DEVELOPMENT OF CONFIGURABLE MCU-BASED STAND-ALONE COFFEE BEAN SORTER AND MOISTURE CORRECTOR USING FREQUENCY-DEPENDENT CAPACITANCE METHOD

A Project Study Presented to the Faculty of

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APPROVAL SHEET

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ABSTRACT

The study employs MCU technology to determine the moisture content of the coffee bean. It was designed with a built-in dryer to correct the moisture content of the coffee bean. The relation of the frequency and the moisture content of the coffee bean were strongly shown during the testing and the moisture content was successfully determined and validated through the oven-drying method. Monitoring and controlling the moisture content level of coffee beans before storage can lessen critical problems to arise. The system is design to be standalone so human control is necessary only before and after the process is complete. Overall, this study allows sorting the beans according to its moisture content based on the desired level and provided an accuracy of 91.67%.

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CHAPTER 1

THE PROBLEM AND ITS BACKGROUND

1.1 Introduction

In agriculture, moisture content level is a very important factor in postharvest practice of farming. It is one of the keys to quality and cost control. The moisture content of the bean must first be settled to the right water content level for it is necessary for a coffee bean to be dried to a moisture content of 9 to 12 percent from approximately 60 percent moisture content level. According to the study conducted by the Food and Agriculture Organization of the United Nations, the determination of moisture content level is important in postharvest of farming. Undesired water content level would result to low cupping quality (Gautz et al., 2008). Having high moisture, the beans are easily deteriorated due to bacteria and may grow mould, yeast or fungi that can produce mycotoxins that can harm or kill humans if consumed. While having low moisture content, the beans will shrink and become distorted that results to low quality and low market value. This study will help us know if it is possible to monitor and control the moisture content of coffee beans one at a time.

The different ways to measure the moisture content level of coffee beans: 1) Oven-dry method; 2) Brittleness of parchment; 3) Color; 4) Hardness of bean; 5) Electronic meters. Oven-dry method is internationally accepted as the standard method of measuring the moisture content level. In this method, the loss of weight on heating is used as the parameter to measure the moisture. This method is only used for laboratory purposes and to serve as reference for devices that measures the moisture content. The empirical methods of measuring the moisture using brittleness, color and hardness of beans are not reliable since different farmers have different perceptions. The better way to measure the moisture is by using the electronic meters. Electronic meters are calibrated using the oven-dry method to serve as its basis. The different types of meter measures the inductance, resistance or capacitance of the bean in order to read its moisture content level. Among the three the most-used type of moisture meter is the capacitance method (Gautz et al., 2008).

1.2 Background of the Study

Conventional methods of moisture measurements in grains like oven-dry method, distillation method, drying with desiccants etc., are time-consuming laboratory methods. Fast as well as field usable portable grain moisture meter is a necessity to meet the requirements of farmers, grain storage personnel, and Agricultural products marketing corporations. The sensor is based on capacitance method and the grain is acting as dielectric medium of the sensor, temperature variations in grain introduce minor error in meter reading. It is anticipated that lack of density correction may slightly affect the accuracy of the measurements. However the developed instrument is working satisfactorily for all practical purposes in the range of 5 - 25% of grain moisture with an accuracy of ±1% (Rai et al., 2004).

A new parallel plate capacitance sensor was built to relate the moisture content and dielectric properties of sugarcane stalks. A high correlation between dielectric constant and moisture content for each sample was found and quadratic trend line was fitted to data. The results revealed a relatively strong quadratic relationship between the moisture content on green weight basis of sugarcane material put through the plates of sensor and the measured voltage (mV) by capacitance sensor circuit output (Taghinezhad et al., 2012).

The relationship between moisture content and capacitance was obtained in 8 groups of experiments. The moisture content of the samples can be determined on the basis of capacitance measured by the detection circuit. The error is smaller than in the drying method. The accuracy in measuring moisture content by the capacitive sensor circuit is high and that the method is appropriate for accurate assessment of the moisture content in corn (Zhang et al., 2013).

1.3 Statement of the Problem

According to the previous studies, there is no device that is designed to monitor and correct the moisture of the beans before storage. This is why the proponents decided to make a design of a standalone device that has a moisture meter, sorter and corrector.

Based on other studies, some methods of measuring moisture is time consuming and needs to be improved. A better way to improve the speed of measuring moisture is by using electronic meters. The most-used type of meter uses a capacitive type sensor. The problem is that the commercially available meter of this type is designed for bulk measurement. Bulk measurement could also be a problem since this method uses averaging method. Combination of beans with low, high and good moisture could be read to be good moisture. These situations could cause problems since high moisture beans are prone to bacteria, fungi and mold growth that could affect the entire beans in the same storage.

Another thing is the separation of well-dried, under-dried and over-dried beans. Other studies are focused on reading the moisture content level. This leads the proponents of this study to design a sorter mechanism to segregate the beans according to their moisture characteristic.

1.4 Objective of the Study

1.4.1 General Objective

This study aims to develop a configurable MCU-based stand-alone coffee bean sorter and moisture corrector using frequency-dependent capacitance method.

1.4.2 Specific Objective

Specifically, it aims:

1. To generate an algorithm and software that will assess the moisture content level of the coffee beans using C++ programming language;
2. To design capacitive-type sensor that will be used in determining the moisture content of the coffee bean;
3. To design a drying system to reduce the moisture content level of the test subject more accurately;
4. To analyse the measured moisture content level based on the standard measurements obtained from oven-drying method.

1.5 Significance of the Study

This study aims to have an impact in the economy of the producers. Monitoring and controlling the moisture content level of coffee beans before storage can lessen critical problems to arise. One of the problems while the coffee beans are in the storage, is the production of moulds, yeast or fungi that can produce mycotoxins that can harm or kill humans if consumed. This problem arises on coffee beans having high moisture content. All the coffee beans that is mixed with this high moisture beans would also be affected. This problem causes rejected beans that would result to less profit for the producers. And when the coffee beans are over-dried, it will also cause a low market value because the lower the water content, the lower also is the weight and the manufacturers buy coffee beans in accordance to its net weight. In order for the producers could sell coffee beans at the right price is to make sure that their coffee beans are at the right quality by means of right moisture content level.

1.6 Scope and Limitations

The research study will focus to design a device for the producers of coffee beans in order for them to store coffee beans at the right moisture content level to avoid production of moulds, bacteria and fungi from under-dried beans and also to separate over-dried beans that would lessen the net worth of their supply. This device could determine the moisture content level of coffee beans one at a time using frequency-dependent capacitance method and could separate coffee beans into three categories: Under-dried to be dried again using a dryer; Good-dried which is already good for storage; and Over-dried which is to be kept separately for it gives low income and gives low quality. Even though the device has a drying part, the research is not centered to it for as in this study shows that drying process is another story and would be better if studied separately.

A decision support system using C++ language will analyze the measured moisture content of the beans and set the drying time to reduce the moisture content level of beans to the desired level.

1.7 Definition of Terms

Algorithm – a specific set of instructions for carrying out a procedure.

Automatic temperature compensation – a technology used for correcting the measured parameter automatically in function of the measured temperature.

C++ – a general-purpose programming language. It has imperative, object-oriented and generic programming features, while also providing the facilities for low-level memory manipulation.

Capacitance – a property of an electric non-conductor material that permits the storage of energy resulting to the separation of charge that occurs when opposite surfaces of the non-conductor are maintained at a difference of potential.

Cherry – a fruit of the coffee tree. Dried coffee cherry is the dried fruit.

Coffee – a general term for fruits (cherries) and seeds (beans) of the genus Coffea plants, as well as products from these fruits and seeds in different stages of processing and use.

Coffee bean – a coffee plant's seed and source of coffee. It is the pit inside the red or purple fruit often referred as a cherry. Even though they are seeds, they are referred as 'beans' because of their resemblance to true beans.

Conductivity – a degree to which a specified material conducts electricity, calculated as the ratio of the current density in material to the electric field that causes the flow of current.

Drying – a mass transfer process, consisting of the removal of water or another solvent by evaporation from a solid, semi-solid or liquid.

Empirical method – a method used to estimate the moisture content of a material by subjective sensory perception (touch, sight and smell) of some of the beans and seeds' characteristics.

Electric flux – a total number of lines force passing through the unit area of a surface held perpendicularly.

Fermentation – a group of any chemical reactions induced by microorganisms or enzymes that split complex organic compounds into relatively simple substances, especially the anaerobic conversion of sugar to carbon dioxide and alcohol by yeast.

Germination – a process by which a plant grows from a seed.

Beans and seeds – are small, hard, dry seeds, with or without attached hulls or fruit layers, harvested for human or animal consumption.

Green coffee – a coffee in the naked bean form.

Humidity – a quantity representing the amount of water vapour in the atmosphere or gas.

Marketing – a management process through which goods and services move from concept to the customer.

Microprocessor – an integrated circuit that contains all the functions of a central processing unit of a computer.

Moisture – a presence of liquid, especially water, often in trace amounts.

Moisture content – a ratio of water and solid mass in a sample, expressed as percentage.

Moisture meter – an essential instrument used in many industries to detect moisture content in materials.

Moulds – a fungus that grows in the form of multicellular filaments called hyphae.

Mycotoxins – are secondary metabolites produced by micro fungi that are capable of causing disease and death in humans and other animals.

Parchment coffee – a green coffee bean contained in the parchment skin.

Postharvest – a stage of crop production immediate following harvest, including cooling, cleaning, sorting and packing.

Processed coffee – a coffee treated through any manufacturing process. To produce green coffee, beans may be processed either by the wet or dry methods of processing, producing washed and unwashed coffees respectively.

Roasted coffee – a green coffee roasted to any degree. The term includes ground coffee.

Robusta – a type of coffee produced from a tree of the botanical species Coffea canephora.

Roasting – an action of cooking something in an oven or over an open fire to enhance flavour through caramelization and mail lard browning on the surface of the food.

Seed – an embryonic plant enclosed in a protective outer covering called the seed coat, usually with some stored food.

Shrink – a change in moisture content of beans and seeds when it changes its weight.

Software – a computer software or simply software is any set of machine-readable instructions that directs a computer's processor to perform specific operations.

Storage – a space for storing goods.

Temperature - the degree or intensity of heat present in a substance or object.

CHAPTER 2

REVIEW OF RELATED LITERATURE AND STUDIES

This chapter presents a review of different related literatures, background theories, principles and studies which include some technical terminologies from previous and present projects related to the development of Configurable MCU-based Moisture Meter using Frequency-dependent Capacitance Method for Green Coffee with Sorter and Moisture Corrector.

2.1 Conceptual Literature

2.1.1 Coffee

Coffee is not only one of the most essential commodities in global exchange but also the world's second most well-known beverage, after water. Coffee has been described as “the intellectual fuel of the contemporary world” (Rothfos, 1984). Everyone has been drinking coffee and throughout history all sorts of theories have been advanced on its possible effects. Coffee increases the level of alertness, improves short-term memory and permits better use of the prefrontal cerebral cortex; coffee has antioxidant and antitoxic properties at cellular level; it reduces the risk of hepatic cirrhosis and prevents the formation of gallstones; it provides protection against degenerative brain diseases like Alzheimer’s and Parkinson’s; it provides protection against colon and skin cancers; it combats caries and has anti-inflammatory properties; it has a moderate slimming effect and improves performance in sports; it helps to alleviate asthma symptoms and helps to calm hyperactive children.

Moisture plays an important role in four important aspects of coffee handling:

Drying: moisture measurement at the end of drying is essential to follow up drying course and to decide whether it is achieved or not. On one hand, too long a drying course may have bad consequences for quality and food safety because of unexpected fermentations and mould growth. On the other hand, the next step in the process is storage. Also, drying to a too low moisture content can result in income losses - for example, a truck which weighs 1000 kg with beans at 12 % moisture, will weight only 967 kg at 9 % moisture;

Storage: storing coffee with too high a moisture content may involve high risks of mould growth and OTA production;

Marketing: a cargo of 25,000 tons of coffee at 12 % moisture represents 3000 tonnes of water. At 14.5 %, the cargo contains 3,625 tons of water. At just 0.20 $ per kg, this difference is worth $125,000;

Roasting: temperature and length of roasting are adjusted to usual moisture of 12 % to 13 %. Above these values, roasting requires more energy and might be incomplete. Below these values, beans might end up being over-roasted (FAO, 2006).

Table 2.1.2 Size Classification for Green Coffee Beans *(PNS BAFPS 001-2012)*

Class	Species				
	Arabica	Robusta		Liberica	Excelsa
Large	Beans retained in sieves of 7.93 mm openings; numbering less than 175 beans per 25 grams	**Dry Processed** Beans retained by 5.6 mm x 5.6 mm (3½ mesh) screen with maximum of 1% (mass/mass) passing through	**Wet Processed** Beans retained by a screen having round holes of 7.5 mm diameter with a maximum of 2.5% (mass/mass) passing through	Beans retained in sieves of 9.52 mm openings; numbering less than 10 beans per 25 grams	Beans retained in sieves of 7.93 mm openings; numbering less than 125 beans per 25 grams
Medium	Beans retained in sieves of 6.73 mm openings; numbering 175-200 beans per 25 grams		Beans passing through a screen having round holes of 7.5 mm diameter and retained by a screen having round holes of 6.5 mm diameter with a maximum of 2.5% (mass/mass) passing through	Beans retained in sieves of 7.93 mm openings; numbering 110-145 beans per 25 grams	Beans retained in sieves of 7.93 mm openings; numbering 125-160 beans per 25 grams

Small	Beans retained in sieves of 6.35 mm openings; numbering 201-250 beans per 25g		through a screen having round holes of 6.5 mm diameter and retained by a screen having round holes of 5.5 mm diameter of 2.5% (mass/mass) passing through	Beans retained in sieves of 6.7 mm openings; numbering 146-200 beans per 25 g	Beans retained in sieves of 6.35 mm openings; numbering 162-200 beans per 25g
Mixed	A mixture of any 2 or more classes none is smaller than class small			A mixture of any 2 or more classes none is smaller than class small	A mixture of any 2 or more classes; none is smaller than class small

2.1.3 Methods of Measuring Moisture Content

According to the Food Agriculture Organization (FAO) in their article entitled "Good Hygiene Practices along the Coffee Chain" the methods of determining moisture content in coffee can be divided into three broad categories; (1) Direct measurement; (2) Indirect measurement; and (3) Empirical measurement.

2.1.3.1 Direct measurement

Direct is a method of determining the water content of a material by removing moisture and then by measuring weight loss. Different methods of direct measurement are used to remove all the water but chemically bound water by heating in an oven, use of microwaves or infrared radiation.

2.1.3.1.1 Oven-dry Method

Oven-dry method is a widely recognized method for determining the moisture of grains. It is a basic method against which other indirect method based moisture meters are calibrated. Two general procedures are available in oven-dry method: (i) Grind the grain and dry it in the oven for 1 to 2 hours at 130 °C or (ii) Place the whole grain in the oven at a temperature of 100 °C for 72 - 96 hours. After heating the grains are transferred to a desiccator where they are allowed to cool to room temperature. The loss in weight is determined and the moisture content calculated either by wet basis or dry basis.

2.1.3.1.2 Distillation method

Moisture is removed by heating the grain in oil and the loss of weight of the sample determined. In the case of desiccant drying, moisture content of a product is determined by placing the sample near an efficient drying agent like anhydrous Sulphuric acid in a closed container. The loss in weight is determined and moisture (%) is calculated.

2.1.3.1.3 Modified distillation method

Modified distillation method is relatively rapid direct method of moisture determination developed in Brazil (EDABO method) is being applied by some agricultural enterprises in their field operations. The EDABO method (direct evaporation of water in an oil bath), is a variation of the official Brawn-Duvel distillation method. This method, which is illustrated and described below, takes about 20 minutes.

For coffee beans, a reference method has been established (ISO 1446: Green coffee – Determination of water content – Basic reference method). Moisture content is given with the relation

$$\%MC_{wb} = \frac{Ww - Wd}{Ww}\ x\ 100$$

Where MC is expressed on wet basis, Ww is wet weight and Wd is dry weight.

Moisture can be expressed on dry basis

$$\%MC_{wb} = \frac{Ww - Wd}{Wd}\ x\ 100$$

This value can be used for particular studies. The conversion $MC_{wb} \Leftrightarrow MC_{db}$ is given by following formulae:

$$\%MC_{wb} = \frac{MCdb}{1+MCdb}\ x\ 100$$

And

$$\%MC_{db} = \frac{MCwb}{1-MCwb}\ x\ 100$$

Direct methods are considered to provide true measurements of moisture content, and are used to calibrate more practical and faster indirect methods. Direct methods are mainly devoted to research purposes because it requires special equipment, and measurements can only be implemented in laboratories.

2.1.3.2 Indirect measurements

Indirect methods involve the measurement of certain property of the material, which depends upon the moisture content. It uses a measured intermediate variable that is converted into moisture content using calibration charts.

2.1.3.2.1 Chemical method

This moisture measurement normally adds certain chemicals, which decompose or combine with water. Calcium carbide method, calcium hydride method and Karl Fischer method etc. are some of the chemical methods.

2.1.3.2.2 Hygrometry method

This method uses relative humidity of the air in equilibrium with the material (grain) is used as a measure of the moisture content.

Hygrometers are devices that measure the relative humidity in the air space between beans. Values given by these meters refer to water activity of beans and are useful for microbiological purposes. The accuracy of measurements depends on the uniformity of the distribution of moisture in the sample and equilibration must be achieved to have reliable measurements. Calibration charts must be established based on desorption and sorption studies. Relations are rather complex and use either moisture content on a wet or dry basis.

2.1.3.2.3 Moisture measurement by Nuclear Magnetic Resonance (NMR)

This method depends on the detection of the hydrogen nuclei within the material. The magnetization in the sample is converted to a voltage, which is proportional to the number of hydrogen nuclei present in the sample. This method is not specific for moisture itself but is specific for hydrogen nuclei. An advantage of this method is that it is rapid, has high accuracy, and is a non-destructive measurement technique. Its disadvantages are that the method senses total hydrogen rather than water, and requires expensive equipment.

2.1.3.2.4 Microwave spectroscopy

A method in which the attenuation of microwaves vary with moisture content of grain, but the method is quite expensive.

2.1.3.2.5 Electrical or Conductivity method

The principle of the method is based on the resistance or conductivity of the material under test. Resistance is influenced by many factors other than moisture content, the error due to non-uniform distribution of moisture, and physical contact with the material are major problems in this method. Furthermore the method cannot give accurate results if moisture level is less than 7% or greater than 23%.

2.1.3.2.6 Capacitance method

Instruments based on this technique are subject to less error that arises from non-uniform distribution of moisture and physical contact with the material under test. This method permits moisture measurement over a wider range than conductance method, and properly calibrated capacitance type grain moisture meters work satisfactorily within ±1% accuracy, which serves almost all practical purposes in agriculture.

Indirect methods always need to establish calibration charts by using standards of known moisture content. Standards are prepared by using a direct method to determine moisture. The size (weight or volume, depending of the type of the equipment) of the standard must meet the recommendation of the manufacturer because the distribution of moisture in a sample is not uniform, the standard must be divided in several sub-samples which the weight of each of them fits with official recommendations. Moisture content is determined for each subsample. The mean of all values represents the standard. Then all sub-samples are bulked and kept in a sealed recipient to avoid uptake of water. Different standards, covering the range of the equipment must be prepared. Usually, in the case of hygrometers, manufacturers provide standards. Verification of functioning of the equipment readings and exact values are plotted on a same graph and data are analyzed to verify if the response of the equipment is always the same. Practically speaking, the two curves must be more or less parallel. If not, the equipment must be returned to the manufacturer and should not be used. The goal of calibration is to ensure that the two curves from the previous step overlap as well as possible. Most modern equipment is equipped with switches which allow adjustments of readings. After filling up the recipient of the meter, the exact value of the standard can be entered. Some equipment allows only one value (single point calibration) whereas others allow several. When this is done, the equipment gives the exact value of moisture of any sample under the condition that respects the range of use of the meter.

2.1.3.3 Empirical measurement

A benchmark study conducted by Maranan et al (1998) revealed that coffee farmers are using three methods of determining the dryness of coffee berry. One method is by shaking the berries and a solid sound inside indicate appropriate dryness. The most predominant practice is by biting the berry; hardness serves as indicator for properly dried berries. One last method is by threshing, if the beans came out of the pulp easily, they are considered as dried. These empirical measurements are both indirect and subjective. Idago, et al (2011) in their study of the coffee supply chain acknowledged that problem in high moisture content of coffee bean produced by farmers is attributable to inaccuracy of measuring the MC of their product using empirical method.

Surveys carried out during the 'Enhancement of Coffee Quality through the Prevention of Mold Formation' project have shown that these subjective methods of moisture determination to be insensitive over the range 12–20% moisture content and therefore unsuitable for determining the end of or for verifying that coffee in the marketing chain is at a safe moisture content.

2.1.4 Moisture Meters

Moisture content affects the electrical properties of materials. These properties include the inductance, resistance, and capacitance of the sample. The electrical characteristics also change with the temperature, density, and chemical make-up of the sample. This is why a good moisture meter measures density and temperature as well as the electrical characteristics (Venkatesh et al 2005).

The moisture meter is test and measurement device that is used for measuring the percentage of moisture in a given material. This instrument is used in a variety of industries where information for the moisture content in the materials is essential.

2.2 Related Studies

2.2.1 Moisture Reading using Capacitive Type Moisture Meter

Conventional methods of moisture measurements in grains like oven-dry method, distillation method, drying with desiccants etc., are time-consuming laboratory methods. Fast as well as field usable portable grain moisture meter is a necessity to meet the requirements of farmers, grain storage personnel, and Agricultural products marketing corporations. The sensor is based on capacitance method and the grain is acting as dielectric medium of the sensor, temperature variations in grain introduce minor error in meter reading. It is anticipated that lack of density correction may slightly affect the accuracy of the measurements. However the developed instrument is working satisfactorily for all practical purposes in the range of 5 - 25% of grain moisture with an accuracy of ±1% (Rai,et. Al., 2004).

A new parallel plate capacitance sensor was built to relate the moisture content and dielectric properties of sugarcane stalks. A high correlation was found between dielectric constant and moisture content for each sample was found and quadratic trend line was fitted to data. The results revealed a relatively strong quadratic relationship between the moisture content on green weight basis of sugarcane material put through the plates of sensor and the measured voltage (mV) by capacitance sensor circuit output (Taghinezhad, et. Al., 2012).

The relationship between moisture content and capacitance was obtained in 8 groups of experiments. The moisture content of the samples can be determined on the basis of capacitance measured by the detection circuit. The error is smaller than in the drying method. The accuracy in measuring moisture content by the capacitive sensor circuit is high and that the method is appropriate for accurate assessment of the moisture content in corn (Zhang, et. Al.,2013).

2.2.2 Calibration of Moisture Meter

An electronic grain moisture meter (Dole Model 400) was calibrated for rapid determination of moisture content in parchment coffee. The meter was found suitable to measure moisture content (from 9% to 40% on a wet weight basis) of parchment coffee with sufficient accuracy for routine use by growers and processors. By using this moisture meter, growers will be able to maintain better control over their drying process and moisture control during storage, resulting in better time scheduling and higher quality coffee (Tsang, 19950).

2.2.3 Factors Affecting the Calibration Transfer

The first promising alternative method was the short termination using a conductive plate at the end of the test cell. This arrangement is more rigid and simple than the original. The tests showed that the sensitivity could be adequate for measurement if the air-filled section length is appropriate. The shorted test cell is an advantageous alternative to the matched load arrangement, because the sensitivity of complex reflection coefficient for the moisture content is almost equal to the matched load arrangement. The sensitivity increases with the increase in the distance of the shorting plate from the grain section, as up to 10 cm. The sensitivity of the magnitude of the reflection coefficient is close to equal for 10 cm distance, and the phase sensitivity is four times larger compared to the matched case. The change of measurement frequency in a +/-30 MHz frequency range is possible using a linear correction on the dielectric constant, and the moisture results will remain in the acceptable error range. The transverse electromagnetic measurement limit was determined to be about 300 MHz, and the theoretical limit is at about 1.5 GHz (Gillay, 2010).

2.2.4 Drying of Coffee Beans/Grains

Several methods were used to measure “weight loss on drying” and moisture content of 120 samples freshly harvested corn grain containing from 12 to 45% moisture (10 different hybrids; 6 harvest dates; grain separated from the butt and tip section of multiple ears). Moisture content varied with measurement method**.** Compared to the direct measurement of water content by chemical reaction (the Karl Fischer method), the drying of whole kernel corn samples for 144 hours at 62 C failed to remove approximately 3% of the water content, especially from drier samples. Weight loss during oven drying at 105 C for 144 h matched Karl Fischer estimates of moisture content very closely. Rapid moisture measurements by near infrared procedures were almost as accurate as 105 C drying. Capacitance-conductance measurements were slightly less accurate than 105 C estimates, particularly for samples that contained more moisture. Compared with moisture content of kernels obtained from the tip half of the ear, kernels from the butt half of the ear contained up to 5% more moisture. Compared with the samples tested, weight loss on drying would be greater from samples that contain volatile compounds derived from microbial fermentation (high moisture corn; silage; wet distillers’ grains). For such samples, more accurate prediction of caloric value would be obtained by measuring volatiles and water content separately by appropriate procedures. If properly calibrated, near infrared techniques hold promise for obtaining such measurements (Owens and Soderlund, 2006).

The M.C. bulk of soybean samples were determined by four methods: 1. Oven-drying individual seeds using copper cups; 2. Oven-drying 5g samples; 3. Oven-drying 10g samples, and 4. a commercial electronics moisture meter. The three oven-drying methods were carried out at 110 degrees Celsius for 20 hours. The mean M.C. results from the oven-drying methods did not differ significantly. The mean M.C. determined by the electronic moisture meter was significantly different from the three oven methods in about 80% of the samples. It differed from 0.2 to 0.6 percentage points from the mean M.C. determined by the oven-drying individual seed method. The individual seed method proved to be reliable and gave consistent results when compared with others (Lazzari, 1994).

CHAPTER 3

METHODOLOGY

This chapter presents the methods and procedures that are used in the development and implementation of the project, including the materials and equipment used, program algorithm, circuit designs and design flow processes.

3.1 Research Design

The project study will be an experimental research, developing Stand-alone Coffee Bean Sorter and Moisture Corrector; and the project study encompasses the following stages:

- Conceptualization of the Design

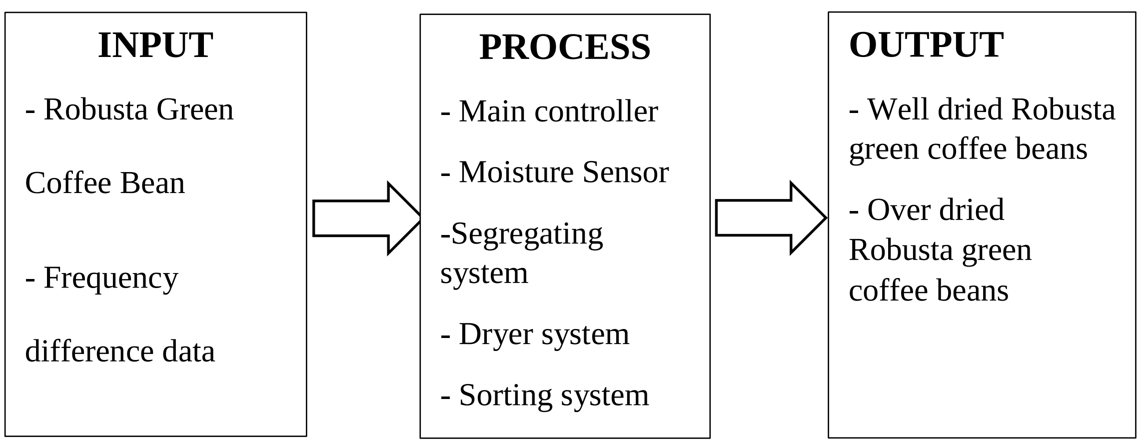

Figure 3.1 Conceptual Framework

Figure 3.1 shows the conceptual framework of the study. The study is based on the idea of developing a configurable MCU-based moisture sensor for Robusta green coffee beans with sorter and moisture corrector using frequency-dependent capacitance method that focuses on the determination and correction of moisture content of Robusta green coffee bean. The figure shows the major section of device that is composed of (a) Input; (b) Process; and (c) Output.

- Block Diagram

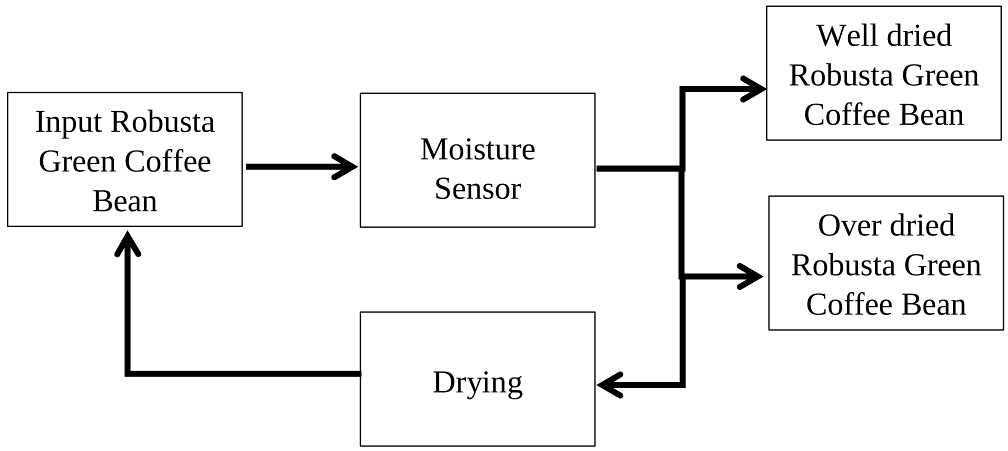

Figure 3.2 Block Diagram

Figure 3.2 shows the block diagram of the study. It shows the major processes of device that is composed of (a) Input; (b) Moisture sensor; (c) Drying and (d) Output.

- Research Process Flow

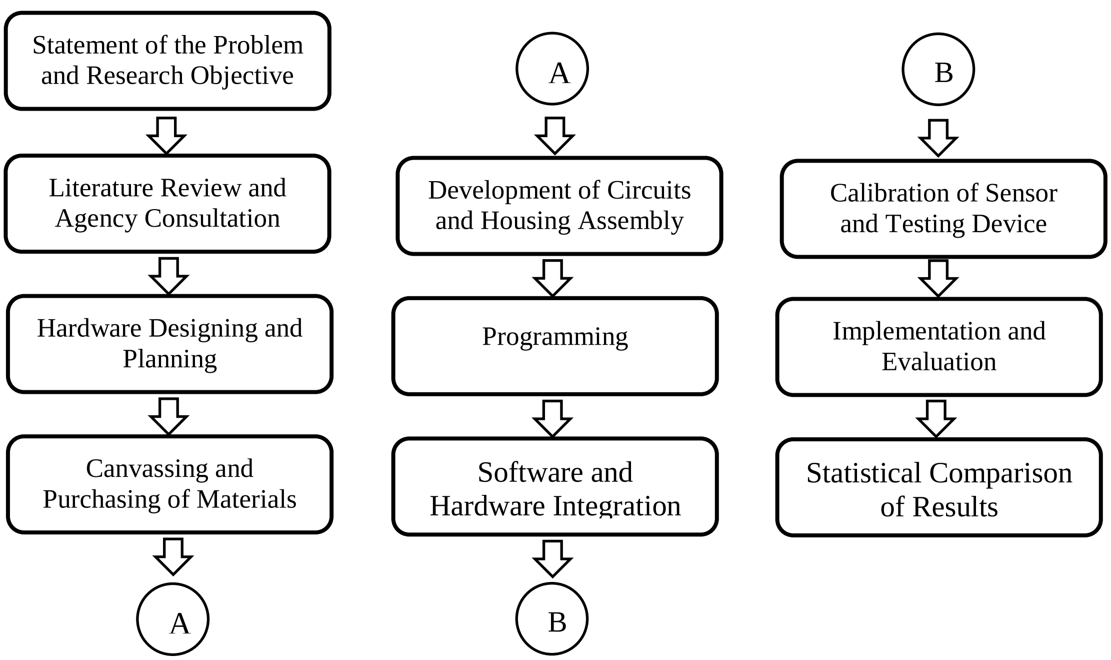

Figure 3.3 Research Process Flow

3.2 Project Development

The device is comprised of (a) Microcontroller; (b) Capacitive sensor; (c) MCU-controlled-Motor and Relay Driver board for moving the input to and from the sections of the device and for the switching of the heater; and (d) fixed 12V and 5V DC power supply for the relay board and microcontroller circuitry, respectively.

The device was constructed according to the specifications utilized by the proponents in reference to the suggestions and recommendations given by the panel.

The actual assembly of the prototype was comprised of the following activities: (1) Construction of the skeleton of the prototype; (2) Installment of the mechanical sections and interfacing them to the MCU module; (3) Arrangement of the input sensors and wiring of the necessary interconnections; (4) Construction of the front control panel and main chassis; (5) Testing and troubleshooting of the device.

3.2.1 Hardware Development

The hardware and the dimensions of the device were designed taking in to consideration the size of the input green coffee beans using SketchUp. The conveyor belts, storage bins and the cover of the device are made up of sintra and acrylic boards that were cut mechanically. The parallel plate of the sensor is made from copper and the strainer is made up of steel.

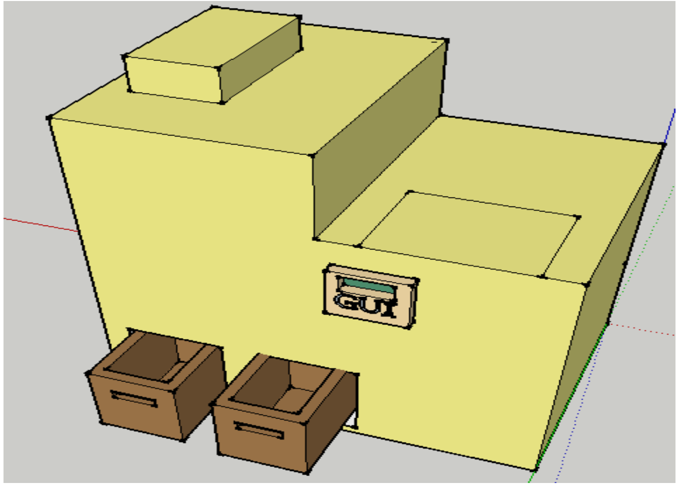

Figure 3.4 Prototype Isometric view

Figure 3.4 shows the isometric view of the prototype

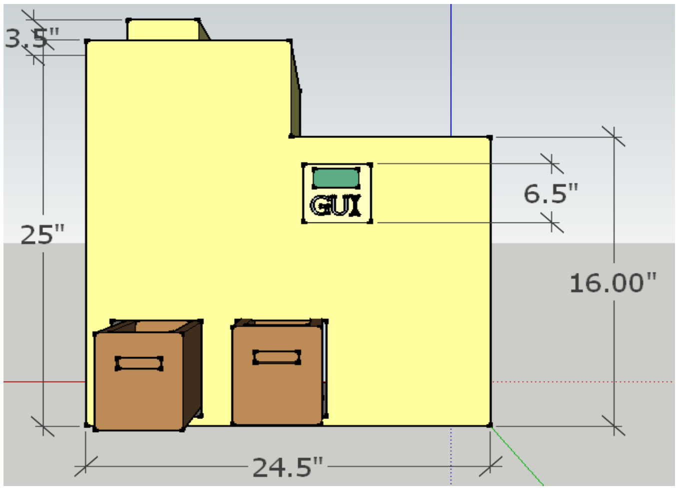

Figure 3.5 Front view

Figure 3.5 shows the dimensions of the front side of the prototype including the graphic user interface.

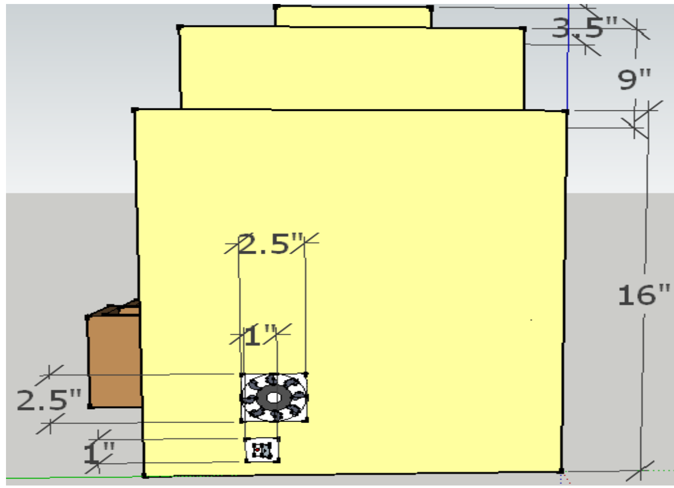

Figure 3.6 Side view

Figure 3.6 shows the dimensions of the side of the prototype where the exhaust fan and the turn on/off switch is located.

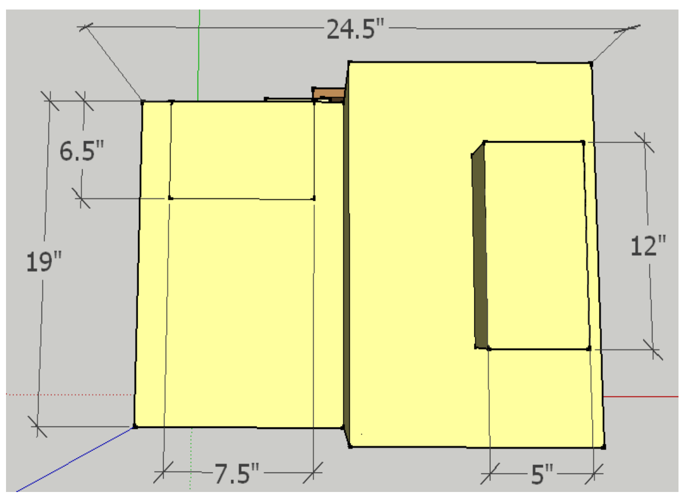

Figure 3.7 Top view

Figure 3.7 shows the dimensions of the top side of the prototype where the input is feed to the system.

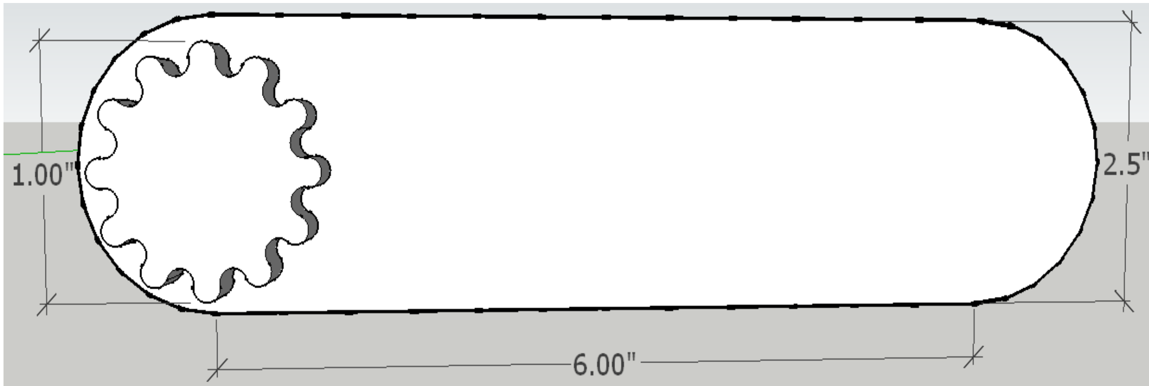

Figure 3.8 Conveyor belt A

Figure 3.8 shows the front view of the conveyor belt A that is used to move the green coffee beans one at a time from the input to the sensor. It shows the dimensions of the conveyor belt including the diameter of the gear that is connected to the motor for movement.

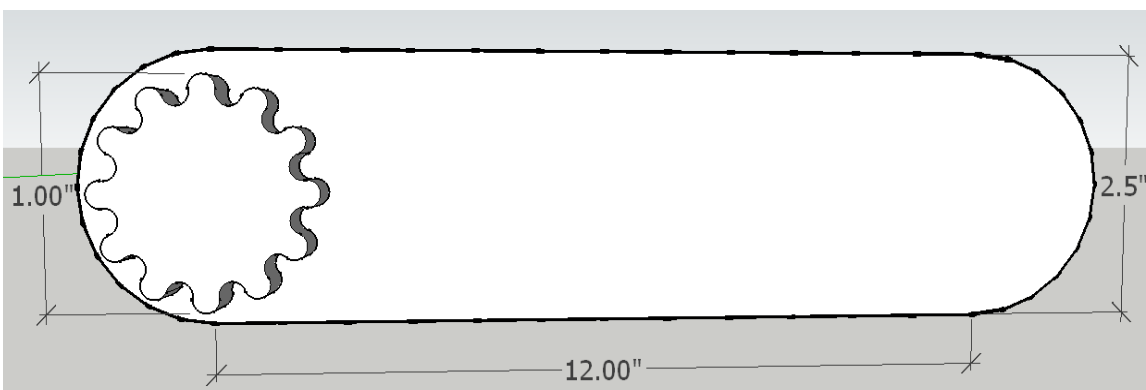

Figure 3.9 Conveyor belt B

Figure 3.9 shows the front view of conveyor belt B. It shows the dimensions of the conveyor belt including the diameter of the gear that is connected to the motor for movement.

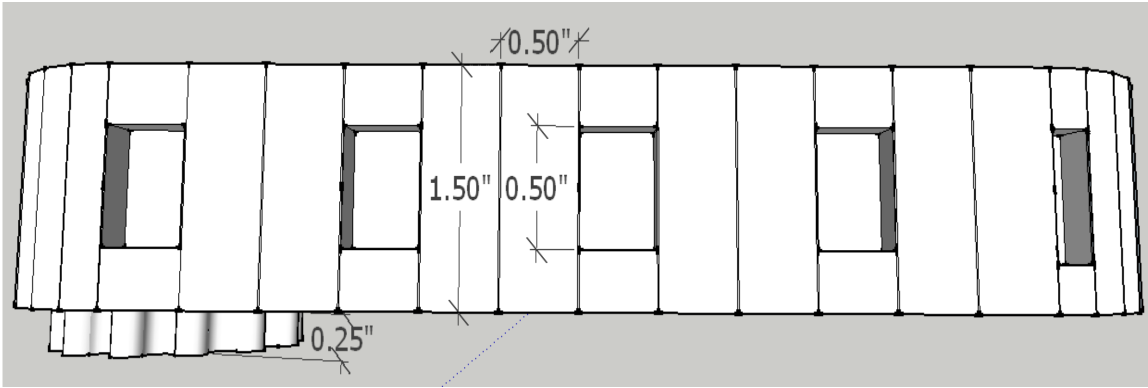

Figure 3.10 Top view of conveyor belt A and B

Figure 3.10 shows the top view of conveyor belt A and B. It shows the dimensions of the rectangle holes that segregate the beans from the input one at a time.

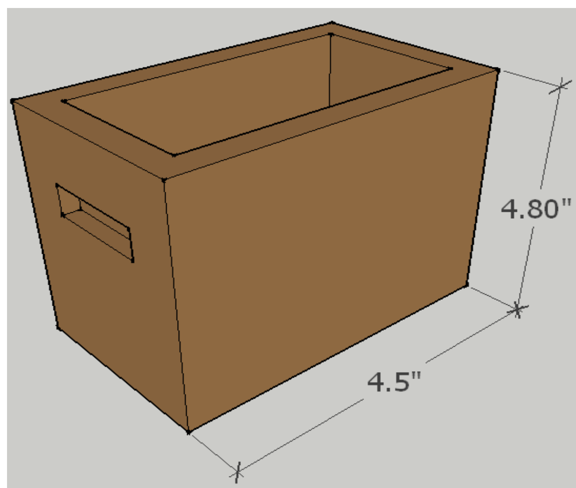

Figure 3.11 Storage Bins

Figure 3.11 shows the dimensions of the storage bins where over dried and well dried beans are placed.

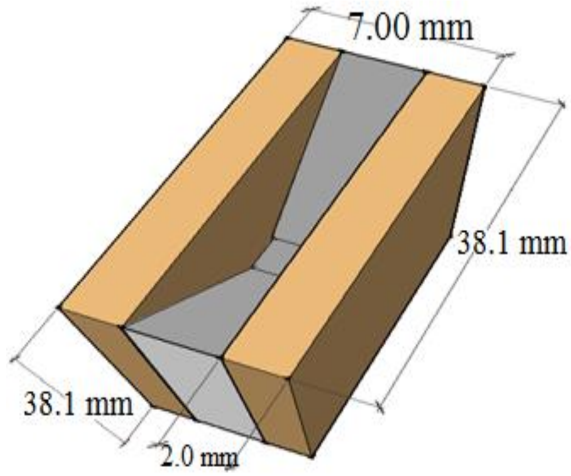

Figure 3.12 Copper Parallel Plates

Figure 3.12 shows the dimensions of the parallel plates that are used as the capacitor of the timing circuit of the frequency generator.

3.2.2 Circuit Schematic Diagram

Schematic diagrams and PCB layouts are accomplished by using the professional PCB design and simulation software Proteus PCB Design Suite.

Power Supply

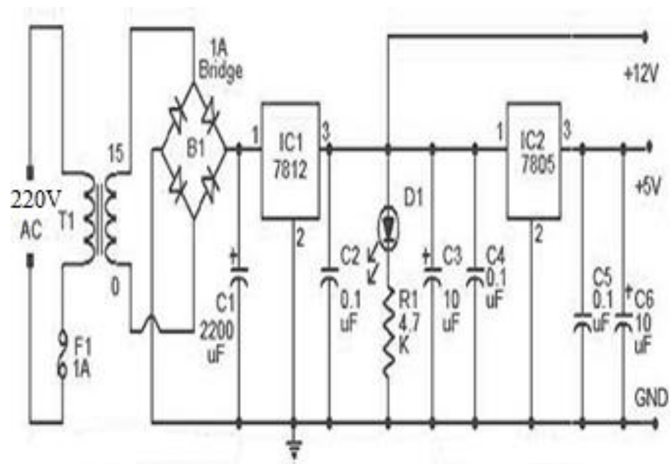

Figure 3.13 Power Supply Schematic Diagram

Capacitive Sensor

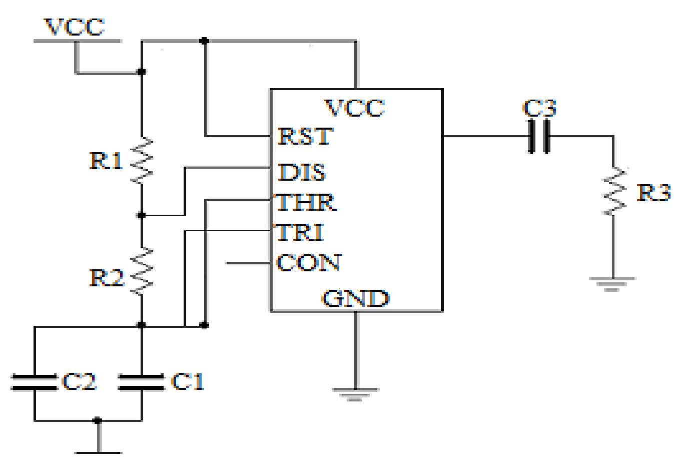

Figure 3.14 Capacitive Sensor Schematic Diagram

Relay Driver

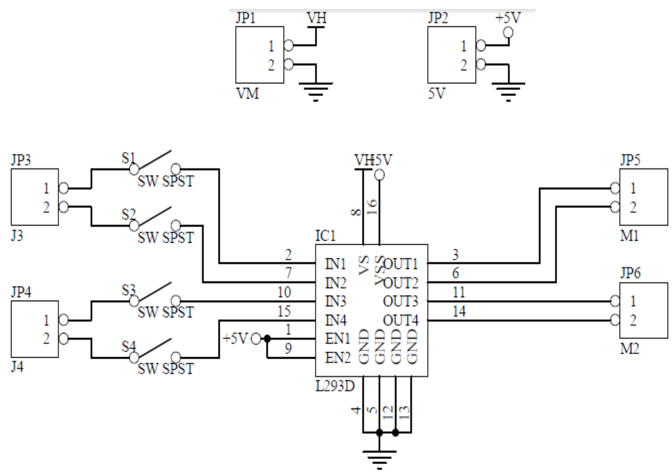

Figure 3.15 Relay Driver Schematic Diagram

Motor Driver

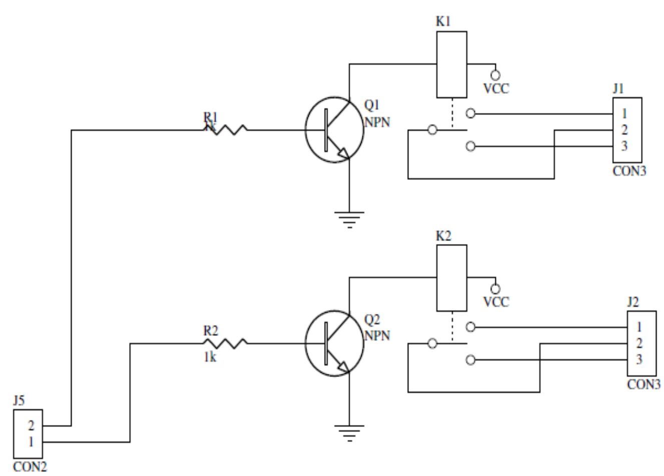

Figure 3.16 Motor Driver Schematic Diagram

Liquid Crystal Display (LCD)

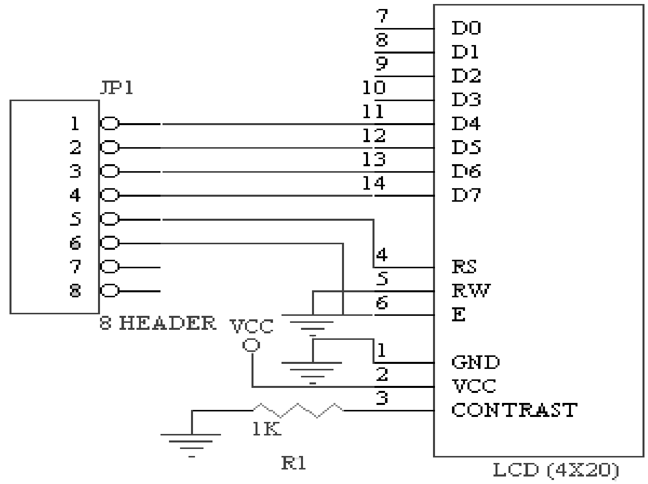

Figure 3.17 Liquid Crystal Display Schematic Diagram

Keypad

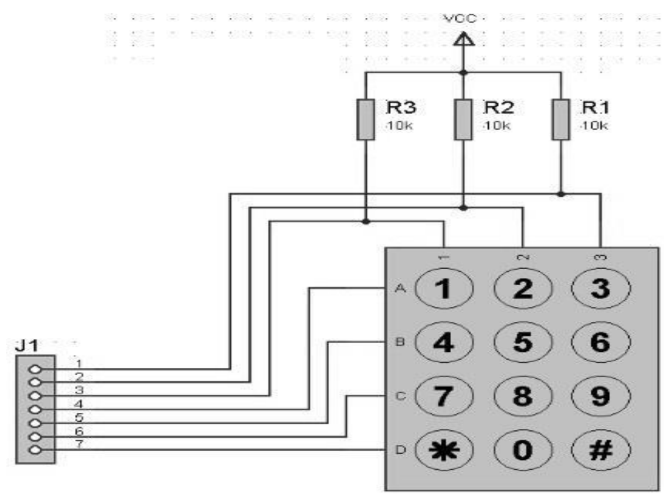

Figure 3.18 Keypad Schematic Diagram

3.2.3 Software Development

The platform used in this project is the Arduino UNO and Arduino MEGA. These electronic circuits are programmed using C language to carry out a vast range of task. The complete source code for the microcontroller program can be found at the Appendix A of this study.

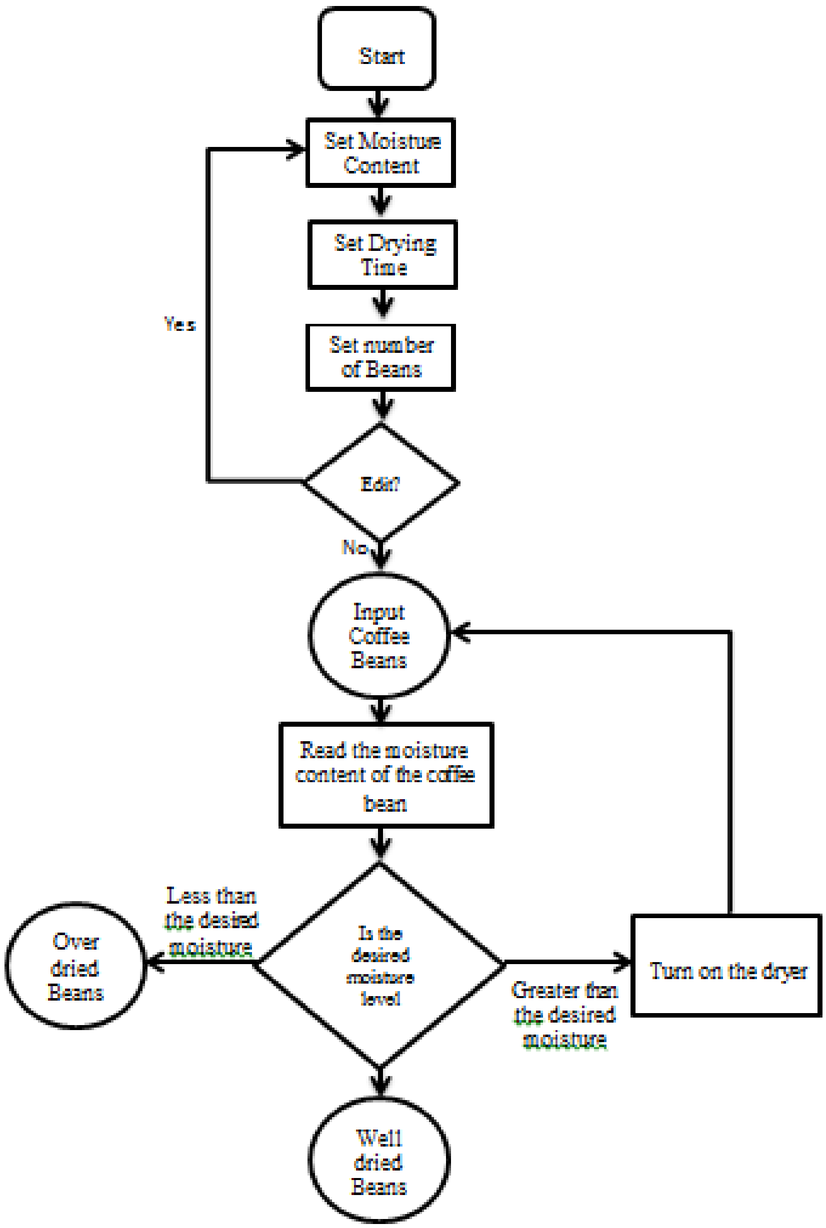

Figure 3.19 Flowchart

Figure 3.19 shows the flowchart of the program. The moisture content, drying time and the number of beans to be dried is configured through the use of the keypad. The moisture of the input coffee beans was measured through the moisture sensor. The beans that are classified as dried and over dried are placed in their respective storage bins while those that are classified as under dried undergo hot air drying to reduce the moisture content before re-entering as input for another moisture reading. The process continues until the under dried beans are classified as dried.

3.3 Materials and Equipment

3.3.1 Project Components

The primary project components used for the project are the Arduino MEGA, Arduino UNO, relay and motor driver, LCD, power supply, keypad, LED modules, nichrome wire, blower fans, LDR and laser.

Arduino UNO

The Uno is a microcontroller board based on the ATmega328P. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz quartz crystal, a USB connection, a power jack, an ICSP header and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started.

Figure 3.20 Arduino UNO

(https://www.arduino.cc/en/Main/ArduinoBoardUno)

Arduino MEGA

The Arduino Mega is a microcontroller board based on the ATmega1280 (datasheet). It has 54 digital input/output pins (of which 14 can be used as PWM outputs), 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started. The Mega is compatible with most shields designed for the Arduino Duemilanove or Diecimila.

Figure 3.21 Arduino MEGA

(https://www.arduino.cc/en/Main/arduinoBoardMega)

Power Supply

The project uses an AC to DC switching power supply with an output voltage of 5Vdc and 12Vdc. The main advantage of the switching power supply is greater efficiency because the switching transistor dissipates little power when acting as a switch. Other advantages include smaller size and lighter weight from the elimination of heavy line-frequency transformers, and lower heat generation due to higher efficiency.

Figure 3.22 Power Supply (http://www.sunpower-uk.com)

Relay Driver

The project uses 12-24VDC, 1A Songle Relay SRS/SRSZ. Relay driver is a logic module which provides high level system control functions such as high/low voltage alarms, load control and generator start. It can provide power directly to external devices that have modest power requirements. Alternatively, these relay drivers can provide control signals to heavy-duty external relays that in turn can control power to heavy-duty, high-power equipment.

Figure 3.23 Relay (http://www.oledtvrepair.com)

Servo Motor

The TowerPro 9805BB is a double bearing, coreless motor with stall torque of 20kg/cm @ 6.0V, speed of 0.2 seconds/60deg. @ 4.8V, dimensions of 66x30.2x64.4mm, temperature range of 0c - 55c, operating voltage of 4.8V - 7.2V, weight of 160 grams.

Figure 3.24 Servo Motor

(http://www.e-gizmo.com/PRODUCT/servo%20motors.pdf)

Liquid Crystal Display (LCD)

The LCD used in this project is a SC2004C model, 20 characters x 4 lines LCD, has 5 x 7 dots with cursor and has a built in controller, which requires 5V DC single power supply. It is an electronic device that can be used to show numbers or text. The display is made up of a number of shaped crystals. In numeric displays, these crystals are shaped into bars, and in alphanumeric displays the crystals are simply arranged into patterns of dots. Each crystal has an individual electrical connection so that each crystal can be controlled independently.

Figure 3.25 LCD Module

(http://www.aliexpress.com/promotion/electronic_4-line-lcd-display-promotion.html)

Light Sensor

The light sensor used in this project is a 320V 75mA 250mW NORP12 and is rated for full -60° to +75° temperature range. A light sensor is a passive device that is used to detect light. It generates an output signal indicating the intensity of light by measuring the radiant energy that exists in a very narrow range of frequencies from the LED panels.

Figure 3.26 Light Sensor (http://www.buildcircuit.net)

Exhaust Fan

The exhaust fan used in this project is a 24V DC 5W Minibea-Matsushita NMB-MAT 4715KL. An exhaust fan dissipates unwanted heat and stale air from the device. It is used to remove unwanted heat and excess humidity which would be trapped in the device.

Figure 3.27 Exhaust Fan

(http://www.aliexpress.com/item/NMB-MAT-4715KL-04W-B56-12V-1-3A-server-cooling-fan-12038-120x120x38mm-12cm/1335805081.html

3.3.2 List of Materials

The needed materials and equipment for the development of the project were gathered from different sources.

Integrated Circuits (ICs), Moisture Sensor, Temperature Sensor, and other electronic components were purchased from E-Gizmo Mechatronix Central, Alexan and other distributors in Manila, Philippines.

The Versa Board, screws and hinges were purchased from OLX, ACE Hardware and other existing hardware in Manila, Philippines.

Other materials and accessories needed for the complete assembly of the system were likewise obtained from other electronics supply stores and bookstores in Manila, Philippines.

Table 3.1 summarizes the components required for the construction of the capacitive sensor.

Table 3.1 Components list for the Capacitive Sensor

Description	**Quantity**
Power Supply	2
Arduino MEGA	1
Arduino UNO	1
Keypad	1
Copper Plates	2
555 IC	1
LM7812	1
LM7805	1
L293D	2
IC socket	5
Servo Motor	3
DC Motor	1
LDR	2
Laser	2
Resistor	17
Electrolytic Capacitor	3

Ceramic Capacitor	6
NPN Transistor	2
Diode	1
Fuse	1
Fuse holder	1
Connector	20
Heat Sink	1
Screw	30
Terminal Block	12
Nichrome wire	1
PCB	
Acrylic	
Sintra board	

3.4 Calibration Procedure

Standard method of determining the moisture content was used in calibrating the moisture content reading of the device.

Forty coffee bean samples are taken from a 100-gram sample using random sampling. A total of 1160 green coffee beans was used as sample and was placed between the parallel plates of the sensor one at a time to produce variations in frequency. These variations are used to correlate the moisture content and the frequency. The sample is then dried in the oven for 24 hours at 105 degrees Celsius and placed in the desiccator for 5-10 minutes to stabilize its condition. It is then weighed using the precision scale to determine its dried weight.

The formula in determining the moisture content is:

$$\text{Moisture Content} = \frac{Initial\,Weight - Dried\,Weight}{Initial\,Weight} \times 100 \qquad \text{(Eq. 3.3 PNS-BAFPS)}$$

The procedures are repeated for moisture contents of 9 to 12%.

3.5 Testing Procedure

Testing the prototype is a main factor to determine whether the project works on how it is set to operate. The circuits are simulated on a breadboard. The PCB design and layout are made after the circuit functions properly.

The proponents organize every part of the research and consult the Philippine Center for Postharvest Development and Mechanization (PHILMECH) and the Cavite State University – National Coffee Research and Extension Center (CvSU-NCRDEC) to develop a simple but fast and accurate device that measures and corrects the moisture content of the green coffee beans. The proponents test the moisture sensor and the drying process mounted inside the chassis of the device. Temperature and humidity is measured using a room thermometer and humidity meter. The device is tested inside the laboratory of the Agricultural and Mechanization Department (AMD) of PHilMECH with a temperature range of 21˚C-26˚C with 60% - 65%. Each level of coolness of the air conditioning unit is measured and the level of the desired temperature is maintained. This is observed to be stable overtime. Evaluation of the moisture content during the storing stage of postharvest practice is necessary. Agriculturists define the acceptable moisture content of green coffee beans to be stored to be at 9% - 12% to avoid deterioration in quality and to prevent spoilage. PHilMECH provided the AGRO LAB TCN50 oven, desiccator, thermometer and precision scale. The personels of PHilMECH assist the proponents on measuring the moisture content of the green coffee bean. The unit for measuring moisture content, percent (%) of volume of the material, indicates the amount of water presence in the coffee bean.

3.6 Evaluation Procedure

The configurable MCU-based coffee bean sorter and moisture corrector is an output-oriented device. The functionality of the system is evaluated upon the basis of the moisture content of the coffee beans. The 100-gram output of the device from twelve (12) trials which is estimated to have 3600 to 6000 pieces of green coffee beans undergo laboratory tests, in cooperation with Philippine Center for Postharvest Development and Mechanization. The moisture content of the output coffee bean is tested by measuring the moisture content through oven drying method. The output of the device which is configured to be at 9%, 10%, 11% and 12% moisture content undergone the standard method of moisture content determination to validate the results as well as to determine the accuracy and the reliability of the device.

3.7 Data Analysis

Statistical method known as t-test is used to analyze the data gathered. It is used to compare the means of two treatments in this study. Essentially, the two sample t-test determined whether the two sample sets have significantly different means. To evaluate this potential difference, the proponents compared a t-test value that is previously calculated from the sample data, with a critical t-test value based on the degree of confidence required in the test.

Statistical data will be gathered from different agricultural respondents through survey whose contents reflect their areas of expertise. Questions pertaining the effectiveness, essentiality, aesthetics, mobility and functionality of the project will be answered by the farmers and other agriculture enthusiasts coming from the Philippines Center for Postharvest Development and Mechanization.

Figure 3.28 shows the evaluation form for the project. It serves as the rating for the overall performance of the device.

EVALUATION FORM

DEVELOPMENT OF CONFIGURABLE MCU-BASED COFFEE BEAN SORTER AND MOISTURE CONTENT CORRECTOR USING FREQUENCY-DEPENDENT CAPACITANCE METHOD

Direction: Rate the following by placing a cross (X) mark on the box provided.
(1- Poor 2-Fair 3-Satisfactory 4-Very Satisfactory 5-Excellent)

I. General Impact

	1	**2**	**3**	**4**	**5**
1. Industrial applicability					
2. Societal impact					
3. Novelty of the project					

II. Device

Structural Design	**1**	**2**	**3**	**4**	**5**
1. Effectivity of the design structure					
2. Appropriate use of material					
3. Aesthetics					
Software System					
1. User-friendly interface					
2. Complete interactive operation					
3. Accurateness of computed/shown data					

III. Objectives

The device met the stated objectives of:	**1**	**2**	**3**	**4**	**5**
1. Portability					
2. Accuracy of results/shown data					
3. Processing time					
4. Safety provisions					

I would recommend this device to others. ______Yes ______No ______Not Sure

Remarks:

____

____

____

Evaluated by:

____

____

Figure 3.28 Evaluation Form

The answers for each survey questions were totaled by getting its mean percentage per question. The formula for computing the mean is written as:

$$\mu = \frac{\Sigma x}{N}$$

Where Σx is the sum of all data values

N is the number of data items in population

The corresponding mean percentage for the evaluation of the project was presented in graphical form. The aesthetics is evaluated based on its physical aspects, circuit design, working space and quality. The mobility is evaluated based on the project's compactness, stability, weight and its transferring capabilities. And the functionality is evaluated based on the project's operation, accuracy and its output.

Table 3.2 Statistical Analysis

Mean (X)	**Descriptive Rating**
4.5 above	*Strongly Agree*
4.0 – 4.49	*Agree*
3.5 – 3.9	*Neither Agree/Disagree*
3.0 – 3.49	*Disagree*
2.9 below	*Strongly Disagree*

Table 3.7 shows the equivalent descriptive rating of the mean which will be computed based on the survey answers.

3.8 Gantt Chart

Activity	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Research of Problems for Topic Defense											
Drafting and Finalization of Documents for Topic Defense											
Topic Defense											
Drafting Chapters 1, 2 and 3 of the Project Document											
Project Research and Consultation for the Title Proposal											
Initial Hardware and Software Design of the Project											
Finalization of Chapter 1 of the Project Document											
Title Defense											
Canvass and Purchase of Components and Materials											
Further Research for the Project Design and Consultation											
Final Hardware and Software Design and Programming											
Project Assembly											
Testing and Evaluation of the Project											
Documentation of the Project for Final Defense											
Final Defense											
Finalization of the Project Document and Bookbinding											

Chapter 4

RESULTS AND DISCUSSIONS

This chapter presents the project technical description, project structural description, project capabilities and limitations, project evaluation and tabulation of results and interpretation.

4.1 Project Technical Description

The project is about developing a device that can sort beans with your desired moisture content to over dried beans and to design a heating section for correcting the moisture content of under dried beans. The project uses MCU technology as central processing system which processes data from the sensors and feed control signals to the motors.

The system is divided into three main parts, the sorter, capacitive sensor and the drying section. Servo and DC motors were used for the mechanical part of the system. The MCU module is responsible for the movement of these motors. Capacitive type measurement is used in the sensor part of the project. Analog outputs are converted to digital signals and fed on the MCU module. For the drying section, nichrome wire is used. This provides approximately 40 degrees Centigrade to lessen the moisture content of the bean.

4.2 Project Structural Description

The Configurable MCU-based Stand-alone Coffee Bean Sorter and Moisture Corrector using Frequency-Dependent Capacitance Method uses the MCU module, oscillator, a system of circuit including the sensor, relay driver, power supply.

4.2.1 System Parts and Layout

Figure 4.1 Isometric view of the Configurable MCU-based Stand-alone Coffee Bean Sorter and Moisture Corrector using Frequency-Dependent Capacitance Method

Figure 4.1 shows the physical layout of the system the isometric view which summarizes the whole view of the system; The front view of the system showing the control section and the and display unit . Display Unit shows a Liquid Crsytal Display, The LCD is a 5V. 4lines x 20 character display which shows the moisture content of the bean and is directly connected to the microcontroller circuit. Control Unit . The keypad serves as the control unit of this device.

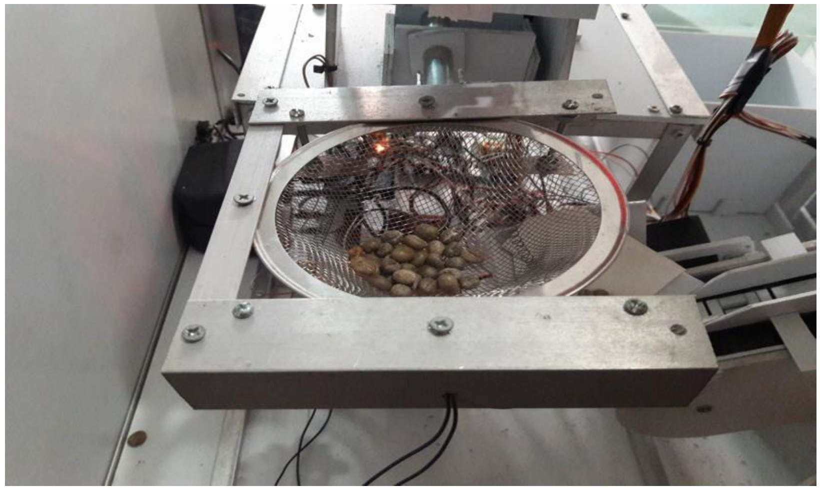

Figure 4.2 Drying Section

Figure 4.2 shows the drying section which builds up heat up to a certain time to correct the moisture content of the bean.

Figure 4.3 Sorter

Figure 4.3 ensures that only one bean will enter the moisture meter.

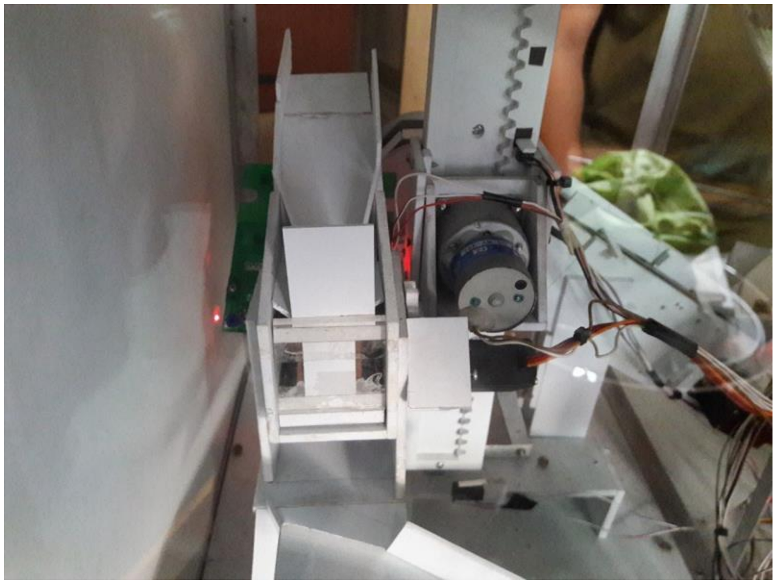

Figure 4.4 Moisture Meter

Figure 4.4 shows the section which measures the actual frequency of the bean and compares it to the frequency measured before the bean enters the meter, then sorts the bean.

4.3 Project Capabilities and Limitations

The Configurable MCU-based Stand-alone Coffee Bean Sorter and Moisture Corrector using Frequency-Dependent Capacitance Method can sort beans of desired moisture and over dried beans and correct the moisture content of under dried beans. The desired moisture content is manually set by the user and automatically turns off whenever the sensor does not detect a bean. Though the drying section can lessen the moisture content of the device it cannot correct the moisture of all the beans in the dryer at the same time.

4.4 Project Evaluation

Various researches and experiments are conducted to obtain the necessary result of this project. The proponents consider the suitable casing for this project and comprehensive calibrations are done to measure the moisture content of the beans. The testing procedures and evaluation are performed in Philippines Center for Postharvest Development and Mechanization to guarantee the accuracy of the device. The proponents consider the statistical method known as t-test to compare the results obtained on the device and on the oven method then further came up with the right computation.

Data Gathering

1. Place the sample in the sensor to obtain frequency difference.
2. Record the measured frequency
3. Measure the weight of the sample.
4. Record the measured weight.
5. Dry the sample under 105°C for 24 hours.
6. Place the sample inside the desiccator for 5 minutes to stabilize the condition of the sample.
7. Measure the weight of the sample.
8. Record the measured weight.
9. Use the formula

   $$\text{Moisture Content} = \frac{Initial\,Weight - Dried\,Weight}{Initial\,Weight} \times 100 \qquad \text{(Eq. 3.3 PNS-BAFPS)}$$

10. Record the moisture content

Table 4.1 Initial Test Trials for the Database of Arduino

Sample	Initial Frequency (Hz)	Measured Frequency (Hz)	Difference (Hz)	Moisture Content (%)
1	29484	29449	35	12.82
2	29481	29428	27	12.04
3	29462	29498	34	11.82
4	29525	29422	27	11.45
5	29455	29581	33	12.42
6	29603	29627	22	11.15
7	29657	29629	30	11.52
8	29656	29603	27	11.27
9	29627	29631	24	11.22
10	29654	29567	23	10.31
11	29581	29576	22	9.98
12	29599	29723	23	9.97
13	29746	29730	23	10.45
14	29754	29720	24	10.36
15	29735	29678	15	9.33
16	29701	29670	23	9.96
17	29692	29680	22	9.85
18	29695	29698	15	9.20
19	29717	29698	19	19.64
20	29643	29628	15	19.51
21	29615	29603	12	9.17

The device was tested with consideration to accuracy and reliability. The group conducted several initial trials. Table 4.1 shows the data gathered from the tests.

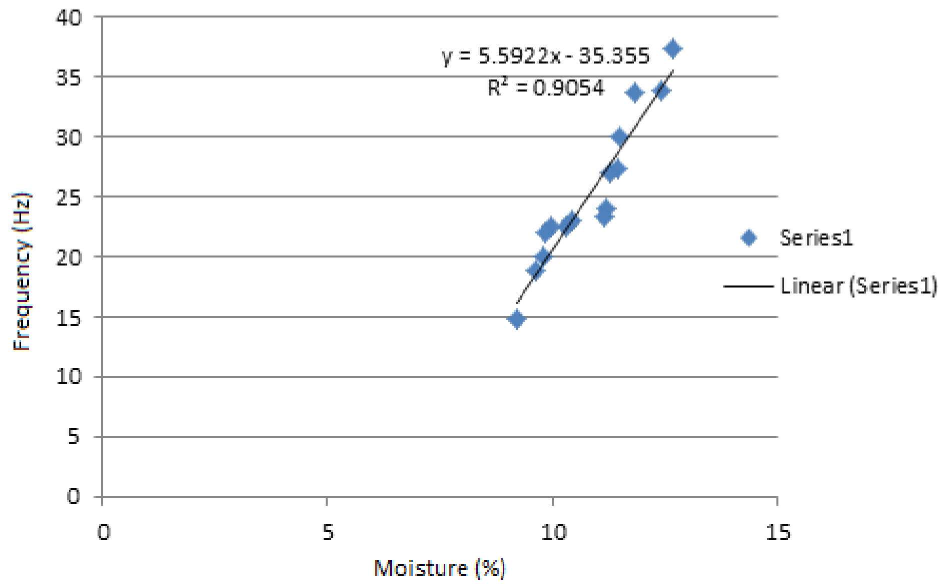

Figure 4.5 Plot of Frequency Reading Vs. Moisture Content

As shown on plot 4.1 the graph of moisture and frequency is linear. Furthermore, according to the test of correlation, the percent moisture and frequency is 0.9054 correlated implying that the data is related.

Table 4.2 Frequency Ranges Classification

Range	Classification
33.6 -37.26	12%
23.4-33.5	11%
18.8-23.3	10%
14.75-18.7	9%

As clearly shown in the plot, each frequency range is directly proportional to the percent moisture. Table 4.2 summarizes the ranges for every moisture content evaluation.

Table 4.3 Comparison of the results

Batch	Initial Weight (g)	Final Weight (g)	Device Reading	Actual Reading	Result
1	100.1347	87.8035	12%	12.31461222	Correct
2	100.0376	88.1032	12%	11.92991435	Correct
3	100.1031	87.8552	12%	12.23528542	Correct
4	99.9831	89.2134	11%	10.77152039	Correct
5	100.0032	89.0345	11%	10.96834901	Correct
6	100.0683	88.7453	11%	11.31527167	Correct
7	100.0937	91.324	11%	8.761490483	Incorrect
8	99.932	90.0032	10%	9.935556178	Correct
9	100.2054	89.8034	10%	10.38067809	Correct
10	100.0634	90.1095	10%	9.947593226	Correct
11	100.1047	91.2045	9%	8.890891237	Correct
12	100.0935	90.8734	9%	9.211487259	Correct

This shows the comparison of the moisture content between measured output of the device, and the computed. The computed value of moisture content is based on the formula.

After conducting several trials it proved that the overall output of the project is satisfactory. The data shows that 11 out of 12 samples have same actual and computed values, having an accuracy of 91.67%. This proves that the project is functional and reliable.

A paired sample t-test is conducted to compare the results of the device and the oven drying method. There is no significant difference in the scores for device (mean = 10.66, Standard Deviation = 1.07) and oven drying method (mean = 10.55, SD = 1.24); $t(11) = 0.574$, $p < 0.05$. These results suggest that the output value of the device and the conventional method are almost the same.

Chapter 5

SUMMARY OF FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary of Findings

After conducting several tests and data gathering, the proponents were able to develop a Configurable MCU-based Moisture Meter using Frequency-dependent Capacitance Method for Green Coffee with Sorter and Moisture Corrector which measures the moisture content of coffee bean one by one.

The project is primarily concerned on establishing a sensor that produces a reading on the frequency and transferring the bean from one point to another. The project utilized a program which was sketched on the microcontroller. This program is used to take the reading of frequency before and after the bean was placed in the sensor. The proponents used Arduino Mega as the central controller of the project and Arduino Uno as the slave controller which is responsible on reading the sensor's frequency.

Some professionals from the Philippine Postharvest Development and Mechanization (PHILMECH) supervised in the development of this project. Also, the agricultural researchers from this sector evaluate the effectiveness, essentiality and technical aspects of the project resulting at a good descriptive rating.

During the testing, the proponents compared the results of the project on the standard oven method which was supervised by the PHILMECH professionals.

5.2 Conclusions

Based on the findings and results of the study, the following are the conclusions drawn out by the proponents:

1. The software program of this project, which functions to read the difference in frequencies and to transfer the bean from one point to another, was successfully implemented using C++ programming language.
2. The device accomplished in sorting the beans according to its moisture content based on the desired level.
3. The drying system is able to reduce the moisture content level of the coffee beans using hot-air drying method.
4. The output of the device was successfully evaluated based on the standard measurements obtained from oven-drying method and obtained 91.67% accuracy.

5.3 Recommendations

The project was successfully implemented and done; however, the proponents would like to make the following recommendations to further improve the project.

1. Add different variety of coffee bean and other crops to be tested.
2. Use multiple sensors for simultaneous measurement and faster sorting mechanism to increase the output over time.
3. Add volume, mass and temperature to the parameters to increase accuracy.

REFERENCES

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Appendix A

Approval Sheets, Certifications and Evaluation Sheets

Technological University of the Philippines
College of Engineering
Electronics Engineering Department

APPROVAL SHEET
of
ECE PROJECT STUDY
(Progress Defense)

Group Members:

1. Alibayan, Jan Paul I.
2. Bobadilla, Ian Renz C.
3. Carnicer, Mark Kevin V.
4. Pascua, Reynaldo Jr., T.
5. Teodosio, Jeschri G.

Title: Development of Standalone Coffee Bean Moisture Content Separator and Corrector

Adviser:
Engr. Ira C. Valenzuela

Action taken by the Advisory Committee:

Advisory Committee			Action Taken	
	Name	Signature	Passed w/ Revisions	Failed
Panel Member	Engr. Nilo M. Arago			
Panel Member	Engr. August C. Thio-ac			
Panel Member	Engr. Gaudencio G. Bansil, Jr.			
Panel Member	Engr. Lean Karlo S. Tolentino			
Panel Member	Engr. Edmon O. Fernandez			

Comments and Suggestions:

- Configurable moisture sensors ~~(9-12%)~~
- Control system design
- Suitable casing (food-grade)
- ~~Adjustable~~ capacitor plate
- Check "overdried" bean

Noted:

Engr. Nilo M. Arago
Head, Electronics Engineering Department

Technological University of the Philippines
College of Engineering
Electronics Engineering Department

APPROVAL SHEET
of
ECE PROJECT STUDY
(Pre-Final Defense)

October 13, 2015

Group Members:

1. Alibayan, Jan Paul I., ECT
2. Bobadilla, Ian Renz C., ECT
3. Carnicer, Mark Kevin V., ECT
4. Pascua, Reynaldo Jr. T., ECT
5. Teodosio, Jeschri G., ECT

Title: Development of Configurable Standalone Coffee Bean Sorter and Moisture Content Corrector

Adviser:
Engr. Ira C. Valenzuela

Action taken by the Advisory Committee:

Advisory Committee			Action Taken	
Name		Signature	Passed w/ Revisions	Failed
Panel Member	Engr. Nilo M. Arago		✓	
Panel Member	Engr. Edmon O. Fernandez			
Panel Member	Engr. Gaudencio G. Bansil Jr.		✓	
Panel Member	Engr. Lean Karlo S. Tolentino		✓	

Comments and Suggestions:

Bean w/ moisture test should not generate over dried coffee bean
Label the parts in your prototype (e.g. sorter, dryer, moisture sensor)
improve the prototype including the belt ~~type~~.

Noted:

Engr. Nilo M. Arago
Head, Electronics Engineering Department

Technological University of the Philippines
College of Engineering
Electronics Engineering Department

APPROVAL SHEET
of
ECE PROJECT STUDY
(Final Defense)

January 26, 2016

Group Members:

1. Alibayan, Jan Paul I., ECT
2. Bobadilla, Ian Renz C., ECT
3. Carnicer, Mark Kevin V., ECT
4. Pascua, Reynaldo Jr. T., ECT
5. Teodosio, Jeschri G., ECT

Title: Development of MCU-based Coffee Bean Sorter and Moisture Corrector using Frequency-dependent Capacitance Method

Adviser:
Engr. Ira C. Valenzuela

Action taken by the Advisory Committee:

Advisory Committee			Action Taken	
Name		Signature	Passed w/ Revisions	Failed
Panel Member	Engr. Nilo M. Arago	[signature]	✓	
Panel Member	Engr. Gaudencio G. Bansil Jr.	[signature]	✓	
Panel Member	Engr. Edmon O. Fernandez	[signature]	✓	
Panel Member	Engr. Lean Karlo S. Tolentino	[signature]	✓	

Comments and Suggestions:

- cite/provide literature / document showing amount of H_2O (tons) for a certain % of moisture content (RKL)
- provide document / certification showing that the coffee samples are ~~from Davao re: PhilMech.~~ provided by PhilMech
- provide user manual
- record processing time e.g. drying, sorting, moisture content determination & and overall..

- 1 kilo (sample) MC per 100g sample
- time
- compare MC
- result

- system design (block)
- aesthetics (labelling)
- ni-chrome why?
- consys design again + again ???
  data of block diagrams.

Noted:

[signature]
Engr. Nilo M. Arago
Head, Electronics Engineering Department

Republic of the Philippines
CAVITE STATE UNIVERSITY (CvSU)
Don Severino de las Alas Campus
Indang, Cavite
Tel: (046) 415-0010 / (046) 415-0011 Fax: (046)-0012
E-mail Address: cvsu@asia.com

NATIONAL COFFEE RESEARCH, DEVELOPMENT AND EXTENSION CENTER (NCRDEC)

CERTIFICATE OF APPEARANCE

To whom it may concern:

This is to certify that **Mr. Jan Paul I. Alibayan**, **Mr. Ian Renz C. Bobadilla**, **Mr. Mark Kevin V. Carnicer**, **Mr. Reynaldo T. Pascua, Jr.** and **Mr. Jeschri G. Teodosio** has appeared at this office on **January 15, 2016** for the purpose of **data gathering for their study.**

Signature over Printed Name: RONALD P. PEÑA
Company Name: NCRDEC
Date: January 15, 2016

Republic of the Philippines
Department of Agriculture
Philippine Center for Postharvest Development and Mechanization
Science City of Muñoz, Nueva Ecija, Philippines
www.philmech.gov.ph

CERTIFICATION

This is to certify that the following students conducted laboratory experiments in the Agricultural Mechnanization Division (AMD) of this office for their thesis project on coffee moisture sensor:

1. Alibayan, Jan Paul I.
2. Bobadilla, Ian Renz C.
3. Carnicer, Mark Kevin V.
4. Pascua, Reynaldo Jr.

This further certifies that the herein attached data have been found to be true and actual results of the experimentations conducted.

This certification is being issued as per request of the abovementioned students for whatever legal purposes it may serve best.

ROMUALDO C. MARTINEZ, PhD
Chief, AMD

09 January 2015

Main Office: CLSU, Science City of Muñoz, Nueva Ecija 3120
Tel.No. (044)456-0213 / 282 / 287 /290 Fax No.: (044)456-0110

Liaison Office: 3rd Floor, ATI Bldg., Elliptical Road, Diliman, Quezon City
Tel. No. (02)927-4019. 927-4029 Fax No. (02)926-8159

Republic of the Philippines
Department of Agriculture
Philippine Center for Postharvest Development and Mechanization
Science City of Muñoz, Nueva Ecija, Philippines
www.philmech.gov.ph

CERTIFICATION

This office certifies that the herein listed students from the Technological University of the Philippines (TUP) have conducted validation and evaluation experiments for the project entitled *Development of Configurable MCU-based Coffee Bean Sorter and Moisture Content Corrector using Capacitance Method:*

1. Alibayan, Jan Paul I.
2. Bobadilla, Ian Renz C.
3. Carnicer, Mark Kevin V.
4. Pascua, Reynaldo Jr. T.
5. Teodosio, Jeschri G.

This further certifies that data generated from these experiments are actual and true results.

This certification is being issued upon request of the abovementioned students for whatever legal purposes this may serve.

ROMUALDO C. MARTINEZ, PhD 01/22/2016
Chief, Agricultural Mechanization Division

Main Office: CLSU, Science City of Muñoz, Nueva Ecija 3120
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Tel. No. (02)927-4019. 927-4029 Fax No. (02)926-8159

Republic of the Philippines
Department of Agriculture
Philippine Center for Postharvest Development and Mechanization
Science City of Muñoz, Nueva Ecija, Philippines
www.philmech.gov.ph

CERTIFICATION

This is to certify that on 21 March 2016, the following students conducted testing at the Agricultural Mechanization Division (AMD) of this office for their thesis project on coffee moisture sensor:

1. Alibayan, Jan Paul I.
2. Bobadilla, Ian Renz C.
3. Carnicer, Mark Kevin V.
4. Pascua, Reynaldo Jr.
5. Teodosio, Jeschri, G

This further certifies that the coffee samples used in the testing were made available by PHilMech as part of the Agency's assistance to thesis projects of students.

This certification is being issued as per request of the abovementioned students for whatever legal purposes it may serve best.

ARLENE C. JOAQUIN
Senior Science Research Specialist
Agricultural Instrumentation Section, AMD

21 March 2016

Main Office: CLSU, Science City of Muñoz, Nueva Ecija 3120
Tel.No. (044)456-0213 / 282 / 287 /290 Fax No.: (044)456-0110
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Tel. No. (02)927-4019. 927-4029 Fax No. (02)926-8159

EVALUATION FORM

DEVELOPMENT OF CONFIGURABLE MCU-BASED COFFEE BEAN SORTER AND MOISTURE CONTENT CORRECTOR USING FREQUENCY-DEPENDENT CAPACITANCE METHOD

Direction: Rate the following by placing a cross (X) mark on the box provided.
(1- Poor 2-Fair 3-Satisfactory 4-Very Satisfactory 5-Excellent)

I. General Impact

	1	2	3	4	5
1. Industrial applicability				X	
2. Societal impact			X		
3. Novelty of the project					X

II. Device

Structural Design	1	2	3	4	5
1. Effectivity of the design structure			X		
2. Appropriate use of material			X		
3. Aesthetics				X	
Software System					
1. User-friendly interface				X	
2. Complete interactive operation				X	
3. Accurateness of computed/shown data					

III. Objectives

The device met the stated objectives of:	1	2	3	4	5
1. Portability			X		
2. Accuracy of results/shown data					
3. Processing time	X				
4. Safety provisions				X	

I would recommend this device to others. _____Yes _____No X Not Sure

Remarks:
For further validation of design parameters and design requirements.

Evaluated by:
DONALD V. MATEO

EVALUATION FORM

DEVELOPMENT OF CONFIGURABLE MCU-BASED COFFEE BEAN SORTER AND MOISTURE CONTENT CORRECTOR USING FREQUENCY-DEPENDENT CAPACITANCE METHOD

Direction: Rate the following by placing a cross (X) mark on the box provided.
(1- Poor 2-Fair 3-Satisfactory 4-Very Satisfactory 5-Excellent)

I. General Impact

	1	2	3	4	5
1. Industrial applicability				X	
2. Societal impact			X		
3. Novelty of the project					X

II. Device

Structural Design	1	2	3	4	5
1. Effectivity of the design structure			X		
2. Appropriate use of material			X		
3. Aesthetics				X	
Software System					
1. User-friendly interface				X	
2. Complete interactive operation			X		
3. Accurateness of computed/shown data			X		

III. Objectives

The device met the stated objectives of:	1	2	3	4	5
1. Portability			X		
2. Accuracy of results/shown data			X		
3. Processing time			X		
4. Safety provisions				X	

I would recommend this device to others. _____Yes _____No _____Not Sure

Remarks:

____

____

____

____

Evaluated by:

ERECSON UY
____

____

EVALUATION FORM

DEVELOPMENT OF CONFIGURABLE MCU-BASED COFFEE BEAN SORTER AND MOISTURE CONTENT CORRECTOR USING FREQUENCY-DEPENDENT CAPACITANCE METHOD

Direction: Rate the following by placing a cross (X) mark on the box provided.
(1- Poor 2-Fair 3-Satisfactory 4-Very Satisfactory 5-Excellent)

I. General Impact

	1	2	3	4	5
1. Industrial applicability				✓	
2. Societal impact				✓	
3. Novelty of the project			✓		

II. Device

Structural Design	1	2	3	4	5
1. Effectivity of the design structure			✓		
2. Appropriate use of material				✓	
3. Aesthetics				✓	
Software System					
1. User-friendly interface			✓		
2. Complete interactive operation			✓		
3. Accurateness of computed/shown data			✓		

III. Objectives

The device met the stated objectives of:	1	2	3	4	5
1. Portability			✓		
2. Accuracy of results/shown data			✓		
3. Processing time			✓		
4. Safety provisions			✓		

I would recommend this device to others. ✓ Yes ____ No ____ Not Sure

Remarks:

SEEMS TO BE A PROMISING INVENTION, APPLICABLE TO OTHER CROPS AS WELL.

Evaluated by:

ALLENE C. JOAQUIN

Appendix B

Source Code

APPENDIX B

SOURCE CODES

For Arduino Mega

```
    // include the library code:
#include <LiquidCrystal.h>
#include <Servo.h>
#include <EEPROM.h>
#include <Keypad.h>

Servo servo1;  // create servo object to control a servo
Servo servo2;  // create servo object to control a servo
Servo servo3;  // create servo object to control a servo

// initialize the library with the numbers of the interface pins
LiquidCrystal lcd(2, 3, 4, 5, 6, 7);

Keypad keypad(A0, A1, A2, A3, A4, A5, A6);

const byte Mot1 = 14;
const byte Mot2 = 15;
const byte Mot3A = 10;
const byte Mot3B = 11;
const byte Mot4 = 16;
```

```
const byte Mot5A = 8;
const byte Mot5B = 9;

const byte Heater = 12;
const byte LDR1 = A8;
const byte LDR2 = A10;
const byte CNY = A12;

byte Mot1RunPos = 174;
byte zeroPos1 = 93;
byte Mot2RunPos = 85;
byte Mot4RunPos = 120;
byte zeroPos4 = 9;
//byte zeroPos2 = 90;

byte STAT;
//bit0 = Heater ON/OFF
//bit1 =
//bit2 =
//bit3 =
//bit4 = Main feeder timeout
//bit5 = Sub feeder timeout
//bit6 =
//bit7 =

int level = 100;
int Sensor;
```

```
int QTY;

byte stat;
int debH;
int debL;
int reload = 25;
byte stat1;
int debH1;
int debL1;
int reload1 = 100;

char  Data[20] ;         // to hold incoming data
boolean DataComplete = false;  // whether the string is complete
byte count;

unsigned long timeout;
unsigned long Refresh;
byte menu = 0;
char key;
byte keycount;

unsigned int Set[3];

byte Index;
char Buff[30];

unsigned int PASSWORD = 1234;
```

```
void setup() {
  lcd.begin(20, 4);
  Serial.begin(9600);

  pinMode(LDR1, INPUT_PULLUP);
  pinMode(LDR2, INPUT_PULLUP);
  pinMode(A9, OUTPUT);
  pinMode(A11, OUTPUT);
  pinMode(Mot3A, OUTPUT);
  pinMode(Mot3B, OUTPUT);
  pinMode(Mot5A, OUTPUT);
  pinMode(Mot5B, OUTPUT);

  pinMode(Heater, OUTPUT);

  servo1.attach(Mot1);
  servo1.write(zeroPos1);        // tell servo to go to position
  servo3.attach(Mot4);
  servo3.write(zeroPos4);        // tell servo to go to position

  ReadSave();

//Test key
  key = keypad.scankey();
  if(key == '1') {
    menu=3;
```

```
        Display();
        keypad.w8_key_release();
    }
    else
    {
        menu = 0;
//      delay(2000);
    }
    Display();
}

void loop() {

    if(menu == 0) {
        key = keypad.scankey();
        if(key == '#') {
            menu = 1;
            Display();
            timeout = millis();
            RUN();
            menu = 0;
            keypad.w8_key_release();
        }
        if(key == '*') {
            menu = 2;
            Display();
            keypad.w8_key_release();
```

```
    }
  }
  if(menu == 2) {
    key = keypad.scankey();
    if(key == '8') {        //HOLD/RELEASE
      Serial.print(key);
      servo3.write(Mot4RunPos);             // tell servo to go to position
      keypad.w8_key_release();
      servo3.write(zeroPos4);             // tell servo to go to position
    }
    if(key == '1') {        //HOLD/RELEASE
      Serial.print(key);
      servo1.write(Mot1RunPos);             // tell servo to go to position
      keypad.w8_key_release();
      servo1.write(zeroPos1);             // tell servo to go to position
    }
    if(key == '7') {        //HOLD/RELEASE
      Serial.print(key);
      servo2.attach(Mot2);
      servo2.write(Mot2RunPos);             // tell servo to go to position
      keypad.w8_key_release();
      servo2.detach();             // tell servo to go to position
    }
    if(key == '4') {        //HOLD/RELEASE
      Serial.print(key);
      analogWrite(Mot3A, 80);
      keypad.w8_key_release();
```

```
    digitalWrite(Mot3A, LOW);
  }
  if(key == '2') {        //HOLD/RELEASE
    Serial.print(key);
    digitalWrite(Mot5A, HIGH);
    keypad.w8_key_release();
    digitalWrite(Mot5A, LOW);
  }
  if(key == '5') {        //HOLD/RELEASE
    Serial.print(key);
    digitalWrite(Mot5B, HIGH);
    keypad.w8_key_release();
    digitalWrite(Mot5B, LOW);
  }
  if(key == '0') {        //Heater ON/OFF
    if(STAT & 0x01)
    {
      digitalWrite(Heater, LOW);
      STAT &= ~0x01;
    }
    else
    {
      digitalWrite(Heater, HIGH);
      STAT |= 0x01;
    }
    keypad.w8_key_release();
  }
```

```
    if(key == '*') {
        menu = 0;
        Display();
        keypad.w8_key_release();
    }
}

if(menu == 4) {
    key = keypad.scankey();
    if(key == '*') {
        menu=0;
        Display();
        keypad.w8_key_release();
    }
    if(key == '1') {
        menu=11;
        Display();
        keypad.w8_key_release();
    }
}
if(menu == 11) {
    key = keypad.scankey();
    if(key == '*') {
        menu=2;
        Display();
        keypad.w8_key_release();
    }
```

```
    if(key == '1') {
        Index = 1;
        menu=12;
        Display();
        keypad.w8_key_release();
    }
    if(key == '2') {
        Index = 2;
        menu=12;
        Display();
        keypad.w8_key_release();
    }
    if(key == '3') {
        Index = 3;
        menu=12;
        Display();
        keypad.w8_key_release();
    }
}
if(menu == 12) {
        lcd.setCursor(8,2);
        lcd.blink();
    keycount = 0;
    while(keycount < 4 && key != '*')
    {
        key = keypad.scankey();
        if(key == '*') {
```

```
    lcd.noBlink();
    menu=11;
    Display();
    keypad.w8_key_release();
}
if(key == '#') {
    Buff[keycount] = ',';
    keycount=4;
    keypad.w8_key_release();
}
if(key >= '0' && key <= '9' && keycount == 0) {
    lcd.print(key);
    Buff[0] = key;
    keycount++;
    keypad.w8_key_release();
    continue;
}
if(key >= '0' && key <= '9' && keycount == 1) {
    lcd.print(key);
    Buff[1] = key;
    keycount++;
    keypad.w8_key_release();
    continue;
}
if(key >= '0' && key <= '9' && keycount == 2) {
    lcd.print(key);
    Buff[2] = key;
```

```
            keycount++;
            keypad.w8_key_release();
            continue;
        }
        if(key >= '0' && key <= '9' && keycount == 3) {
            lcd.print(key);
            Buff[3] = key;
            keycount++;
            keypad.w8_key_release();
        }
        if(keycount == 4)
        {
            Buff[4] = ',';
            Serial.print(Buff);
            Set[Index-1] = atoi(Buff);
            if(Set[Index-1] > 1023)
                Set[Index-1] = 1023;
            EEPROM.write((Index-1)*2, Set[Index-1] >> 8);
            EEPROM.write(((Index-1)*2)+1, Set[Index-1] & 0xFF);
            lcd.noBlink();
            menu=4;
            Display();
        }
    }
}
if(menu == 3) {
        lcd.setCursor(8,1);
```

```
    lcd.blink();
  keycount = 0;
  while(keycount < 4 && key != '*')
  {
    key = keypad.scankey();
    if(key == '*') {
      lcd.noBlink();
      menu=1;
      Display();
      keypad.w8_key_release();
    }
//    if(key == '#') {
//      keycount=4;
//      w8_key_release();
//    }
    if(key >= '0' && key <= '9' && keycount == 0) {
      lcd.print(key);
      Buff[0] = key;
      keycount++;
      keypad.w8_key_release();
      continue;
    }
    if(key >= '0' && key <= '9' && keycount == 1) {
      lcd.print(key);
      Buff[1] = key;
      keycount++;
      keypad.w8_key_release();
```

```
        continue;
      }
      if(key >= '0' && key <= '9' && keycount == 2) {
        lcd.print(key);
        Buff[2] = key;
        keycount++;
        keypad.w8_key_release();
        continue;
      }
      if(key >= '0' && key <= '9' && keycount == 3) {
        lcd.print(key);
        Buff[3] = key;
        keycount++;
        keypad.w8_key_release();
      }
      if(keycount == 4)
      {
        Buff[4] = ',';
        Serial.print(Buff);
        if(atoi(Buff) == PASSWORD)
          menu = 4;
        else
          menu = 0;
        Display();
      }
    }
  }
```

```
  if((millis() - Refresh)  >= 1000){  //1 sec
    Refresh = millis();
      Display();
  }

}

long tarefreq;
long freq;

void RUN()
{
start:
  analogWrite(Mot3A, 80);        //run main feeder
  QTY = 0;
  while(QTY < 30 && (millis() - timeout) < 10000)
  {
    Fetch(LDR1);
  }
  digitalWrite(Mot3A, LOW);
  if(QTY == 0)
  {
    menu = 0;
    return;
  }
  delay(1000);
```

```
    digitalWrite(Heater, HIGH);
    delay(Set[0] * 1000);
//    delay(10000);
    digitalWrite(Heater, LOW);

//    insert cooling time
    servo1.write(Mot1RunPos);              // tell servo to go to position
    delay(2000);
    servo1.write(zeroPos1);              // tell servo to go to position
test:
    Serial.print("WTA\r");
        clearString(Data);
        count = 0;
        DataComplete = false;
    while(!(DataComplete)) {
        serialPoll();
    }
//    Serial.println(Data);
    tarefreq = atol(Data+4);
    Serial.println(tarefreq);

    timeout = millis();
    servo2.attach(Mot2);
    servo2.write(Mot2RunPos);              // tell servo to go to position
    QTY = 0;
    while(QTY < 1 && (millis() - timeout) < 10000)
    {
```

```
     Fetch(LDR2);
   }
   servo2.detach();              // tell servo to go to position
   if(QTY == 0)
   {
     goto start;
   }
//   delay(1500);

   Serial.print("WTA\r");
     clearString(Data);
     count = 0;
     DataComplete = false;
   while(!(DataComplete)) {
     serialPoll();
   }
//   Serial.println(Data);
   freq = atol(Data+4);
   Serial.println(freq);
   Serial.println(tarefreq - freq);

   if(Set[1] == 9)
   {
     if((tarefreq - freq) <14)
     {
       lcd.setCursor(0,1);
       lcd.print("     DRY BEAN     ");
```

```
      Dry();
    }
    else if((tarefreq - freq) <18)
   {
      lcd.setCursor(0,1);
      lcd.print("      GOOD BEAN      ");
       Good();
   }
    else
    {
      lcd.setCursor(0,1);
      lcd.print("   UNDERDRIED BEAN   ");
       Back();
    }
}
if(Set[1] == 10)
{
    if((tarefreq - freq) < 18)
    {
      lcd.setCursor(0,1);
      lcd.print("      DRY BEAN      ");
       Dry();
    }
    else if((tarefreq - freq) < 23)
    {
      lcd.setCursor(0,1);
      lcd.print("      GOOD BEAN      ");
```

```
      Good();
    }
    else
    {
      lcd.setCursor(0,1);
      lcd.print("   UNDERDRIED BEAN   ");
      Back();
    }
  }
  if(Set[1] == 11)
  {
    if((tarefreq - freq) < 23)
    {
      lcd.setCursor(0,1);
      lcd.print("      DRY BEAN      ");
      Dry();
    }
    else if((tarefreq - freq) <33)
    {
      lcd.setCursor(0,1);
      lcd.print("      GOOD BEAN      ");
      Good();
    }
    else
    {
      lcd.setCursor(0,1);
      lcd.print("   UNDERDRIED BEAN   ");
```

```
          Back();
        }
    }
    if(Set[1] == 12)
    {
        if((tarefreq - freq) < 33)
        {
          lcd.setCursor(0,1);
          lcd.print("     DRY BEAN     ");
           Dry();
        }
        else if((tarefreq - freq) < 37)
       {
          lcd.setCursor(0,1);
          lcd.print("     GOOD BEAN     ");
           Good();
       }
        else
        {
          lcd.setCursor(0,1);
          lcd.print("   UNDERDRIED BEAN   ");
           Back();
        }
    }
//   Good();
    goto test;
}
```

```
void Dry()
{
   digitalWrite(Mot5A, HIGH);
   QTY = 0;
   while(QTY < 1)
   {
      Fetch1();
   }
   digitalWrite(Mot5A, LOW);
   servo3.write(Mot4RunPos);              // tell servo to go to position
   delay(3000);
   servo3.write(zeroPos4);               // tell servo to go to position
   delay(1000);
   digitalWrite(Mot5B, HIGH);
   delay(5000);
   digitalWrite(Mot5B, LOW);
}

void Good()
{
   digitalWrite(Mot5A, HIGH);
   QTY = 0;
   while(QTY < 2)
   {
      Fetch1();
   }
```

```
  digitalWrite(Mot5A, LOW);
  servo3.write(Mot4RunPos);            // tell servo to go to position
  delay(3000);
  servo3.write(zeroPos4);            // tell servo to go to position
  delay(1000);
  digitalWrite(Mot5B, HIGH);
  delay(7000);
  digitalWrite(Mot5B, LOW);
}

void Back()
{
  digitalWrite(Mot5A, HIGH);
  delay(15000);
  digitalWrite(Mot5A, LOW);
  servo3.write(Mot4RunPos);            // tell servo to go to position
  delay(3000);
  servo3.write(zeroPos4);            // tell servo to go to position
  delay(1000);
  digitalWrite(Mot5B, HIGH);
  delay(8000);
  digitalWrite(Mot5B, LOW);
}

void Fetch(byte pin)
{
  Sensor = analogRead(pin);
```

```
  if(Sensor < level) {
    debL = reload;
    if(debH > 0)
      debH--;
    else if(!stat){
//          Serial.print("WTAOFF1\r");
      stat = 1;
    }
  }
  else {
    debH = reload;
    if(debL > 0)
      debL--;
    else if(stat){
      stat = 0;
      QTY++;
      timeout = millis();
      Serial.println(QTY);
    }
  }
}

void Fetch1()
{
  if(digitalRead(CNY)) {
    debL1 = reload1;
    if(debH1 > 0)
```

```
        debH1--;
      else if(!stat1){
//          Serial.print("WTAOFF1\r");
        stat1 = 1;
      }
    }
    else {
      debH1 = reload1;
      if(debL1 > 0)
        debL1--;
      else if(stat1){
        stat1 = 0;
        QTY++;
        timeout = millis();
        Serial.println(QTY);
      }
    }
}

void Display()
{
    //delay(2000);
    lcd.begin(20, 4); //DISPLAY REFRESH
    if(menu == 0)
    {
        lcd.setCursor(0,0);
        lcd.print("    KOFFIE RIGHT    ");
```

```
        lcd.setCursor(0,1);
        lcd.print("   MOISTURE RIGHT   ");
        lcd.setCursor(0,2);
        lcd.print("      BS ECE      ");
        lcd.setCursor(0,3);
        lcd.print("       TUP        ");
      }

  if(menu == 1)
  {
        lcd.setCursor(0,0);
        lcd.print("   Running...     ");
        lcd.setCursor(0,1);
        lcd.print("                ");
        lcd.setCursor(0,2);
        lcd.print("                ");
        lcd.setCursor(0,3);
        lcd.print("                ");
  }

  if(menu == 2)
  {
        lcd.setCursor(0,0);
        lcd.print("                ");
        lcd.setCursor(0,1);
        lcd.print("      MANUAL      ");
        lcd.setCursor(0,2);
```

```
        lcd.print("       MODE       ");
        lcd.setCursor(0,3);
        lcd.print("                    ");
    }

    if(menu == 4)
    {
        lcd.setCursor(0,0);
        lcd.print("Set Heating Time = ");
    lcd.print(Set[0]);
        lcd.setCursor(0,1);
        lcd.print("Set MC = ");
    lcd.print(Set[1]);
        lcd.setCursor(0,2);
        //lcd.print("Set3 = ");
    //lcd.print(Set[2]);
        lcd.setCursor(0,3);
        lcd.print("1. Edit Set Values  ");
    }

    if(menu == 3)
    {
        lcd.setCursor(0,0);
        lcd.print("   ENTER PASSWORD   ");
        lcd.setCursor(0,1);
        lcd.print("                    ");
        lcd.setCursor(0,2);
```

```
    lcd.print("                    ");
    lcd.setCursor(0,3);
    lcd.print("                    ");
}

if(menu == 11)
{
    lcd.setCursor(0,0);
    lcd.print("1. Set Heat Time ");
    lcd.setCursor(0,1);
    lcd.print("2. Set MC           ");
    lcd.setCursor(0,2);
    //lcd.print("3. Set3             ");
    //lcd.setCursor(0,3);
    //lcd.print("                    ");
}

if(menu == 12)
{
    lcd.setCursor(0,0);
    lcd.print("                    ");
    lcd.setCursor(0,1);
    lcd.print("Enter Count (0-1000)");
    lcd.setCursor(0,2);
    lcd.print("                    ");
    lcd.setCursor(0,3);
    lcd.print("                    ");
```

```
    }
}

void ReadSave()
{
    Set[0] = (EEPROM.read(0) << 8) | EEPROM.read(1);
    Set[1] = (EEPROM.read(2) << 8) | EEPROM.read(3);
    Set[2] = (EEPROM.read(4) << 8) | EEPROM.read(5);
}

void serialPoll() {
    while (Serial.available()) {
        char inChar = (char)Serial.read();      // get the new byte:
        if(count == 0 && inChar != 'W')
            continue;
        if((count == 1 && inChar != 'T') || (count == 2 && inChar != 'A')) {
            clearString(Data);
            count = 0;
            continue;
        }
        // if the incoming character is a newline, set a flag
        // so the main loop can do something about it:
        if (inChar == '\r') {
            DataComplete = true;
            return;
        }
        if(count < 19 && DataComplete == false) {
```

```
        // add it to the inputString:
          Data[count] = inChar;
          count++;
        }
    }
}

void clearString(char *strArray) {
  int j;
  for (j = 20; j > 0; j--)
    strArray[j] = 0x00;

}
```
For Arduino Uno

```
            #include <FreqCounter.h>

unsigned long frequency;
unsigned long frq;
int cnt;
int pinLed=13;
byte samples = 20;

char  Data[20] ;         // to hold incoming data
boolean DataComplete = false;  // whether the string is complete
byte count;
a
void setup() {
    pinMode(pinLed, OUTPUT);
```

```
  Serial.begin(9600);        // connect to the serial port

  FreqCounter::f_comp=10;   // Cal Value / Calibrate with professional Freq Counter
  FreqCounter::start(100);  // 100 ms Gate Time
  while (FreqCounter::f_ready == 0)
  frq=FreqCounter::f_freq;
}

int d;

void loop() {
  if (DataComplete) {
  frequency = 0;
  for(d=0; d<samples; d++)
  {
    // wait if any serial is going on
    FreqCounter::f_comp=10;   // Cal Value / Calibrate with professional Freq Counter
    FreqCounter::start(100);  // 100 ms Gate Time

    while (FreqCounter::f_ready == 0)

    frq=FreqCounter::f_freq;
    frequency += frq;
//        Serial.println(frequency);
  }
  frequency = frequency / samples;
```

```
    Serial.print("WTA,");
    Serial.println(frequency);
    Serial.print("\r");
//    delay(20);
    digitalWrite(pinLed,!digitalRead(pinLed));  // blink Led

        clearString(Data);
        count = 0;
        DataComplete = false;
    }

}

/*
  SerialEvent occurs whenever a new data comes in the
 hardware serial RX.  This routine is run between each
 time loop() runs, so using delay inside loop can delay
 response.  Multiple bytes of data may be available.
 */
void serialEvent() {
  while (Serial.available()) {
    // get the new byte:
    char inChar = (char)Serial.read();

    if(count == 0 && inChar != 'W')
      continue;
    if((count == 1 && inChar != 'T') || (count == 2 && inChar != 'A')) {
```

```
      clearString(Data);
      count = 0;
      continue;
    }
    // add it to the inputString:
    if (inChar == '\r') {
    //  digitalWrite(led, HIGH);
      DataComplete = true;
      return;
    }
    if(count < 19 && DataComplete == false) {
      Data[count] = inChar;
      count++;
    }
    // if the incoming character is a newline, set a flag
    // so the main loop can do something about it:
  }
}

void clearString(char *strArray) {
  int j;
  for (j = 20; j > 0; j--)
    strArray[j] = 0x00;
}
```

Appendix C

Validation of Results

APPENDIX C

VALIDATION RESULTS

Batch	Initial weight (g)	Final weight (g)	Device	Actual
1	100.1347	87.8035	12%	12.31461222%
2	100.0376	88.1032	12%	11.92991435%
3	100.1031	87.8552	12%	12.23528542%
4	99.9831	89.2134	11%	10.77152039%
5	100.0032	89.0345	11%	10.96834901%
6	100.0683	88.7453	11%	11.31527167%
7	99.932	90.0032	10%	9.935556178%
8	100.2054	89.8034	10%	10.38067809%
9	100.0634	90.1095	10%	9.947593226%
10	100.0937	91.324	9%	8.761490483%
11	100.1047	91.2045	9%	8.890891237%
12	100.0935	90.8734	9%	9.211487259%

Appendix D

User's Manual

APPENDIX D

USER’S MANUAL

Technological University of the Philippines
College of Engineering
Electronics Engineering Department

Koffie RIGHT

User's Manual

TABLE OF CONTENTS

i

Introduction

Good moisture management is needed in the storing stage of post-harvest practice of coffee farming to prevent the growth of bacteria, fungi, moulds, and yeasts as well as insect infestation and spoilage. It increases the maximum yield of coffee farmers by ensuring premium quality coffee beans that can be sold at

- Determines the moisture content of Green Coffee Beans.
- Classify and sorts the green coffee beans as under dried, dried, and over dried.
- Corrects the moisture content of green coffee beans using hot-air drying.
- Increases the maximum yield of coffee

1

Parts of Koffie Right

2

Sensor—uses copper parallel plates that serves as the capacitor of the timing circuit. The capacitance varies as the dielectric between the plates changes.

Segregator/Sorter – made up of sintra board, servo and gear motors that are controlled by Arduino.

Moisture Corrector—an Arduino-controlled dryer that uses hot-air drying to dry the green coffee beans

3

Keypad —used to configure the parameters of the device and display the classification of coffee beans.

Storage Bins —the device separates the coffee beans according to their respective moisture content and place

Exhaust fan—used to maintain the temperature and humidity inside the device.

4

How to Operate the Device

1. Plug the AC cord of the device to 220V AC outlet connection.
2. Turn on the device while pressing the number " 1" key.

5

How to Operate the Device

3. Enter the password " 1234 " .

4. Set the Moisture content, drying time and the number of beans.

5. Press " * " key to go back and edit the parameters.
6. Press " # " to run the device.

6

Safety and Notice

This section contains important information pertaining to correct and safe usage of the device. Read carefully before using the device.

- Be sure to follow the scope and limitations of the device.
- Power off the device when not in use. Keep the device away from children.
- The device uses conveyor belts and a feedback system in order to operate. Do not misalign the segregator and feedback system.
- Keep the device dry. Precipitation and humidity may corrode electronics circuits.
- Do not expose the device under direct sunlight or under the rain. Too high or too low temperature affects the reading of the sensor.

Troubleshooting

Be sure to follow the scope and limitations of the device.

Always check the power connection of the device.

- When the feeder system is not working, check its connection to the motor driver circuit then the connection of the motor driver to the microcontroller.
- When multiple beans goes to the sensor for measuring, check the size of the green coffee beans and the position of the laser and the light-dependent resistor.
- When the heater doesn't produce heat, check its connection to the transformer then the connection of the transformer to the relay driver.

Maintenance of the Device

- Occasionally, clean the device and the storage bins to avoid contamination.

About us

The Proponents

- Reynaldo T. Pascua, Jr.
- Mark Kevin V. Carnicer
- Ira C. Valenzuela—Adviser
- Jan Paul I. Alibayan
- Jeschri G. Teodosio

Appendix E

Bill of Materials

APPENDIX E

BILL OF MATERIALS

PARTICULARS	QUANTITY	PRICE PER UNIT	AMOUNT
Arduino Mega	1 pc	1,100.00	1,100.00
Arduino Uno	1 pc	795.00	795.00
Transformer	1 pc	600.00	600.00
4x20 LCD	1 pc	750.00	750.00
Keypad	1 pc	115.00	115.00
SMPS	1 pc	275.00	275.00
AC to DC Adaptor	2 pcs	200.00	200.00
AC Switch	1 pc	18.00	18.00
Strainer	1 pc	30.00	30.00
Laser	2 pcs	20.00	40.00
LDR	2 pcs	10.00	20.00
Relay Circuit	1 pc	100.00	100.00
L293D	1 pc	215.00	215.00
CNY70 Comparator	1 pc	100.00	100.00
Servo Motor	4 pcs	600.00	2,400.00
DC Motor	1 pc	390.00	390.00
Nichrome Wire	1 pc	30.00	30.00
Sintra Board	1 cut	600.00	600.00
Aluminum Frame	1 cut	200.00	200.00
AC Cord	1 pc	25.00	25.00
Arcylic	1 cut	500.00	500.00
Copper Plate	2 pcs	30.00	60.00
Miscellaneous			375.00
		TOTAL	**P 8,938.00**

Appendix F

Project Documentation

APPENDIX F

PROJECT DOCUMENTATION

Coffee Bean Samples to be tested

Measuring the weight of single coffee bean sample

Testing of the prototype

Oven Drying Method of Coffee Bean Samples

After Validation of the Results together with the head of AMD Dr. Romualdo C. Martinez and Engr. Arlene C. Joaquin

Appendix G

Proponents' Profile