Classification of Coconut Maturity through its Meat Thickness and Acoustics Properties using FFT Algorithm

CRUZ, Mark B.
Electronics Engineering Department
Technological University of the Philippines

LUMOGDANG, Camille V.,
Electronics Engineering Department
Technological University of the Philippines

sREAL, Eddieson P.
Electronics Engineering Department
Technological University of the Philippines

ESCOSIO, Jonalyn E.
Electronics Engineering Department
Technological University of the Philippines

HERNANDEZ, Louiejim C.
Electronics Engineering Department
Technological University of the Philippines

TAMASE, Michelle Andrea V.
Electronics Engineering Department
Technological University of the Philippines

FERNANDEZ, Edmon O.
Faculty
Electronics Engineering Department
Technological University of the Philippines

Abstract— The farmers and vendors in the Philippines classify coconuts through knocking manually either by bare hands or knife as 'mala-uhog', 'mala-kanin' and 'mala-tenga'. The said technique is very well-known but yet carries no scientific proof. Thus, the proponents conducted this study which is to characterize the coconut maturity according to meat thickness and the acoustic properties of the sound produced when the shell is knocked, named as peak frequency. Sixty coconuts were sampled; each being initially categorized by a 'mangangatok' to the stage it belongs using the conventional method. These were taken into an improvised sound proof box that is equipped with an electret microphone connected to the computer. Each were knocked five times using a bolo knife at a constant distance and then opened right after for the measurement of its meat thickness using a Vernier Caliper. The recorded sounds were then analyzed using Fast Fourier Transform (FFT) Algorithm in OCTAVE. The results showed that each stages have specific range of frequency. Statistical analysis shows that each of the three stages has high correlation between 0.869 and 0.897 in terms of meat thickness vs. peak frequency. Based on the values obtained, it can be concluded that the Peak Frequency has high correlation to meat thickness in each of the stages, proving that these are directly proportional with each other (increases at the same time).

Keywords------mangangatok,mala-uhog,mala-tenga,mala-kanin, Fast Fourier Transform,Peak Frequency (Key Words)

I. INTRODUCTION

According to the Philippine Coconut Authority, the coconut industry comprises 26% of the agricultural lands in the Philippines, an evidence to its large economic potential. About 3.26 million hectares is planted to coconut that represents 64 out of 81 provinces in the Philippines. The farmers and vendors in the Philippines use the sound produced by coconuts through knocking manually either by bare hands or knife to identify the maturity stages of coconuts namely as 'mala-uhog', 'mala-kanin' and 'mala-tenga' [1]. *Mala-uhog (mucous-like), (about 6-month old)* has very soft and gelatinous meat which can be consumed along with its juice [2]. It also appears that the highest volume of water is achieved during the first 9 months of the fruit [3] .*Mala-kanin (cooked rice-like), (7-8 month old)* has soft meat turned into a firm solid mass [2] and *mala-tenga (leather-like), (8-9 month old)* has thick meat which is no longer suitable for fresh consumption [2]. Figure 1 shows the coconut in three different stages. The said technique is very well-known but yet carries no scientific proof. Thus, the proponents has conducted this study to gather and prove that the sounds produced by tapping can classify coconut maturity.

Figure 1.a. *Mala-uhog*

Figure 1.b. *Mala-kanin*

Figure 1.c. *Mala-tenga*

Over the years, many efforts were taken to characterize coconuts. Two of which is by having the coconuts dehusked before being dropped [4] and by using an acoustic tester for the investigation of the physical, mechanical, physiological and acoustic properties [3]. In addition, the design of costumed environments, such as a box, made for knocking the shell is also has been done [1]. All of the acquired sounds in the said techniques were all processed using Fast Fourier Algorithm (FFT) which is an algorithm that can visualize the signal in frequency domain from time domain [8]. It is also said that FFT has the best abilities when compared to other algorithms such as Autocorrelation [7]. This algorithm can be used for characterization of different crops aside from coconuts such as eggs [5] and watermelons [6] by acquiring vibrations on the surface.

The main objective of the study is to fully characterize the tapped sounds through sound processing. The proponents aims to tabulate and separate each maturity into categories having ranges that does not overlap with each other. These ranges are acquired by considering the best sampling method that can be done in obtaining the sounds through recording. The importance of this initial study is very essential to the later study, authored also by the same proponents, which is for the development of a standalone coconut knocking device [10].

The scope of the study mainly focuses on the characterization of the coconuts through sounds. Any visual characteristics such as color and size is not considered since many coconuts looks the same but belongs to different maturity stages.

Through this study, the grading of coconuts will be more trustworthy. It will help farmer and vendors to identify coconuts that will be made into several products [9] (e.g. as copra, virgin coconut oil, coconut cream, coconut milk, desiccated coconut, coconut water, nata de coco, etc). On the side of the consumers, they would be able to find their preferred quality by knowing the qualities of the tapped sounds produced. Also, as the demand for ‘buko’ in the food industry increases, the need to identify their correct maturity is very important and impactful for business owners since errors are very costly. .

II. METHODOLOGY

Sixty coconuts were sampled; each being initially categorized by a *‘mangangatok’* to the stage it belongs using the conventional method. Figure 2 shows the block diagram of the sampling method done by the proponents. The coconuts are first knocked inside a soundproof box and then opened to measure the meat thickness. The sound produced was then analyzed using OCTAVE and Fast Fourier Algortihm.

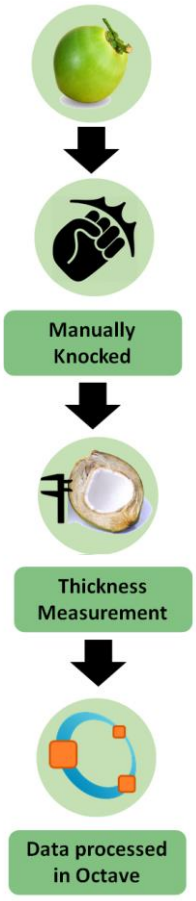


Fig 2. *Sampling Method Block Diagram*

A. Manual Knocking

Each coconuts were taken into an improvised sound box. . Inside is an electret microphone connected to a computer. This box would isolate each to the outside environment so that the recorded sounds will be as quiet as possible. Before knocking the coconuts with a knife edge, the distance is considered. The distance is measured from the top of the box to the shell. Figure 3 shows the actual set up of the Sampling method used.

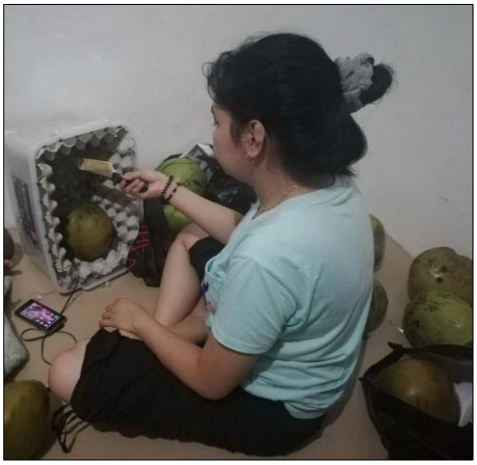


Fig 3. *Actual Set-up of the Sampling Method done with the Soundproof box*

Each coconuts were knocked five times so that the best quality of sound could be obtained. It is also for knowing if each sounds produced in any location of the shell will yield the same peak frequency.

B. Thickness Measurement

After acquiring the sounds, the coconuts are opened right after for the measurement of meat thickness using a Vernier caliper as seen in Figure 4.

Fig 4. *Measuring of meat thickness using a Vernier Caliper*

C. Sound Processing

The recorded sounds were then processed through OCTAVE using the Fast Fourier Algorithm (FFT). The Peak Frequency was considered and tabulated. Figure 5 shows an example spectral graph of the sound files using the algorithm. The first shows the original sound signal in Time domain and the second shows the signal in the Frequency domain. The graph of the signal in Frequency domain is used for finding the value of the highest peak frequency .

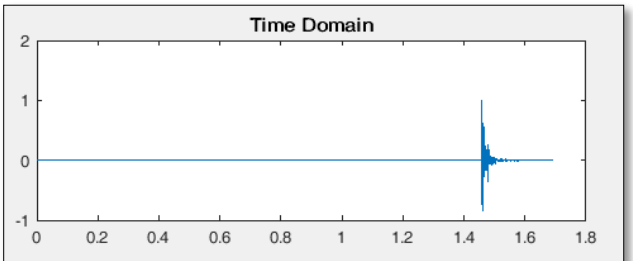


Fig 5. *Spectral Analysis of Recorded Coconut Sounds*

III. RESULTS

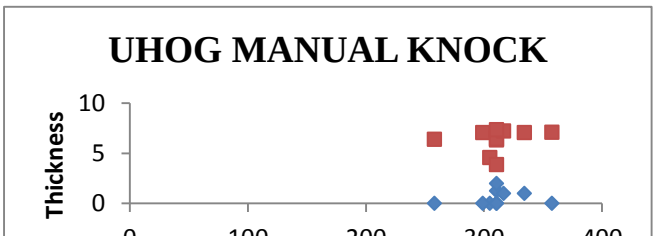
The meat thickness and peak frequency collected in the experiment done is summarized in Table 1.

TABLE I. *SPECIFIC RANGES OF FREQUENCY AND MEAT THICKNESS ACCORDING TO MATURITY*

Coconut Maturity Level	Range		r^2
	Frequency (Hz)	Meat Thickness (mm)	
Malauhog	200-399	0-2.0	**0.86993**
Malakanin	400-599	2.1-5.5	**0.87472**
Malatenga	600-800	5.6-7.0	**0.89747**

As we can see, the peak frequency of each sounds from each of the maturity differs from one another. It could be observed that the mala-tenga has the highest peak frequency in all of the three stages. This means that the pitch and tone of the sound it produces is the most notable, which can be described as high and piercing. It is also observed that mala-tenga has the thickest meat and lowest water content. On the other hand, the sound produced by mala-uhog has the lowest peak frequency. The tone it produces can be described as surface-like. The meat thickness of it is almost zero and the water content is high in volume. Lastly, the ranges of mala-kanin lies in the middle of the two previous stages. The tone it produces is almost as high as mala-tenga but not as piercing. The meat thickness and water content also lies in the middle.

To further prove the strong relationship of the peak frequency to maturity, the proponents applied a statistical analysis on it by relating it to the meat thickness. It can be seen that all maturity has high correlation (above 80%). Figure 6 displays the correlation diagram between the fruit's meat thickness and frequency.



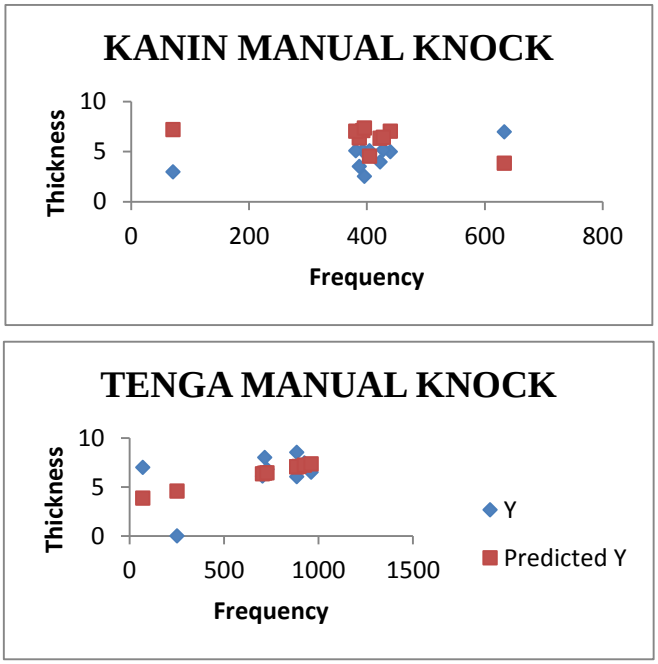


Fig 6. *Meat Thickness vs. Peak Frequency Correlation Plot*

IV. CONCLUSION

After gathering data, analysis of soundwaves produced by tapping the nuts by using either bare hands or knife was done on the coconuts. After the results are in, it can be concluded that:

1) The frequency has high correlation to meat thickness of coconuts. The frequency range of the sound wave produced and meat thickness of the three classification of coconuts is different from one another. Moreover, coconut maturity has direct relationship both to meat thickness and frequency, whereas the coconut matures where its meat thickens, its frequency also increases.

2) A standard (range of meat thickness) was also established in categorizing the stages of maturity of the fruit. For the reason that current practices in our country only consider personal feeling and opinions which may differ from person to person.

In conclusion, the knocking of coconuts has scientific basis. Its acoustic property, which is the frequency of sound waves produced of the coconuts when knocked, has correlation value to its meat thickness of above 70% as provided by the study.

V. RECOMMENDATIONS

As experienced by the proponents, the following can be recommended for future progress of the study :

1) Attach an even more efficient noise cancellation system that can improve accuracy

2) Increase the sample size to build a good database.

3) Design an updated sound box capable of sound recording.

4) Use different types of mic modules for better sound quality.

VI. ACKNOWLEDGEMENT

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