Optimization and Construction of a Cost-Effective, Adaptive Heating and Mixing System for Efficient Drying of Value-Added Agricultural Products to Support MSMEs

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***Abstract*— This research focuses on on the design, optimization, and construction of a cost-effective, multi-functional heating and mixing system tailored to enhance the drying efficiency of value-added agricultural products for micro, small and medium-sized enterprises (MSMEs). The system was initially developed for dried Nipa Palm but has demonstrated versatility by performing additional functions such as mixing liquids, producing jams, and homogenizing powders. A detailed framework encompassing material selection, control system development, and construction processes was implemented to ensure flexibility, energy efficiency, and consistent performance. Performance results indicate that this newly developed system is able to reduce drying times and operational costs significantly compared to conventional methods. Notably, its total cost is nearly 50% lower than the combined cost of three separate machines (mixer, stirrer, and roaster) available on the market, making it an economically viable solution for MSMEs. The system's motor power is sufficient for processing up to 0.5 kg of Nipa Palm and 15 liters of viscous liquids or semi-solid materials, though scalability for larger quantities would require adjustments in container size and motor capacity. Energy efficiency is achieved through adjustable speed and temperature controls, which minimize power consumption by eliminating the need for continuous operation of the hot plate. These features contribute to reduced labor costs, improved operational efficiency, and enhanced adaptability for various food processing applications. This research shows that the Automatic Heating and Mixing System is a practical, scalable, and energy-efficient solution for small-scale agricultural production environments.**

***Key words* — Heating and Mixing System, Agricultural Products, MSMEs, Drying Efficiency, Cost-Effective Design, Multi-Function System**

I. Introduction

In the agricultural sector, micro, small and medium-sized enterprises (MSMEs) often face challenges in adopting efficient and cost-effective technologies for processing value-added products. Traditional methods of drying, mixing, and homogenizing agricultural materials are labor-intensive, time-consuming, and energy-inefficient, limiting the scalability and profitability of MSMEs. To address these issues, there is a growing need for innovative, multi-functional systems that can streamline operations while reducing costs and improving productivity.

This research focuses on the design and development of an Automatic Heating and Mixing System tailored to meet the needs of MSMEs. Initially designed for drying Nipa Palm, the system has been optimized to perform multiple functions, including mixing liquids, producing jams, and homogenizing powders. By integrating the functionalities of three separate machines (mixer, stirrer, and roaster) into a single compact unit, the system offers significant cost savings, operational flexibility, and energy efficiency. This research documents the system’s design framework, material selection, control system development, and construction process, highlighting its potential to enhance drying efficiency and support sustainable agricultural practices. The findings aim to provide MSMEs with a practical and scalable solution for small-scale production environments, paving the way for broader applications in the food processing industry.

II. Literature Review

The design and optimization of heating and mixing systems have been extensively studied across various industries, including agriculture, food processing, and pharmaceuticals. These studies provide valuable insights into the principles of efficient system design, energy optimization, and multi-functionality, which are integral to the development of the Automatic Heating and Mixing System.

Nipa Palm is a vital mangrove species found in tropical and subtropical coastal regions, particularly in Southeast Asia. In Myanmar, it is found in Tanintharyi, Rakhine and Ayeyarwaddy region. It grows not only naturally in seawater, but it also absorbs nutrients from the mud, so it has a natural sweetness, saltiness, bitter flavors and aroma, providing a sustainable source of income for local communities. Its leaves are traditionally used for thatching, basket weaving, and eco-friendly packaging. Moreover, this research explores potential value-added and sustainable production of dried Nipa Palm tea, offering new opportunities for sustainable economies can enhance local environmental conservation.

A comprehensive review of agitator design, emphasizing material selection and structural configurations, was conducted to achieve optimal performance. Their work highlights the need for cost-effective yet durable designs, a principle that aligns with the objectives of this study. The current design builds on these findings by selecting materials and components that ensure affordability, durability, and adaptability for MSMEs in the agricultural sector. Additionally, the mechanical forces, involved in mixer design particularly torque, bending, and thrust are crucial for maintaining consistent performance and longevity. This is particularly relevant to the present study, where the motor's power capacity and container size were optimized to handle varying loads while ensuring operational efficiency.

In the context of food processing, it is proposed a variable-speed stirrer impeller for homogenizing food, demonstrating the benefits of adjustable operational parameters in enhancing energy efficiency and process flexibility. This concept directly applies to the Automatic Heating and Mixing System, which incorporates adjustable speed and temperature controls to optimize energy consumption and accommodate diverse processing needs, such as drying, mixing, and homogenizing. Estimating the power is required to rotate agitator impellers that guided motor selection and scalability. These methods informed the design of the current system, ensuring that the motor’s power is sufficient for processing viscous or semi-solid materials. Additionally, scalability challenges were addressed by outlining the need for increased motor capacity and container size when handling larger quantities. The versatility of multi-functional systems considered for diverse industrial demands, which inspired the integration of drying, mixing, and homogenizing functionalities into a single compact unit. This innovation reduces costs and improves operational efficiency for MSMEs by consolidating the roles of three separate machines (mixer, stirrer, and roaster) into one system.

III. Methodology

The methodology for this research involved a systematic approach to designing, optimizing, and constructing the Automatic Heating and Mixing System. The development process began with an extensive literature review to identify key design parameters and energy-efficient strategies. A Computer-Aided Design (CAD) model was created to visualize the system layout, including the heating chamber, mixing blades, and control unit. Materials were carefully selected based on durability, heat resistance, and cost-effectiveness, ensuring an optimal balance between performance and affordability. The fabrication process incorporated precision engineering techniques to assemble the system, integrating a variable-speed motor, speed reducer, and temperature-controlled heating elements. Performance testing was conducted by processing various agricultural products, including Nipa Palm and dairy-based mixtures, to assess drying efficiency, mixing uniformity, and energy consumption. The data collected from these tests were analyzed to evaluate the system’s reliability, cost-effectiveness, and adaptability for MSMEs. The results were then compared with traditional drying and mixing methods to determine improvements in efficiency and operational cost reduction. Materials will be selected from the local market.

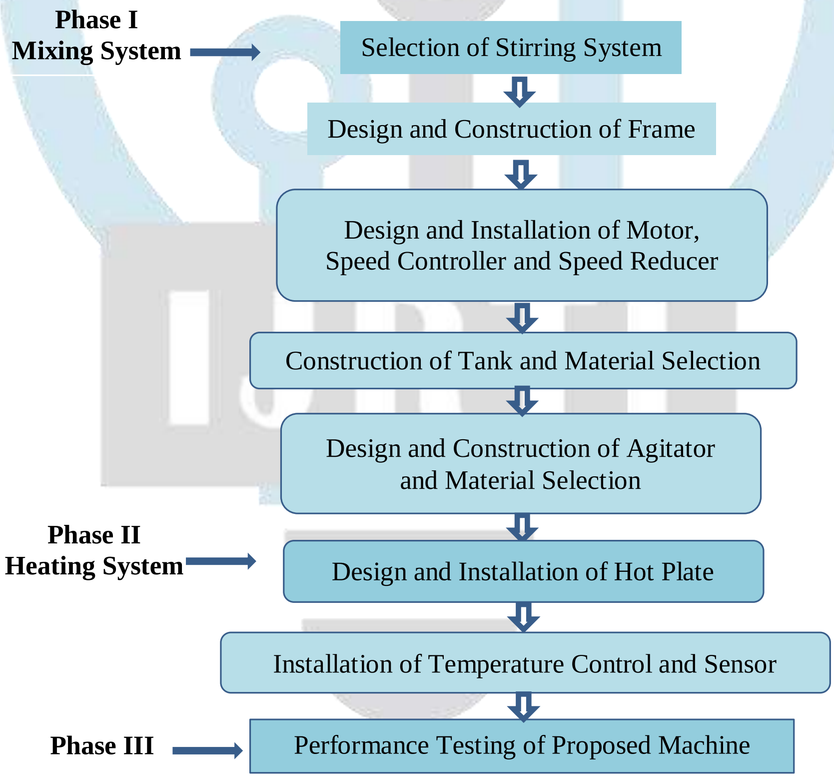

Figure1. Design and Construction Phase for Automatic Heating and Mixing System

IV. Design and Construction

The Automatic Heating and Mixing System is designed for efficient and adaptable processing of various agricultural products. A CAD model outlines the heating chamber, mixing blade, and control unit, ensuring optimal heat distribution and uniform mixing. The system's heating mechanism reaches up to 800°C without product degradation, while the mixing blades are angled for maximum movement. Variable-speed motors prevent clumping and ensure even moisture removal. Three types of stirring methods were considered (Overhead, Magnetic, and Hotplate Stirrers) with overhead stirrers chosen for their multifunctionality. The frame and mixing components are made from stainless steel (304) for durability and heat efficiency, with interchangeable pots for easy handling.

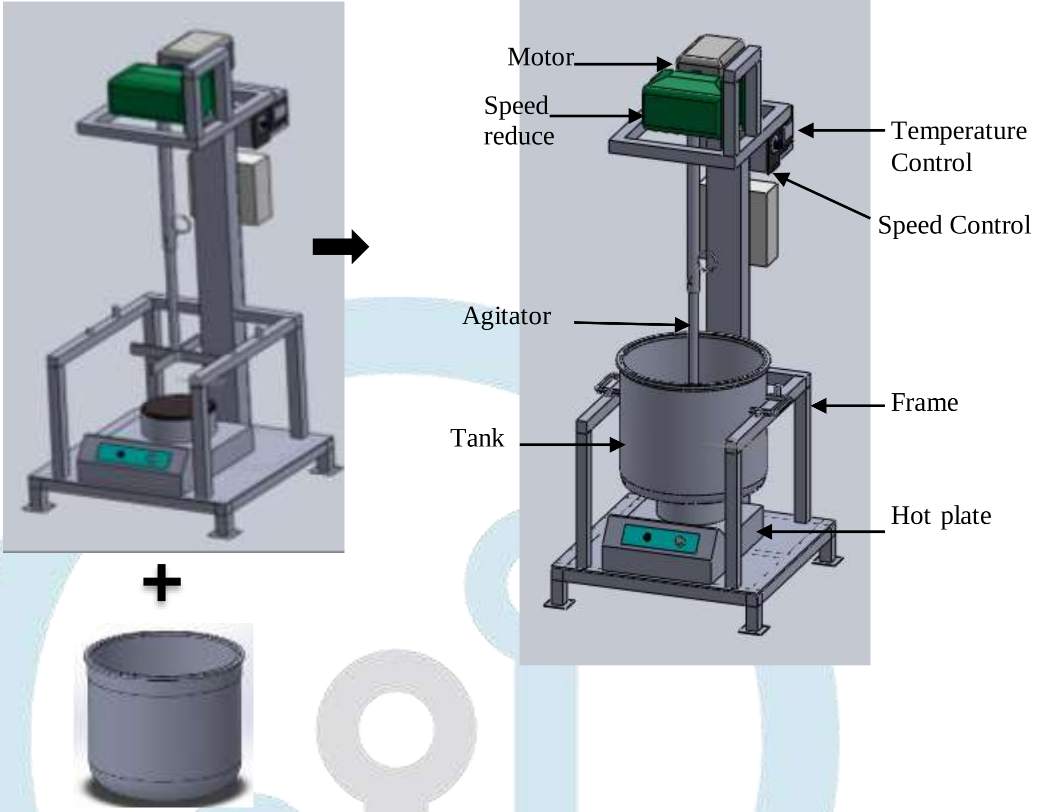

Figure 2. Assembly drawing of the Automatic Heating and Mixing System drawn in Solid Works

The system includes three interchangeable agitator blades are shown in Fig. 3, the Paddle Blade for high-viscosity liquids, the Turbine Blade for uniform material distribution, and the Anchor Blade for efficient heat transfer. These blades, made of stainless steel (304), ensure strength and ease of use. The motor, rated at 120W, 220V AC, operates at speeds from 90 to 1400 rpm, with a speed control feature for precise adjustments. A speed reducer with a 1:10 gear ratio maintains efficiency by adjusting the motor's rotational speed from 14 to 140 rpm. This setup ensures the system's longevity while optimizing the mixing process.

Figure 3. Three interchangeable agitator blades

The heating unit utilizes electrical resistance elements with temperature sensors to maintain uniform heat distribution. A removable temperature sensor, attached to the steel pot's side-bottom, connects to the temperature control system, regulating heat from 0°C to 1300°C with sensor sensitivity up to 800°C. The control interface provides real-time data on temperature and mixing speed, offering adjustable presets for different agricultural products. Designed for affordability and ease of use, this system is particularly suitable for MSMEs.

Table (1): Specifications of the Automatic Heating and Mixing System

Parameter	Value
Motor Power	120Watt 220V
Motor speed Control	14rpm ~ 140 rpm
Speed Reducer	1:10
Temperature Control	0 ~ 800˚C
Hot plate	1500Watt 220V
Capacity	15 Liters
Material	Stainless steel
Agitator	Paddle, Turbine, Anchor
Frame	15" x 15" x36"

V. Performance Testing of the Automatic Heating and Mixing System

The system was tested under various conditions to assess its performance. The motor speed was adjusted using a speed controller, and the temperature was monitored with a sensor. The testing included roasting Nipa Palm and heating cow's milk to achieve a solidified state.

Table (2): Measured Data of the Automatic Heating and Mixing System

Ingredient	Temperature (°C)	Motor Speed (rpm)	Starting Humidity (%)	Operation Time (min)
Nipa Palm	69	28	22.7	10
	75	28	35	20
	100	28	35	16
Milk (Creamy)	80	72	100	60
	100	72	100	32

Figure (3): Images obtained during the performance testing of the machine.

During the testing process, the motor speed was adjusted using a speed controller to operate at various speeds. Additionally, the heat from the hot plate was monitored using a temperature sensor installed in the steel tank, and the temperature was controlled via a temperature controller with predefined settings. This innovation is designed not only for roasting Nipa Palm but also for other multi-functional purposes, such as mixing liquids, producing jams, blending thick juices, and homogenizing powder mixtures (e.g., powders like detergent). Therefore, after the practical construction of the system, the performance of the equipment was evaluated according to the following procedures:

(a) Testing the performance by roasting dried Nipa Palm

(b) Testing the performance of the Automatic Heating and Mixing System by heating cow's milk to achieve a solidified state.

During the roasting of dried Nipa Palms, different temperatures were applied, and for each temperature, the motor speed was varied. The time taken to achieve the desired condition of the dried Nipa Palm was measured. The measured motor speeds and corresponding time durations are presented in the table below.

Milk was mixed with sugar and heated while stirring continuously until it thickened, and the time taken was recorded. Afterward, when the mixture reached a near-solidifying state, rice flour was added, and the stirring continued to achieve the desired milk solidification.

VI. Results and Discussion

The Automatic Heating and Mixing System was designed primarily for drying Nipa Palm but has proven to be versatile, capable of handling other functions such as mixing liquids, producing jams, and homogenizing powders. The total cost of the newly developed system is nearly 50% lower than the combined cost of three separate machines (mixer, stirrer, and roaster) available on the market. The system has successfully reduced labor costs and operational time while improving overall efficiency. The motor's power is sufficient for processing up to 0.5 kg of Nipa Palm and 15 liters of viscous liquids or semi-solid raw materials. However, for larger quantities, the container size must be increased, requiring a more powerful motor. The system's energy-efficient design ensures lower power consumption, as the hot plate does not require continuous power during operation. The adjustable speed and temperature settings further optimize energy usage.

The compact design of automatic heating and mixing system can be achieved for easy integration into small-scale and large-scale production environments without compromising space. With low power consumption and an adjustable heating system, the mixer is not only energy-efficient but also provides precise temperature control for maintaining product quality. The variable speed control can be maintained for mixing processes to achieve desired consistency. Moreover, the operation will be cost-effective and labor cost can significantly reduce production expenses while improving productivity. The cost of proposed mixer is cheaper than the total cost of mixer, stirrer, roaster with single used machine from the market.

VII. Conclusion

This system was successfully designed and fabricated a cost-effective, multi-functional Automatic Heating and Mixing System to address the challenges by MSMEs in agricultural processing. By integrating as a single compact unit, the system reduces costs by 50% compared to conventional methods with enhancing operational efficiency and energy savings. The use of adjustable speed (14–140 rpm) and temperature controls (up to 800°C) optimized performance for diverse tasks, including Nipa Palm drying and viscous material processing, with a capacity of 0.5 kg of Nipa Palm or 15 liters of semi-solid substrates. This system was designed and constructed with stainless steel to ensure adaptability by adjustments of motor and containers. It can support sustainable agricultural industries by small-scale production with reducing labor costs, and promoting mangrove conservation through value-added Nipa Palm utilization. Although the current design meets MSME needs, next step will explore scalability for industrial applications and integration with renewable energy sources. This innovation shows significantly it's potential to transform resource-limited agricultural economies by balancing affordability, efficiency, and environmental conservation.

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