Green Coffee Bean Sorter and Corrector based on Moisture Content using Capacitive Method

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Green Coffee Bean Sorter and Corrector based on Moisture Content using Capacitive Method

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***Abstract* - In postharvest farming, moisture content is important in determining the quality and controlling the cost of the coffee beans. However, meeting the right moisture level of the coffee bean is one of the common challenges in the coffee industry. Nonetheless, this study proposes a capacitance-based moisture measurement with quality and moisture corrector. The system is composed of electrical plates, microcontroller, built-in dryer and display. A software program was developed to determine the moisture content of the bean and classify it based on the set value of moisture content for high quality coffee bean. A built-in dryer is included to correct the moisture content of under dried coffee beans. The developed system is designed to be stand-alone and it prohibits human intervention unless during loading and unloading of the beans. Based on the results, the system can sort the beans according to moisture content and is able to measure the moisture content with 91.67% accuracy.**

Index Terms— Capacitance, Green Coffee, Moisture Corrector, Moisture Meter

I. INTRODUCTION

Water content or moisture content is the quantity of water contained in a material. In agriculture, moisture content level is a very important factor in postharvest practice of farming. Also, it is one of the keys to quality and cost control. Fermentation, drying, storage [1], marketing and roasting are important aspects of handling farm products where moisture content plays an important role [2]. According to the study conducted by the Food and Agriculture Organization of the United Nations, unable to meet the right moisture content level of grains and seeds results in heat buildup, mold growth, insect infestation, loss in seed germination and additional transport cost that cripples a whole year worth of harvest.

Too high or too low moisture content will result to a low cupping quality of coffee beans [3] [4]. Coffee beans that have low moisture will shrink and become distorted and have a low-quality coffee with low market value [5]. It also deteriorates due to bacteria, mold, yeast or fungi that are capable of producing mycotoxins that can harm or kill humans if consumed [6]. To avoid these problems moisture level of the beans must be lowered to 12% soon after harvest. One way to ensure the quality of coffee beans is to monitor its moisture content [7]. There are different ways to measure the moisture content of beans but these are time consuming laboratory methods [8] [9] [10]. A convenient moisture meter is a necessity to meet the requirements of the farmers, storage personnel and agricultural corporations [11].

This study aims to develop a simple and fast method of determining and correcting the moisture content of green coffee beans. Further, the system will be able to determine the moisture content of a single green coffee using frequency-dependent capacitance method. Also, a capacitive-type sensor that will be used in determining the moisture content of the coffee bean will be designed. An algorithm and software that will assess the moisture content level of the coffee beans using C++ programming language will be developed. The system can also be able to of the coffee bean.

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. 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.

II. MOISTURE CONTENT AND CAPACITIVE MEASUREMENT

Capacitance frequency dependence was the method employed in this research [12]. This method focuses on determining the relationship between the dielectric of the capacitive plates and the frequency [13] [14] [15]. In this paper, the variations in frequency resulting from the different amounts of water as dielectric were analyzed. The research began by developing a hypothesis regarding the sensitivity of the response of the frequency as the dielectric of the capacitor changes. A series of experiments were conducted for a certain number of specimens to further investigate and validate the reliability and accuracy of the device.

The capacitive type of measurement similarly works with capacitor. An electric field is created by the capacitor once the two conductive plates are biased. Figure 1 shows the capacitor where A is the area of the plate, D is the distance between the plates and ε is the permittivity of the material.

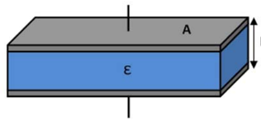

Fig 1. Capacitor

Equation 1 shows that the capacitance is directly proportional to the area and permittivity of the material and inversely proportional with the distance between plates [1].

$$C = \frac{\varepsilon A}{D}$$

When the area and the distance between plates are kept constant, the capacitance will be based only in the permittivity of the material. This principle is used in the capacitive type of measurement. The permittivity of different materials is shown in Figure 2. It can be seen that water has the highest permittivity compared to other bulk solid materials.

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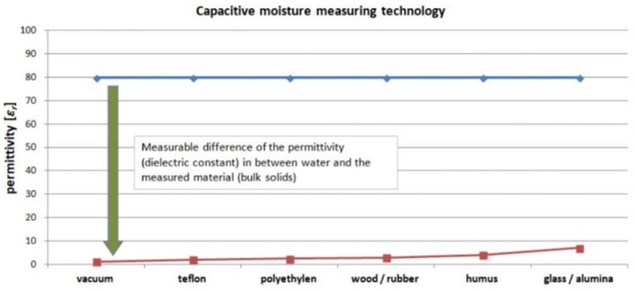

Fig 2. Capacitive Moisture Measuring Technology

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% [10].

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 [14].

In the study conducted by [15], 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.

III. Methodology

Figure 3 presents the block diagram of the system. The input of the system is the coffee bean sample. The moisture level will be measured and will be sorted according to the prescribed moisture content. The output will be the sorted beans. If the bean is under dried, it will undergo the drying procedure and repeat the process.

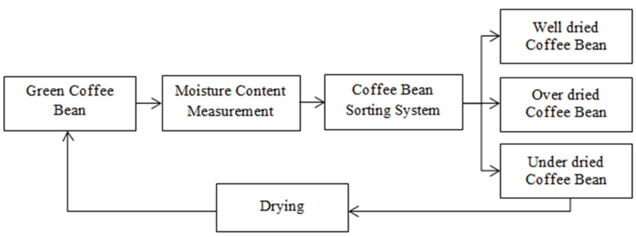

Fig 3. Block Diagram of the System

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 microcontroller unit module is responsible for the movement of these motors. Capacitive type measurement is used in the sensor part of the prototype. Analog outputs are converted to digital signals and fed on the microcontroller unit module. For the drying section, nichrome wire is used. This provides approximately 40 degrees Centigrade to lessen the moisture content of the bean.

Figure 4 illustrates the physical layout of the system the isometric view which summarizes the whole view of the system. The front view of the system includes the control section and display unit. The display unit used is a 4 lines x 20-character liquid crystal display (LCD) that needs a 5V power. It shows the moisture content of the bean and is directly connected to the microcontroller circuit.

Fig 4. Actual Prototype

The hardware and the dimensions shown in Figure 5 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.

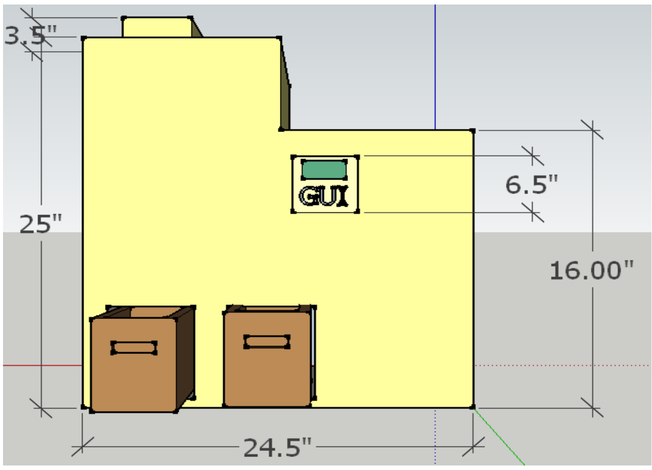

Fig 5. Dimensions of the Prototype

The platform used in developing the prototype is the Arduino UNO and Arduino MEGA. These electronic circuits are programmed using C language to carry out a vast range of task. Figure 6 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 will 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.

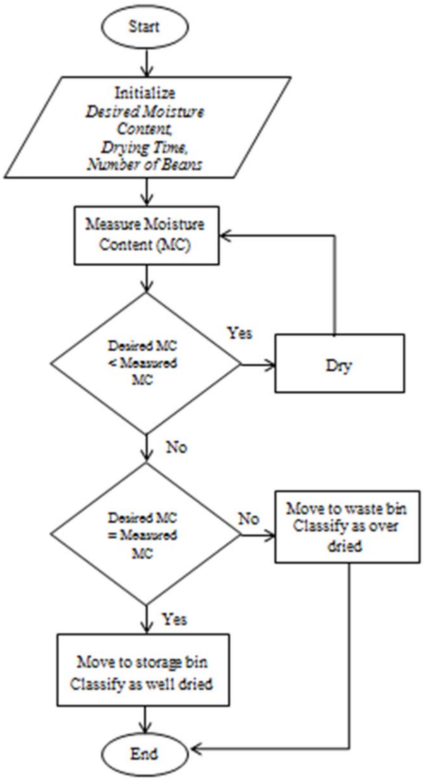

Fig 6. Program Flowchart

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 personnel's 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.

IV. Results and Discussions

This device 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.

Standard method of determining the moisture content was used in calibrating the moisture content reading of the device Forty (40) coffee bean samples are taken from a 100-gram sample using random sampling. A total of 1160 green coffee beans were 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°C 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 moisture content of the coffee bean is computed using Equation 2 [2].

$$Moisture\ Content = \frac{Initial\ Weight - Dried\ Weight}{Initial\ Weight} x\ 100\%$$

Figure 7 shows the relationship of moisture content (%) and frequencies (Hz). It can be observed that the relationship is linear. Furthermore, according to the test of correlation, the percent moisture and frequency is 0.9054 correlated implying that the data is related.

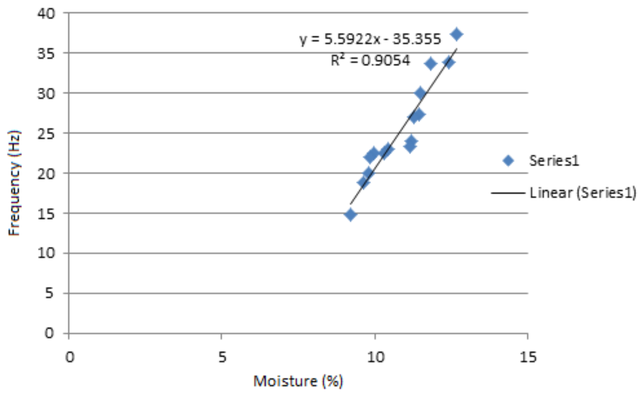

Fig 7. Moisture Content vs Frequency

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 1. Correlation of Training Parameters

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

Table 2 shows the comparison of the moisture content between measured output of the device and the computed moisture content (actual). 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 this is functional and reliable.

TABLE 2. Comparison of Actual and Measured Moisture Content of Coffee Bean

Sample	Initial Weight (g)	Final Weight (g)	Measured Moisture Content (%)	Actual Moisture Content (%)
1	100.14	87.80	12.31	12
2	100.04	88.10	11.93	12
3	100.10	87.86	12.24	12
4	99.98	89.21	10.77	11
5	100.00	89.03	10.97	11

6	100.07	88.75	11.31	11
7	100.09	91.32	8.76	11
8	99.93	90.00	9.93	10
9	100.21	89.80	10.38	10
10	100.06	90.11	9.95	10
11	100.10	91.20	8.89	9
12	100.09	90.87	9.21	9

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. 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.

V. Conclusion

The algorithm developed in this study which able to read the difference in frequencies and to transfer the bean from one point to another was successfully implemented using C++ programming language. The device accomplished in sorting the beans according to its moisture content based on the desired level. The study was successfully implemented and done. However, it is recommended to study the use of multiple sensors for simultaneous measuring and faster sorting mechanism to increase the output over time. Also, a dryer can be separated from the sorter to dry large amount green coffee at the same time.

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