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Non-Destructive Quality Evaluation of Coconut Water Based on Fruit's Maturation Using Acoustic Resonance Technique

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ABSTRACT

Coconuts are harvested at various maturity stages. Apart from kernel, coconut water also has got good market value. Coconut water from the nut can be directly collected, processed and sold at market. It can be fermented and can also be used as a by-product. So, it is important to ensure the quality of water content before processing it. It was reported that chemical composition of coconut water like TSS content and pH are affected significantly ($p<0.05$) with maturity. Thus, in this study simple linear regression models were developed to non-destructively evaluate the quality of coconut water using acoustic response of the dehusked coconuts in terms of coconut's resonance frequency. This way it helps in examining the quality and segregation of coconuts without doing destructive analysis. Acoustic model for predicting TSS content of water has got good prediction efficiency with R^2 = 0. 963 and the one for predicting pH of water has got R^2 = 0. 865. These non-destructive models therefore replaces the destructive analysis in estimating the water quality of coconuts.

Key words: *Coconut water, Quality analysis, Non-destructive method, Acoustic technique, Regression model.*

INTRODUCTION

The coconut (*Cocos nucifera*) is an economically important versatile crop. Coconut becomes the chief source of raw material for the production of large variety of products which has got commercial importance. Apart from fruit's kernel which is used for oil extraction, coconut milk and cream production, the nut's water content has also got good market value. Coconut water can be directly bottled and sold in a market or after fermentation it can also be used as a by-product in the preparation of Nata de coco. With suitable pre-treatments and aseptic packaging techniques, coconut water can extend its shelf life up to a year. The chemical composition of coconut water changes based on the nut's maturation and variety[1]. Thus, in the aspect of meeting out the specific needs and standards, it is very important to check the quality of water content before processing it to a useful product.

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This study therefore, focuses on the development of non-destructive quality evaluation of coconut water content using acoustic resonance technique. Total soluble solids (TSS) and pH were chosen as the variables to explain the quality as they indicate the sweetness and sourness of the water content respectively.

MATERIAL AND METHODS

2.1 Determination of Acoustic property

Husked coconuts of three different maturity stages namely immature, matured and over matured fruits, 30 coconuts each for each stage of maturity were procured from local farm located in Pattukottai (Thanjavur district), India. Each husked coconut was placed horizontally in a continuous sorting acoustic system developed at IIFPT[2,3], shown in fig. 1. Each sample was then subjected to impact force to its equatorial position at three different places around the equator with three repetitions at each point. The sound signals were then acquired using microphone (M/s m+p international, Germany) placed on the opposite side of the striking point. It was placed such a way that it remains few millimetres away from the sample. Further the acquired signals were processed using signal analyser (M/s m+p international, Germany) to get Fast Fourier Transformation (FFT) frequency spectra of the fruits[4]. For coconuts of all three maturity stages the sample rate of frequency range (8000 Hz) and force (533 N/m2) were maintained constant and the fruit's acoustic response was studied in terms of their resonant frequency (R_f)[4].

2.2 Quality determination of coconut water

Coconuts taken for the study were dehusked and halved. Coconut water was then extracted to conduct the study. Total Soluble Solids (TSS) content was determined by using handheld digital refractometer (ATAGO Co. Ltd, Japan) as described by Harrill and Terdwongworakal[4,5]. TSS value is expressed in terms of °Brix. pH of fruit juice was measured using a digital pH meter (Horiba Scientific, Japan) as described by A.O.A.C method[6].

2.3 Statistical analysis and modelling

The effect of maturity on TSS and pH were performed by carrying out Analysis of Variance (ANOVA) using SPSS software (IBM software, USA). Here in this research paper, Duncan's test was carried out to compare the mean values of TSS and pH of coconuts of different maturity stage. The test was carried out at 95% confidence level[7]. A simple linear regression model was then used to analyse the quality of water content in terms of TSS and pH content using XLSTAT software (Addinsoft company) in MS-Exel.

RESULTS AND DISCUSSION

3.1 Acoustic property

Resonant frequency (frequency at maximum amplitude) obtained from husked coconut samples showed only acceptable variation of frequency value within the sample when they were subjected to impact at three different locations with three repetitions at each location. Thus, average value was noted down as the sample's resonant frequency. From the results obtained (Table 1) it can be seen that the Resonant frequency was affected significantly ($p<0.05$) by maturity. The average resonant frequency value varies from 686.77±75.89 Hz to 966.83±84.50 Hz as we go across matured group of coconuts from the immature slot and further consistently increases up to 1224.67±72.14 Hz for over-matured coconuts. The result was in agreement with the report by Terdwongworakul[4]. Spectra obtained for immature, matured and over-matured samples were shown in Fig. 2. Within the samples of same maturity group variations in frequency value was obtained due to slight variation in the size and mass of the samples which was associated with standard errors. The observed variations were in acceptable range since samples of more or less similar size and mass were chosen for the study

3.2 Quality of coconut water

Like resonant frequency, TSS and pH too varied significantly ($p<0.05$) with maturity levels. Average TSS content increased from 5.80±0.44°Brix to 7.05±0.25°Brix as the coconut gets matured from immature stage and it slightly increases to 8.31±0.82°Brix in case of over-matured coconuts (Fig. 3). The result was in agreement with the report by Terdwongworakul[4]. The increasing trend of TSS might be due to the consistent increase in sucrose content when the coconut matures. Average pH significantly increased at a rate of 4.97±0.16 to 5.52±0.35 as the coconut gets matured from immature stage and it further increases to 5.84±0.26 in case of over-matured coconuts (Fig. 4). The result was in agreement with the report by Terdwongworakul[4]. This might be due to the increase in sugar content and decrease in ion concentration as the coconut gets matured from immature stage.

3.3 Statistical analysis and modelling

As mentioned before, resonant frequency of dehusked coconuts, TSS and pH of the nut's water content varied significantly ($p<0.05$) at 95% confidence level. Using simple linear regression, models were developed which non-destructively evaluates the quality of water content in terms of TSS and pH of the water. Resonant frequency, a non-destructive parameter was used as an explanatory variable in creating these models. The first model (Equ. 1) built with TSS content of the coconut water as the dependent variable has got good prediction efficiency with R^2 = 0. 964. The second model (Equ. 2) with pH as a dependent variable has got R^2 = 0. 966.

$$TSS = 3.2449 + 0.003*R_f \quad \text{Equation (1)}$$

$$pH = 4.0864 + 0.0054*R_f \quad \text{Equation (2)}$$

These models were then validated with randomly chosen 15 fresh coconuts and checked for their prediction efficiency. The model used for predicting TSS content of the coconut water has got prediction efficiency of 96.3% (R^2 = 0. 963) with 3.7% of prediction error. The other model used in the prediction of pH of coconut water has got prediction efficiency of 86.5% (R^2 = 0. 865) with 13.5% of error. Prediction efficiency of models were shown in Table 2.

List of figures

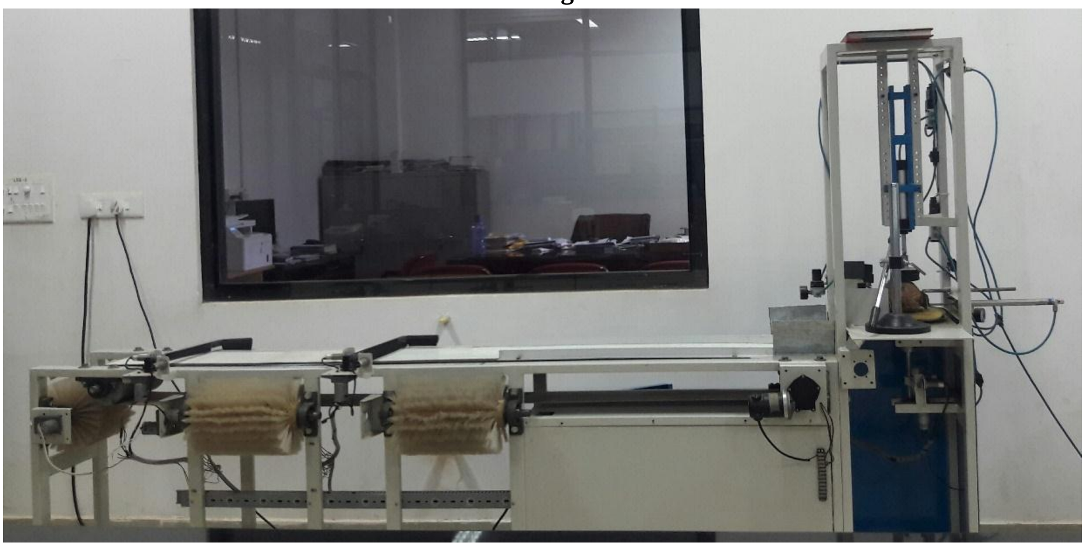
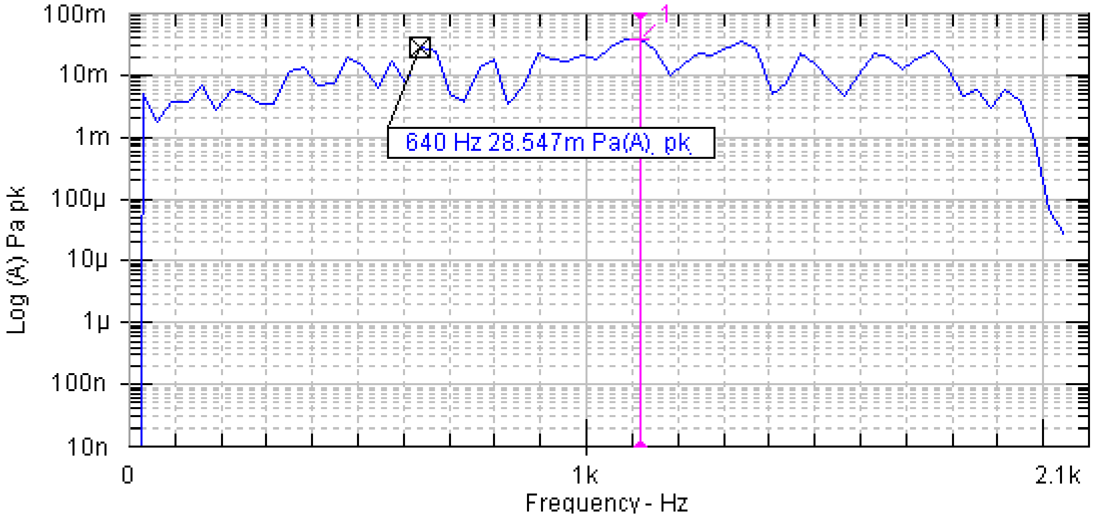
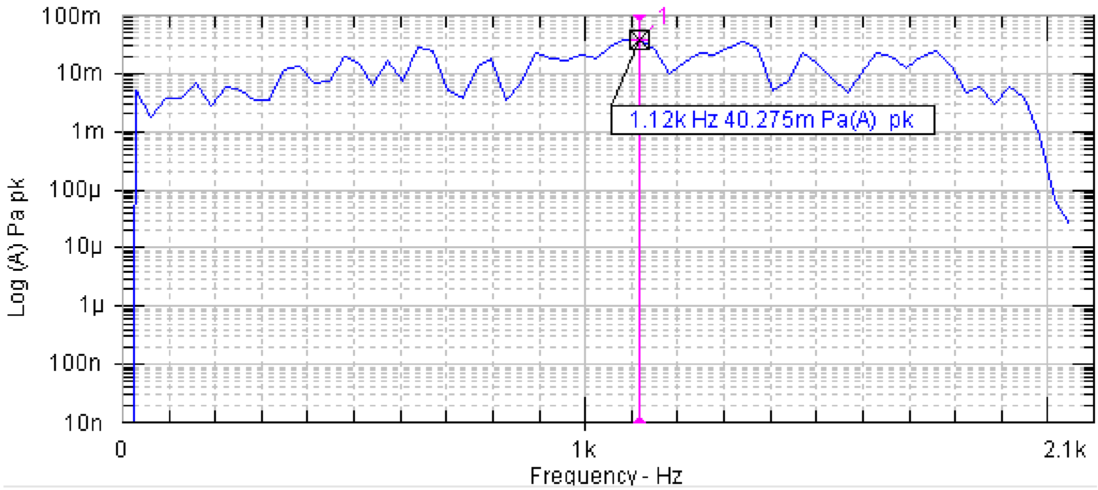


Fig. 1: Continuous sorting acoustic system



a)



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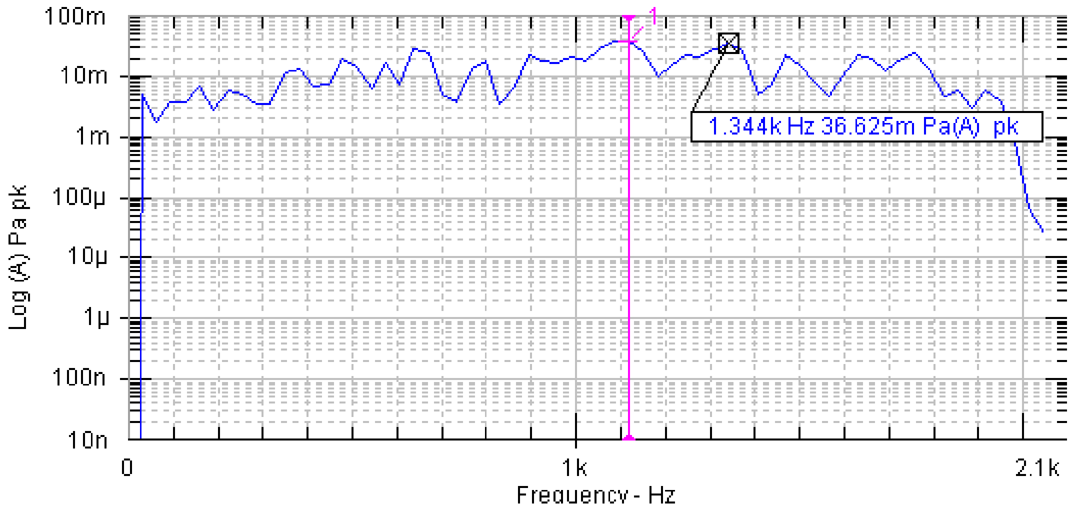

c)

Fig. 2: Spectra image of a) Immature coconut, b) Matured coconut and c) Over-matured coconut

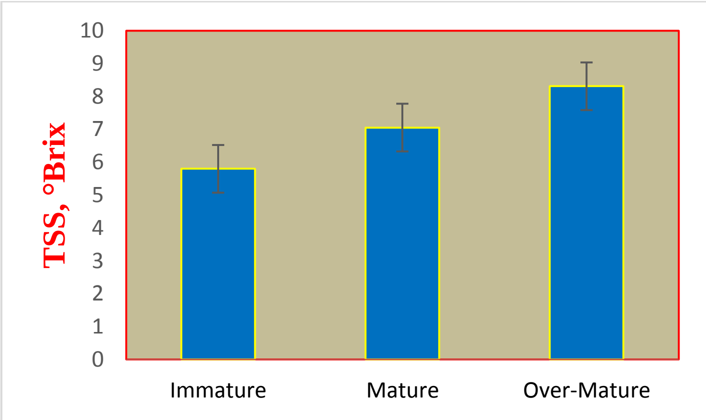

Fig.3. Changes in TSS of coconut water content at different maturity stages

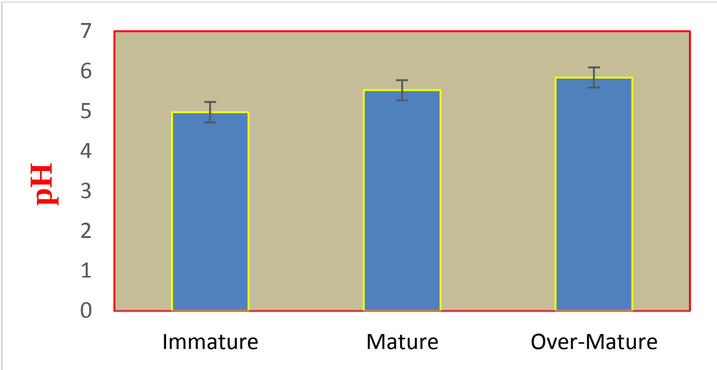

Fig. 4: Changes in pH of coconut water content at different maturity stages

Table 1: Duncan's Multiple Range Test at 95% confidence level showing effect of dependent variables on maturity

Maturity level of Husked Coconut	Source of variation		
	TSS	pH	Resonant frequency
Immature	5.80±0.44[a]	4.97±0.16[a]	686.77±75.89[a]
Mature	7.05±0.25[b]	5.52±0.35[b]	966.83±84.50[b]
Over-mature	8.31±0.82[c]	5.84±0.26[c]	1224.67±72.14[c]

Table 2: Prediction efficiency of the models in finding the TSS and pH value of the coconut water content

TSS °Brix			pH		
Observed TSS	Predicted TSS	Deviation	Observed pH	Predicted pH	Deviation
5.37	5.1259	0.2441	4.77	5.4722	0.7022
5.83	5.5309	0.2991	4.69	6.2012	1.5112
7.12	6.1759	0.9441	5.29	7.3622	2.0722
7.18	6.2509	0.9291	5.48	7.4972	2.0172
5.6	5.2099	0.3901	4.67	5.6234	0.9534
7.27	6.4039	0.8661	5.66	7.7726	2.1126
8.09	6.8299	1.2601	5.83	8.5394	2.7094
5.63	5.4469	0.1831	5.05	6.05	1
8.05	6.7489	1.3011	5.86	8.3936	2.5336
6.57	5.5909	0.9791	4.87	6.3092	1.4392

CONCLUSION

These findings on variations in TSS content and pH of the coconut water reveals that significant changes are observed on fruit's maturity. Hence it is clear that maturity affects the chemical composition of the fruit. In coconut water bottling and beverage industries, to standardize the quality of the coconut water being used, coconuts at proper maturity stage having desirable amount of TSS and pH are likely to be used. Thus, in this study a simple linear regression models of resonance frequency were created. These models are therefore considered to be the replacement for real time traditional destructive methods in estimating the water quality of coconuts.

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