Sugar Content Estimation of Date (*Phoenix dactylifera, L.*) Fruits in Tamr Stage

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ABSTRACT

Annual production of dates in the United Arab Emirates is about 250,000 tons which used to be consumed in tamr stage where fruit moisture content becomes less than 30%. Date sugar content is considered one of the most important fruit commercial characteristics where it is significant for both fresh consumption and fruit processing as well. In a previous research work Fadel *et al*. (2001) and Fadel *et al*. (2006) studied color properties of date fruits and introduced a novel computer-based method for date sugar content estimation. This method depends on calculating the intensities of the red, green, and blue components of fruit color via image processing algorithm. Color ingredients intensity was correlated to glucose, fructose and sucrose levels. In this paper, two date varieties were focused on in order to validate the concept. Lolo and Bomaan are among the most famous date varieties in the UAE. In order to enhance research credibility, fructose and glucose content were determined for each variety using the HPLC (AOAC 1990). Using the above-mentioned concept, sugar content was estimated in 43 samples of each variety and compared with the chromatography results.
The results showed that, for the two varieties, glucose and fructose might be estimated using this technique with a minimum accuracy of about 86%. This paper focuses on the validation of this technique to evaluate its practicability.

Keywords: Sugar content, date color, sugar estimation, UAE.

1. INTRODUCTION

Jahromi *et al*. (2007) studied physical properties of date fruit and concluded physical properties of Lasht cultivar. The concluded properties included mean projected area, whole fruit density, pitted fruit density and coefficient of static friction. Since most of the Total Soluble Solids (TSS) represents sugars, researchers used to determine TSS value in order to estimate date fruit total sugar content (Farag 1999). TSS determination leads to poor date sugar content estimation in addition to being a time consuming process. Al-Hooti and Sidhu (1999) investigated color measurements of specimens of fresh date fruits in terms of CIE L*a*b* color coordinate values and hue angel. The need for easy, low cost and acceptably accurate means for sugar estimation was a great motivation to start looking in this direction. The researched procedure is urgently needed in the research field as well as in the market where date harvesting, storage and processing depend on its sugar content. This paper is complementary to a previous paper, where Fadel *et al.* (2001) and Fadel *et al.* (2006), studied five varieties, Lolo, Bomaan, Khalas, and Fard which are commonly grown in the Gulf area where ten samples of each variety were studied. A 1216 X 912 pixels image of each sample was captured using

Sony Mavica digital camera (FD83, 6X model) for each fruit. Fluorescent light was used as illumination source as recommended by Davies and Perkins (1991). A brief code was developed in order to analyze color of each image separately and plot the RGB frequency distribution (Color Histogram) (Fadel *et al.* (2006)). For each variety, image data for the whole ten samples were stacked together to determine its RGB frequency distribution. R, G, and B intensity values of each pixel were used to calculate standard deviation, mean and median for each fruit as well as for the stacked data (for the whole sample of the fruit variety). Analysis of variance (ANOVA) between means was used as a statistical tool to find out if there was a significant difference within the same variety as well as between varieties. Sucrose, fructose, and glucose content in each sample were determined using the HPLC. Each sugar content value was correlated to the color intensity mean of R, G, and B resulting from the color analysis process of the sample's image. A prediction equation was concluded to estimate the content of each sugar type in each variety. To validate the stated concept, 43 samples of Lolo and Bomaan varieties' glucose and fructose content were estimated and compared with the HPLC measurements. Comparisons between measured and estimated values were carried out using error frequency distribution and the cumulative error. Research results showed the possibility of estimating date sugar content using fruit color analysis. Due to the great variation among date fruits, this procedure may be used with promising accuracy.

1.1. Image Analysis

Davis and Perkins (1991) reported that the combination of cool white and daylight fluorescent tubes produced the sharpest contrast between different grades of fruit and distinguished best when the fruit was viewed against a medium green background. Fadel *et al.,* (2001) studied color properties of different date varieties in *tamr* stage. They concluded that, for human eyes, color differences might not be the best criteria to differentiate between date varieties. Digital equipment is used to respect images as a mathematical format. They added that blue ingredient could be used as separation factor among investigated date varieties. Furthermore, they suggested a sugar content estimation via color analysis. Wulfshon *et al*. (1989) used a color camera to capture date fruit images to determine the relative reflectance in the range of 400-1000 nm for good and defective dates. Furthermore they used an infrared cutoff filter. They noted that the red band image was most effective for detecting defective Majhul dates, the green band image performed best for Zahidi dates.

1.2. Date Fruit Sugar Content

Hulme (1970) mentioned that, at one end of the sugar content range, the juice of the lime may contain no more than traces of sugar. At the other extreme 61% of the fresh weight of the date consists of sugar. He added that sugar content of fruits of a particular species might vary considerably with variety, soil, and climatic conditions during their life on the plant. He also listed glucose, fructose and sucrose content as 32, 32.7, and 8.2 respectively for date fruit.
Al-Noimi and Al-Amir (1980) stated that in the *tamr* stage the fruit shows a sharp increase in sucrose content and dramatic decrease in water content. They added that sucrose content exceeds glucose and fructose content in the first growth stages, and then sucrose starts to convert into mono saccarides until sucrose content is less than 5% in the *tamr* stage. The conversion rate depends on temperature and relative humidity of storage environment in addition to the physiological activities of the fruit.

Fadel *et al*. (2001) concluded that, due to the significant correlation factors between sugar contents and red and green colors, both colors' intensities should be used to estimate sugar contents in date fruits under specific conditions of illumination.

2. MATERIALS AND METHODS

This paper focuses on two varieties of date fruits in the *tamr* stage. Bomaan and Lolo are among the most common date fruits in the Gulf area. Ten date fruits of each variety were picked from the El-Sad factory randomly. The image of each fruit was captured using the Mavica digital camera under fluorescent illumination. Matlab of Mathworks was used to find out the R, G, and B intensity of each pixel of each fruit's image and then to calculate the mean value for each fruit. The fructose and glucose content of each fruit were determined using the HPLC technique. Since sucrose decomposes into mono sugars under storage conditions, it was neglected in this study. Furthermore, HPLC results showed that sucrose content is less than 0.2% in the whole sample. SPSS regression tools were used to relate each fruit fructose and glucose content to its associate R and G intensity mean value. As a result, prediction equations of fructose and glucose content according to R or G intensity were developed for each variety. For validation, additional samples of 43 fruits of the two varieties were collected from two different sources. 31 of them were gathered from the El-Sad factory and the rest were collected from the local market were nobody could trace their producer. The fruits in the additional samples were handled in the same way the first sample's fruits were handled. The one exception was that the values of color intensity were applied in the associated prediction equation and the predicted values of sugar content were compared to the resulting values from the HPLC system. SPSS was used to find out the prediction error for each variety.

3. DISCUSSION

Comparisons between measured and estimated values were carried out using error frequency distribution and the cumulative errors were determined. Table 1, shows image analysis results for both Bomaan and Lolo collected from different producers. Color intensity means of market samples exceeded those of El-Sad samples except in the blue where in both cases (Bomaan and Lolo); the intensity mean of market samples exceeded that of El-Sad's samples.

Table 1. Image analysis results of date fruits samples

Variety		**Intensity Mean**			**Intensity Median**			**Intensity Standard Deviation**		
		Red	Green	Blue	Red	Green	Blue	Red	Green	Blue
Bomaan										
Sources	**El-Sad**	0.1368	0.1079	0.0763	0.1216	0.0902	0.0667	0.0657	0.0664	0.0505
	Local market	0.1448	0.1152	0.0714	0.1333	0.1509	0.0667	0.0540	0.0463	0.0347
Lolo										
Sources	**El-Sad**	0.1289	0.1266	0.1158	0.0863	0.0824	0.0706	0.1925	0.1933	0.1957
	Local market	0.1972	0.1449	0.0686	0.1843	0.1216	0.0667	0.0904	0.0820	0.0344

3.1. Bomaan Variety

Ten date fruits from the El-Sad date factory were used to develop a prediction equation that can be used to estimate sugar content of Bomaan variety in general. Equation 1 is the prediction equation of fructose content as a function of red color intensity. As a result, the predicted values of 43 samples are plotted in figure 1 in addition to the observed measurements. It should be mentioned that various types of errors may exist under experimental conditions such as fruit curvature and surface brightness.

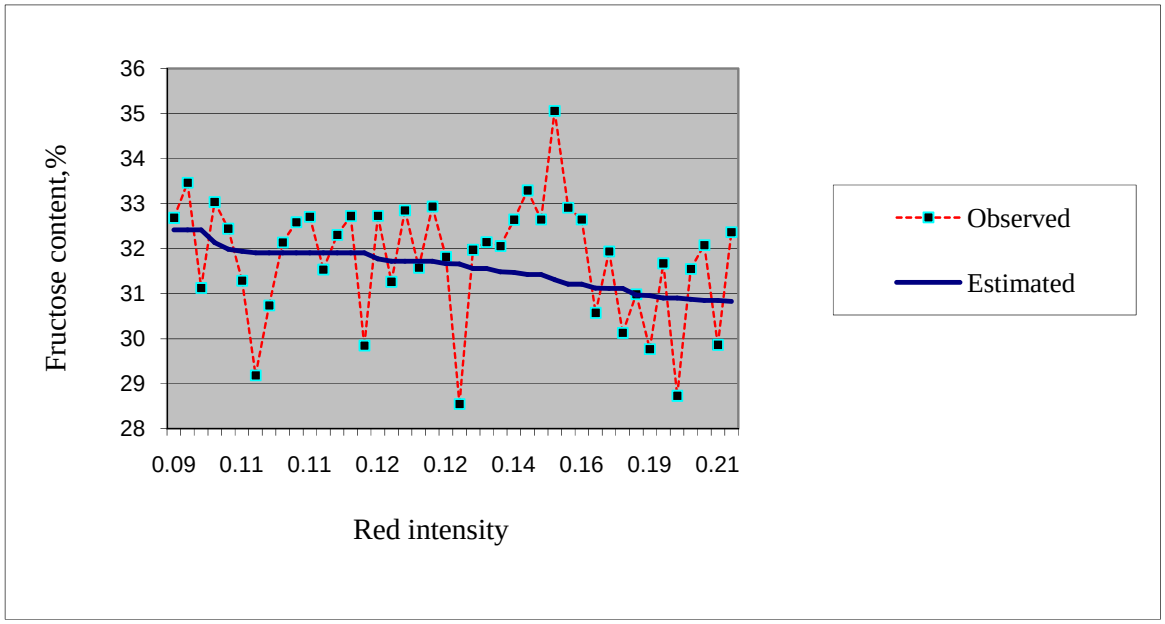

Figure 1. Bomaan, Fructose content estimation

Figure 2 shows that more than 50% of the estimated fructose content had less than 3.7% of error where 80% had less than 5.5% error. On the other hand, 80% of the glucose content estimations for Bomaan variety deviated less or more than 5.4% of the measured values.

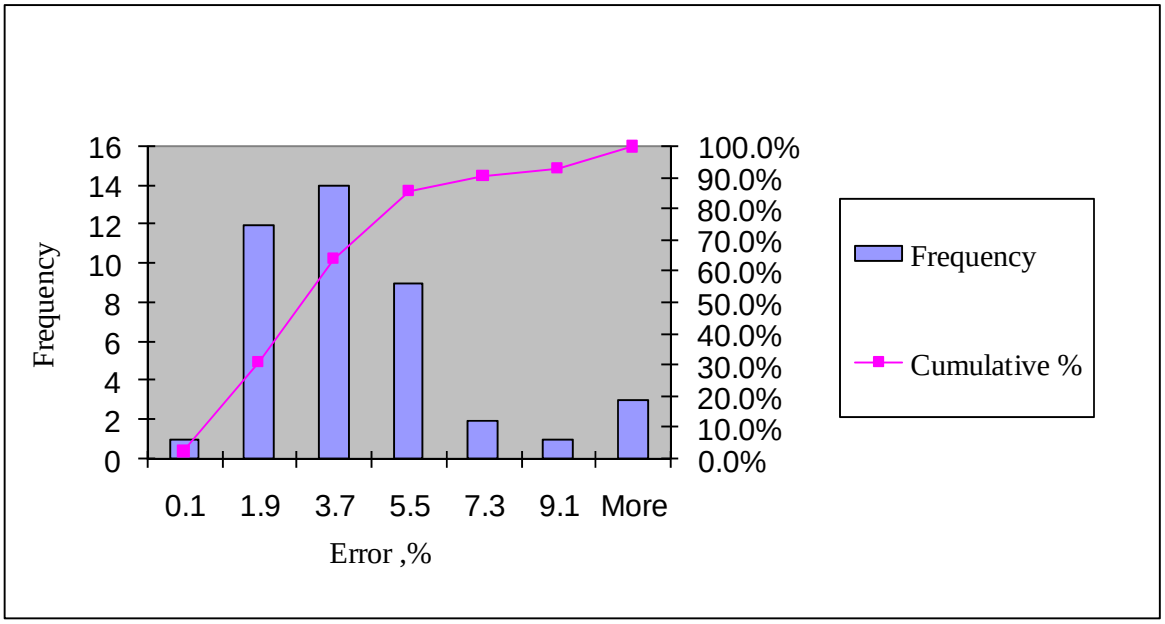

Figure 2. Fructose estimation error histogram for Bomaan variety

Figure 3 displays a comparison between estimated and measured Bomaan glucose content as a function of the green ingredient intensity mean values, while figure 4 represents error analysis of the estimated values.

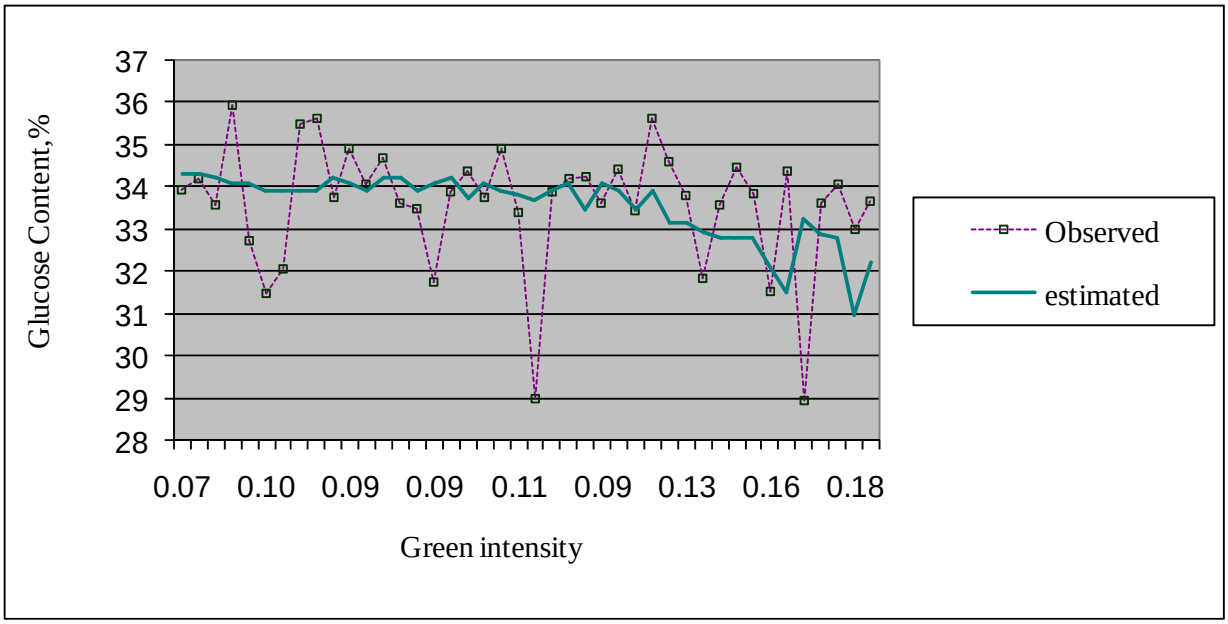

Figure 3. Bomaan glucose content estimation

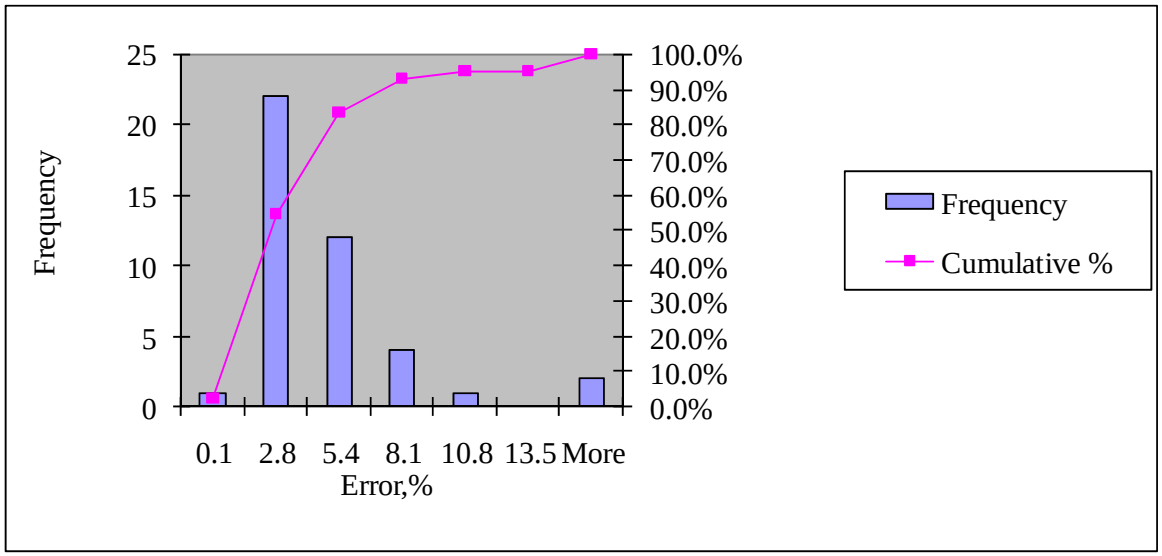

Figure 4. Glucose estimation error for Bomaan variety

It is noticeable in figure 4 that about 60% of the predicted glucose content has less than 2.8% error; while more than 80% of the estimated values were 5.5% more or less than the measured glucose content.

$$Fructose,\% = e^{(3.3919+(\frac{0.0078}{R})} \quad \text{..... (1)}$$

$$Glucose,\% = 33.6009 + 26.0049G - 225.7G^2 \text{ ..... (2)}$$

Where R and G represent red and green color intensities mean values respectively.

3.2. Lolo Variety

The relation between red color intensity and fructose content in Lolo date fruit is represented by an exponential equation, equation 3. In addition to equation 4 this equation was used to estimate both fructose and glucose content respectively. Figure 5 exhibits both measured and estimated values of 43 Lolo fruits' fructose content as a result of applying R intensity mean values in equation 3 in addition to the HPLC readings for the same fruits.

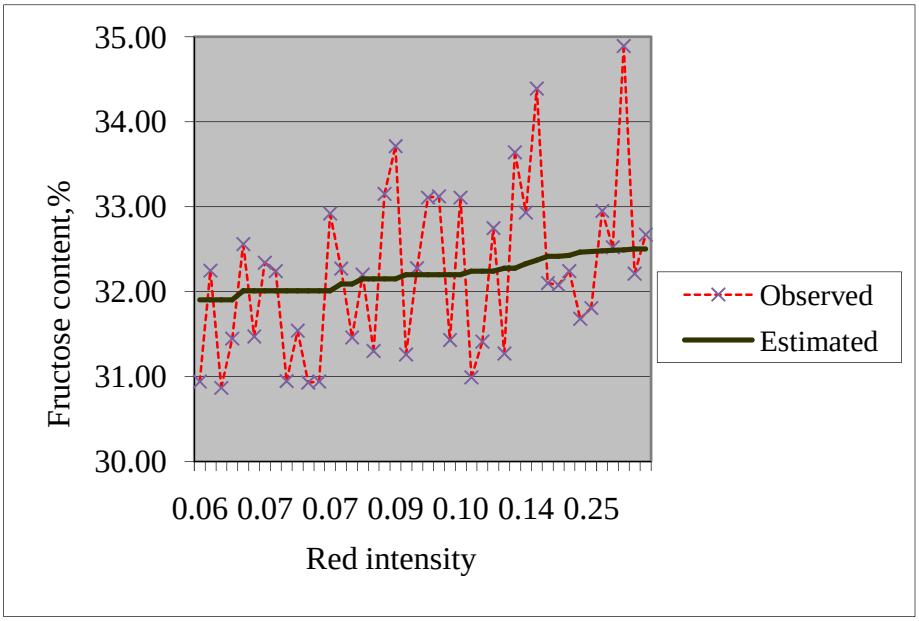

Figure 5. Lolo fructose content estimation

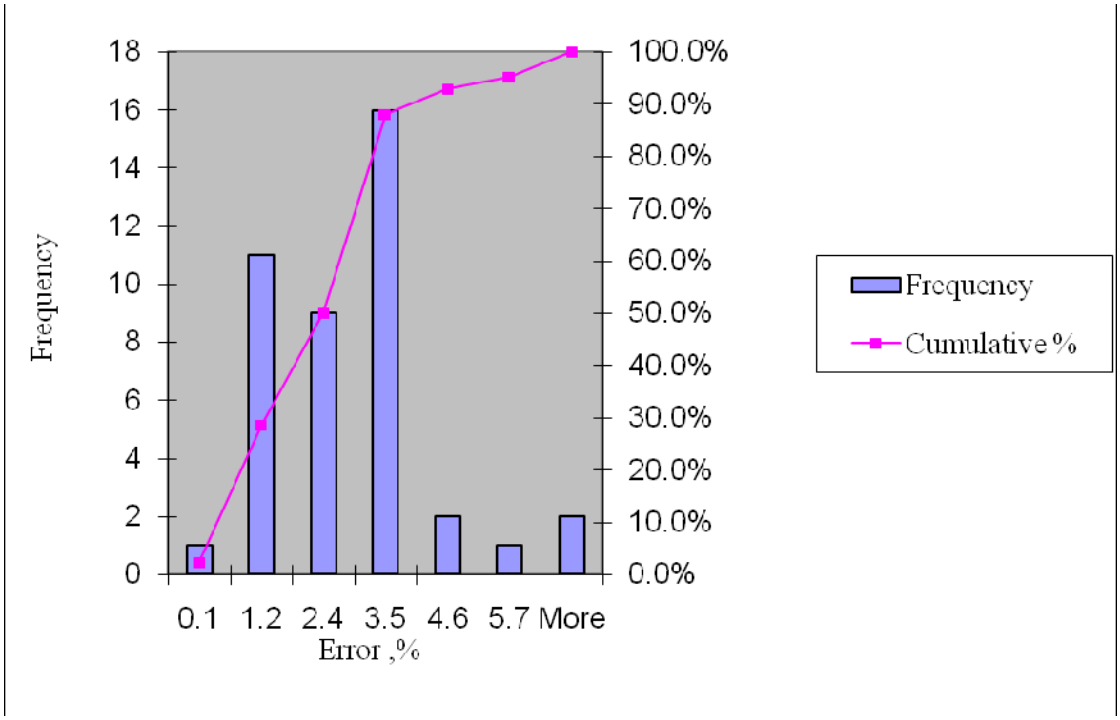

Figure 6. Fructose estimation error for Lolo variety

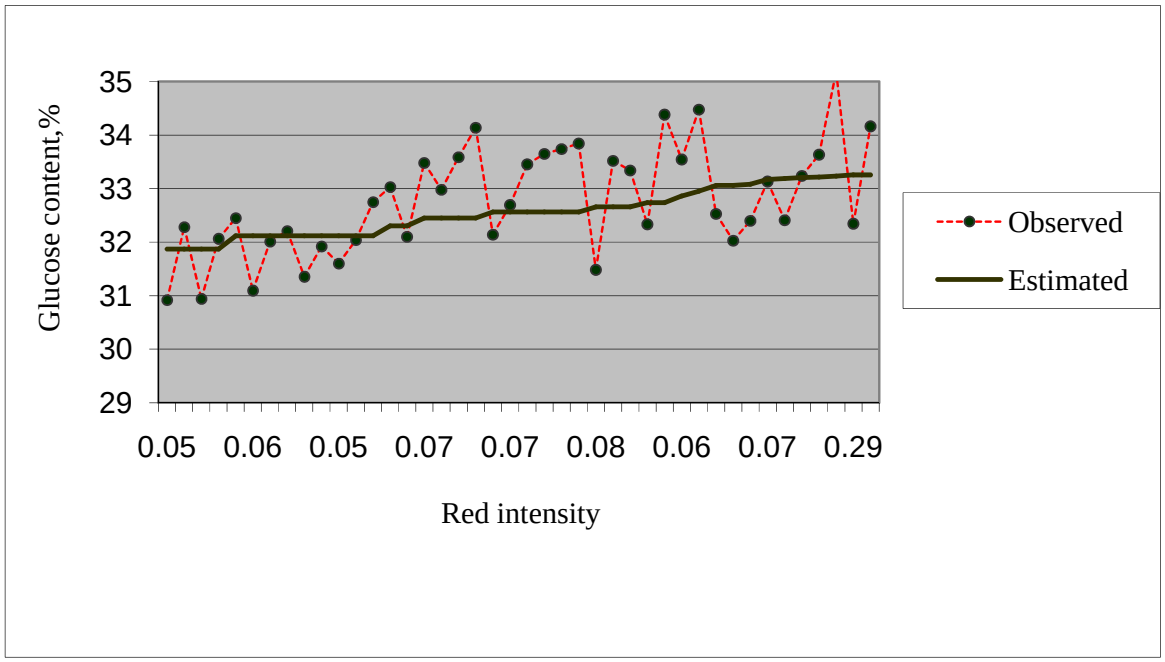

Figure 7. Lolo glucose content estimation

Lolo glucose estimated values were plotted in figure 7 as a result of applying fruit red intensity mean values in equation 4 as well as the associated measured glucose content.

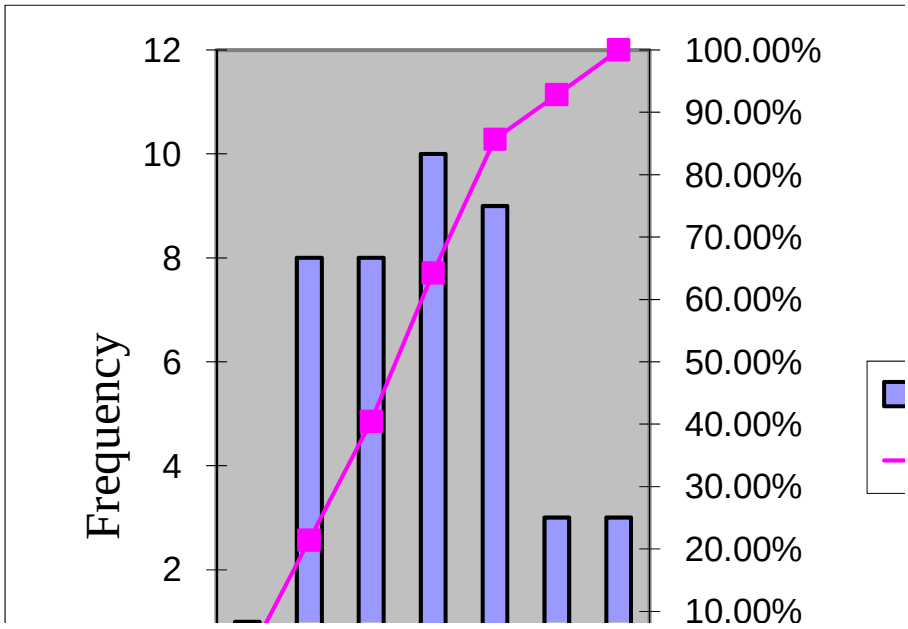

Figure 8. Glucose estimation error for Lolo variety

$$Fructose,\% = e^{(3.486+(\frac{-0.0014}{R})} \quad \text{……..……} \quad \textbf{(3)}$$

$$Glu\cos e,\% = 33.602 - (\frac{0.1038}{R}) \quad \text{……} \quad \textbf{(4)}$$

From figure 6 and Figure 8, about 90% of fructose content in Lolo was estimated with an error of less than 3.5%, whereas this ratio was 3.7% for the glucose content in the same variety.

4. CONCLUSION

Since fruit color might be a function of various genetic, growing, and storage conditions, it was difficult to trace all of those factors in real life. The samples under investigation were collected from different sources in order to avoid their color being affected by one or more of the above-mentioned factors. The resulting data showed a minimum accuracy of 86%, while higher accuracies were experienced in some cases. Using color intensity to estimate sugar content of date fruits in its *tamr* stage proved its practicality, but is waiting for application of hardware/software cooperation to build a stand alone system for date sugar content estimation.

5. REFERENCES

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