Investigation of Relationship between Variation of Colour Change of Fruits with their Shelf-Life and other Physical Properties

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Abstract**—** *Relation between diffused reflectance (in spatial and in spectral domains), soluble solid content and firmness of "Mauritius" variety of pineapple (Ananas comosus) grown in Labuduwa farm, Galle, Sri Lanka together with the shelf-life have been studied for estimating the physiological maturity of them. It is found that there is no significant variation in the firmness with the shelf-life. The soluble solid content shows a liner relationship with respect the shelf-life for this sample of size ten with a coefficient of determinant (R2) of 0.87. Diffused reflectance measured using an RGB web camera with the help of two liner polarisers and converted in to spherical coordinate system and two-dimensional histograms were plotted considering the zenith and azimuth angles. It is found that the peak of the two-dimensional histograms follows similar paths and converged to the same region for all pineapple in the sample with the shelf life. Also, it is found that the average colour (by considering each pixel) ratio of red to green show a liner relationship with the soluble solid content (R2=0.1255) and shelf life (R2=0.6929).*

Keywords— Pineapples, shelf-life, multispectral imaging, Soluble Solid Content (SSC)

I. INTRODUCTION

Consumers judge the quality of fresh fruits by considering its physical properties such as appearance, firmness and smell. Better sorting method would allow fruit industry to provide more consistent fruit to the consumer and the competitiveness and the profitability of the industry can be improved. Surface colour, shape, size, soluble solids content (SSC), specific gravity, titratable acidity and total solids content are the parameters mostly used in the food industry for estimating the quality [1]. Image processing techniques have been used with different segmentation algorithms and colour grading systems for maturity estimation of fruits like papaya [3, 6]. However, Camelo et. al. found out that defined colour categories were significantly different with the environmental conditions[5].

Fernando Lopez-Garcaa *et. al* used another spectroscopic system with a 3-CCD camera in capable of acquiring images of 768x576 pixels at a resolution of 0.17mm per pixel, a lightning system with polarized filters in their front to avoid bright spots in the scene caused by cross-polarization. The lighting system was composed of eight fluorescent tubes (daylight type, 25W) powered by means of electronic high frequency ballast in order to avoid the flicker effect.[4]

Mechanical wave based non destructive tests have also been conducted for estimating the maturity. Santulli *et. al* studied fruit maturity using scanning laser Doppler vibrometry to measure fruit firmness of 'Rosa' mangoes, has revealed that the resonant frequency of the fruit decreases with ripening[7]. Mizrach *et. al* compared a method of measuring the ultrasound acoustic wave attenuation in Mangoes with penetrometer firmness measurement and resulted a correlation of r^2=0.94.

The main objective of this study is to make use of multispectral imaging techniques to estimate the physiological maturity of the "Mauritius" variety of pineapple.

II. MATERIALS AND METHODS

A sample of pineapple (Mauritius variety) grown in Labuduwa farm, Galle, Sri Lanka was selected for the study. Destructive type firmness tester (WAGNER FT Fruit tester with a plunger of 8 mm and FDK30 14 Kgf) was used to measure the firmness of the sample. Another sample of size 10 was used for diffused reflectance imaging and soluble solid content measurements. Each measurement was taken around 09.00 h from picked up day to rotting starting day. Pineapple juices have been extracted with the help of a needle punched close to the stem, in order to measure soluble solid content with the help of Atago refractometer (ATAGO).

2.1 Imaging system

The imaging system was developed using a web camera (Logitech C120,V-U0012) as the imager and white LEDs were used as the controlled light source. Two film liner polarisers (Edmund Optics Inc., NJ, USA, 600 nm in diameter and 0.22 numerical apertures) were place in front of the light source, the camera and the axes of polarisation were crossed, and the whole experiment set up was placed in a dark box.

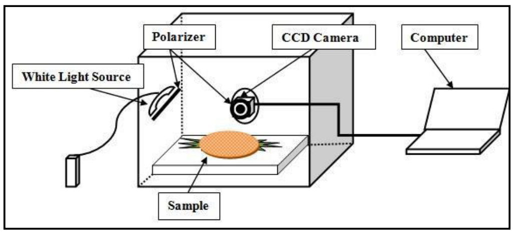


Figure 1. Diffused reflectance imaging system

Reflectance measurements were taken from the web cam as bright reference**,** dark reference and the sample. Bright reference was taken using a white paper with known reflectance and the dark measurement were taken without anything in the system. The diffused reflectance $R_D(\lambda, x, y)$of at (x,y) coordinates at wavelength λ can be calculated according to the equation (1),

$$R_D(\lambda, x, y) = \frac{S(\lambda, x, y) - D(\lambda, x, y)}{B(\lambda, x, y) - D(\lambda, x, y)} R_B(\lambda, x, y) \quad \textbf{(1)}$$

where S, D and B refer sample (without illumination or sample), dark reference and bright reference respectively and $\mathbf{R_B}$ is the reflectance of the bright reference.

IV. ANALYSIS AND RESULTS

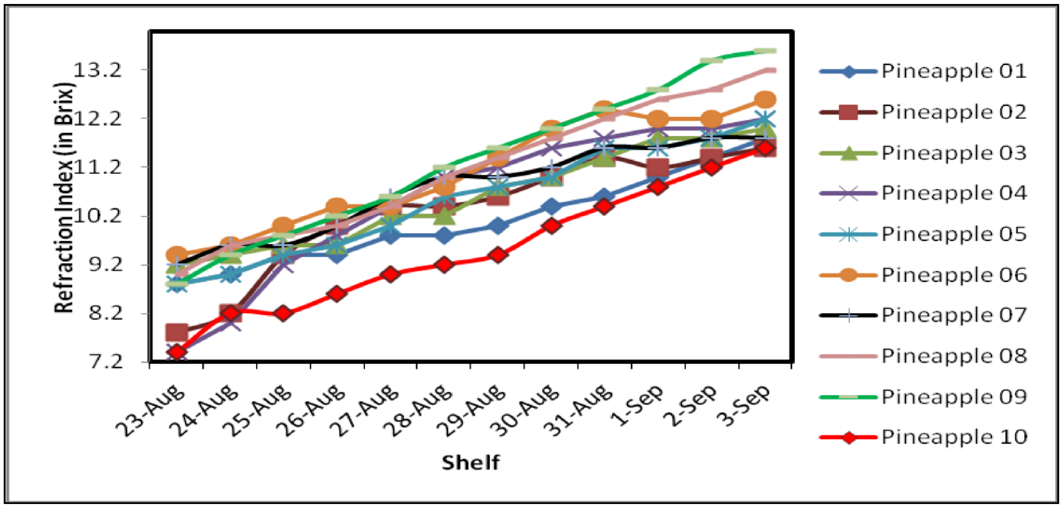
It is very clear that the soluble solid content increases linearly with the shelf-life (see **Error! Reference source not found.**) and the fitted line shows coefficient of determinant R^2=0.7816 with root mean squire error of 0.6177.

Daily measured defuse reflectance data is plotted in Figure 3, against its shelf-life, and When the diffused reflectance variation is consider as a whole (averaged in partial domain), it is found that the blue colour does not change throughout the experiment and red increases up to several days and get saturated and then green starts decreasing. Also it shows a gradual increase and finally reaching a saturation value after 8th day. Also in figure 8 we could clearly see that surface colour significantly varies from Green colour to Yellow/Orange colour.

When the relationship of soluble solid content and ratio of averaged diffused reflectance colour channel red to green ratio is considered, it can be modeled with a second order polynomial and the adjusted R^2 is 0.6929 (see Figure 5).

According to the Figure 6 the image is mostly biased to green spectra at the beginning, and when days pass by it gradually shifts to the mixture of colour Red and Yellow spectra. Though images consist of considerable number of points of images in Blue range, we could clearly observe in Figure 6 that Blue is not much affected by age, and they gradually bias towards green and red spectres with time.

Figure 2. Variation of soluble solid content with the shelf life



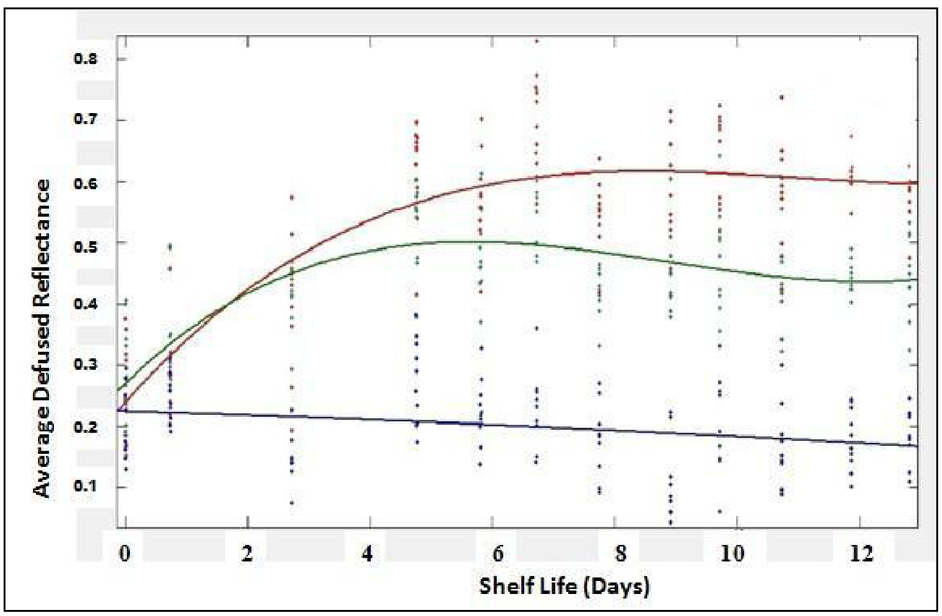


Figure 3 Average diffused reflectance of each channel with the shelf life

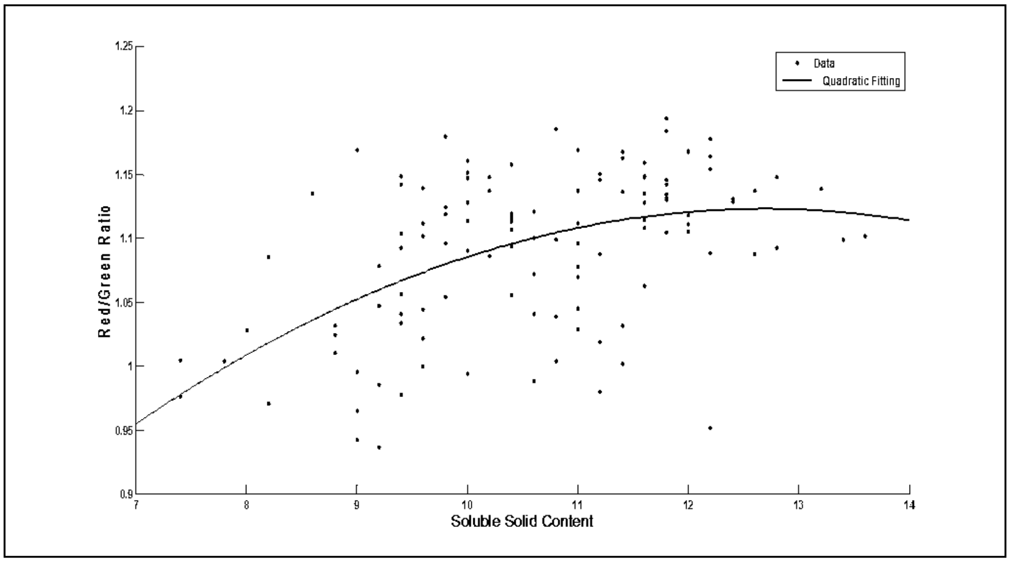


Figure 5. Plot of Colour vs. Soluble Solid Content

Diffused reflectance data obtained for red (R), green (G) and blue(B) channels considered as there axis of the camera have been transformed to spherical coordinates r, θ and Φ (See Figure 6).Refer figure 7 to understand Cartesian and spherical coordinates.

The Red and Green spectral ratios and soluble solid content were plotted in figure 5 and it shows a linear increase at the beginning and saturated in between Brix value 12 and 13, and colour ratio in between 1.1 and 1.15. The relationship has a correlation of 0.2602, standard error of 0.05457, and mostly near to a quadratic fitting. According to the figure colour property and soluble solid content property of the pineapple has a linear relationship at the beginning and after the 7th day both stay constant.

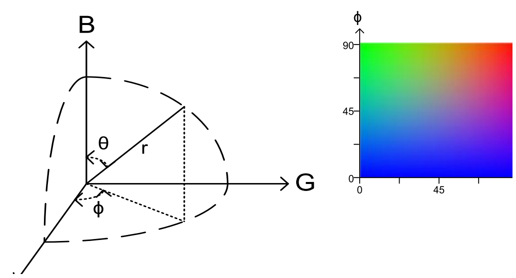
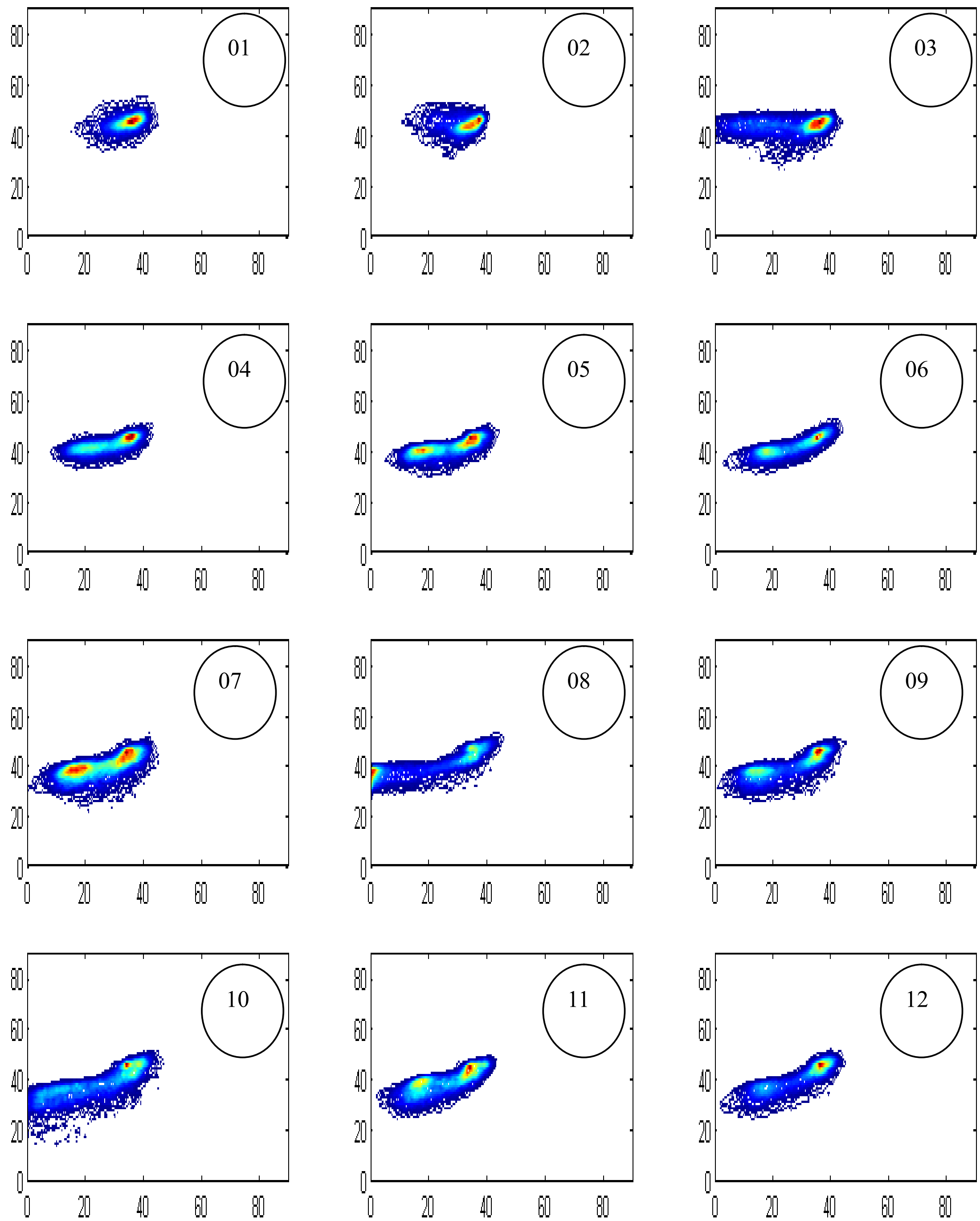


Figure 4 Conversion of the red (R), green (G) and blue (B) from the Cartesian coordinates to spherical coordinates r, θ and Φ; Right: New spectral space generated by considering θ and Φ disregarding r which carried intensity information.

Figure 6. 2-D Histogram of θ and ϕ



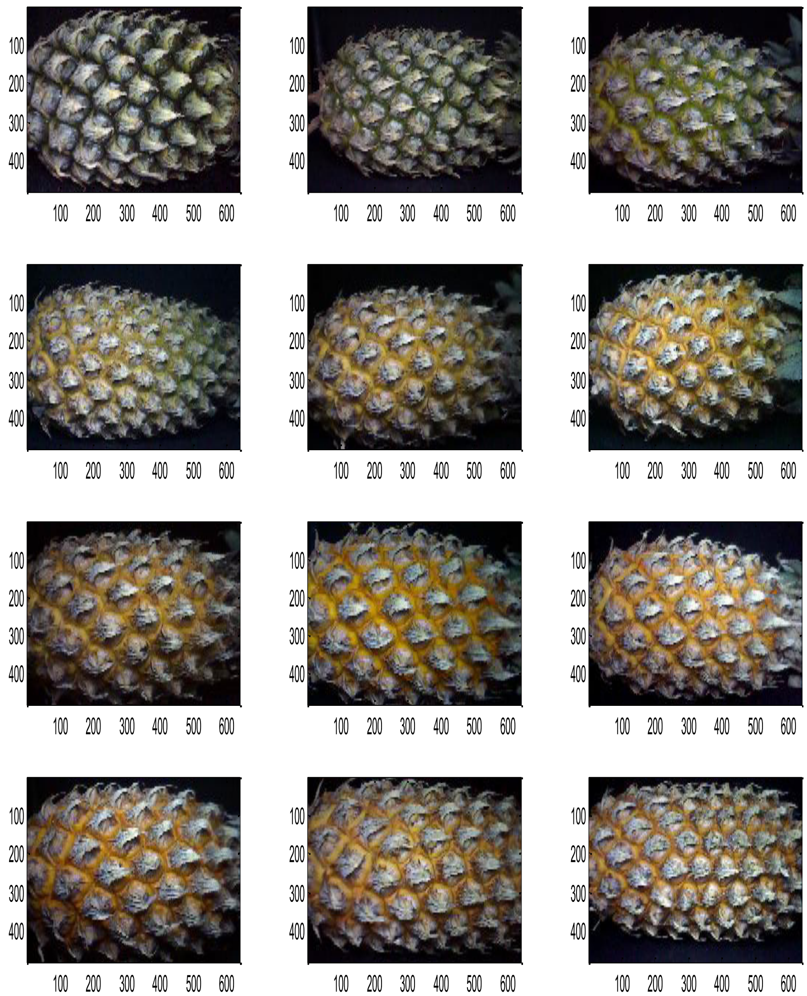


Figure 8. Daily Images of a Pineapple in 12 Days

IV. DISCUSSION

To reduce colour intensity variation occurred by changing the position of the sample daily, pictures of a dark and a white references were taken before taking sample images and defined a filter code not to have negative on infinite values of defuse reflectance. To reduce geometric error occurred due to the lighting at curved surfaces causing a significant contrast in Green and Red spectral at image analysis we used a ratio of Red by Green as one parameter.

Daily collected data for soluble solid content (in Brix scale) plotted with its shelf-life (Days) shows a significant increase and linear variation (See figure 1) with a correlation of 0.7816 and standard error of 0.6177. This linear relationship could be treated as an invariant and good signature for at least this variety of pineapples. It was also found that within 12 days the soluble solid content increases nearly 2 times. Maximum soluble solid content for pineapple in Brix scale is 13, while the minimum value is around 7.

When linear fits are made to the individual curves shown in figure 1, their gradients show the following distribution in the Table 1.

Table 1. Gradients and Intercepts of figure 4.1 curves

Pineapple No.	Gradient	Intercept
01	0.25804	8.4394
02	0.35035	8.0727
03	0.30699	8.4565
04	0.41107	7.7727
05	0.31888	8.4606
06	0.31259	9.0848
07	0.25245	9.1091
08	0.38531	8.6455
09	0.43846	8.4667
10	0.36224	7.1455
Average value	0.339638	8.36535

Normally gradients vary in between 0.2 and 0.4 and intercept vary in between 7 and 9. Already at the picking level soluble solid content is in between 7 and 9 (Brix), according to the Table 1.This average gradient which indicates the rate of increase of solid soluble content of pineapples with shelf-life can be treated as a signature for at least this variety of pineapples.

It was also found that within 12 days the soluble solid content increases nearly 2 times. Maximum soluble solid content for pineapple in Brix scale is 13, while the minimum value is around 7. In between the 6th day and 8th day whole sample exceeds the Brix value 10, so around 7th day pineapple fruit is in the eatable condition. Figure 3 shows a gradual increase and subsequent saturation of the diffuse reflectance with Shelf life. At the beginning green is higher, and Red gradually increases with time, which highly supports the Yellow and Orange colours. Blue variation shows a different behaviour from other two spectres. This may be because Green gradually changes to Yellow-Orange.

Diffuse reflectance of Red colour is more than that of Green and Blue and Blue shows smallest diffuse reflectance. Observing the figure 7 we can conclude that until the Pineapples get Yellow, Red and Green colours increase, and when the yellow gradually reaches to light Orange colour, Red gets saturated, while Green decreases. In between the 10th and 12th days Green also gets saturated. Observing the figures 6 and 2 it is apparent that with the shelf life, colour of the Pineapple gain Yellow/Orange from Green.

According to figure 2, surface colour significantly increases and saturates around 7th day when the pineapple reaches threshold in maturity, and after 10th day the colour stays constant. The variation of colour of different Pineapples always shows a constant range. According to the figure 2, at least at the beginning the Colour has an approximate linear relationship with its shelf-life. Although the actual relationship as shown below predicts a nonlinear behaviour the coefficient associated with the x^2 term is very small implying an approximate linear behaviour. The non linear model Red/Green Ratio vs. Shelf life,

$$f(x) = p1x^2 + p2x + p3 \qquad (2)$$

Coefficients (with 95% confidence bounds):

p1 = -0.0009801 (-0.001404, -0.0005564)
p2 = 0.02479 (0.0192, 0.03038)
p3 = 0.9832 (0.9672, 0.9992) with R^2=0.6929

The Red and Green spectral ratios and soluble solid content were plotted in figure 5, it has a linear increase at the beginning followed by saturation in between Brix value 12 and 13 and colour ratio in between 1.1 and 1.15. The similar behaviour is shown in Figure 2 at the plot in between surface colour and the Shelf-life. Linear model Colour vs. Soluble solid content:

$$f(x) = p1x^2 + p2x + p3 \qquad (3)$$

Coefficients (with 95% confidence bounds):

p1 = -0.005197 (-0.009868, -0.0005265)
p2 = 0.1319 (0.03365, 0.2302)
p3 = 0.2862 (-0.2259, 0.7982) with R^2=0.6602

Respective orders of magnitudes of P^1, P^2, and P^3 are somewhat similar, and therefore we can conclude that the correlation in between SSC and the Colour of the Pineapple is good. As the R^2 value is greater than 0.5, we can conclude that the correlation in between the Colour and the SSC of Pine apple is higher.

V. CONCLUSION

Surface colour of pineapple changes to yellowish orange colour from dark green colour with its shelf-life. And when the fruit get mature diffuse reflectance increases significantly and in pineapple it gets saturated nearly after 10 days (R^2= 0.6929 and SSE=0.1447). Naturally Pineapple has white portions and when the fruit get mature it decreases, but fruit is beginning to dry. So then again white portions appear. Because of these changes in natural appearance of Pineapple, Red and Green colour increases with a deceleration and Blue colour decreases at the beginning with the decrease of natural white portion and again begins to increase with the start of the drying.

Soluble solid content of pineapple increases linearly with a correlation of 0.7816 and Pineapple maximum soluble content is 13 in Brix. The increasing rate of soluble solid content of Pineapple is constant and independent from its size. It was also found that within 12 days the soluble solid content nearly doubles its value. Already at the picking level soluble solid content is in between 7 and 9 (Brix).

The resulted model in between surface colour and soluble solid content with its shelf-life is correlated in 0.2602 and RMSE is 0.3485.If there is no artificial chemical added Pineapple minimum ripping age is 7 days after picked day from the farm, and it is qualified to put in the showcase of the market. Also it gets rot within 12 days and also in before the 6th day after picking is suitable for transporting in room temperature.

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Miss. K M W Udeshi graduated from the University of Colombo in 2013 with a second class pass. Her final year dissertation was on non-destructive tests on fruits and vegetables. Currently she works as an Instructor in the Faculty of Science, University of Colombo. Her research interests include Optics, Electronics and Instrumentation.

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