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Smart Cacao Processing A Microcontroller-Based System for Automated Fermentation, Drying, and Roasting

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ABSTRACT

. “Cacao” and “Cocoa” are both derived from the word “Theobroma cacao”, the taxonomic classification for the cacao tree. There are many terms used to name this plant. Some say "cacao" applies to the farm/origin level (pods, seeds, trees), and "cocoa" is accurate once the bean is fermented and dried or roasted. (Retrieved from: https://www.lakechamplainchocolates.com/, 2022). Cocoa bean is a commodity largely produced in different countries and mostly consumed worldwide in several forms. During the last few decades, rapid detection of cocoa beans and cocoa bean products quality has gained center stage with many kinds of research conducted.(Teye, et.al, 2020)

1. INTRODUCTION

Philippines is well placed as future supplier of cocoa beans for local, regional and international trade markets. Researchable areas for Cacao included: integrated pest management, package of technologies, good agricultural practices, identification of location, specific clones and drying and other post-harvest technologies. (Nabua, 2013). However, with the production volumes progressing since 2006, the government undertook policy measures to secure the industry’s progress through R.A. 7900 or the High Value Crop Development Program Act, which lists the intensification of cocoa production as one of its priorities.

In view of the increasing global demand for cacao beans, the production of cacao, as a commercial production activity, is among the preferred activities listed in the Philippines’ 2014-2016 Investment Priorities Plan. (Retrieved from: www.industry.gov.ph., 2022) The Philippines has already penetrated the Japanese and US markets. In April 2020, the Philippines shipped for the first-time some 20,000 kilograms of Mindanao-sourced premium cacao beans to Belgium, supplied by Mindanao Davao-based premium chocolate brand Auro Chocolate.

Madarang (2019) conducted a study to design and develop a mechanical dryer for small-scale cacao processing with the goal of increasing the income of cacao growers. It is therefore imperative that the drying operation be given utmost importance during cacao processing since it also affects the quality of cacao beans. The method was employed in the context of designing and developing a solar-powered cacao mechanical dryer for small-scale processing. Burguillos, (2017) developed a solar dryer adopting the structural arrangement of

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a direct-type and the heating mode of an indirect-type was constructed and tested for drying fermented cacao beans. The dryer consists of an integrated drying chamber and solar collector, DC fans in series to enhance moisture removal, air holes for airflow, and bicycle wheels for mobility.

Bimont, (2017) study shows that beans exposed to the sun did not ferment properly. However, beans exposed to the shade were better fermented than the others. No significant difference was observed between the two varieties used and the natural inoculation of the beans by *D. Melanogaster* in the shade improves the quality of the fermentation.

Angelia (2000), mentioned on his study (*Philippines National Standard in Cacao Beans Specifications*, PNS) that in cacao beans classification aspects, quality of beans can be classified after fermentation and drying procedure. Fermentation is necessary in order to reach the right acidity of the beans which usually takes 6-7 days then the drying procedure to lower the moisture content of the beans for about 2-3 days. Well fermented beans are relatively brown in color and have well developed cracks due to the drying of the developed cotyledon before it is roasted. Under-fermented beans, however are purple in color.

Last 2016, the Department of Agriculture (DA) conducted cacao planting in Eastern Visayas and is expected to raise the production of dried cacao beans to 5,000 metric tons (MT) in 2022. The intensive cacao planting promotion is in support to the 100,000 MT nationwide output goal, in an attempt to address the one million MT global cacao beans production shortfall (Tempo, 2016).

This paper aims to develop a microcontroller based device for rapid fermentation, drying and roasting of small scaled cacao bean. The proposed development of the device will focus on adapting and improvement of existing cacao bean drying and fermenting technique.

Objectives:

This study specifically aims to:

1. Design and develop an auto mixing device that has a temperature and humidity controlling mechanism during cocoa production using Arduino microcontroller

2. Develop a device that monitors the number of cocoa production days.

3. Conduct an evaluation of the developed device using the System Usability Scale.

2. METHOD

I. METHODOLOGY

This study employed Research and Development method. This focused in developing a device that automates the processes in fermenting, drying and roasting cacao bean. This considered the information related to the development of the study including the existing reviews in drying, designing, constructing, testing and evaluating. After the development, the device was evaluated using *ISO 9126 evaluation tool.*

Schematic Diagram

Schematic diagrams are visual representations of the different parts of a system. It provide the actual layout of the parts, exact locations and how everything works. Instead of using realistic images, symbols are used to show the different parts and their connections. (Retrieved from: https://nameplatesdiv.com/, 2022). Before the actual development of the device, the researchers created a schematic diagram for the connections of different modules installed in the microcontroller. Fig 1 shows the

schematic diagram of the device. A design shown in Fig 2 was provided by the researchers. As shown in fig2, different materials are connected to the device, each material has different uses in controlling the temperature, the number of fermenting hours and the auto mixing mechanism.

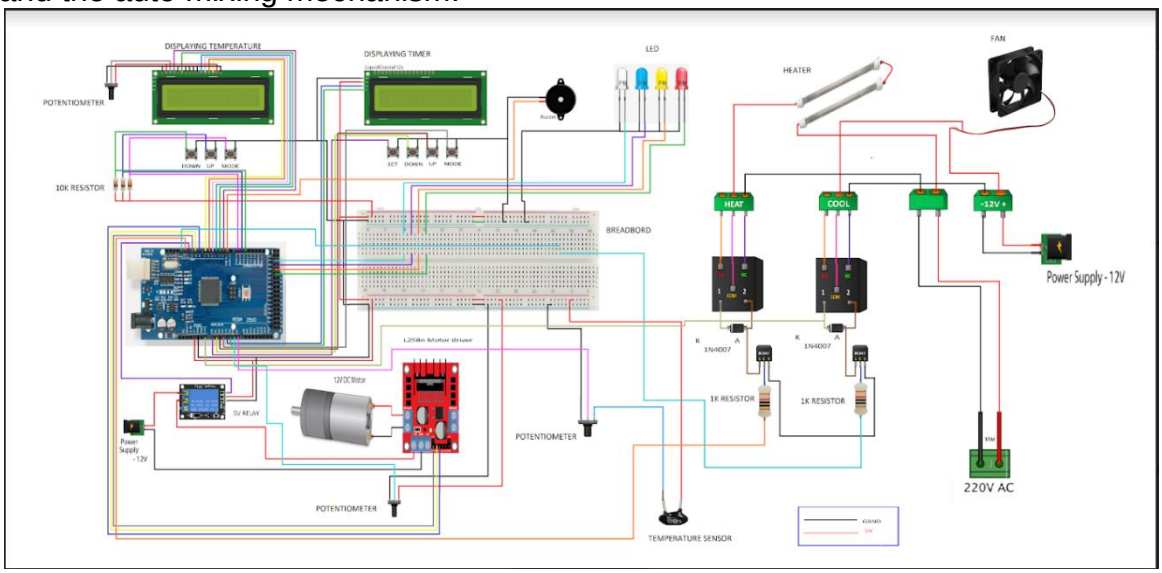

Fig. 1 Schematic Diagram

Following are the modules used in the development of the device:

NTC 10K Thermistor Sensor. The Thermistor is a solid-state temperature sensing device which acts a bit like an electrical resistor but is temperature sensitive. The Thermistor measures the temperature. Toaster oven quartz heating element is a device for supplying heat.

LCD Display. It shows the value of temperature and the temperature limit as well as the status of the fan, if it is cooling, normal, or heating.

LCD Display. For timer the value of the time limit is shown.

3x buttons. To choose the maximum temperature.

4x buttons. To set the time limit. Buzzer when the timer is over, the buzzer will automatically go on, signaling that fermentation is over.

LED. to show the value of time or days of fermentation. It takes 24 hours per LED.

Fan 12v. When the temperature is greater than the temperature limit. The microcontroller continuously reads the temperature from its surroundings. The fan will run automatically to cool down to the set temperature, and then it will shut off automatically. When the temperature rises above the set temperature, the fan will turn itself back on automatically.

Arduino Mega2560. Reads the input codes of relay, sensor and LED, it's also control relays, motor as an output.

Breadboard. Helps to connect the pins and circuit, and it also used to hold electronic components that wired together.

5v relay. It is an automatic switch that is commonly used in an automatic control circuit and to control a high-current using a low-current signal. This 5v relay is used to control the motor 12v relay Use it to control the heater and the fan.

Potentiometers. Controls the speed of the 12v motor, the temperature limit, and the contrast of the (1) LCD display L298N motor driver Motor drivers act as an interface between the motors and the control circuits. The motor requires a high amount of current, whereas the controller circuit works on low current signals. So the function of motor drivers is to take a low-current control signal and then turn it into a higher-current signal that can drive a motor.

10K resistors. Are frequently used in breadboards and perf boards and work well as pull-up, pull-down, and current limiters.

1K resistors. It is part of a voltage divider. This allows the threshold voltage to be set to the desired value. BC547 is usually used for current amplifier, quick switching and pulse-width modulation (PWM). This device controlling the temperature limit as well.

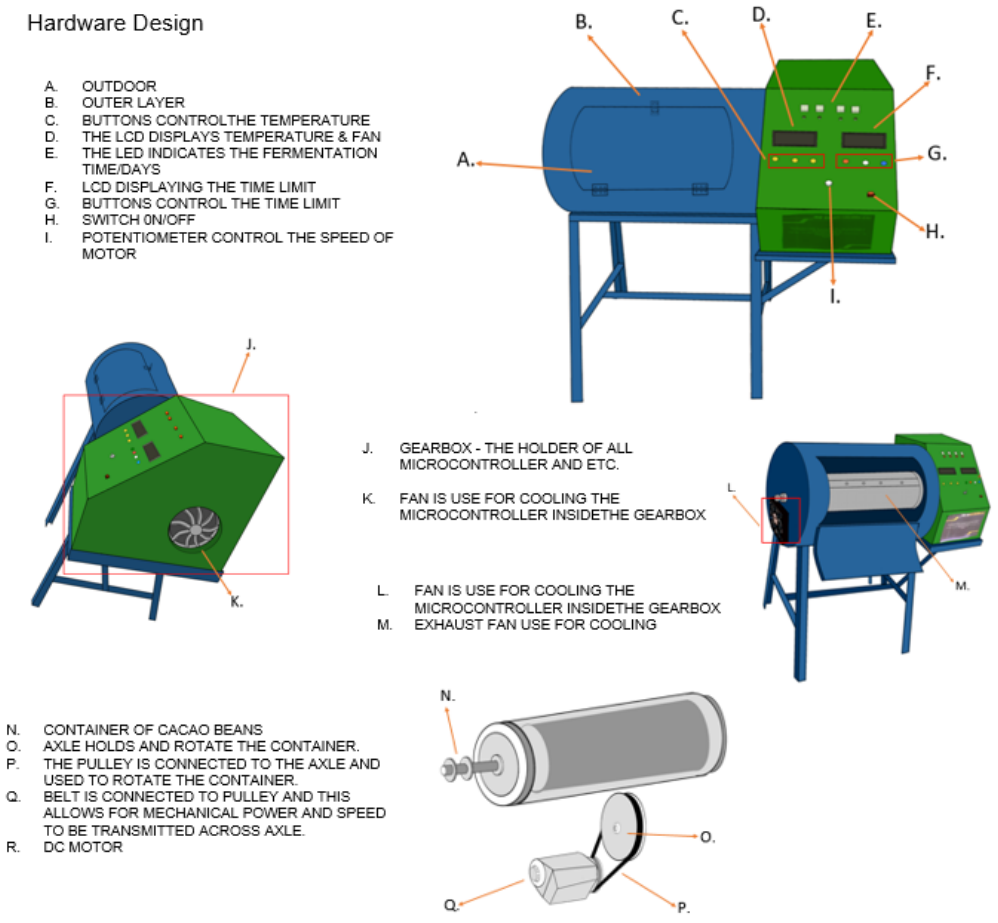

Fig. 2 Device Design

Evaluators, Evaluation and Data Analysis

This study will utilize the **Research and Development (R&D) method**, focusing on the creation of a device that automates the **fermentation, drying, and roasting** processes for cacao beans. The study will consider relevant information related to system development, including existing literature on **drying techniques, device design, construction, testing, and evaluation**. Once the device is developed, it will be assessed using the **System Usability Scale (SUS)** to measure its usability, efficiency, and user satisfaction.

Evaluators

The evaluators for this study will be the **twenty (20) members** of the **Godofredo Cacao Fermenting Organization** in **Brgy. Calico-an, Borongan City, Eastern Samar.** This group consists of **one (1) founder** and **nineteen (19) project-in-charge members**, who are directly involved in cacao processing. They will assess the system's usability, efficiency, and effectiveness based on their expertise and experience in cacao fermentation, drying, and roasting.

Research Instruments

Scoring

The System Usability Scale is a Likert scale consisting of 10 questions that device users will respond to. Research Respondents rate each statement on a scale of 1 to 5, where 5 indicates strong agreement with the statement and 1 signifies strong disagreement. Table 1 shows the scoring method for the System Usability Scale (SUS), which uses a Likert scale with 10 questions. Respondents rate each question on a scale from 1 to 5, reflecting their level of agreement with the statement. A score of 5 indicates "Strongly Agree," while a score of 1 indicates "Strongly Disagree." The table provided clarifies the qualitative descriptions corresponding to each score, ranging from strong agreement (5) to strong disagreement (1). This method is designed to quantify users' subjective assessments of a system's usability, providing a consistent way to measure user satisfaction of the website.

Table 1 METHOD OF SCORING

Rating Scale	**Qualitative Description**
5	Strongly Agree
4	Agree
3	Slightly Agree
2	Slightly Disagree
1	Strongly Disagree

Computation

Step 1: Convert the scale into numbers for each of the 10 questions:

1. Strongly Disagree: 1 point

2. Disagree: 2 points
3. Neutral: 3 points
4. Agree: 4 points
5. Strongly Agree: 5 points

Step 2: Calculate:

- X = Sum of the points for all odd-numbered questions − 5
- Y = 25 − Sum of the points for all even-numbered questions
- SUS Score = (X + Y) x 2.5

Interpretation

SUS score will be able to tell the website's usability performance in the aspects of effectiveness, efficiency, and overall ease of use. Although each response yields a score on a scale of 0–100. The interpretation is shown in Table 2.

Table 2 Survey Result Interpretation

SUS Score	Grade	Adjective Rating
> 80.3	A	Excellent
68 − 80.3	B	Good
68	C	Okay
51 − 68	D	Poor
< 51	F	Awful

Retrieved from (https://uiuxtrend.com/measuring-system-usability-scale-sus/)

A. RESULT AND DISCUSSION

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Discussion

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B. CONCLUSION

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C. ACKNOWLEDGE

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