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Test Frequency Optimization Using Single Factor ANOVA for Capacitive Oil Palm Fruit Ripeness Sensor

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Abstract. The traditional method of palm oil fruit ripeness grading requires manual human observation imposing time consumption. This paper describes the work to determine best frequency gritted for capacitive ripeness grading. To find the ripeness, the frequency response of ripe and unripe fruitlet in between capacitive plates is evaluated. Parallel plate that is connected to resistor in series is used as the sensor. The function generator is used to give a sinusoidal wave frequency or known as Vin that gives input from 20 kHz to 300 kHz and the oscilloscope is used to obtain the output reading which is the difference in value of the Vpp. From the result, it is observed that there is difference between ripe and unripe fruitlet also the frequency of 100 kHz and below shows that the reading can be differentiate between fruitlet. After the frequency past the 100 kHz the reading is hard to differentiate before at one point the graph will become static even the weight of each fruitlet is difference.

1. Introduction

The palm oil industry extract oil from the palm fruit and the technique used to pluck the fresh fruit bunches (FFB) is mainly used based on the grading by human. Using this method, the oil palm FFB will be determining by a harvester whether it is matured enough to be harvested. The importance of the FFB to be matured enough before harvesting is to make sure the oil extracted from mesocarp is maximum. If the FFB is harvested not in the right time zone of ripeness the quantity of the oil that get extract will decrease than what have been expected. When this condition occurs, it may induce losses to the producers.

There are few drawbacks when using the conventional method in determining or grading the oil palm fruit or bunch. There might be misunderstanding among the human expert and resulting to a different grading results. Another reason is because the time consuming to determine the grade of the oil palm is too long, and this is not practical in an industry that prioritize time management. Therefore, an automated fruit grading system that is reliable, accurate and less time consuming is demanded.

This study intents to evaluate the ripeness of the oil palm fruitlet using capacitive sensing, particularly to distinguish the frequency response of ripe and unripe fruitlet in between capacitive plates. The function generator is used to generate a sinusoidal wave frequency or known as Vin that gives input from 20 kHz to 300 kHz and the oscilloscope is used to obtain the output reading whichobserves value difference of the Vpp. 60 fruitlets of oil palm fruit has been tested to collect the Vpp reading.

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2. Related Work

Scientist reported investigation on prediction of banana quality during ripening stage using capacitance sensing system(Husin, Aziz, & Ahmad, 2008; Sankhe, 2015; M. Soltani, Alimardani, & Omid, 2010, 2011; Mahmoud Soltani, Alimardani, & Omid, 2011). In this paper, capacitive property of banana fruit was studied in order to develop a rapid and non-invasive ripening assessment method to control their ripening treatment. A sine wave frequency generator with parallel plate's capacitor sample was used to spot the changes of the capacitance, where it is trigger by the present of banana fruit into the sensor.

These researchers show employing dielectric properties in sensing quality parameters and other properties of agricultural products. To predict quality factors of banana fruits, measured changes in the firmness of banana fruits during the ripening treatment by means of a sonic technique tried to apply a delayed light emission to evaluate ripening quality of banana fruits evaluated changes in quality of ripening bananas using light reflectance technique. Optical chlorophyll is used in sensing system for banana ripening. The seat tempts were fundamental approaches and they were far from reaching a practical application. Therefore, it is a wise decision to develop a system that is used to evaluate the banana ripening quality. The purpose of this study was to obtain some basic data to estimate ripening quality of banana fruits during the ripening treatment by capacitance properties, aiming to apply the capacitance technique and turn it into automatic control system.

The soluble solid contents usually act as the quality indicators. This soluble solid content is acquired from the samples of internal tissue. The test carried out to get the contents is called as a destructive test. The process of this experiment started with the 10g of banana flesh is sampled and is diluted in a blender together with 50 g of distilled water for a 1-minute period. Refractometer is used to measure the 10 g soluble solids content which each stage is done with three replications. Using Instron universal testing machine the firmness of the banana pulp is measured. The model of the machine is SANTAM ST-5 that equip with an 8 mm cylindrical probe. The head speed of the testing machine is set to 50 mm/min. the maximum forced that are used to make the tissue failure describe the firmness. To get the firmness accurate value it is measure 2 cm away from the centre of the fruit.

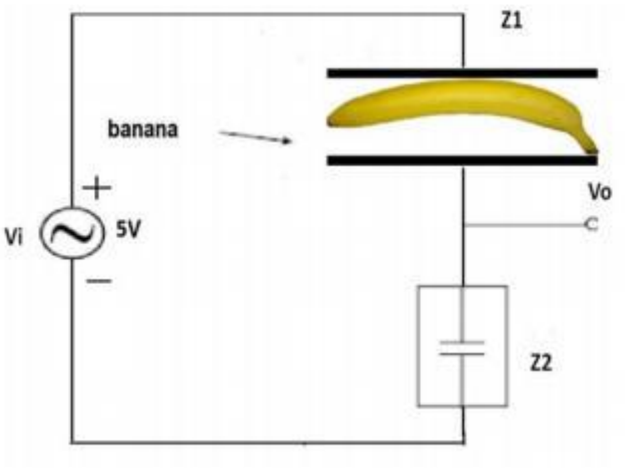


Figure 1: Sensor in a voltage divider setup (Mahmoud Soltani et al., 2011)

In the year of 2014, A. A. Bhosale and K. K. Sundaram have publish their work on the firmness prediction of the apple using capacitance measurement(Bhosale & Sundaram, 2014). Using the parallel-plate capacitor, study is conducted on the non-destructive fruit firmness based on capacitive properties testing method. The dielectric of the apple is as the target to find the fruit firmness. The sample of the apple has been stored at room temperature, and the apples are randomly selected from apple boxes. The experiment was carried out at daily atmospheric temperature and humidity at three intervals for six days; the time needed for decaying of fruits. Firmness is currently assessed by penetrometer. Standardized firmness charts that describe various stages of ripeness are available. The colour stage is judged visually by using a chart scale provided to categorize apple based on its level of ripeness. To measure capacitive properties of apple, a rectangular parallel plate capacitor with 8.5 cm in length and 8.5 cm in width was constructed as a standard hardware instrument. The conductive plates were selected from aluminium materials because of its consistency that would not be easily ionized, as a factor that will ruin the results of the experiment.

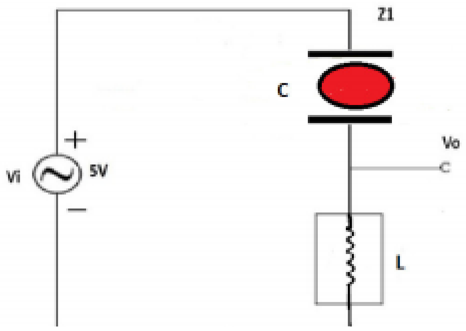


Figure 2: LC circuit used for the firmness measurement (Bhosale & Sundaram, 2014)

3. Methodology

The methodology will include on the capacitance preparation and the circuit design. The capacitance preparation will include several variables which are plate types and size, circuit resistance, the distance between two plate and sensor capacity. Then, the sample preparation of sample selection phase is done before being tested in sample testing phase. After that, the data collection and analysis are run to be documented. Figure 3 shows the process work flow.

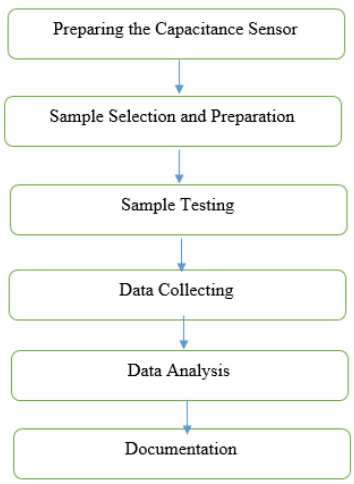


Figure 3: Process work flow

For the circuit design, capacitance is measured to control the frequency of an oscillator or to manipulate level of coupling or attenuation of an AC signal. Therefore, to design the capacitance sensor circuit, the suitable type of capacitance sensor for oil palm fruit need to be decided.

3.1 Circuit Design

Capacitance is typically measured indirectly, by using it to control the frequency of an oscillator, or to vary the level of coupling or attenuation of an AC signal. Therefore, to design this capacitance sensor circuit the type of capacitance sensor that are suitable to test an oil palm fruit need to be decided. Parallel plate capacitance sensor is a good choice and is easier to use to test the oil palm due to its varies characteristic.

It is made of breadboard, resistor, and the plate. The plate used for the sensor is a 2 cm in length and 2 cm width. The resistor that is used is 10 kΩ connected in series in order to get the initial reading of the Vpp is 10 V. For the sinusoidal input, it is set to100 kHz and 20 Vpp for starter in order to test the sensitivity of the sensor.

During the unit testing the circuit is design using 1 kΩ and 4.6 kΩ that is connected in series. The sinusoidal wave frequency is set 20 kHz and the initial value to 14.4 V. The frequency will be a manipulative variable that will varies from 20 kHz to 300 kHz. Figure 4 shows the schematic circuit of the capacitance sensor.

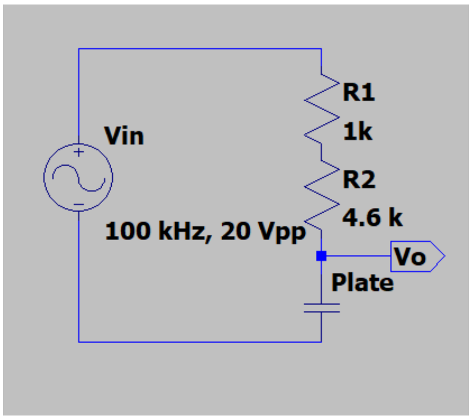


Figure 4: The schematic circuit of the capacitance sensor

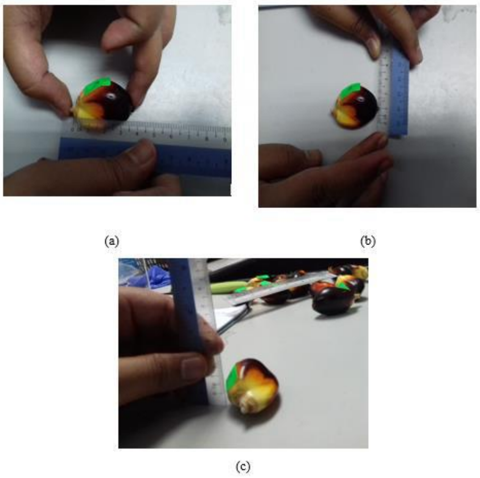
3.2 Sample Preparation

The fruit or sample need to be prepared specifically based on the planning. An oil palm tree that is located at the main campus of University Malaysia Perlis (UniMAP) are chosed. Each fruit is singlehandedly pick from the tree. Due to the tree height, usage of ladder in order to reach to the fruit bunch are needed. After the selection process, the fruit or sample is labelled from number 1 to 30.

The purpose of number labelling is to ensure the fruit has a unique identification based on each sample characteristic. The number labelling also ease the process of sample weighting and measuring the sample length, width and height. Each of the sample is weighing first using the weighing scale and then their length and width is measured. Through this, the relationship between the value of Vpp and the weight, length and width can be viewed. Figure 5 shows the process preparation of the sample from number labelling, to weighting and measuring the sample width.

(a) Sample number labelling

(b) Weight measure process



(c) Height measure process

Figure 5: The steps to measure (a) length; (b) width; (c) height

3.3 Sample Testing

After the sample measurement is done, the testing phase is proceeded. Through testing process, a different and varies value of frequency is tested to the sample. The frequency or sinusoidal wave input frequency given from the function generator is starting from 20 kHz to 300 kHz. During this testing phase, two channel oscilloscopeare used to check the difference for the value of Vpp and wave sign. The first channel is set at the first resistor by setting theVpp value to 20 V and by ensuring the frequency display on the oscilloscope is similar to the function generator. The second channel is set to the legs of the second resistor to give the reading of the output. The sample is tested once for every two days. Figure 6 shows the sample is being tested. Figure 7 shows the reading of Vpp value set for sinusoidal wave, initial Vpp value and frequency displayed on the oscilloscope.

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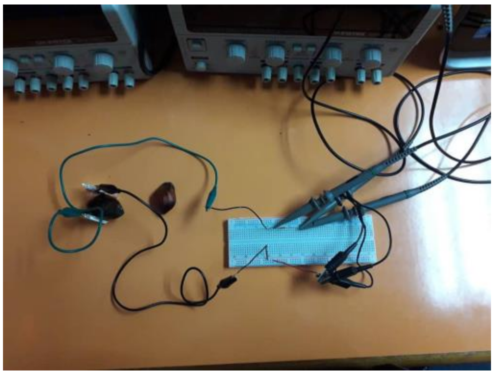

Figure 6: Sample is being tested

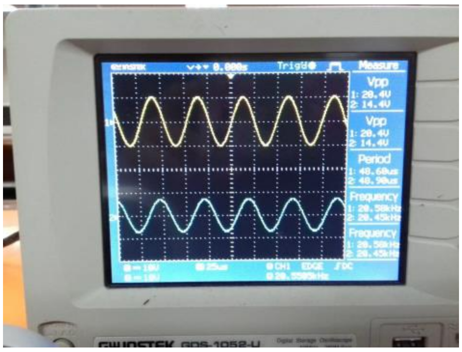

Figure 7: Reading of Vpp value set for sinusoidal wave, initial Vpp value and frequency displayed on the oscilloscope

3.4 Sample Analysis and Documentation

The final step in methodology process is sample analysis and documentation. The data that have been collected from the testing process is documented and then is analysis. The data is filled in a table form and also transform it into graphical data. All of the data is compared and analyze on the causes and factor that effecting the data reading that has appeared. Errors during the testing period is included due to its possibility of cause to the difference in reading that were recorded.

4. Result and discussion

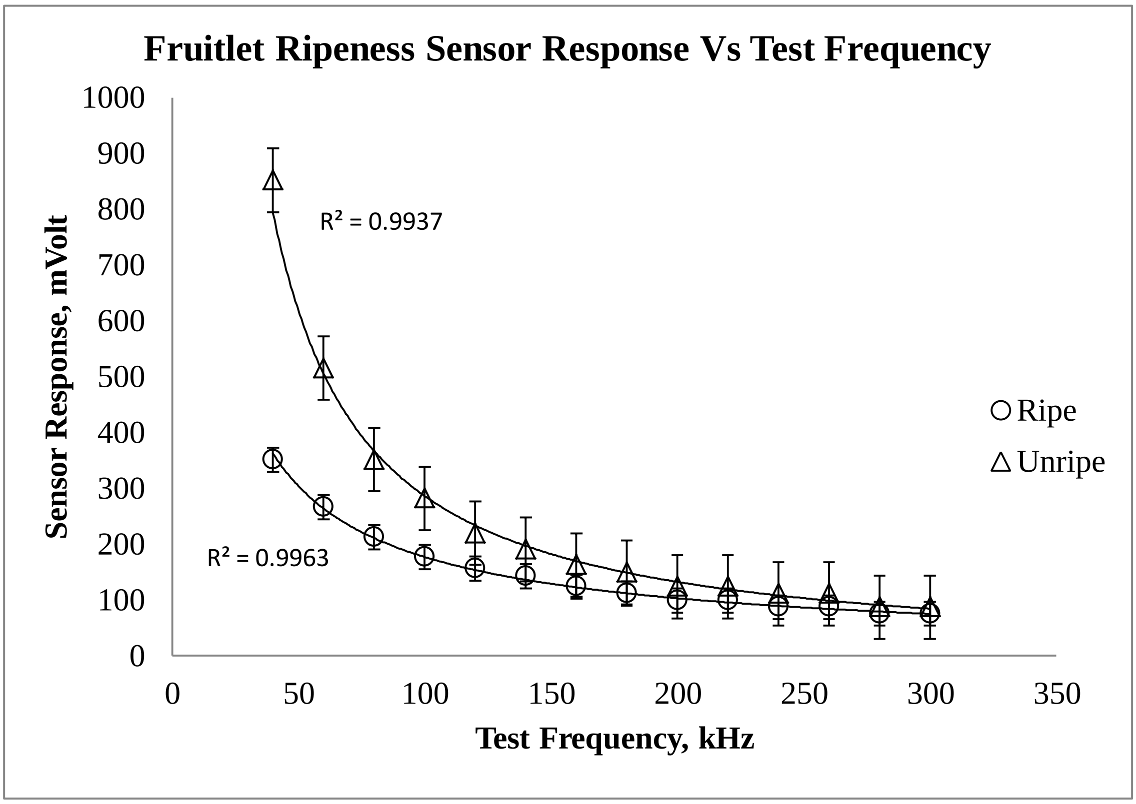

Figure 8: Frequency Response of Oil Palm Fruitlet for Frequency Between 40 kHz to 300 kHz

Figure 8 shows frequency response for ripe and unripe oil palm fruitlets. The fruitlets tested for frequencies between 40 kHz to 300 kHz with sensor output level ranging between 50 millivolts to 900 mV. Both group (ripe and unripe) exhibits negative linear relationship between sensor levels against test frequency.

Ripe and unripe groups correlate linearly to its testing period (1/frequency) with R values of 0.995 and 0.996 respectively (Table 1). Strong linear correlation to testing period suggests a stable dielectric permittivity of the fruitlets within the test frequency range. Ripe regression line traces below unripe regression line suggesting that ripe fruitlet having lower dielectric value (higher impedance) and unripe fruitlet having higher dielectric value (lower impedance). This is in agreement with previous reported studies as it is known in oil palm taxonomy that ripe fruitlet store more oil content (average permittivity less than 3) compared to unripe fruitlets storing more water (average permittivity more than 60). Each point of ripe and unripe ripeness groups fits strongly onto a separate inverse power regression line. Fitting correlation strength, R^2 values for ripe fruitlet is 0.996 and for unripe fruitlet is 0.993 (Table 1). This is in agreement with verified scientific observation stating that Xc as an inverse function of its material permittivity.

Table 1: Correlation and Determination Coefficient of Fruitlet

No	Fruitlet	Correlation Coefficient to Testing Period (1/f), R	Determination coefficient (fitting) of regression line, R^2
1.	Ripe	0.995	0.996
2.	Unripe	0.996	0.993

Table 2: Single Factor ANOVA Test Result to Nullify Equal Population

Item	Test Frequency	ANOVA Result p-Value
1	100 kHz	0.00022
2	200 kHz	0.05067
3	300 kHz	0.22656

Single factor ANOVA was used to identify which frequency best differentiate fruitlet ripeness. The null hypothesis is that Ripe and Unripe data are from the same population. Table 2 shows single factor ANOVA test result on ripeness sensor data collected over ripe and unripe oil palm fruitlet over 3 major frequencies of 100 kHz, 200 kHz and 300 kHz. The p-value for test frequencies of 100 kHz, 200 kHz and 300 kHz is 0.0022, 0.05067 and 0.22656 respectively.

The resulting single factor ANOVA for testing fruitlet ripeness with frequency of 200 kHz and 300 kHz suggest weaker strength for the samples to be of differing groups. The confidence level for the two groups tested at 200 kHz and 300 kHz are less than 94.93 % and 77.34 % respectively. The probabilities of errors for testing at these two frequencies are 5.067% and 22.656% respectively (more than widely accepted threshold 5.0 %). Hence the null hypothesis for testing at 200 kHz and 300 kHz cannot be rejected. Testing at these frequencies may not result conclusive findings.

The result from single factor ANOVA strongly suggests that the result from testing fruitlet ripeness with frequency of 100 kHz originates from two differing groups at above 99 % confidence level. The probability of error of the samples originating from the same group is 0.0022 %. Hence the null hypothesis for testing at 100 kHz can be rejected. Variation of measured data which contributes to sample variance was largely seen to be influenced by each fruitlet weight (size), ripeness level (chemical composition) and system (measurement instrument) noise.

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5. Conclusion

It was observed that smaller fruitlets with less weight give smaller sensor reading compared to bulky fruitlet and unripe fruitlets give bigger sensor reading compared to ripe fruitlet of similar weight. This is in agreement with studies by other researchers reporting dielectric permittivity influenced by mass, density and ripening chemical composition.

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