

THE DESIGN AND DEVELOPMENT OF LIMPUPU COATING MACHINE

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Abstract

The Limpupu Coating Machine is a dedicated device designed to coat Limpupu seeds by significantly improving their durability and surface hardness. This innovation aims to make the seeds more resilient, providing enhanced protection during handling and use. The machine utilizes a semi-automated dipping process, where the seeds are immersed five times with five minutes holding time in an acrylic resin coating solution. By adjusting the switch to regulate the ascending and descending motions, the machine ensures consistent coating, resulting in seeds that are firm enough to withstand wear and exhibit increased surface hardness. This process enhances the limpupu seed's overall quality and longevity, making it more robust for various applications.

Keywords: Acrylic resin, Design and fabrication, Limpupu seeds,

INTRODUCTION

Limpupu seed (Figure 1) is a unique type of seed commonly used in handicrafts alongside dalai seeds in Sabah. Due to deforestation, Limpupu seeds have become scarce in Borneo, making them increasingly valuable as a material for handcrafted items. The Limpupu plant typically grows in the foothill areas of Kiulu, Ranau, and Keningau. Limpupu seeds bear some resemblance to bitter beans but differ significantly in size and characteristics. Unlike bitter beans, Limpupu seeds are much harder, inedible and approximately ten times larger. It takes about 6-7 months for Limpupu fruits to ripen, after which the seeds naturally detach from its shell.

Traditionally, Limpupu seeds have been used by the Dusun ethnic group for medicinal practices and as tools for body massages. Today, they are integral to handicrafts and cultural clothing ornaments. Lokub village in Kiulu exemplifies this tradition, with a thriving industry centered on the use of dalai and Limpupu seeds. These seeds undergo a preparation process when the outer layer of the ripe fruit is cleaned with water and a brush, sun-dried, and then crafted into handmade items. Sizes of the seeds vary, with the largest measuring up to 6 cm in width and 7 cm in length, and the smallest around 3 cm in width and 4 cm in length.

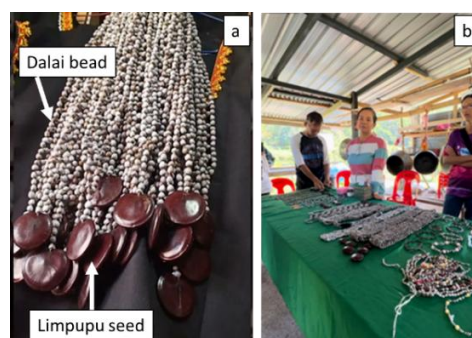


Figure 1. a. Limpupu seed handicraft; b. Kiulu handicraftsmen

Given their scarcity, Limpupu seeds hold significant cultural and ecological value. They are not only a reflection of traditional heritage but also a resource requiring conservation. Sustainable harvesting and use can preserve their cultural significance and support local artisans and communities, ensuring that the traditions associated with Limpupu seeds endure for future generations. However, according to the Ratau Village craftsmen, there are several challenges in working with Limpupu seeds. One issue is that the color of the seeds fades when exposed to moist air and sunlight. Additionally, Limpupu seeds are prone to wearing out and scratching when used as massage tools. Lastly, if the seeds are exposed to water for an extended period, they may sprout, rendering them unsuitable for handicrafts.

In addressing these challenges, this project aims to innovate a solution by designing a Limpupu coating machine. The machine fabricated according to design specifications to ensure its functionality and efficiency. Finally, the coating efficiency will be tested based on key parameters such as coating thickness and hardness, providing a robust solution to enhance the durability and usability of Limpupu seeds for handicrafts and other applications.

LITERATURE REVIEW

Coating by resin is a widely used technique in various industries to protect and enhance the surface properties of materials. Resin coatings are typically applied to provide a durable, protective layer that can resist wear, corrosion, moisture, and chemical damage. These coatings are versatile, as they can be customized to meet specific requirements, including hardness, flexibility, and thermal resistance (Ramakrishnan *et al.*, 2022). Commonly used in sectors such as automotive, aerospace, construction, and electronics, resin coatings also offer aesthetic improvements by providing smooth finishes and enhancing the appearance of products. The process of coating by resin involves the application of liquid resin that hardens to form a protective film, which can be applied through methods such as spraying, brushing, or dipping, depending on the material and intended use. Coating methods are essential processes used to apply protective or decorative layers to various materials and surfaces. These methods help improve the durability, appearance, and functionality of products across multiple industries, from automotive and aerospace to electronics and construction. The choice of coating method depends on factors such as the type of coating material, the substrate, the desired finish, and the application's environmental conditions. Common coating methods include spraying, dipping, brushing, rolling, and electroplating (Peng *et al.*, 2022; Siau *et al.*, 2005).

Acrylic resins, combined with appropriate hardeners, form a vital component in various industrial, commercial, and artistic applications. Known for their robustness, versatility, and aesthetic appeal, these materials are indispensable in fields ranging from automotive and construction to fine arts and jewelry making. The interplay between acrylic resin and its hardener determines the final characteristics of the cured material, making a thorough understanding of their properties, usage methods, and mixing ratios essential for achieving optimal results. Acrylic resin, a type of thermoplastic or thermosetting plastic, is valued for its clarity, strength, and resistance to environmental factors (Fink, 2018). It is frequently employed in applications that demand transparency and durability, such as coatings, adhesives, and castings. The hardener, or curing agent, plays a crucial role in the polymerization process, transforming the liquid resin into a solid state. This reaction not only sets the resin but also enhances its mechanical properties, ensuring it meets the specific requirements of its intended use (Kaiser & McAllister, 2023).

The method to use the acrylic resin and hardener involves meticulous preparation, precise mixing, careful application, and proper curing. Each step is critical to ensure that the final product meets the desired specifications for strength, clarity, and durability. By adhering to these procedures and paying attention to detail, users can achieve high-quality results in their projects, whether in industrial applications or artistic endeavors. Understanding and following the correct method not only enhances the performance and longevity of the resin but also ensures a safe and efficient working process (Raszewski *et al.*, 2022). The correct usage of acrylic resin and hardener involves precise measurement, thorough mixing, and adherence to specified ratios, which are critical for the integrity and performance of the final product. An improper mix can lead to defects such as incomplete curing, brittleness, or reduced resistance to environmental factors. Thus, the successful application of these materials hinges on understanding their chemical properties, the proper techniques for their use, and the significance of maintaining the correct ratio between resin and hardener. The standard ratio for many acrylic resin and hardener is 2:1, two parts resin to one part hardener (*Acrylic Resin - an Overview* | ScienceDirect Topics, n.d.).

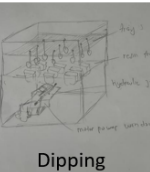
Dip coating or liquid deposition techniques involves submerging the object into a bath of liquid coating material and then withdrawing it to allow excess coating to drip off and the surface to dry. This method ensures that the entire surface of the object, including hard-to-reach areas, is evenly coated. Dipping is frequently used for applying protective coatings such as resins, varnishes, or metal-based coatings on items like wires, pipes, and medical devices. One of the key benefits of dipping is that it can easily coat intricate or complex parts, making it suitable for a wide range of applications. Dip coating is a versatile technique employed across various industries for the precise deposition of thin films onto solid substrates. It involves immersing a substrate into a liquid solution or dispersion containing the coating material, followed by controlled withdrawal at a constant speed. This process facilitates the formation of a uniform, adherent coating layer on the substrate's surface (Puetz & Aegerter, 2004; Siau *et al.*, 2005).

One of the key advantages of dip coating is its simplicity and cost-effectiveness compared to other deposition methods like chemical vapor deposition (CVD) or physical vapor deposition (PVD). Additionally, dip coating allows for the deposition of a wide range of materials, including polymers, ceramics, metals, and composites, making it suitable for diverse applications such as protective coatings, functional coatings, and thin film fabrication (Asatekin *et al.*, 2010). The thickness and properties of the deposited film can be precisely controlled by adjusting parameters such as withdrawal speed, solution viscosity, and drying conditions. Furthermore, dip coating offers scalability, enabling the coating of small laboratory samples to large-scale industrial production. Despite its widespread use, dip coating does have limitations, such as limited control over film thickness uniformity on complex geometries and the potential for solvent retention in the deposited film. Nonetheless, with ongoing advancements in process control and material science, dip coating continues to be a valuable technique for achieving tailored surface properties and functionalities in various industrial and research applications (Fink, 2018).

RESEARCH METHOD

The project performed according to the systematic process involving designing, fabricating, and analyzing. It begins with the design process, where initial concepts are generated based on project objectives. The design selection phase follows, evaluating the proposed ideas to select the most feasible option as in Figure 2. Next is material selection, where suitable materials are identified

to ensure the product meets functional and aesthetic requirements. The process then transitions to the fabrication process, where the selected design is constructed according to the specifications. After fabrication, the product undergoes design testing to ensure its functionality and quality. If it fails, a feedback loop prompts modification and retesting until it meets the desired standards. Upon passing, the process moves to analysis, where results are evaluated and concluded regarding the project's success.

NO	DRAWING	EXPLANATON
1	 Brushing	1. The brush rotates with the help of a motor. 2. Use the switch to lower and raise the tray. 3. Limpupu seeds are tied using wire.
2	 Spray	1. Use the switch to lower and raise the tray <u>limpupu</u>. 2. When the tray goes down into round wall spray, the tray rotates and ready to spray.
3	 Dipping	1. The resin tray will up and down with the help of a hydraulic scissor jack 2. The hydraulic jack will up and down be using motor power window. 3. Tray <u>limpupu</u> seeds can pull out and pull in. 4. Use iron wire in place of the tray to hang <u>limpupu</u> seeds.

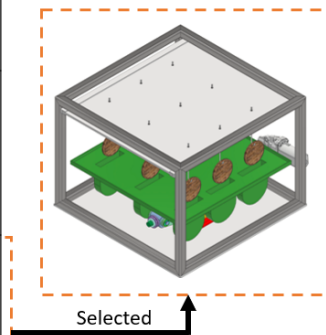


Figure 2. Design selection

The process of developing the coating machine involves several steps as in Figure 3. It begins with measuring and marking materials, where rulers, tapes, and markers are used to measure steel sections, which are then cut using a grinder and cutting machine. The cut steel pieces are welded together using Arc welding to form a cube-shaped frame. Post-welding, grinding ensures a smooth surface for further welding. Next, wiring connects a battery-powered window motor to a scissor jack, allowing the resin tray to move up and down for the dipping process. Rails are installed on the frame to guide the resin tray's movement, and a 3D-printed resin tray with 12 seed slots is assembled using hot glue and epoxy. Finally, all parts are assembled into the body frame using drills and grinders, creating a fully functional coating machine. The machine is designed to coat 12 limpupu seeds simultaneously, with the seeds secured in a tray to remain stationary during the resin coating process. Powered by a battery-driven scissor jack, the resin tray moves up and down within a box-shaped body frame. The addition of side rails ensures smooth movement, while the seed hanger tray facilitates the dipping process, enabling efficient seed coating. The seed was dipped in the acrylic resin solution for five minutes and cured for five minutes. The steps were repeated five times to obtain uniform coating thickness. During the coating process, ensure to used all protective gear and gas mask to avoid the operator inhale the chemical gases.



Figure 3. Fabrication process flow

The layer morphology of the coated limpupu seed was observed using optical microscope. In this study, optical microscope model of BV41M by Olympus was used. The microscope equipped with Universal Infinity System (UIS) to enable object with different interference contrast only have a minimal effect on focus. The optical microscope used to observe the thickness of the acrylic coated limpupu seed. The specimen is analyzed using different magnification level ranging at 50x. The image is captured and analyzed using Image J software. ImageJ software used to scale and to adjust the brightness and contrast of the image obtained from the microscope. The images are scaled by converting the pixel-based images into a real-world scale in "mm". Meanwhile, the image brightness and contrast were adjusted to have a clear differentiation between the acrylic resin layer and limpupu seed boundary.

The Leeb hardness test on acrylic-coated parts requires careful preparation to ensure accurate results. Prior to testing, the coated surface was thoroughly cleaned to remove any contaminants such as dust or grease. The coating then inspected to confirm a smooth, uniform application and allowed to fully cure. The hardness tester is then calibrated using standard reference blocks or materials with hardness values similar to the coated part. An appropriate impact device, such as the D-type, is selected based on the geometry and thickness of the sample. To prevent vibrations or movement during testing, the sample was placed on a stable surface, with additional support provided for lightweight or thin parts. The testing procedure involves positioning the Leeb hardness tester perpendicular to the coated surface to minimize errors caused by angular misalignment. Multiple impact measurements were taken at different points on the surface, ensuring adequate spacing between test locations to prevent overlapping results. The hardness values obtained from these measurements are recorded, and the average was calculated to provide a representative hardness value for the coating. The results are then analyzed by comparing the measured values to expected hardness ranges for acrylic coatings, with any deviations potentially indicating issues such as improper curing or inconsistent coating thickness. Finally, all testing conditions, calibration details, and results are documented in detail to ensure repeatability and reliability of the findings.

RESULTS AND DISCUSSION

The Limpupu coating machine can be observed as Figure 4. The frame of this coating machine is made from mild steel, which has been chosen due to its combination of availability, cost and strength. This means the structure is durable and resistant for the process it is working in. The tray was specifically designed for the dipping process. Above it, there are wires that suspend limpupu seeds so each of them would fall exactly in place for dipping. This form of suspension promotes evenness in the exposure to the dipping medium, hence enhancing efficiency in the process. A scissor jack is set under the tray, which is essentially a major lifting mechanism. The scissor jack is connected to a power window motor by means of a shaft for mechanical linkage, which will provide the required motorized force for the up-and-down motion of the tray. The connection is such that movements during operation are smooth and consistent.

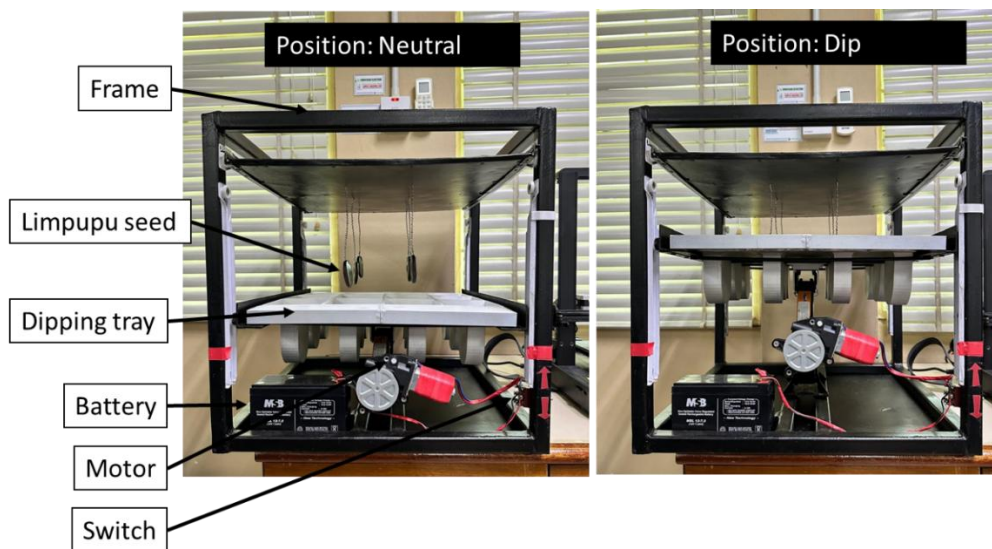


Figure 4. Limpupu coating machine

The tray is further guided by railways integrated into the system, which help maintain stability and alignment as it ascends and descends. This ensures the tray's movement is controlled and accurate, and it does not misalign or dip unevenly. It operates using a three-way button switch; it is easy for the user to manage the tray moving up or down accurately using this switch. It shows thoughtful engineering that is combined with durable materials, like aluminum, with a well-integrated mechanical and electrical control system. Equipped with a motorized scissor jack and guided railways, the dipping process is efficient and reliable, simple to use, and thus perfectly suited for applications where precision and consistency are required.



Figure 5. Comparison between coated and uncoated Limpupu seed

According to Figure 5, the coated Limpupu seed with acrylic resin significantly enhances its visual appeal by making it more glossy, smooth finish, more vibrant and attractive compared to the matte, textured appearance of the uncoated seed. This coating not only improves the aesthetic appeal but also provides a protective layer, increasing the seed's durability against environmental factors such as moisture and scratches.

The outlines the coating thickness values for five different lines presented in Figure 6, measured in millimeters (mm). Each line represents a specific observation, and the corresponding thickness values vary slightly. Line No. 1 recorded the lowest thickness of 0.962 mm, whereas Line No. 3 exhibited the highest thickness at 1.165 mm. The other three lines (Lines 2, 4, and 5) measured 0.974 mm, 1.021 mm, and 1.021 mm, respectively, indicating minor variations across the samples. The average coating thickness for the five lines is calculated to be 1.0286 mm. This value suggests a relatively consistent coating application, with minimal deviations from the mean. The table indicates good control over the coating process, as the differences between the highest and lowest values are within an acceptable range. Such uniformity is critical for ensuring the quality and performance of the coated.

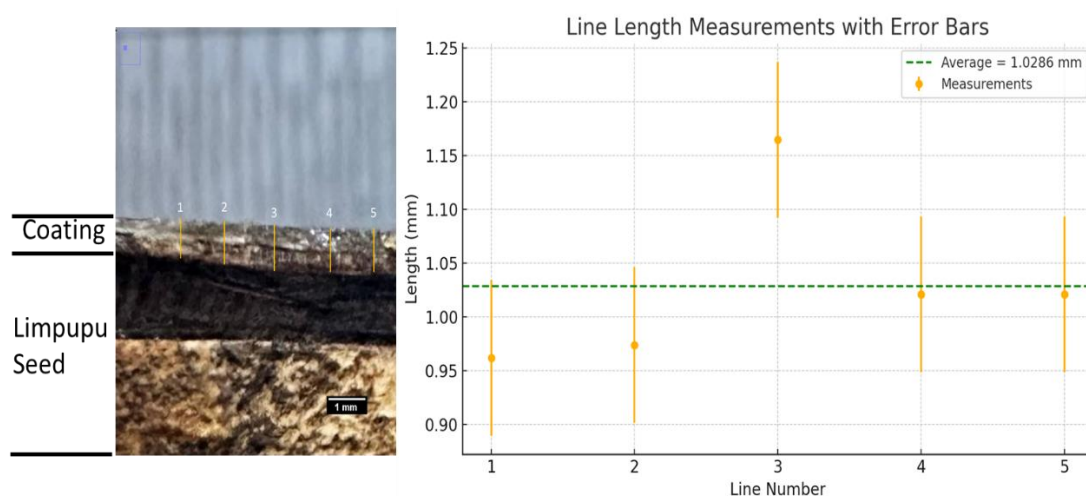


Figure 6. Limpupu seed coating thickness

The graph in Figure 7 demonstrates that Limpupu seeds coated with acrylic resin significantly enhances its surface hardness compared to uncoated samples. The coated samples consistently show higher hardness values across all tests, with an average hardness of 230.67 HL, approximately 24.7% higher than the uncoated samples average of 185 HL. This increase highlights the coating effectiveness in improving the mechanical properties of the seeds, likely due to the structural reinforcement provided by the acrylic resin. Additionally, the coated samples display greater uniformity in their hardness measurements, particularly in Test 2 and Test 3, suggesting enhanced mechanical stability. These findings suggest that the application of acrylic resin is a reliable method for improving the durability of Limpupu seeds.

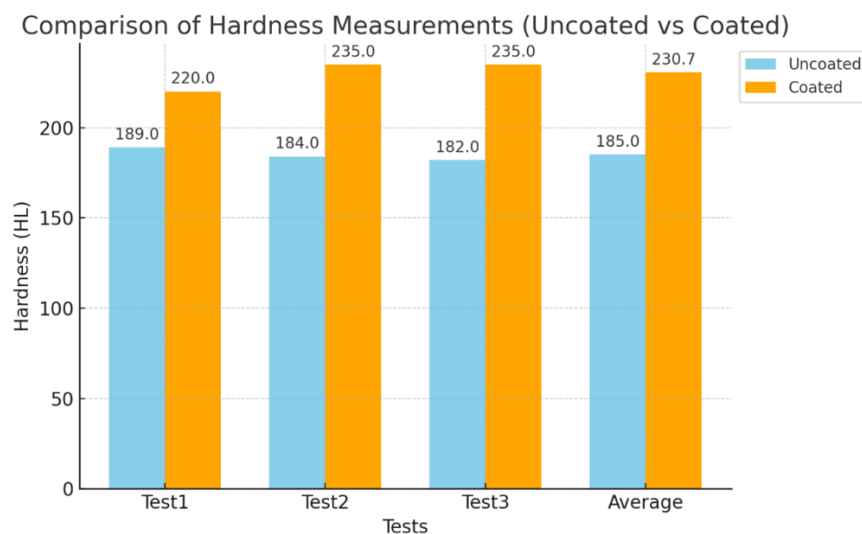


Figure 7. Limpupu seed coating thickness

CONCLUSION

The Limpupu Coating Machine project successfully addresses the challenges faced by handicraft makers in maintaining the quality and durability of Limpupu seeds used in traditional crafts. By utilizing innovative design and advanced mechanical processes, the project demonstrates a significant improvement over manual methods in terms of efficiency, precision, and usability. The machine ensures uniform coating of Limpupu seeds, enhancing their resistance to environmental factors such as moisture and scratches, while also preserving their aesthetic and functional value for craft production. Overall, the Limpupu Coating Machine represents a significant step forward in supporting the sustainability of traditional crafts, providing an effective and user-friendly solution to a longstanding issue in the Lokub Kiulu community. By bridging traditional craftsmanship with modern engineering, this project contributes meaningfully to preserving cultural heritage while improving efficiency and output for artisans.

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