a composite material that combines ABS and polycarbonate properties, offering high tensile strength, impact resistance, and toughness. Its durability and cost are influenced by factors such as the ABS PC ratio, formulation,

	and its specific formulation. The impact resistance of ABS PC improves design efficiency, particularly in applications where the material may be subjected to physical stress or impact forces.	and additives. The cost-effectiveness of ABS PC should be evaluated based on performance and durability for specific application requirements. ABS PC is versatile and offers good impact resistance, making it suitable for various applications. The design process should consider material properties, intended use, and manufacturing constraints, with prototyping and testing.
AISI347 Annealed Stainless Steel	AISI 347 annealed stainless steel, valued for strength and durability, is selected for force application despite its higher cost. Its robustness ensures reliability, making it well-suited for long-term performance in applications requiring resistance to high temperatures and corrosion.	-
1060 Alloy Steel	-	The 1060 alloy, a pure aluminium variant, is prized for its high electrical conductivity, corrosion resistance, and workability. Although it has lower mechanical strength (yield: 27.6 MPa, tensile: 68.9 MPa, modulus: 69 GPa), it is extensively utilized in electrical and chemical industries where electrical conductivity and corrosion resistance strongest matches.

ABS PC: acrylonitrile butadiene styrene polycarbonate; FEA: finite element analysis

5.0 DISCUSSION

This study analysed and compared tool designs A and B, with a focus on ergonomic design, material quality, and FEA insights. We examined tool design A, which used ABS PC and AISI 347 annealed stainless steel, and tool design B, which used a 1060 alloy and ABS PC. The analysis revealed that tool design A had an efficient design but only one ergonomic aspect, whereas tool design B had three ergonomic design aspects, including a curved handle, an adjustable tool stick, and a net basket for efficient kernel accumulation.

Von Mises stress data were used to determine tool durability, and both tools met the established safety standards. The choice between AISI 347 stainless steel and the 1060 alloy depends on their application and requirements, with AISI 347 stainless steel being preferred for corrosion resistance and the 1060 alloy for strength and stiffness. The final decision should be based on an in-depth analysis of the key factors. Tool design B excelled in ergonomic design and benefited from the mechanical properties of the 1060 alloy, making it a strong competitor in the market.

6.0 CONCLUSION

In summary, this study aimed to investigate the ergonomic postures of workers in palm oil mills, particularly during the collection of kernels scattered on the floor. The project successfully assessed workers' postures using both initial and advanced ERA using the REBA method. The second goal was to propose a design tool to address MSDs and ergonomic issues among workers, to improve well-being and efficiency. Usability testing and employee feedback will confirm the positive impact of these ergonomic interventions, with an emphasis on improved comfort and reduced physical strain. This project promotes the incorporation of these solutions into palm oil mills and emphasises the importance of comprehensive training programs. We suggest that prototypes be fabricated to facilitate the comparison of postures before and after use of the proposed tools.

ACKNOWLEDGEMENT

This research was supported by the Universiti Tun Hussein Onn Malaysia (UTHM) through GPPS Vot Q212.

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