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Revolutionizing Tomato Jam Production: Automation and Efficiency Optimization

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Tomato and Vegetable Production Consortium. Milly [locally known as Kamatis] is a significant fruit and vegetable crop grown in Roxas, Isabela, Philippines. Despite its profitability, tomato production in Roxas faces substantial challenges, particularly in the post-harvest stage. These include oversupply, inconsistent product quality, and contamination risks. Consequently, this study addressed these challenges by designing an Automated Jam Making Machine (AJMM).* The research involved 25 employees of Roxas LTI as representatives of tomato processing stakeholders. A survey using questionnaires and interviews was conducted to assess the functionality and usability of the machines. The Likert scale, ranging from 1 (Strongly Disagree) to 5 (Strongly Agree), was used to measure the respondents' level of satisfaction with the machines' functionality and usability. *The findings revealed that the developed devices successfully automated some tomato jam production processes. This system comprises five key machines: the washing machine, seed separator, cooking machine, sieving machine, and filling machine. The washing machine ensures the tomatoes are cleaned before further processing. The seed separator separates the seeds from the pulp, while the sieving machine filters the puree to ensure consistency. The cooking machine then cooks the tomato puree to become jam, and the filling machine fills the jars with the finished product. The high satisfaction with the automated system suggests that the devices effectively restructure operations and usability, enhance the user experience, and are suitable for tomato jam processing.

Keywords: Microcontroller , Sensors , Automation ,washing, pureeing , pilling , filling.

1. Introduction

Tomato (Lycopersicon esculentum, Miller), locally known as "kamatis,"is a versatile and economically significant crop in the Philippines, especially for off-season production (Department of Agriculture, 2018). From April to June 2023, tomato production reached 70.33 thousand metric tons, with the Ilocos Region being the top producer (Philippine Statistics Authority, 2024). However,oversupply and significant post-harvest losses pose economic challenges for farmers. For example, Cordillera farmers have had to discard large quantities of tomatoes due to limited storage and low demand, leading to substantial financial losses (Cariaso, 2023; SEARCA, 2022).To address these issues, the Roxas West Ladies Tomatoes Industry (RoxWeLTI) was established in Roxas City, Isabela. RoxWeLTI produces various

tomato-based products, including tomato jam. Currently, their production process is entirely manual, involving labor-intensive steps such as washing, cutting, removing seeds, blending, cooking, filling, labeling, capping, and packaging. This manual method is time-consuming, inconsistent, labor-intensive, and prone to safety and contamination risks. To streamline production and improve efficiency. This research aims to develop an automated process for tomato jam production to reduce labor, enhance consistency, and ensure safety.

Statement of Objectives

Develop a series of automated machines for processing tomato jam. Specifically, the project aims to create devices for each of the following processes: washing, pureeing, seed removal, cooking, and filling. Additionally, the project seeks to evaluate users' perspectives on the "JAMATO" automated machines in terms of functionality and usability.

Scope and Limitation

The JAMATO machine processes tomatoes into jam through several automated steps: washing with a roller and water spray system, pureeing, seed separation, and cooking with a nichrome wire heating element. The cooking involves 30 minutes of high heat with stirring, followed by 15 minutes of reduced heat after adding ingredients. After cooking, an ultrasonic sensor and motor system fill jars with the jam, controlled by a valve and weight sensor. Limitations include no ripeness classification, automatic cooking monitoring, or integrated jar sterilization, capping, labeling, and packaging. It also requires a stable power source for operation.

Significance of the Study

This study aims to automate and optimize small-scale tomato jam production to reduce labor intensity and improve product quality. The primary beneficiaries include:

1. RoxWeLTI Association: Enhances efficiency and reduces workload for its 34 members.
2. Small-Scale Enterprises: Enables scaling operations and competitiveness.
3. Employees: Reduces physical demands through automation.
4. Consumers: Ensures consistent high-quality jam products.
5. Local Community: Promotes economic growth and job creation.
6. Investors and Entrepreneurs: Offers investment and business opportunities in food processing.
7. Educational Institutions: Provides a case study for academic courses.
8. Future Researchers: Contributes to advancements in food processing and technology.

2. Review of Related Literature

Tomato Supply and Prices

Tomato cultivation is economically important in the Philippines, with significant production in the Ilocos Region, Central Luzon, and Cagayan Valley. In 2023, production was 70.33 thousand metric tons, though prices have fluctuated significantly, highlighting market instability.

Tomato Post-harvest Losses

Significant post-harvest losses affect the tomato value chain. For example, Nueva Ecija and Bukidnon experience losses up to 24.14% due to transport durations, resulting in substantial financial losses. Farmers often face oversupply and low prices, leading to wasteful practices.

Machine Automation

Technological advancements are crucial in automating various processes in tomato jam production:

- Washing: Efficient washing machines are essential for removing soil and contaminants from produce.
- Pureeing: High-power blenders can rapidly process tomatoes, increasing efficiency.
- Seed Separation: Advanced seed separators improve seed quality and reduce waste.
- Cooking: Automated cooking systems use technologies like laser cooking and 3D food printing for precision and efficiency.
- Filling: Automated filling machines enhance precision and efficiency, reducing labor and improving product quality.

These technologies collectively aim to reduce labor intensity, improve product quality, and enhance the overall efficiency of tomato jam production processes.

3. METHODOLOGY

The research process is described in this chapter. It includes information about the method used in conducting this research as well as a justification for using the method. This Chapter also describes the various stages of the research, such as the locale of the study, the respondents of the study, the project flow chart, the block diagram, and the sketch.

Locale of the Study

The study was conducted in Barangay Marcos, Roxas City, Isabela, Philippines.

Respondents of the Study

The study involved 25 randomly selected employees of RoxWeLTI in Roxas, Isabela. They participated in machine testing and answered questionnaires to evaluate the general satisfaction, functionality, and usability of the JAMATO machines.

Design Procedure

This section explained the three phases in the development of the design project namely, the conceptualization, design and implementation, and testing. This section also includes the discussion of the block diagrams and flowcharts of the different machines.

Data Gathering Procedure

The data-gathering procedure utilized in this project involves the administration of a questionnaire. The purpose of this questionnaire is to assess the perceptions of the respondents regarding the functionality, and usability of the machine. The questionnaire consists of 14 questions, divided equally between functionality and usability assessment, with 7 questions dedicated to each aspect.

Data Analysis and Statistical Tools

The data collected was computed using a weighted average. The weighted average was calculated based on the questionnaire responses from the respondents and interpreted using the Likert Scale

Conceptualization of the Design Project

Figure 1 shows the system flow chart. the tomato washing machine, tomato pureeing, and seed separation will start its operation when triggered. After separating the seeds, the juice and pulp of the pureed tomatoes will enter the cooking machine. Upon completion of the cooking process, the mixture will be transferred to the filling machine to conclude the process.

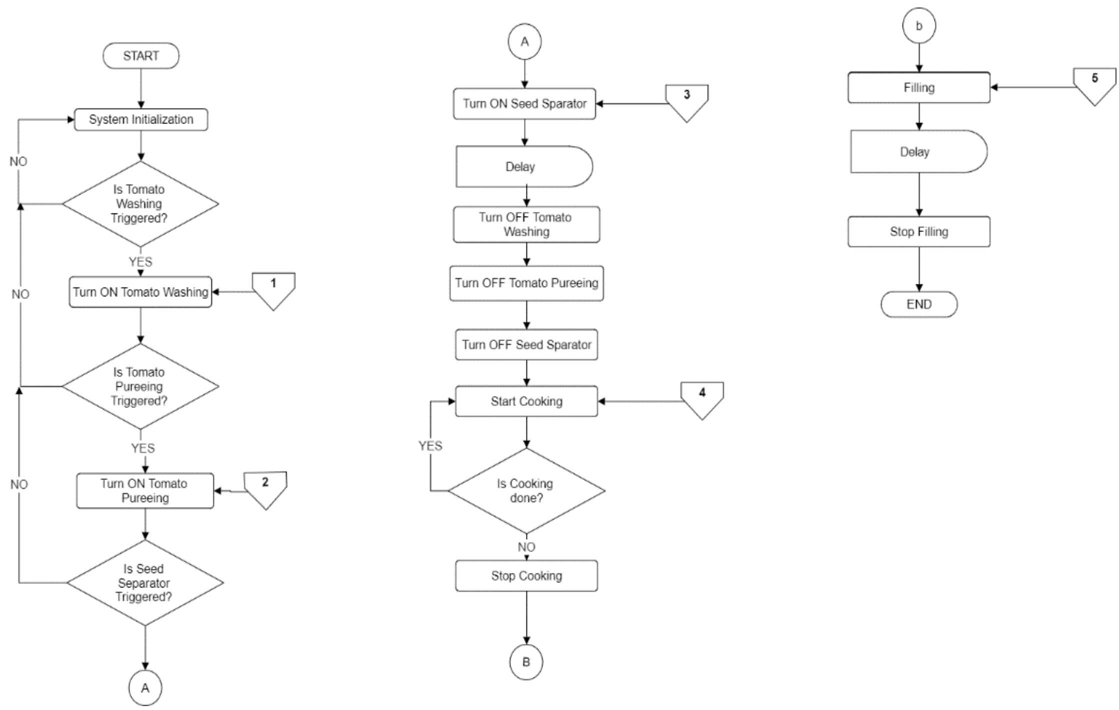

Figure 1. Flowchart of the Tomato Jam Machines

The design process for the tomato washing machine includes two block diagrams shown in Figures 2 and 3. Both utilize an Arduino Uno microcontroller powered by a 5V source.

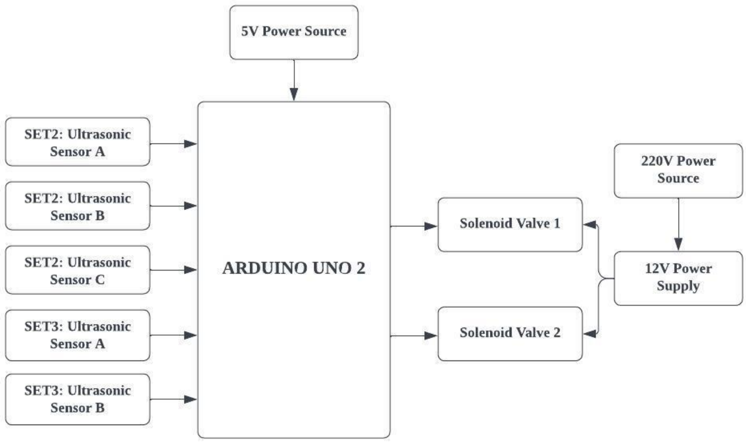

Figure 2. Block Diagram Tomato Washing Machine

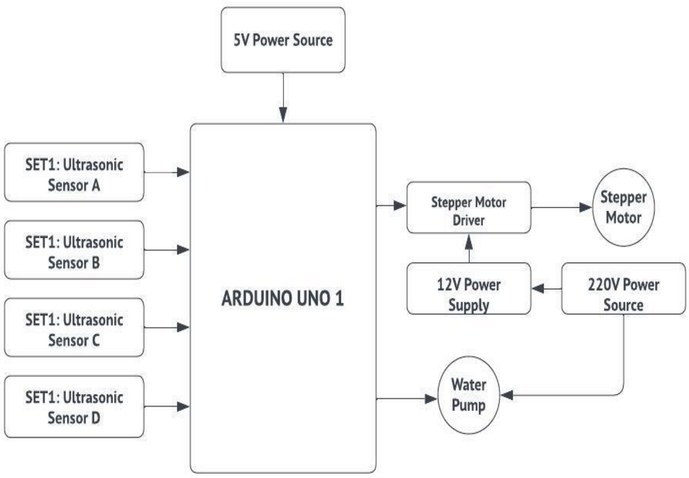

Figure 3. Block Diagram of Arduino 2 of Tomato Washing Machine

- Figure 1: The inputs consist of four ultrasonic sensors (set 1). Outputs include a stepper motor, driven by a micro-step driver powered by a 12V supply, and a water pump, both connected to a 220V power source.

- Figure 2: The inputs include five ultrasonic sensors (three from set 2 and two from set 3). The outputs are two solenoid valves (Solenoid Valve 1 and Solenoid Valve 2), each powered by a 12V supply from a 220V source.

The flowchart for the washing machine begins with system initialization. Once initialized, four ultrasonic sensors in set 1 check for the presence of an object. If an object is detected, the water pump activates, and the motor moves forward and backward for a set duration. If no object is detected, the system remains in the initialization state. Subsequently, three ultrasonic sensors in set 2 check for objects; if detected, Solenoid Valve 1 activates after a delay. Finally, if any of the sensors in set 3 detect an object, both Solenoid Valves 1 and 2 activate for a specified period, completing the washing process.

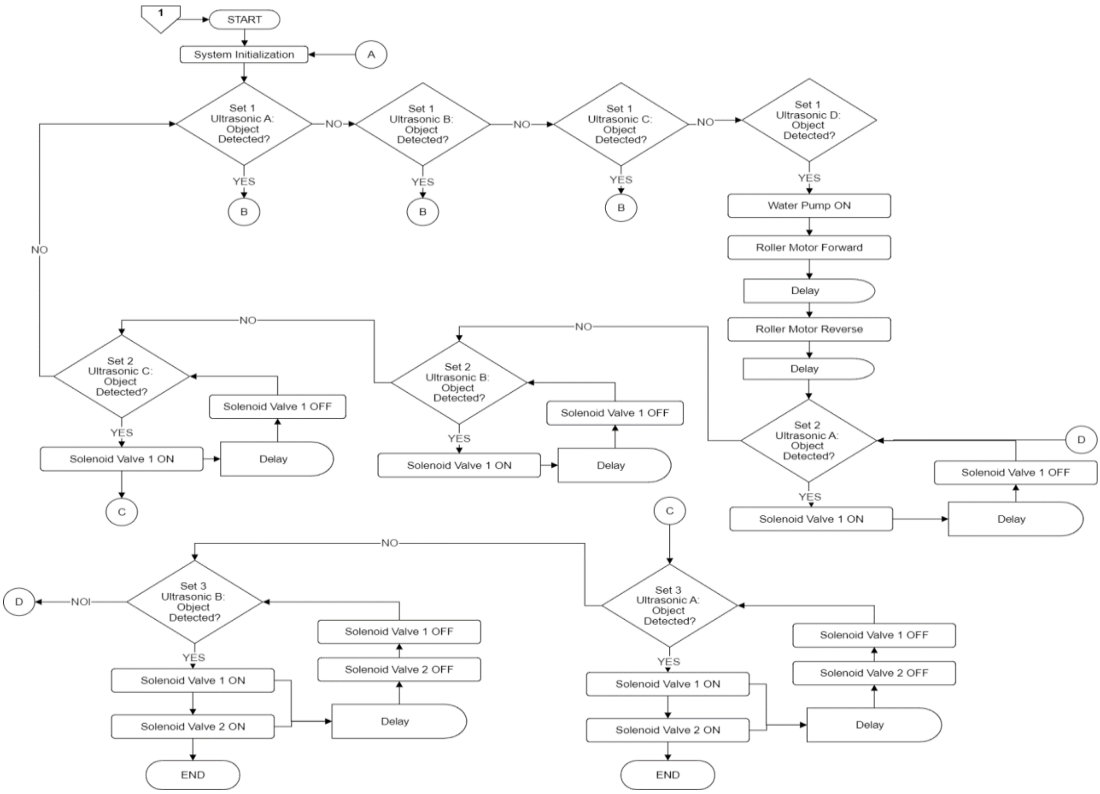

Figure 4. Flowchart of Tomato Washing Machine

Designing the Project

The project began with the conceptualization of the JAMATO machine process, leading to the creation of a flowchart outlining the entire workflow. Following this, the researchers developed block diagrams and flowcharts for each of the five machines: washing, pureeing, seed separation, filling, and cooking. These block diagrams served as the foundation for designing the circuit diagrams for each machine. The researchers then acquired the necessary electronic components and modules that were best suited for the system's requirements.

4. RESULTS AND DISCUSSION

Project Design

In this part of the project, researchers created a wiring connection between each device and its control panel. The circuit diagram includes the microcontroller and the specific components used in different machines.

Firstly, as shown in Figure 5, the circuit diagram of the tomato washing machine operates using 220V, 24V, and 12V power sources. A TB6600 driver is used to control the stepper motor. The circuit is composed of two Arduino Uno boards equipped with nine ultrasonic sensors, four for the first Arduino Uno and five for the second Arduino Uno. Additionally, it includes two push buttons (red and green), two 220V LEDs (red and green), and three relays for the water pump and two solenoid valves.

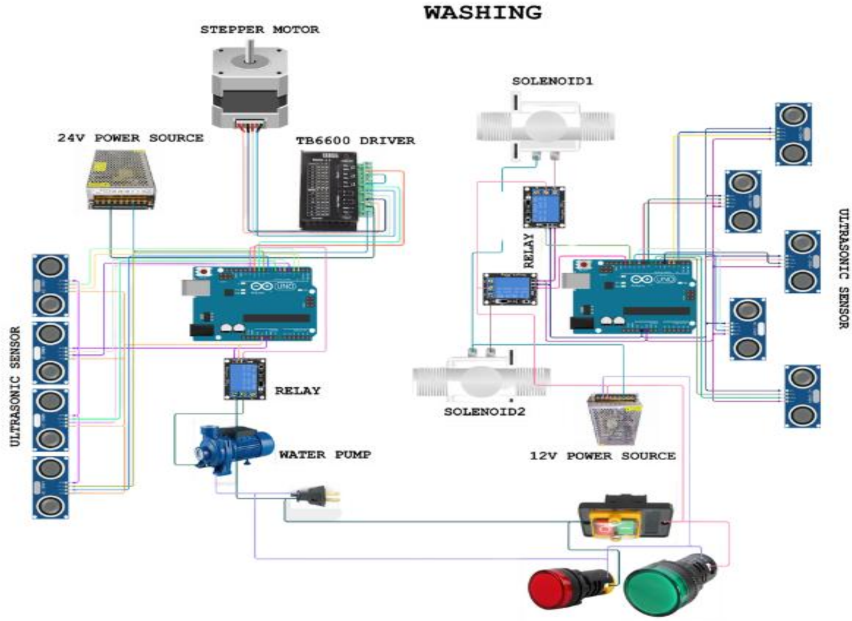

Figure 5. Tomato Washing Machine Circuit Diagram

Figure 5 illustrates the Circuit diagram of the Filling Machine. The system is powered by 220V and 12V power sources. The stepper motor is controlled through the use of the TB6600 driver. The circuit also includes two relays for the solenoid, the 12V LED, two push buttons and buzzer, and a weight sensor driven by the HX711 driver. Moreover, two more push buttons are included, and two 220V LEDs. The system is controlled by Arduino Uno microcontroller.

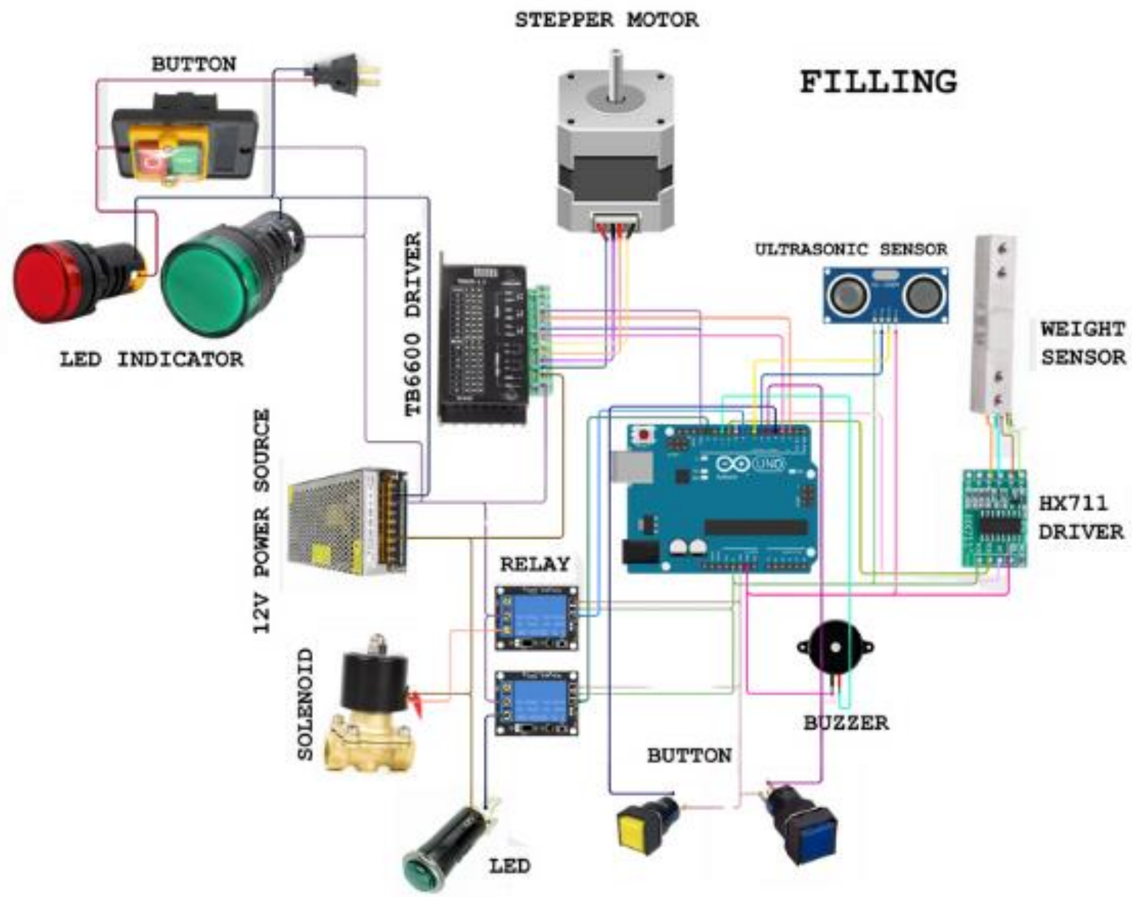

Figure 6

Project Development

This part includes project development from hardware development, software development to device development.

A. Hardware Development

Figure 7 depicts the main components of tomato washing. In Figure 7 (a), the highlighted main components include two solenoid valves and three sets of ultrasonic sensors. Set 1 comprises four ultrasonic sensors, set 2 consists of three sensors, and set 3 contains two sensors. Meanwhile, Figure 7(b) highlights the water pump and stepper motor.

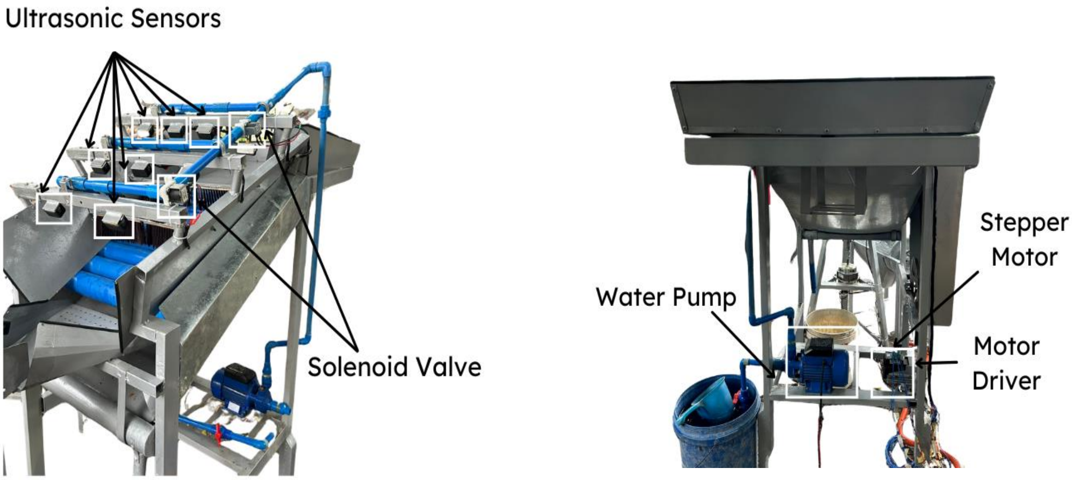

Figure 7 Main Components of Tomato Washing Machine

Figure 8 shows the main components of the tomato pureeing. The main components are the AC motor, actuator, and ultrasonic sensor.

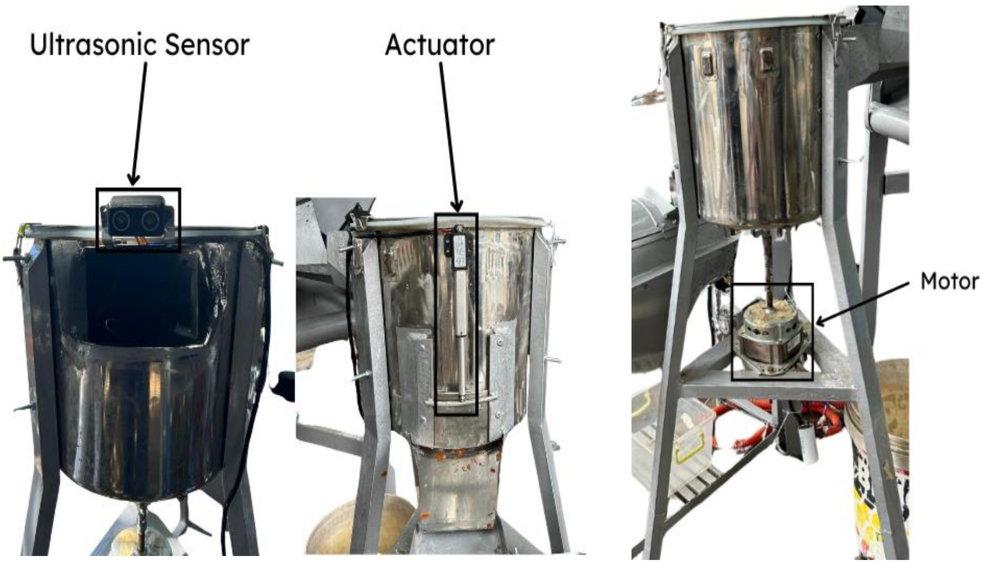

Figure 8 Main Components of Tomato Pureeing

Figure 9 shows the two main components of the cooking machine, namely the stepper motor and its microstep driver.

Figure 9 Main Components of Cooking Machine

Figure 10 shows the components of the filling machine. These are the stepper motor and its microstep driver, solenoid valve, weight sensor, ultrasonic sensor, push button, and LED.

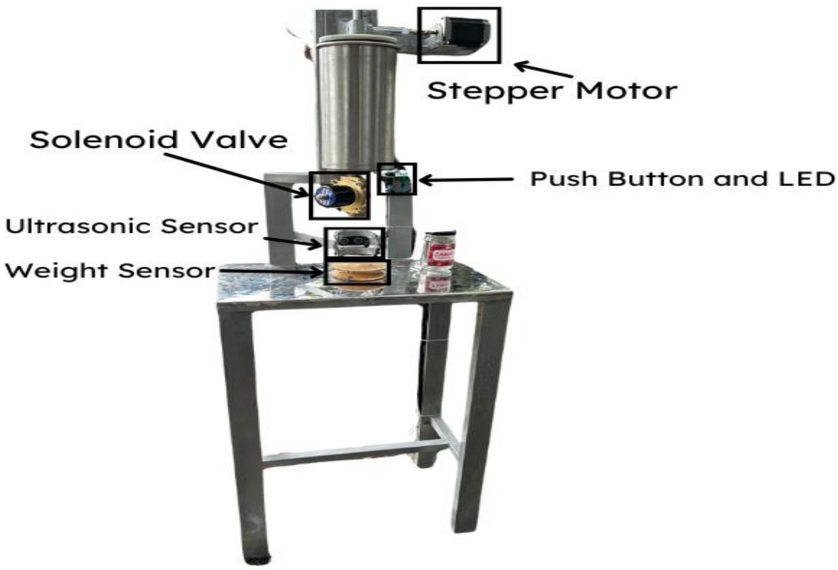

Figure 10 Main Components of Filling Machine

The control panel of the whole system is shown in Figure 10. components that can be viewed outside are push buttons, LEDs, and a breaker. The components in the inner set-up of the control panel are power supplies, one 2-gang outlet, three single-gang outlets, Arduino UNOs, relays, and a breaker.

B. Device Development

The measurements of each device where shown in Figures 11 to 15.

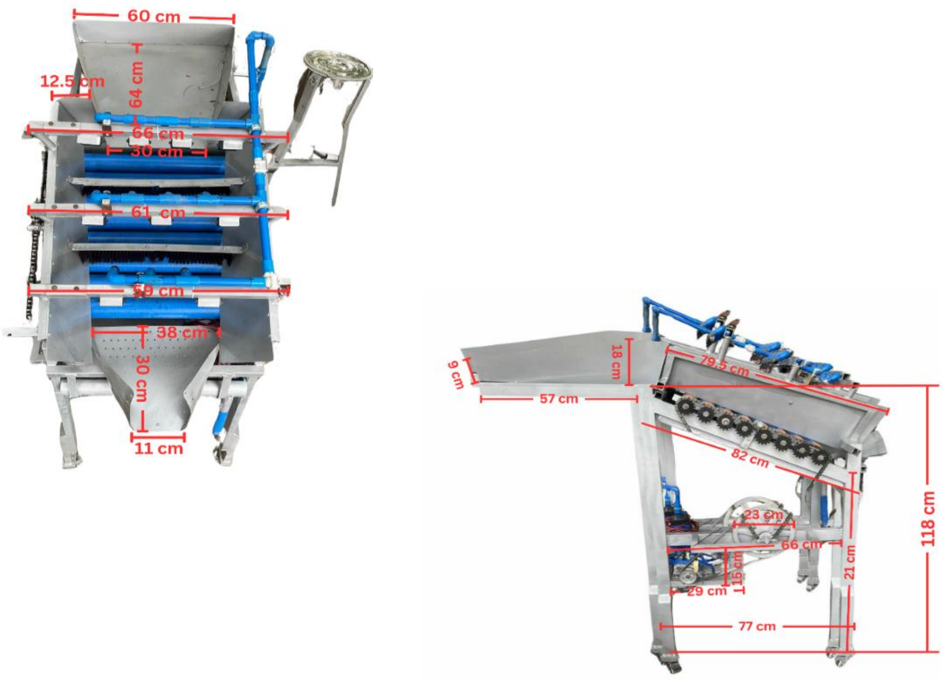

Figure 5. Tomato Washing Machine

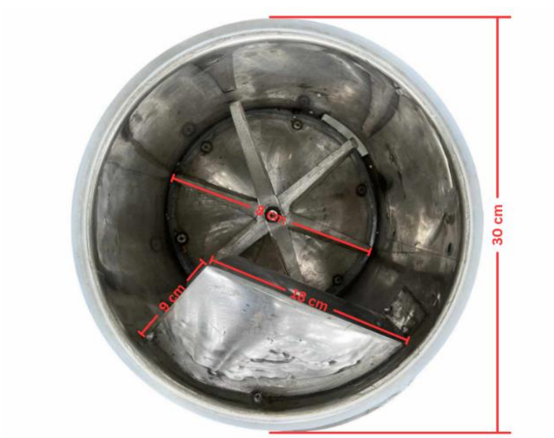

Figure 12. Tomato Pureeing Machine

Figure 13. Seed Separator Measurements

Figure14. Cooking Machine Measurements

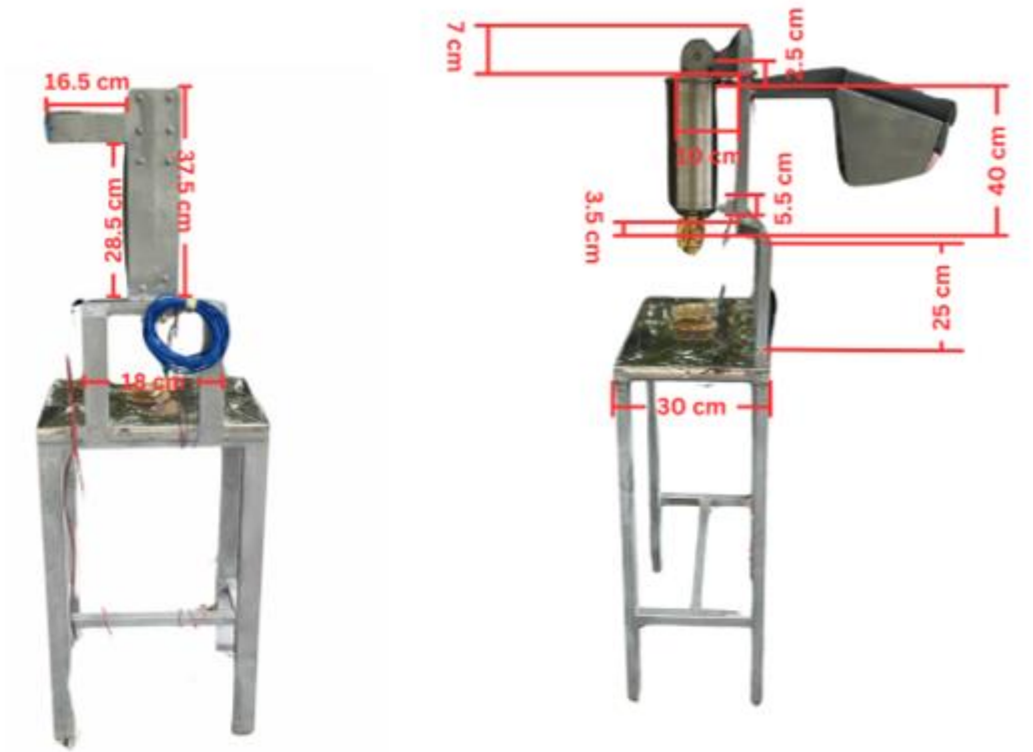

Figure 15. Filling Machine Measurements

As indicated in Table 1, the mean of the respondents' responses for each statement falls within the "strongly agree" range from the Likert Scale, indicating that the respondents strongly agree that each machine's functionality has been achieved. The categorical mean of the respondents' assessment of the device's functionality is 4.52, showing that overall, the machines' functionality requirements have been achieved.

Table 1. Assessment of the Respondents on the Functionality of the Device

The device has the ability to wash the tomatoes.	4.76
Functionality	Mean
The device has the ability to puree the tomatoes.	4.72
The device has the ability to separate seeds and pulp of the tomatoes.	4.2
The device has the ability to properly cook the tomatoes and become a tomato jam.	4.48
The device has the ability to fill the tomato jam in a jar with a precise amount.	4.6
The device sensors are set to relevant sensitivity levels.	4.56
The device operates smoothly without frequent breakdowns.	4.32
Categorical Mean	4.52

Meanwhile, the results regarding the machines' usability, as evidenced by Table 1, show that the respondents strongly agree that the machines are usable for operation. The categorical mean of the respondents' assessment of the device's usability is 4.58, which falls within the "strongly agree" range on the Likert Scale shown in Table 1.

Table 2. Assessment of the Respondents on the Usability of the Device.

Usability	Mean
The machine’s features and menu are simple to use.	4.56
The device is safe and easy to operate.	4.6
The given directions are straightforward to follow and comprehend.	4.64
Buttons or controls are easy to find.	4.8
The machine provides clear feedback during operation.	4.4
The machine's overall design enhances the user experience.	4.48
The machine's operation requires minimal supervision or intervention.	4.6
Categorical Mean	4.5829

5. CONCLUSIONS AND RECOMMENDATIONS

This chapter summarizes the results and findings of the study Jam Automated Manufacturing and Tomato Optimization.

Conclusions

The researchers draw the following conclusion based on the result of the study:

1. The research has successfully resulted in the development of a comprehensive device capable of automating the processes of washing, pureeing, seed separator, cooking, and filling in the production of tomato jam.

2. Feedback from respondents regarding the device's functionality and usability indicates that it effectively meets their requirements, suggesting high levels of satisfaction among users. This positive response underscores the device's efficacy in streamlining operations and enhancing user experience.

Recommendations

Based on the results and inputs from end users, the following recommendations are proposed:

1. Aim to optimize operations for unmanned use wherever feasible, potentially integrating automated transferring control systems to reduce labor requirements and increase productivity.

2. Implement a selection and display feature in the filling machine, allowing users to customize the type of jar to be used and monitor the filling process.

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