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SB21: DEVELOPMENT OF PORTABLE WATERMELON RIPENESS DETECTOR USING NEAR-INFRARED SPECTROSCOPY (NIRS) AND ACOUSTICS ANALYSIS

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Abstract: Watermelon is one of the toughest fruits to distinguish if it is ripe, unripe, or overripe. Its quality must be monitored to improve its commercial viability and profitability. Manual procedures deploy tapping, color examination, and approximate the number of days to determine its maturity stage. These are useful, but their accuracy and precision are constrained since they rely on assumptions. This research aims to develop a non- destructive method of identifying watermelon maturity in the Sugar Baby variety through Acoustics Analysis and Spectral Identification using Fast Fourier Transform and Near-Infrared Spectroscopy (NIRS). A portable and automated device is built, which includes operations such as detecting sound and internal content quality using a NIRS sensor and microphone, analyzing the wavelength and frequencies collected, and interpreting the results per the standard values provided. The K-Nearest Neighbor approach is applied in which altered signals are computed, compared, and voted on. Three hundred (300) watermelon samples were assessed, wherein two hundred ten (210) were used for standardization, seventy-five (75) for testing and assessment, and fifteen (15) for repeatability. In addition, thirty (30) cohorts were polled to rate the device's efficacy. Based on the findings, combining NIRS and Fast Fourier Transform showed that the ripeness condition of watermelon can be readily identified with high accuracy. Additionally, the data indicated that the device is reproducible and that the human and automated approaches differed significantly. With an overall accuracy of 90.7%, the automated watermelon ripeness detector outperformed the manual detection method.

Keywords: *ripeness detector development, spectral identification, acoustics analysis, watermelon ripeness*

1. INTRODUCTION

1.1 Background of the Study

For agricultural products, the current market is rather selective. Productivity is enhanced tremendously by the use of automation during manufacturing (Shah Rizam *et al*., 2009). Similar to other fruits, watermelons come in various varieties that differ in terms of sweetness, shape, size, and color. In the Philippines, the recommended watermelon varieties, as stated by the Philippine National Standard's Fresh Fruits, Watermelon grading and classification— include Sugar Baby, Crimson Sweet, and Charleston Gray.

The Sugar Baby watermelon displays a resilient, nearly round shape with a hard, dark green exterior measuring 20.3 cm in diameter, making it resistant to damage during handling and shipping. Watermelon varieties vary in their nutritional composition, and according to Amin *et al*. (2014), the dark green variety exhibits the highest sugar content among all watermelon varieties. This research indicates that watermelon types not only differ visibly but also possess diverse compositions. Therefore, when formulating nutritional compositions, it is crucial to take into account the unique nutritional profiles of each watermelon variety. Internal quality, on the other hand, plays a critical role in influencing how consumers perceive the fruit's quality. Watermelon is a good example of this. Since it does not ripen after being picked, unlike other fruits, harvesting it while still unripe and allowing it to mature is not a good idea. It does not ripen on the counter. The watermelon's quality is a critical factor in assuring the continuous marketing of watermelon. As a result, it is critical to monitor and regulate fruit maturity which has developed into a critical issue in fruit production. Due to the detrimental nature of traditional methods like tapping and checking its yellow spot for fruit ripeness detection, they cannot be used in large-scale production (Arboleda *et al*., 2020). While they are advantageous, they do not provide great accuracy or precision since such methods rely heavily on guessing and it takes a lot of time and work.

1.2 Objectives and Significance of the Study

SB21 aims to provide a solution for the conventional method of determining the maturity of watermelons. The device incorporates non-destructive technology offering convenience to customers and distributors who purchase watermelons, as it eliminates the need to open the fruit to check its ripeness. This technology also reduces the likelihood of distributing or buying spoiled or unripe watermelons in the market. By making the device portable, customers can easily utilize it. It can be employed on large farms to assess ripeness before harvesting or utilized by mobile watermelon vendors when selling in various locations. Furthermore, the device is expected to provide high accuracy, as researchers are developing a portable tool that utilizes near-infrared spectroscopy for spectral identification and Fourier Transform acoustics analysis for precise detection of watermelon ripeness. The introduction of this device is likely to benefit the general public involved in the watermelon industry. Three (3) users conducted three (3) trials, examining a total of fifteen (15) watermelon samples to assess the device's ability to determine ripeness, repeatability, and reproducibility. To ensure that watermelons brought to market are sufficiently mature, they undergo rigorous maturity testing. The current methods for testing watermelon maturity are known to be inaccurate, but this technology could assist retailers in accurately presenting ripe watermelons to customers. Furthermore, the device has the potential to enhance customer satisfaction by reducing losses caused by customer ignorance and misunderstandings regarding watermelon maturity.

1.3 Conceptual Framework

The objective of this study is to identify the ripeness of a watermelon in a non-destructive way using a near-infrared spectroscopy (NIRS) spectral sensor and a modified microphone. The process starts by placing the watermelon in the device, ensuring that the equator of the watermelon is placed at the speaker and modified microphone, and the NIRS is pointed at the ground spot.

By pressing the yellow button, the process will start by activating the NIRS spectral sensor. Then, it will begin gathering different wavelengths, analyze the wavelengths gathered from the NIRS, set the standard value according to the researchers' preferences, interpret the result based on the standard value, and store the collected output. After that, the process will continue gathering data based on vibration by using a speaker and a modified microphone. The device will capture watermelon vibrations triggered by the speaker, analyze those vibrations, set the standard value according to the researchers' preferences, interpret the result based on the standard value, and store the collected output. Lastly, the stored collected output from the NIRS spectral sensor and a modified microphone will be examined, and its result will be the final output. The device will display its final output as unripe, ripe, or overripe (Figure 1).

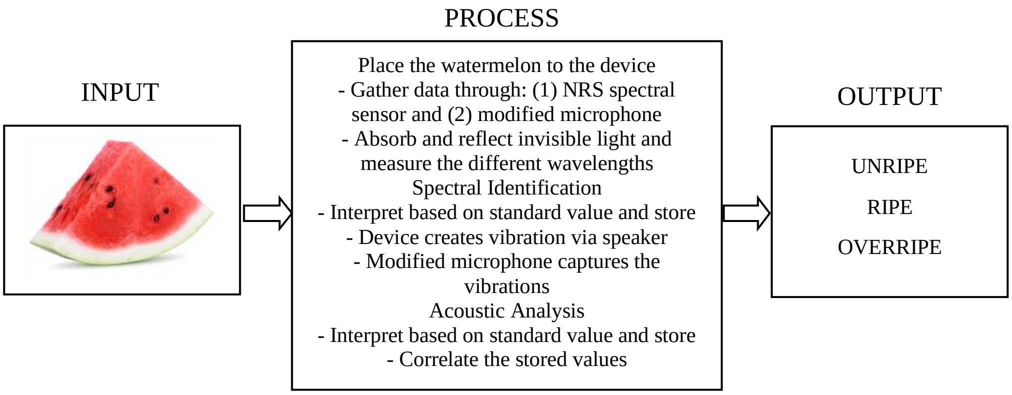

Figure 1. Conceptual framework showing the operational system of the device.

2. METHODOLOGY

2.1 Research Design Flowchart

Upon creation of the device, the watermelon samples were prepared. Sensor was placed on the ground spot and equator of the watermelon to record the wavelength from NIRS and frequency from the microphone. Data gathered were analyzed through correlation and validated by opening the sample. After the device standard was set, repeatability test was conducted. Lastly, experts were asked to identify ripeness of watermelon to compare the result of the device and the traditional method.

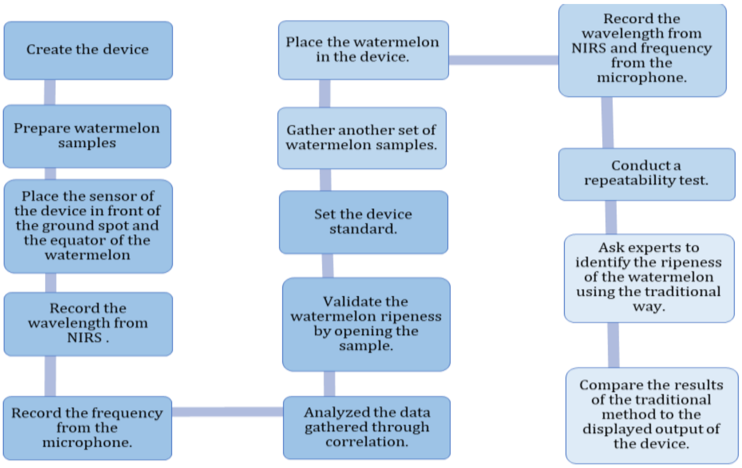

Figure 2. Research design flowchart portraying the creation of the device.

2.3 Material Requirements

2.3.1 Hardware

The hardware of this project consists of a speaker, microphone, soundcard, near-infrared spectroscopy, microprocessor, display, battery, battery holder, switch, push button, and casing.

Speaker. This simulated a 120 Hz sinusoidal wave, generating vibrations.

Microphone. This was used to capture acoustic signals coming from the watermelon, affected by the vibrations produced by the speaker.

Sound card. This served as one of the Raspberry Pi's ports, which was used to connect the speaker and microphone to the microcomputer.

Near-infrared spectroscopy. The AS7263 NIR spectral sensor was used to measure and characterize the internal structure of the watermelon using the absorption and reflection of light in different wavelengths.

Microprocessor. The ARM Cortex-A controls the functions of the system in the project prototype, which are to detect sound and internal content properties of watermelon using near-infrared spectroscopy and microphone, analyze the data received, and display the corresponding ripeness state.

Display. The 1.5-inch Red Green Blue Organic Light Emitting Diode (RGB OLED) Module displays the output of the system that determines the ripeness state of a watermelon.

Battery and battery holder. Lithium batteries supply power to the prototype. In series, two (2) rechargeable Li-ion 18650HP 2200mAh batteries provide 16.28W to the entire circuit. This is mounted to an I2C Battery Expansion board that provides power to both the Raspberry Pi and the speaker.

Switch and push buttons. These were used for turning the device on and off and sending commands to the system

2.2 Process Flowchart

Figure 3 shows the step-by-step diagram of how the device operates.

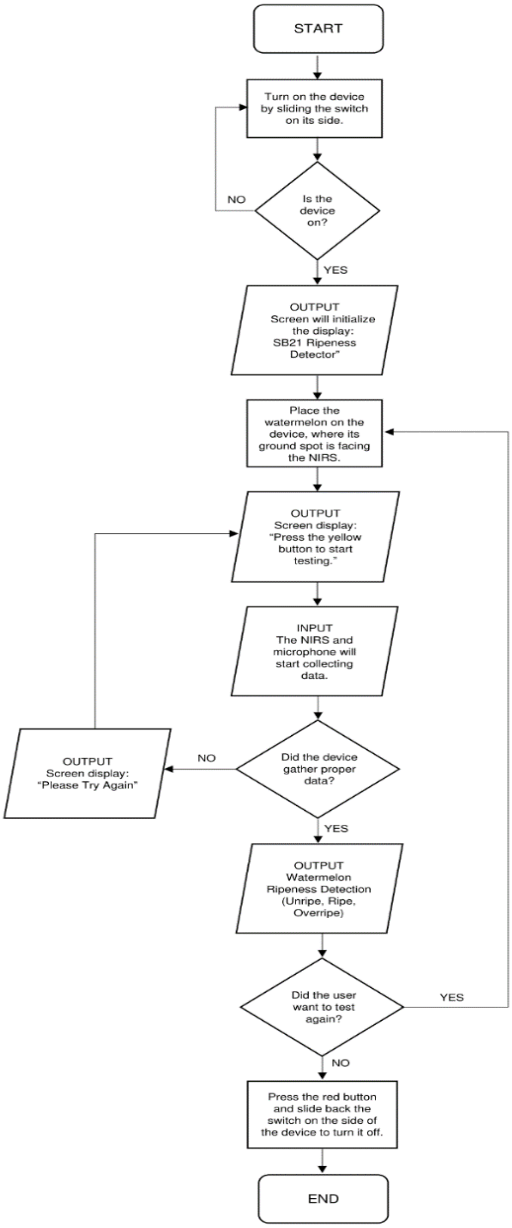

Figure 3. Process flowchart showing how the device works.

2.3.2 Software

A code was created in the Raspberry Pi 4 Model B using Python language. This code has its user interface for the developers and general users and has the main logic of the device. The code has a Fast Fourier Transform to analyze acoustic signals and Spectral Identification for the Near-Infrared Spectroscopy (NIRS) wavelengths. It is automatically executed as Integrated Development Environment (IDLE) Shell Python as soon as the device starts up.

2.4 Prototype design and assembly

Presented in this section are the step-by-step procedures in the construction of SB21: Portable Watermelon Ripeness Detector through Acoustics and Spectral Identification Using Fast Fourier Transform (FFT) and Near-Infrared Spectroscopy (NIRS).

2.4.1 Step-by-step process

Step 1: Gather all the materials needed to construct the casing of the device (Figure 4). Properly measure and cut the fiberglass to form the general housing.

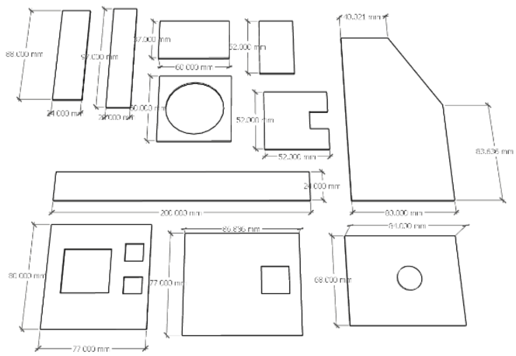

Figure 4. Raw casing dimensions.

These cut-outs (Figures 5 and 6) are made of fiberglass to ensure the device's sturdiness and integrity. Fiberglass allows the design to be created easily, maintaining the measurements when they are combined. Fiberglass also helps the design to not be deformed when watermelons are placed above it even though it has no central support, making the inside spacious for the working components.

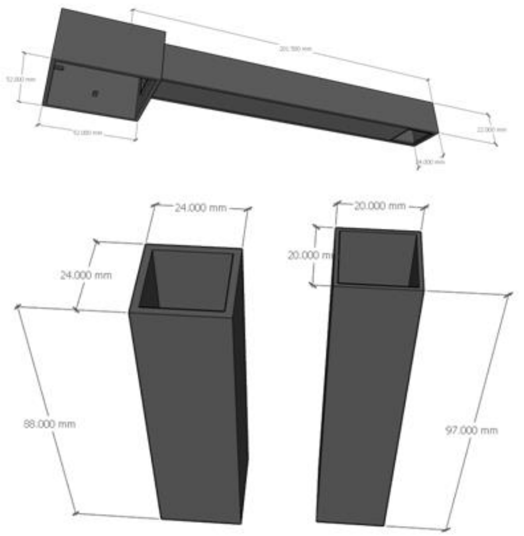

Figure 5. Arm of the device dimensions (upper part). The arm of the device is designed to retract and expand which allows the device to be flexible to different sizes of sugar baby watermelons.

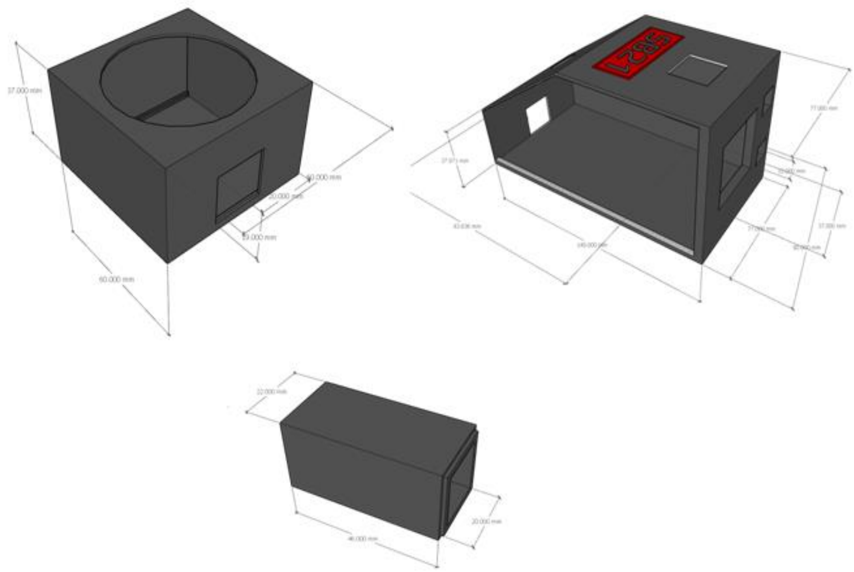

Figure 6. The base of the device dimensions (lower part).

The base of the device is divided into two (2) sections. The main base is where the Raspberry Pi is located, and the minor base resides in the speaker (Figure 7). Since the watermelon will be placed on top of the speaker, the connection between the two (2) sections has enough spacing for the Sugar Baby watermelon to fit in.

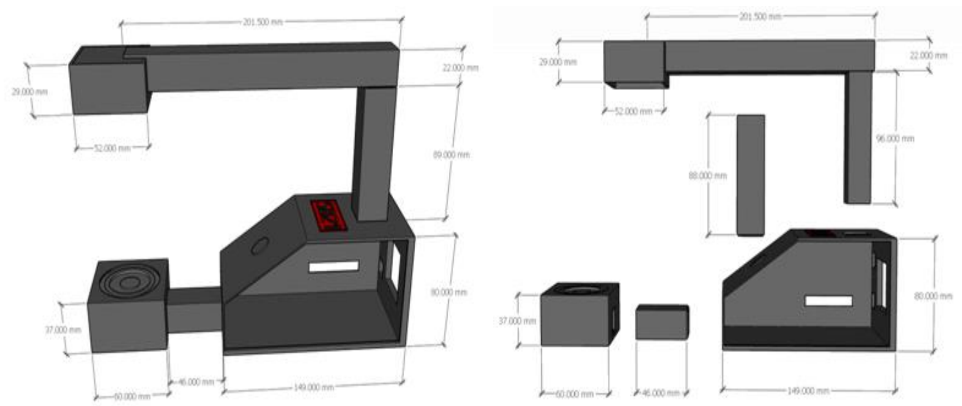

Figure 7. Device casing assembly showing the casing parts are held together by superglue.

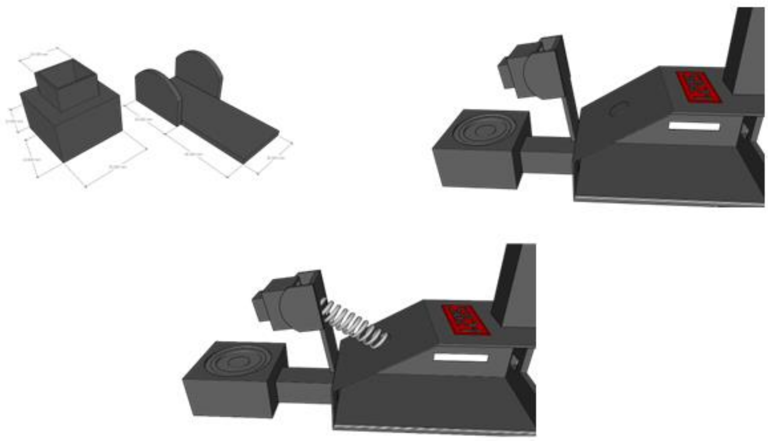

Figure 8. NIRS holder placement is designed to make the NIRS be at the right spot of the watermelon when testing; done through the use of a spring and the tilting mechanism that makes it adjustable.

Figure 9. Footing placement. The footing has rubber in it to maintain the stability of the device while testing watermelons.

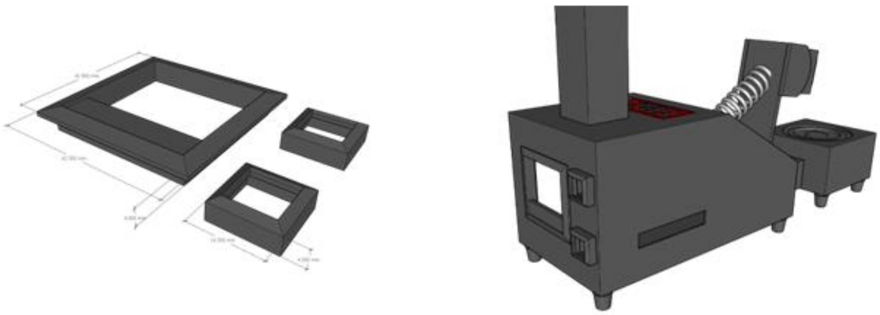

Figure 10. OLED and 3D printed button caps. The 3D printed caps were placed to protect the OLED and button caps and also the internal components in the main base.

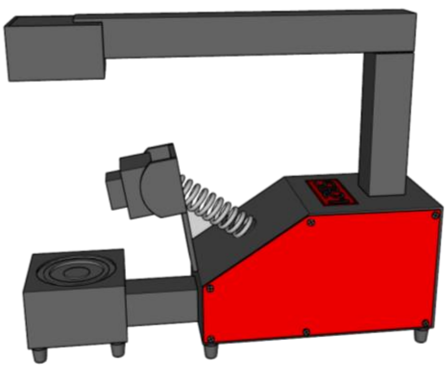

Figure 11. The cover for component protection is made of aluminum that is screwed on the device to protect its internal components.

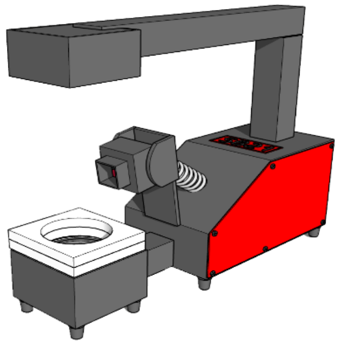

Figure 12. The foam extender comes in different sizes, depending on the size of the watermelon to be tested, making its placement intact to the device. It is placed on top of the speaker, which helps in minimizing external noise that might be captured by the microphone.

Step 2: Prepare all the components (Figures 8, 9, 10) to be placed inside the assembled casing including the NIRS Sensor, personalized digital stethoscope, speaker, amplifier, USB sound card, OLED Display, push buttons, UPS module, the Raspberry Pi 4 Model B (Figure 11 and 12).

Step 3: Place the components within the assembled casing under the schematic diagram connections (Figure 13).

2.5 Schematic Diagram

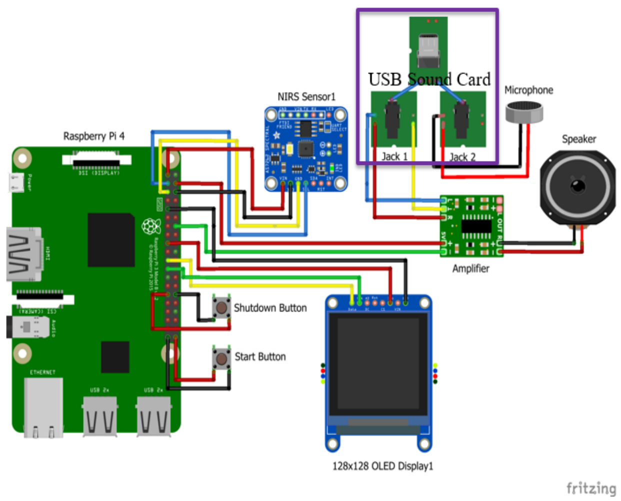

Figure 13. Schematic diagram showing the interconnection of the device components.

2.6 Research Design

The experimental research method is the design used in this study. The researchers provided descriptions regarding the problem statement. The researchers established the standard frequency and wavelength values through testing, which defines the freshness of the watermelons. This system employs the Fast Fourier Transform and Spectral Identification.

The researchers use the Python language on a Raspberry Pi 4 Model B to recognize data from the light spectrum and sound waves of the tested watermelons, as well as determine its classification by collecting samples for each watermelon. This is also used by researchers to set the standards for watermelon classifications.

The researchers gathered data by placing the watermelon in the device. The device sends light and vibration to the watermelon automatically. The reflected and absorbed light from the NIRS is converted by the NIRS into wavelength. The acoustic signals were captured by the microphone. The watermelons were acquired by researchers from Paniqui, Tarlac, where three hundred (300) watermelon samples were used in this study. In setting the standards, 70% or two hundred ten (210) of them were utilized, 25% or seventy-five (75) samples for the testing of accuracy, and 5% or fifteen (15) samples for repeatability. A display shows the output that determines whether the watermelon is ripe, unripe, or overripe. The device is evaluated by comparing its output and by opening the watermelon to confirm its ripeness, also through the help of experts.

2.7 Description of Instruments Used

Methods of Data Gathering

To determine the interior composition of the watermelon, the researchers used a spectral sensor. Moreover, to make the watermelon vibrate and record the resulting sound, they used a speaker and a microphone. The data recorded by the spectral sensors and microphones are preserved and analyzed. Based on the wavelengths and frequencies generated, a classification of ripeness is established for watermelons.

Methods of Data Conversion

By measuring the wavelength and frequency domains of each sample, invisible light and sound wave variations per maturity level are quantified.

Methods of Data Transformation

Using spectral identification, the wavelength spectrum of the converted invisible light waves is transformed. On the other hand, the Fast Fourier Transform is used to transform the frequency spectrum of sound waves that have been converted.

Methods of Data Analysis

The transformed signals went through computation, comparison, and voting using K-Nearest Neighbor. The distance formula was used to compute the distances that have been measured from standard data. The distance computation process has been speeded up thanks to Dynamic Time Warp. The values closest to the standards are selected, grouped, and compared before a voting decision is taken.

Methods of Display of Output

The classification of watermelon's ripeness is displayed through an OLED where the result of the analysis is shown.

2.8 Data Gathering Instrument and Procedure

As a data-gathering tool for this study, the survey questionnaire was applied. In particular, the solution to the problem was the focus of the prepared question. A total of 14 questions were included in the questionnaire. Questionnaires have been provided to respondents to gather data that are needed for the study.

A scale from one (1) to four (4) has been used for the data collection instrument. The responses were divided into the following categories: (1) Strongly Disagree, (2) Disagree, (3) Agree, and (4) Strongly Agree. To be able to make an accurate examination of the data gathered in the survey, this legend was used by researchers.

Once verification has been carried out on the authenticity and reliability of the method by which data were collected, the following steps were included in the development of questions appropriate for a study, as well as the necessary modifications to the survey questionnaire. Thirty (30) copies of the survey questionnaire were distributed completed and returned by the respondents. The respondents and the researchers have reached an agreement, and the related answers have been stored following that agreement. Per the statistical analyses carried out, the collected information has been summarized and compiled.

2.9 Statistical Treatment of Data

The researcher utilized the following statistical method to evaluate and interpret the data:

Likert scale. It has been used to measure changes in attitudes, knowledge, perceptions, values, and behavior. For rating how strongly they agree or disagree with an argument in question, a scale was used based on the Likert method which asked respondents to choose one or more arguments from their list.

Percentage. It was a tool that illustrated the number of observations for each data point or group of data points. A common way to show the frequency of events in a survey or other data type was by using this method.

Mean. It was a statistical representation of central tendency because it showed an average of all figures in the data.

Paired t-test. It was used to predict the difference between the NIRS results over the actual result and the FFT result over the actual result.

Chi-square test. For a set of events or variables, it calculated the difference between manual and automated results. To assess these differences between categorical variables, in particular nominal variables, the Chi-square analysis was considered as an ideal.

Attribute measurement system. It was used in the context of an assessment of device repeatability between users. For an effective analysis of these results, Fleiss Kappa statistics and Kendall's Coefficient of Concordance were used.

3. RESULTS AND DISCUSSION

3.1 Is it feasible to develop a portable tool that uses spectral identification to assess the interior composition of a watermelon to identify when it is ripe?

To demonstrate the discrepancies more clearly, a paired t-test was performed to compare the NIRS data with the actual results, as shown in Table 1. A paired t-test is carried out because data collection is needed for two variables that are being researched simultaneously on the same subject. There is no statistically significant difference between the mean of the NIRS and the actual result, as indicated by the value of p=0.836, which is shown in the results of the Minitab program. The paired difference between the mean of the NIRS and the actual results is 0.0133, implying that the 75-sample size yielded a little difference between the two. This suggests a close relationship between the two (2). The NIRS mean was 2.0133 while the actual mean was 2.0, therefore the difference is substantial.

Table 1. Paired t-test for the mean of NIRS and actual results.

Paired Differences		
Statistics	*Paired Differences	
Sample Size	75	
Mean	0.013333	
95% Cl	(-0.11490, 0.14157)	
Standard Deviation	0.55734	
Difference = NIRS - ACTUAL		
Individual Samples		
Statistics	**NIRS**	**ACTUAL**
Mean	2.0133	2
Standard Deviation	0.66766	0.82199

The data gathered by the NIRS comprises all six (6) NIR channels (Channel R, Channel S, Channel T, Channel U, Channel V, and Channel W), in contrast to the study by Arboleda *et al.*, 2020, which only uses Channel T, Channel U, Channel V, and Channel W with a 92.5% accuracy rate. The percentage success rate is lowered as a result. Collecting all of the near-infrared light waves required to establish the standards for watermelon maturity detection is doable by utilizing all of NIRS's channels.

3.2 Using the Fast Fourier Transform (FFT), can the device identify the ripeness of a watermelon using its acoustic signals?

The FFT data and actual results were examined further using a paired t-test to highlight any inconsistencies, as shown in Table 2. A paired t-test is utilized because it is critical to obtain data for two variables that are being studied concurrently on the same issue. Using the Minitab program, the difference between the mean of the FFT and the actual result is not statistically significant (p=0.810). The paired mean difference between FFT and the actual results with a sample size of 75 is 0.0133, demonstrating a little difference between the two (2). This indicates that there may be a strong link between them. Considering the FFT mean was 2.0133 and the actual mean was 2.0, the difference is substantial.

Tapping is a common traditional method for determining the maturity level of a watermelon. Unlike Pamungkas *et al.*'s (2021) study, which discovered that a watermelon's maturity could be determined with a frequency of 150 Hz or less, the results reveal that a 120 Hz frequency yields a high proportion of success.

The frequency being employed is thought to be low, allowing these frequencies to pass through things with less attenuation.

Table 2.Paired t-test for the mean of FFT and actual results.

Paired Differences		
Statistics	*Paired Differences	
Sample Size	75	
Mean	0.013333	
95% Cl	(-0.12357, 0.096901)	
Standard Deviation	0.47911	
Difference = FFT - ACTUAL		
Individual Samples		
Statistics	**FFT**	**ACTUAL**
Mean	2	2.0133
Standard Deviation	0.77110	0.81362

3.3 Is there a significant difference in the findings between manual and automated methods used to determine watermelon ripeness?

Table 3 displays a cross-tabulation of manual and automated results versus real results provided by the Statistical Package for the Social Sciences (SPSS) program. The automated method using the device, sixty-eight (68) out of seventy-five (75) samples, produced the same results as the actual with 90.7%, while only seven (7) samples produced different results with 9.3%. In contrast, forty-nine (49) out of seventy-five (75) samples from the manual method produced the same results as the actual, with 65.3%, while twenty-six (26) samples produced different results, with 34.7%. The difference in percentage results is evident, with the automated approach providing higher accuracy than the manual approach. This fills in a gap when DengfeiJie *et al*. (2018) stated that acoustic technology and NIRS are still being researched in the non-destructive detection of watermelon, proving this study's accuracy rate. Furthermore, the accuracy testing findings are relevant to research reported by Bruel and Kjaer Company (n.d.), which indicates that the proponents' test utilizing an accelerometer and analyzer in evaluating the acoustic response of the watermelon is 71%, which is slightly higher than the 67% accuracy rate of a human tester.

Table 3. Collation of actual results between manual and automated results

			Same / Different		**Total**
			DIFF	**SAME**	
Manual & Automated vs. Actual	Automated	Count	7	68	75
		% within Manual & Automated vs. Actual	9.3%	90.7%	100.0%
		% within Same / Different	21.2%	58.1%	50.0%
		% of Total	4.7%	45.3%	50.0%
	Manual	Count	26	49	75
		% within Manual & Automated vs. Actual	34.7%	65.3%	100.0%
		% within Same / Different	78.8%	41.9%	50.0%
		% of Total	17.3%	32.7%	50.0%
Total		Count	33	117	150
		% within Manual & Automated vs. Actual	22.0%	78.0%	100.0%
		% within Same / Different	100.0%	100.0%	100.0%
		% of Total	22.0%	78.0%	100.0%

The asymptotic significance in Table 4, or p-value, is calculated using the SPSS chi-square tests. This value is used to determine the statistical significance of the relationship between manual and automated methods. The tests yielded p-values less than 0.05, which is the commonly accepted statistical significance threshold. This implies that the two variables have a statistically significant relationship.

Table 4. Analysis results using chi-square.

	Value	**df**	**Asymp. Sig. (2-sided)**	**Exact Sig. (2-sided)**	**Exact Sig. (1-sided)**
Pearson Chi-Square	14.024864[a]	1.000000	.000180		
Continuity Correction[b]	12.587413	1.000000	.000388		
Likelihood Ratio	14.741154	1.000000	.000123		
Fisher's Exact Test	150.000000			.000294	.000147
N of Valid Cases					

3.4 Is the device designed to provide a repeatable and convenient product to end-users and intended beneficiaries?

After using fifteen (15) samples in three (3) different trials, User one accumulated an 86.67% success rate and 13.33% error rate as shown in Table 5.

Table 5.Success and error percentage after three trials by user one.

USER 1				
SAMPLE	**TRIAL 1**	**TRIAL 2**	**TRIAL 3**	**REMARKS**
1	Ripe	Ripe	Ripe	**1**
2	Ripe	Ripe	Ripe	**1**
3	Ripe	Ripe	Ripe	**1**
4	Unripe	Unripe	Unripe	**1**
5	Overripe	Overripe	Overripe	**1**
6	Unripe	Unripe	Unripe	**1**
7	Ripe	Ripe	Ripe	**1**
8	Ripe	Ripe	Ripe	**1**
9	Unripe	Unripe	Unripe	**1**
10	Ripe	Ripe	Ripe	**1**
11	Ripe	Unripe	Unripe	**0**
12	Overripe	Ripe	Ripe	**0**
13	Ripe	Ripe	Ripe	**1**
14	Overripe	Overripe	Overripe	**1**
15	Overripe	Overripe	Overripe	**1**
PERCENTAGE OF SUCCESS				86.66666667
PERCENTAGE OF ERROR				13.33333333

User two (2) resulted in a 93.33% success rate and only a 6.67% error rate within the fifteen (15) samples with three trials for each sample as shown in Table 6. User 3 achieved a 93.33% success rate and a 6.67% error rate after using fifteen (15) samples in three (3) different trials as shown in Table 7.

Table 6. Success and error percentage after three trials by user two (2).

USER 2				
SAMPLE	**TRIAL 1**	**TRIAL 2**	**TRIAL 3**	**REMARKS**
1	Ripe	Ripe	Ripe	**1**
2	Ripe	Ripe	Ripe	**1**
3	Ripe	Ripe	Ripe	**1**
4	Unripe	Unripe	Unripe	**1**
5	Overripe	Overripe	Overripe	**1**
6	Ripe	Ripe	Ripe	**1**
7	Ripe	Ripe	Ripe	**1**
8	Ripe	Ripe	Ripe	**1**
9	Ripe	Ripe	Ripe	**1**
10	Unripe	Unripe	Unripe	**1**
11	Ripe	Unripe	Unripe	**0**
12	Ripe	Ripe	Ripe	**1**
13	Ripe	Ripe	Ripe	**1**
14	Overripe	Overripe	Overripe	**1**
15	Overripe	Overripe	Overripe	**1**
PERCENTAGE OF SUCCESS PERCENTAGE OF ERROR				93.33333333 6.666666667

Table 7. Success and error percentage after three trials by user three (3).

USER 3				
SAMPLE	**TRIAL 1**	**TRIAL 2**	**TRIAL 3**	**REMARKS**
1	Ripe	Ripe	Ripe	**1**
2	Ripe	Ripe	Ripe	**1**
3	Ripe	Ripe	Ripe	**1**
4	Unripe	Unripe	Unripe	**1**
5	Overripe	Overripe	Overripe	**1**
6	Ripe	Ripe	Ripe	**1**
7	Ripe	Ripe	Ripe	**1**
8	Ripe	Ripe	Ripe	**1**
9	Ripe	Ripe	Ripe	**1**
10	Unripe	Unripe	Unripe	**1**
11	Ripe	Unripe	Unripe	**0**
12	Overripe	Overripe	Overripe	**1**
13	Overripe	Overripe	Overripe	**1**
14	Ripe	Ripe	Ripe	**1**
15	Ripe	Ripe	Ripe	**1**
PERCENTAGE OF SUCCESS PERCENTAGE OF ERROR				93.33333333 6.666666667

Throughout the repeatability stage, data collected suggested a promising outcome of 91.11% for the three (3) users. This demonstrates that the prototype is repeatable and yields consistent results when tested on each individual. During the repeatability test, User One had the most unexpected results, with a success rate of only 86.67%. Users two (2) and three (3) had a success percentage of 93.33% during the repeatability stage. Table 8 shows that their values are only slightly different.

According to Fleiss' Kappa Statistics, this study indicates that the device's repeatability is not achieved through chance alone, having a p-value of 0.0000 and an alpha of 0.05 for all users (appraisers) and results (responses). Furthermore, because the samples are ordinal, Kendall’s Coefficient of Concordance is used, and a range of 0.943723 to 0.964912 denotes a high level of agreement among all users.

Table 8.a. Repeatability test analysis within each user: Within Appraisers

Within Appraisers

Assessment Agreement

Appraiser	**# Inspected**	**# Matched**	**Percent**	**95% Cl**
1	15	13	86.67	(59.54, 98.34)
2	15	14	93.33	(68.05, 99.83)
3	15	14	93.33	(68.05, 99.83)
		Average	91.11	

Matched: Appraiser agrees with him/herself across trials.

Table 8.b. Repeatability test analysis within each user: Fleiss' Kappa Statistics

Fleiss’ Kappa Statistics

Appraiser	**Response**	**Kappa**	**SE Kappa**	**Z**	**P(vs. > 0)**
1	Unripe	0.87968	0.149071	5.90107	0.0000
	Ripe	0.82143	0.149071	5.51031	0.0000
	Overripe	0.87143	0.149071	5.84572	0.0000
	Overall	0.85342	0.108250	7.88377	0.0000
2	Unripe	0.84797	0.149071	5.68838	0.0000
	Ripe	0.90546	0.149071	6.07402	0.0000
	Overripe	1.00000	0.149071	6.70820	0.0000
	Overall	0.91788	0.110238	8.32637	0.0000
3	Unripe	0.84797	0.149071	5.68838	0.0000
	Ripe	0.90546	0.149071	6.07402	0.0000
	Overripe	1.00000	0.149071	6.70820	0.0000
	Overall	0.91788	0.110238	8.32637	0.0000

Table 8.b. Repeatability test analysis within each user: Fleiss' Kappa Statistics

Kendall’s Coefficient of Concordance

Appraiser	**Coef.**	**Chi – Sq.**	**DF**	**P**
1	0.943723	39.6364	14	0.0003
2	0.964912	40.5263	14	0.0002
3	0.964912	40.5263	14	0.0002

The overall survey results are shown in Table 9, which avers that the majority of respondents "Strongly Agree" with every aspect of the researchers' survey questionnaires. With a mean score of 3.7 of "Strongly Agree," the respondents agreed that the device was safe. Meanwhile, respondents gave the device a mean of 3.67 or "Strongly Agree" for its appearance, user-friendliness, durability, instructions, and accuracy. The watermelon can be easily placed on the prototype, with a mean of 3.83 for handiness and immediate detection. Finally, an acquired mean of 3.57 or responses for "Strongly agree" indicates that the device is superior to the traditional method of determining the ripeness of watermelon and is suitable for commercial use.

Table 9. Overall survey results.

Questions	Mean	Results
Q1. The device is pleasing to the eyes.	3.666666667	Strongly Agree
Q2. The device is easy to carry or handy.	3.633333333	Strongly Agree
Q3. The device is user-friendly.	3.666666667	Strongly Agree
Q4. The watermelon can be easily placed on the device.	3.566666667	Strongly Agree
Q5. The device is durable.	3.666666667	Strongly Agree
Q6. The instructions are easy to read.	3.666666667	Strongly Agree
Q7. The instructions are easy to understand.	3.666666667	Strongly Agree
Q8. The instructions are easy to follow.	3.666666667	Strongly Agree
Q9. The device does not produce unnecessary noise.	3.666666667	Strongly Agree
Q10. The device is safe for the user.	3.700000000	Strongly Agree
Q11. The detection of the watermelon is almost instantaneous.	3.633333333	Strongly Agree
Q12. The detection of the watermelon is accurate.	3.666666667	Strongly Agree
Q13. The device is recommendable for business and consumer use.	3.533333333	Strongly Agree
Q14. The device is a better option than the manual method in terms of watermelon ripeness detection.	3.566666667	Strongly Agree

4. CONCLUSIONS

Tapping and color inspection methods have been widely used to determine the ripeness of watermelons. Many people have difficulty detecting the maturity level of the watermelon. As a result, many watermelons go to waste due to inaccurate identification of the watermelon's maturity. The primary objective of this research is to develop a non-destructive instrument for determining the maturity level of a watermelon. To conclude the study, the researchers developed a device that fulfills the requirements of the objectives outlined in Chapter 1.

The detection success rate increases when using K-Nearest Neighbor since it uses data from both the spectral identification and the FFT analysis. The KNN gathers data from both sensors' 210-watermelon standards and balances it to achieve the closest result. This outcome is determined by counting the number of nearby standards in unripe, ripe, and overripe to determine the ripeness of the watermelon.

When the two sensors were not correlating with each other, their results were low in contrast with the outcome when the KNN was integrated. Based on the Minitab software, there is no statistically significant difference between the NIRS mean and the actual result, as demonstrated by the value p=0.836 with a sample size of seventy-five (75). The p=0.810 score indicates that there is no statistically significant difference between the FFT mean and the actual result.

Using the NIRS sensor and a 120 Hz frequency for data collection, the two (2) approaches provided sufficient precision to determine the ripeness of a watermelon. The device's total accuracy of 90.7% demonstrated that an automated watermelon ripeness detector is far more accurate compared to manual detection, which has an accuracy rate of only 65.3%.

During the repeatability test, User One has the lowest repetition rate of 86.67% since the first user is still adjusting how to properly place the watermelon on the device. With this, User two (2) and User three (3) acquired the proper way to place the watermelon on the device, which is to place the NIRS sensor on the ground spot or the yellow point of the watermelon and ensure that there is no air gap between the speaker, the watermelon, and the microphone. On User Two (2)and User Three (3), the repeatability rises to 93.33%. The average percentage of success in the repeatability test shows impressive results with 91.11%, proving that the device is repeatable.

Furthermore, after performing a survey of thirty (30) vendors regarding the device’s construction, accessibility, and accuracy, the majority of participants strongly agreed that the device is safe for users, with a mean of 3.7. Even while the results show that the device is better than the traditional way of measuring watermelon ripeness and is suitable for commercial usage, it still has the least favorable evaluation, with a mean of 3.57. Overall, the poll findings show that the device is convenient for users, with a mean of 3.64, implying that respondents "Strongly Agree" with the item's convenience.

Several data were acquired and deemed to be significantly relevant based on the tests and surveys performed using the SB21 Watermelon Ripeness Detector. The combination of NIRS for spectral identification and Fast Fourier Transform for acoustic analysis showed that the watermelon ripeness level can be easily determined in a non-destructive manner with high accuracy.

Furthermore, the researchers discovered a significant difference between the manual and automated methods of determining watermelon ripeness. Researchers have also shown that the device's findings are repeatable. With this, findings demonstrated that the device is functional to the user in terms of device construction, accessibility, and accuracy.

5. ACKNOWLEDGMENT

The authors would like to take this opportunity to express their deepest gratitude to God for making this research possible. Likewise, they extend their appreciation to their families, mentors, friends, respondents, the Polytechnic University of the Philippines Research Institute for Science and Technology (PUP-RIST) through its Undergraduate Research Pitching Competition Grant, and the Department of Science and Technology–SEI. Their consideration, unending support, patience, advice, encouragement, and coaching have made this research possible.

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