Streamlining Kapok Pillow Production: The Kekabu Pro Solution

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Abstract -Kapok, also known as kekabu in Malaysia, is most often used as pillow and mattress stuffing as a great alternative to down or feathers. As a result, it led to the emergence of numerous Small Medium Enterprises (SME) focusing on producing pillows, bolsters, and mattresses. To keep up with domestic demand, productivity increase by incorporating machines is a must. This led to the development and fabrication of Kapok Pro machine. Kapok Pro aims to streamline the process of separating kapok fibre from seed pods and subsequently fill a various sized pillowcase, thus increasing productivity. A prototype was designed and developed before producing the final product. The time taken to fill 10 pillowcases measuring 26×17 inch was recorded for three methods: traditional method, the prototype, and Kapok Pro. Kapok Pro is proved to reduce production time by 84.4%. The productivity test was conducted using three different sizes of pillowcases shows that with each additional hours, the number of kapok pillows produced effectively doubles. Kapok Pro significantly simplifies the kapok processing process, increases productivity, and holds the potential for international commercialization. It offers a cost-effective solution for the kapok industry, addressing the challenges faced by SMEs in Malaysia.

Index Terms—*kapok, kekabu, seed separator, filling machine*

Introduction

In Malaysia, kapok fibre is most often used as pillow and mattress stuffing. It is a great alternative to other nature made stuffing materials such as down or feathers. Kapok is also known as *kekabu* locally, with the prevalent variety found is from ceiba pentandra (L.) Gaertn. The Ceiba species is a deciduous tree known for its rapid growth, with the most common variety being Java kapok [1]. Despite the numerous properties of kapok fibre, which includes a cotton-like texture, hypoallergenic, non-hazardous, hydrophobic, and resistant to deterioration, the main uses are still restricted to cushion padding, pillows, stuffed toys like dolls and bears, upholstery, meditation cushions, and mattresses [2]. An interesting development in the field of packaging materials, there has been research to transform kapok fibres into paper with the potential to serve as water-resistant packaging material [3]. The fluff like kapok fibres is easily removable from the seed pods, owing to the relatively weak adhesion of kapok fibres and the shell of the capsule inner wall [1, p. 65]. This makes it easy to do the separation process by hand, albeit a bit laborious. As a result, it has led to the emergence of numerous Small Medium Enterprises (SME) focusing on producing pillows, bolsters, and mattresses. The SME involves individuals with diverse backgrounds, which in the case of kapok by product includes Persons with Disabilities (PWD) and senior citizens. An SME census conducted in 2011 stated that a a significant 97.3 percent of all establishments in Malaysia were categorized as SMEs, with a primary focus on serving the domestic market [4]. The SMEs are further categorized into Micro, Small and Medium enterprises with the defining criteria for these categories include having fewer than 50 full-time employees or an annual sales turnover of less than RM5 million [5]. The SMEs in the domestic market are eager to increase their productivity by incorporating machines to separate the kapok fibres. The demand for an automatic or semi-automatic machine to separate the kapok fibres from their seed pods and subsequently fill a pillowcase has led to the development and fabrication of Kekabu Pro machine. The Kekabu Pro Filler aims to streamline the whole process of separating kapok fibre from

seed pods and subsequently filling a standard size pillowcase, thus increasing productivity.

The conventional technique for extracting kapok fibre from seedpods entails the manual process of removing the seed pods and transferring the kapok fibre into a receptacle with holes at the bottom. The next step is to remove any seeds that may be trapped within the fibres. This process is carried out by agitating the kapok fibres with a specialized tool made from bamboo. The receptacle is then shaken to subsequently shaken to strain and filter out the seeds. The last step involves placing the cleaned kapok fibres into fabric cases, which will then be transformed into pillows, bolsters, or mattresses. This step is completed either by hand for stuffing mattresses or using a filling machine for pillows. When it came to the pillow-making process, the only time machinery was used was when the employees operated the filling machine. While this process can be labor-intensive, it results in higher-quality and fluffier kapok fibres [6]. The obvious drawback being productivity rate, since only small batches of kapok fibres are being produced at a time.

Kapok pillow SMEs encounter various challenges such as the significant amount of time required to produce kapok fibre, excessive labor, lack of exposure to technology, equipment that does not meet safety standards, and high machine costs.

In the traditional method of kapok production, the process of extracting seeds from the kapok seedpod and placing the processed kapok into pillowcases is time-consuming, leading to reduced productivity. This process often takes around 30 minutes for 5 pillows, equivalent to 6 minutes per pillow. Therefore, to enhance productivity, it becomes necessary to employ additional workers. However, this subsequently raises labor expenses for a small kapok SME, costing them approximately RM 60 to RM 90 per day per worker. The heavy reliance on manual labor is primarily a result of many micro and small enterprises lacking significant technological integration in their kapok pillow production. This traditional approach proves to be inefficient in terms of increasing kapok pillow output for the market, as it cannot meet the demands on a larger scale. It is also worth noted that none of the equipment used in traditional methods complies with worker safety standards, as the tools employed are highly hazardous and can result in injuries during the process. Examples of such traditional equipment include bamboo sticks used for separating kapok fibres and tools for filling kapok into pillowcases, which are sharp and pose a risk to workers. The solution to this issue, which comes in the form of Kapok Pro, involves replacing all processing equipment with machinery that meets the required worker safety standards. That being said, considering that the majority of SMEs are relatively small in scale, they don't require large machinery for kapok pillow production. Thus, a small or medium size machine, which is also portable, is preferable. Most machines currently available in the market are not suitable for small kapok SMEs in terms of cost, functionality, and machine capacity. The costs of machines available in the market are very high for small industries that have a capital of only RM1000. Furthermore, the kapok machines available in the market often have separate functions, and there is a lack of machines with dual functions in one machine.

To boost productivity, machines were introduced into the process. Nevertheless, there is a limited availability of machines in the market capable of both separating and filling pillowcases simultaneously. One study concluded the use of motor-operated blades that rotate to separate the fibres from the seeds. The seeds are then filtered and directed into a chamber at the bottom, leaving the fibres ready for collection. The machine resulted in 52.8% increase in production rate [7]. In another design, a combination of an agitator and a blower is employed. The agitator functions to separate the kapok fibre while the blower while the blower is used to propel the clean and lightweight kapok into the output tank through the suction feed [8]. In addition, a machine that incorporated the 2 in 1 approach of peeling the kapok seedpods and then separating the fibre from the seed was also introduced. This design involved the use of both rotary and stationary blades to peel the kapok seedpods, followed by the separation of the fibres using rotating blades [9].

Methods

The procedures associated with each stage of Kekabu Pro development can be summarized as indicated in the timeline depicted in Fig. 1.

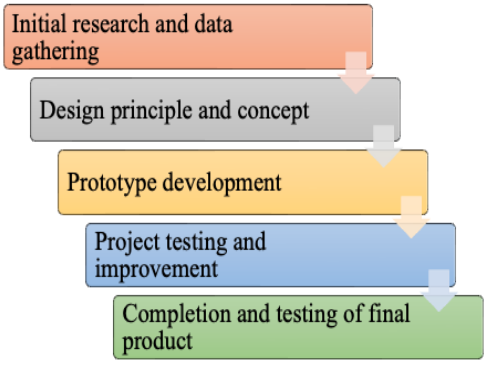

Fig. 1 Implementation Phase Block Figure

A. Initial research

Prior to initiating any design and development work, interviews and a survey was conducted as a preliminary step. The interview was conducted with various micro and small-scale kapok pillow producers, to gauge their interest in a portable and affordable machine. The purpose of the interview was also to ascertain the methods they employed in the production of kapok pillows and any potential by-products derived from kapok. Next, a questionnaire was designed to gather data related to the production of kapok fibres and the challenges encountered during the manufacturing process. In the initial section of the questionnaire, demographic information such as age, educational level, marital status, and job details (including job category, job experience, and daily working hours) was collected. The closed-ended questionnaire was used to assess the demand for a machine that could produce higher-quality kapok fibres and its by-products. It also examined safety concerns associated with traditional methods and production rates. The survey also examined the reception to machines in the likes of the Kapok Pro. A sample size calculator was used to determine the maximum sample size with confidence level of 90% and a 10% margin of error.

B. Design principle

Numerous concepts were evaluated for Kekabu Pro. A particular design that was considered was the concept of an annatto (Bixa orellana L.) seed separator machine. This machine operates by utilizing impact and shear forces generated by beaters to separate annatto pods from the seeds. Subsequently, aspirators are employed to remove the husk and any contaminants, while the remaining seeds are collected in a material chamber [10]. The initial design approach for Kekabu Pro involved adapting the concept of a cyclone separator. A cyclone separator works by using centrifugal force to manipulate dust particles, and the thought of adapting this concept to the light and fluffy kapok fibres were considered. However, although it can process particles larger than 200 microns, this will inevitably affect efficiency. The limitation in efficiency due to the necessity of processing particles smaller than five microns raised concerns about the feasibility of this approach [11].

C. Design concept

Upon research and data collection, it has been determined that the Kekabu Pro will comprise four primary components: a 100-liter barrel, a rod shaft with blades, a motor, and a blower. It will utilize a 2 in 1 concept, in a sense that it will separate the seeds from the kapok fibres and subsequently fill a predetermined sized pillowcase. The process of separating kapok seeds from the fibre involves using a rod shaft that is connected to a motor positioned at the top of a barrel. The motor generates vertical rotational motion, creating a powerful vortex that causes the kapok fibre to move in sync with the motion of the vortex, thereby ultimately separating the seeds from the kapok fibre. The separated seeds will gather at the bottom of the barrel and can be conveniently removed by means of a collection chamber. Previously, the tasks of separating seeds from kapok fibres and filling pillowcases were conducted as distinct and separate processes. To increase productivity and decrease manufacturing time, it has been decided that the 2-in-1 approach, where these tasks are combined is the most suitable solution It is important to highlight that this method does not involve the removal of kapok fibres from their respective seedpods.

Results

D. Survey result

A survey conducted received active participation from a diverse group of 42 kapok production employees, each representing various backgrounds. The findings indicate that 87.5% of respondents continue to rely on traditional methods, while only 12.5% utilize machines. This suggests that production employees have limited exposure to advanced technology in kapok processing. Moreover, 95.2% of respondents concur that traditional methods are more challenging to execute, although 54.8% agree that they result in higher-quality kapok fibre. A higher quality kapok fibre offers a more long-lasting finish, and it provides excellent comfort during use [12]. In reference to the risk of injury, a significant 95.2% of respondents agree that the traditional method can indeed pose a risk of injury to workers due to the lack of adherence to proper safety standards while handling the equipment itself. Although injuries during kapok manufacturing process are rarely documented, the response from the employees does this give a cause for concern. It is strongly recommended that the utilization of the Kapok Pro machine could help prevent future injuries in kapok processing. Conversely, a substantial 97.6% of respondents agree that the use of machines would optimize kapok manufacturing process as well as providing a more systematic process for kapok SMEs. Furthermore, a noteworthy 90.5% of respondents agree that Kapok Pro is more efficient in producing kapok pillows when compared to manual traditional methods. It is worth mentioning that all 100% of the respondents acknowledge the use of machines such as the Kapok Pro can help maintain cleanliness in the processing area. This is due to the fact that the machine processes kapok without exposing it to the environment. There is also unanimous agreement from all respondents, totalling 100% that agree machines are capable of producing kapok pillows and further increasing production to meet market preferences and demands.

E. Prototype A

Prototype A, as shown in Fig. 2, was designed with an environmentally sustainable approach in mind, making the use of recycled materials a suitable choice. Given this perspective, a 100-liter plastic barrel drum made from high density polyethylene (HDPE) was chosen. The plastic drum, commonly known as a poly drum, was selected due to its cost-effectiveness, durability and most important its recyclability [13]. Correspondingly, the effective ability of polyethylene to absorb vibrations will also help reduce the noise generated by the electric motor [14]. In order to align more closely with a sustainable approach, a used poly drum was chosen as opposed to a brand new purchase.

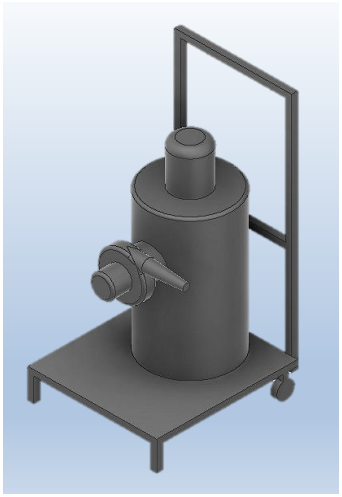

Fig. 2 Prototype A design

After a thorough design and fabrication process, the final product can be seen on Fig. 3. Following controlled testing, the test results indicated that the utilization of Prototype A does significantly reduce the time required to fill a pillowcase by nearly half. The comparison was made with a conventional method of producing kapok pillows. Prototype A was deemed a success and there were demand for commercialization. However, there are areas for improvement, such as refining the barrel design to better facilitate the removal of kapok seeds at the bottom of the barrel. The current procedure requires the machine to be switched off before the separated seeds can be collected. Looking at the design, there were also suggestions in enhancing overall maneuverability. Prototype A was intentionally designed with portability as a primary feature to appeal to kapok pillow SMEs. The reason for this is the majority of industrial machines promoted for the same

process are typically large and cumbersome, not to mention expensive. Since the focus is on micro and small SMEs, a portable and medium-sized machine is an added advantage. Additionally, the affordability of it is also an extra benefit that cannot be denied.

Fig. 3 Prototype A

F. Prototype B

Due to the positive response garnered by Prototype A, a more comprehensive design was considered for Prototype B. It was decided after numerous feedback from kapok pillow SMEs and the employees. Prototype B new design is illustrated in Fig. 4. It was designed to have a more industrial look with increased rigidity. The capacity has also been increased, surpassing the previous 100-liter volume. The new design introduced a new mild steel barrel to replace the recycled poly drum. It is also given a primer coating finish, providing it with a more cosmetic appearance. The aim of this alteration is to ensure long-term durability. Correspondingly, the inlet chute was designed to be more ergonomic, making it easier to fill the barrel with kapok fibres. In addition, the bottom of the barrel also underwent changes as it was redesigned to have a tapered, cone-like shape, which better funnels the seeds. With the upgraded design, kapok seed will drain automatically from the bottom nozzle. This design eliminates the need for a collecting chamber drawer, which was emptied manually in intervals by employees before. To ensure mobility and portability, the four legs attached to the barrel were equipped with casters.

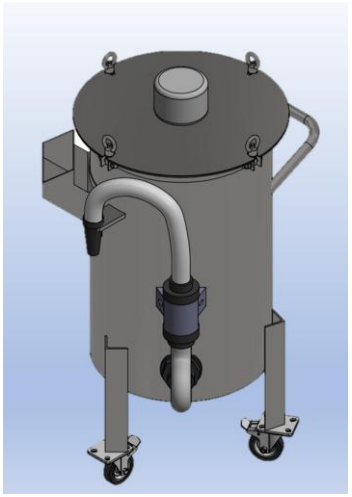

Fig. 4 Prototype B design

This marked a significant improvement from Prototype A, where it used trolley to move the machine around. The new design as a whole imparts a more streamlined and professional appearance to Kapok Pro.

(a) (b)

Fig. 5 Prototype B at (a) side view, (b) front view

G. Data collection

A series of data was collected to compare the productivity of each method of producing kapok pillows, namely conventional, using a Prototype A and Prototype B (Kapok Pro). Each method requires a total of 10 pillowcases with dimensions of 26×17 inches. The filling process is repeated until the entire 10 pillowcases are used up to accurately gauge the time taken for each pillow.

This testing allows for a comparison of productivity in terms of output and input between the traditional method and Prototypes A and B. The data collected is then compiled in Table 1 below.

Table 1 Pillow filling duration comparison

Method	Conventional	Prototype A	Prototype B
Seed separation (minutes)	30	3	2
Pillow filling (minutes)	15	10	5
Total time (minutes)	45	13	7

There is marked improvement in the total time taken to produce kapok pillows, with the conventional method requiring the longest time, clocking in at 45 minutes, while Prototype B boasts a notably shorter production time of just 7 minutes. The reduction in production time is inversely proportional to the production rate of kapok pillows. This implies that a greater number of kapok pillows are now being manufactured within a shorter timeframe, consequently leading to an augmented production rate. When comparing the production time with the conventional method, it is evident that both Prototype A and Prototype B show significant reductions in production time. Prototype A reduced production time by 71.1%, while Prototype B achieved an even more remarkable reduction, with an 84.4% decrease. It can be stated that the redesigned Prototype B exhibits a reduction of 46.1% in production time when compared to Prototype A. This signifies an improvement in the efficiency of Prototype B production process.

Kapok Pro has the flexibility to accommodate pillows of different sizes. To illustrate this, extensive testing was conducted on Kapok Pro, involving the use of up to three different sizes of pillowcases to measure the time it takes to fill each one. The testing was conducted in cooperation with a local SME specializing in kapok pillows. Multiple tests were conducted to gather data on time, kapok weight, and the quantity of pillows that can be produced. The results are displayed in Table 2 comparing time, kapok weight used, and size differences in a single process.

Table 2 Various pillow sizes production

Time (minute)	Number of pillows		
	26×17 inch	24×16 inch	13×18 inch
60	85	93	161
120	159	170	345
180	256	264	510

Table 2 demonstrates that when a single worker operates the Kapok Pro machine, they have the capacity to produce up to 161 kapok pillows within a one-hour timeframe, and this production quantity varies depending on the specific size of the pillows. For a standard size pillow of 26×17 inch in dimension, a single worker utilizing Kapok Pro has the capability to manufacture as many as 85 kapok pillows in one hour. Consequently, in a span of two hours, as much as 159 kapok pillows can be produced, with the number increasing to 256 kapok pillows in three hours. In essence, with each additional hour of operation, the number of kapok pillows produced effectively doubles, showcasing the scalability of Kapok Pro and its potential to significantly boost productivity over extended periods. This means that as the hours accumulate, the Kapok Pro machine can consistently generate more pillows, meeting the demand for kapok products in an efficient and time-effective manner. Hence, it signifies that Kapok Pro is highly efficient for kapok SMEs due to its very effective and faster workflow compared to the traditional manual method. It can be inferred that productivity using Kapok Pro can be as high as 700 kapok pillows per day. This differs greatly with the traditional method, which typically yields a maximum of 60 kapok pillows per day. It should be noted that the inference is based on a 4 hours work day for a PWD or senior citizen as opposed to the normal 8 hours of work. It can be stated that for a full 8-hour work shift, the output will be noticeably larger. This further confirms that Kapok Pro is a significant advancement for local kapok SMEs. It is important to note that as workers gain

experience with the Kapok Pro machine, their skill levels will likely improve. This could lead to even greater productivity gains over time. In time, this will not only increase efficiency but also contribute to the overall development and success of the kapok SMEs. This adaptability and skill development among workers highlight the potential of Kapok Pro for long-term benefits and continuous advancement in kapok production.

H. Operating Kapok Pro

Below are the steps for operating Kapok Pro in their respective order:

1. Turn on the main motor switch.
2. Insert the kapok into the inlet chute.
3. Activate the blower switch.
4. Continue to feed kapok until it's completed.
5. Turn off the blower switch.
6. Turn off the main motor switch.

II. CONCLUSION

Kapok Pro has achieved its primary objective of streamlining the whole process of separating kapok fibre from seed pods and subsequently filling a standard size pillowcase. Previously, the two processes had to be carried out independently, but now they can be performed simultaneously. The innovative production method has had a notable impact on kapok pillow SMEs by raising the technological standard in kapok pillow production and preserving the quality of kapok fibres. Kapok Pro also provides a platform to increase production on a large scale to meet current market demands. This is due to the fact that Kapok Pro has minimized the dependence on manual labor, commonly employed in traditional procedures, and can process a larger number of pillows in a shorter timeframe. Furthermore, the concern regarding compliance with safety standards has been addressed as well, making Kapok Pro a safe and much more reliable option for kapok pillow production.

However, Kapok Pro also will benefit from a few improvements. One of the new features under consideration is the integration of Internet of Things (IoT) applications. Utilizing apps accessible through mobile phones can be particularly beneficial for individuals with disabilities, allowing them to participate in kapok pillow production and generate income, as it simplifies the process and provides remote control over the machinery. This can be accomplished through several avenues, including conducting trials with companies that have diplomatic ties to foreign nations in the kapok pillow production industry. This approach can help introduce Kapok Pro to international markets and expand its potential beyond domestic borders. Kapok Pro holds high potential for commercialization in the kapok industry due to its ergonomic design and cost-effectiveness compared to machines currently available in the market.

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