American-Eurasian J. Agric. & Environ. Sci., 7 (3): 366-369, 2010
ISSN 1818-6769

Prediction of Carrot Total Soluble Solids Based on Carrot Water Content

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Abstract: A regression model is useful tool in development of prediction method of some fruit quality characteristics. For example, fruit total soluble solids (TSS) are often determined using laboratory tests, but it may be more suitable to develop a method which uses a determined quality characteristic. In this study, one linear regression model for predicting TSS of Nantes carrot based on carrot water content (WC) was suggested. The statistical results of the study indicated that in order to predict TSS of carrot based on WC the linear regression model TSS = 34.9-0.30 WC with R^2 = 0.86 can be recommended.

Key words: Carrot · Quality characteristics · Prediction · Total soluble solids (TSS) · Water content

INTRODUCTION

Carrot (*Daucus carota* L.) is an important vegetable because of its large yield per unit area throughout the world and its increasing importance as human food [1]. It belongs to the family Umbelliferae. The carrot is believed to have originated in Asia and now under cultivation in many countries [2]. It is orange-yellow in color, which adds attractiveness to foods on a plate and makes it rich in carotene, a precursor of vitamin A. It contains abundant amounts of nutrients such as protein, carbohydrate, fiber, vitamin A, potassium, sodium, thiamine and riboflavin [1-4] and is also high in sugar [5]. It is consumed fresh or cooked, either alone or with other vegetables, in the preparation of soups, stews, curries and pies. Fresh grated roots are used in salads and tender roots are pickled [6]. Its use increases resistance against the blood and eye diseases [2].

Fruits and vegetables contain large quantities of water in proportion to their weight. Vegetables contain generally 90-96% water, while for fruits normal water content is between 80 and 90% [7]. Water content has important effects on the storage period length of fruits and vegetables [8-10]. It also exerts a profound influence on the quality characteristics of fruits and vegetables [6, 7, 11]. Therefore, the present investigation was undertaken to develop a model for predicting carrot total soluble solids based on carrot water content.

MATERIALS AND METHODS

Plant materials: Carrots (*Daucus carota* L., cv. Nantes) were purchased from a local market in Karaj, Iran. They were visually inspected for freedom of defects and blemishes. Carrots were then washed with tap water and treated for the prevention of development of decay by dipping for 20 min at 20°C in 0.5 g L^{-1} aqueous solution of iprodione and then air dried for approximately 1 h.

Experimental procedure: In order to obtain required data for determining linear regression model, two quality characteristics of carrot, i.e. water content and total soluble solids of seventy-five randomly selected carrots were measured using laboratory tests (Table 1). Also, in order to verify linear regression model by comparing its results with those of the laboratory tests, ten carrots were taken at random. Once more, water content and total soluble solids of them were determined using laboratory tests (Table 2).

Water content: The water content (WC) of carrots was determined using the equation 1:

$$\text{Water content (\%)} = (M_1 - M_2)/M_1 \times 100 \quad (1)$$

Where:
M_1 = Mass of sample before drying, g
M_2 = Mass of sample after drying, g

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Table 1: The mean values, Standard Deviation (S.D.) and Coefficient of Variation (C.V.) of water content (WC) and total soluble solids (TSS) of the seventy-five carrots used to determine liner regression model

Parameter	Minimum	Maximum	Mean	S.D.	C.V. (%)
WC (%)	76.30	88.5	83.60	3.23	3.87
TSS (%)	8.60	12.3	9.83	1.05	10.60

Table 2: The mean values, Standard Deviation (S.D.) and Coefficient of Variation (C.V.) of water content (WC) and total soluble solids (TSS) of the ten carrots used to verify linear regression model

Parameter	Minimum	Maximum	Mean	S.D.	C.V. (%)
WC (%)	75.60	88.5	83.30	3.84	4.61
TSS (%)	8.60	12.2	9.83	1.24	12.60

Total soluble solids: The total soluble solids (TSS) of carrots were measured using an ATC-1E hand-held refractometer (ATAGO, Japan) at temperature of 20°C.

Regression models: A typical linear regression model is shown in equation 2:

$$Y = k_0 + k_1X \quad (2)$$

Where:
Y = Dependent variable, for example TSS of carrot
X = Independent variable, for example WC of carrot
k_0 and k_1 = Regression coefficients

In order to predict TSS of carrot based on carrot WC one linear regression model was suggested.

Statistical analysis: A paired sample t-test and the mean difference confidence interval approach were used to compare the TSS values predicted using model with the values measured by laboratory tests. The Bland-Altman approach [12] was also used to plot the agreement between the TSS values measured by laboratory tests with the TSS values predicted using model. The statistical analyses were performed using Microsoft Excel (Version 2003).

RESULTS AND DISCUSSION

Linear regression model, p-value of independent variable and coefficient of determination (R^2) of the linear regression model (TSS-WC model) are shown in Table 3. In TSS-WC model TSS of carrot can be predicted as a function of carrot WC. The p-value of independent variable and R^2 of the TSS-WC model were 5.04E-22 and 0.86, respectively. Based on the statistical results, the TSS-WC model was judged acceptable.

Table 3: Linear regression model, p-value of independent variable and coefficient of determination (R^2)

Model	p-value of independent variable	R^2
TSS = 34.9 – 0.30 WC	5.04E-22	0.86

Table 4: Water content (WC) and total soluble solids (TSS) of the ten carrots used in evaluating linear regression model

		TSS (%)	
Sample No.	WC (%)	Laboratory test	TSS-WC model
1	75.6	12.20	12.20
2	80.0	11.00	10.90
3	81.0	10.40	10.60
4	82.3	10.90	10.20
5	82.7	9.70	10.10
6	84.5	9.20	9.60
7	85.4	8.80	9.30
8	86.1	8.80	9.10
9	87.2	8.70	8.70
10	88.5	8.60	8.30

A paired samples t-test and the mean difference confidence interval approach were used to compare the TSS values predicted using the TSS-WC model and the TSS values measured by laboratory tests. The Bland-Altman approach [12] was also used to plot the agreement between the TSS values measured by laboratory tests with the TSS values predicted using the TSS-WC model.

The TSS values predicted by the TSS-WC model were compared with TSS values determined by laboratory tests and are shown in Table 4. A plot of the TSS values determined by TSS-WC model and laboratory tests with the line of equality (1.0: 1.0) is shown in Fig. 1. The mean TSS difference between two methods was 0.070% (95% confidence interval:-0.196% and 0.336%; P = 0.566). The standard deviation of the TSS differences was 0.371%. The paired samples t-test results showed that the TSS values predicted with the TSS-WC model were not significantly different than that measured with laboratory tests. The TSS differences between these two methods were normally distributed and 95% of these differences were expected to lie between $\mu+1.96\sigma$ and $\mu-1.96\sigma$, known as 95% limits of agreement [12-15]. The 95% limits of agreement for comparison of TSS determined with laboratory tests and the TSS-WC model were calculated at-0.658 and 0.798% (Fig. 2). Thus, TSS predicted by the TSS-WC model may be 0.658% lower or 0.798% higher than TSS measured by laboratory test. The average percentage differences for TSS prediction using the TSS-WC model and laboratory test was 2.9%.

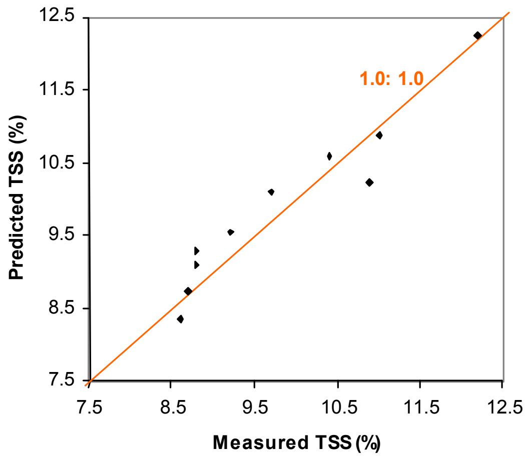

Fig. 1: Measured TSS and predicted TSS using the TSS-WC model with the line of equality (1.0: 1.0)

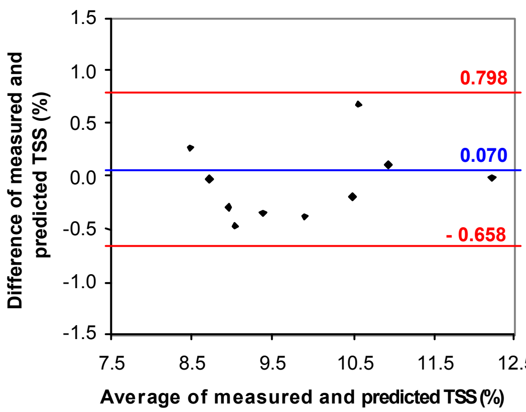

Fig. 2: Bland-Altman plot for the comparison of measured TSS and predicted TSS using the TSS-WC model; the outer lines indicate the 95% limits of agreement (-0.658, 0.798) and the center line shows the average difference (0.070)

CONCLUSION

In conclusion paired samples t-test results indicated that the difference between the values predicted by the model and measured by laboratory tests were not statistically significant ($P > 0.05$). Therefore, the TSS-WC model provides a simple method to predict total soluble solids of carrot based on carrot water content.

ACKNOWLEDGEMENT

The authors are very much grateful to the Islamic Azad University, Takestan Branch, Iran for giving all type of support in conducting this experiment. Also, thanks to Eng. Borzoo Ghareei Khabbaz for technical help.

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