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Prediction of Carrot Total Soluble Solids Based on Water Content and Firmness of Carrot

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Abstract: Fruit total soluble solids (TSS) is frequently determined using laboratory tests, but it may be more appropriate and suitable to develop a model which uses other determined quality characteristics. In this study, a two-variable linear regression model for predicting carrot TSS based on water content (WC) and firmness (FIR) of carrot was suggested. Paired samples t-test results showed that the difference between the TSS values predicted by two-variable linear regression model and measured by laboratory tests were not statistically significant and to predict carrot TSS based on WC and FIR of carrot the two-variable linear regression model TSS = 36.94 - 0.368 WC + 0.001 FIR with R^2 = 0.87 can be suggested.

Key words: Carrot · Prediction · Total soluble solids · Water content · Firmness

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].

The present study was carried out to develop a two-variable linear regression model for predicting carrot total soluble solids based on water content and firmness of carrot.

MATERIALS AND METHODS

Plant Materials: Carrots (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. After that, they were transferred to the laboratory and held at 5±1°C and 90±5% relative humidity until laboratory tests.

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

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

$$WC = 100 \times (M_1-M_2)/M_1 \quad (1)$$

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

Parameter	Minimum	Maximum	Mean	S.D.	C.V. (%)
WC (%)	76.3	88.5	83.6	3.23	3.87
FIR (N)	2543	3271	2975	195	6.57
TSS (%)	8.60	12.3	9.83	1.05	10.6

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

Parameter	Minimum	Maximum	Mean	S.D.	C.V. (%)
WC (%)	75.6	88.5	83.3	3.84	4.61
FIR (N)	2467	3271	2980	209	7.00
TSS (%)	8.60	12.2	9.83	1.24	12.6

Where:
WC = Water content, %
M_1 = Mass of sample before drying, g
M_2 = Mass of sample after drying, g

Total Soluble Solids (TSS): The TSS of carrots was measured using an ATC-1E hand-held refractometer (ATAGO, Japan) at temperature of 20°C.

Firmness (FIR): The FIR of carrots was analyzed using a Hounsfield texture analyzer (Hounsfield Corp., UK). The test used was a shear or cut test on the 50 g carrot pieces closely placed into a 6×6×6 cm test box with 8 chisel knife blades. The variations in carrots size and geometry were minimized by testing the pieces of same thickness from the carrots. The test mode used for the texture analysis was "Force in Compression". A 5000 N load cell, test speed of 100 mm min^{-1} and post-test speed 600 mm min^{-1} were used. The "Trigger Type" was set to "Button" and distance to be traveled was set to 68 mm. The range of the cutting force was set to 2000-3400 N based on pre-tests and the maximum cutting force measured during each test was considered as FIR.

Regression Model: A typical two-variable linear regression model is shown in equation 2:

$$Y = k_0 + k_1X_1 + k_2X_2 \quad (2)$$

Where:

Y = Dependent variable, for example TSS of carrot
X_1 and X_2 = Independent variables, for example WC and FIR of carrot, respectively
k_0, k_1 and k_2 = Regression coefficients

In order to predict carrot TSS based on WC and FIR of carrot a two-variable 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 the model with 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 model. The statistical analyses were performed using Microsoft Excel 2007.

RESULTS AND DISCUSSION

Two-variable linear regression model, p-value of independent variables and coefficient of determination (R^2) of the model are shown in Table 3. In this model carrot TSS can be predicted as a function of WC and FIR of carrot. The p-value of independent variables (WC and FIR) and R^2 of the model were 5.13E-11, 0.09212 and 0.87, respectively. Based on the statistical results, the two-variable linear regression model was accepted.

A paired samples t-test and the mean difference confidence interval approach were used to compare the TSS values predicted using the 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 model.

The TSS values predicted by the model were compared with TSS values determined by laboratory tests and are shown in Table 4. A plot of the TSS values determined by the model and laboratory tests with the line

Table 3: Two-variable linear regression model, p-value of independent variables (WC and FIR) and coefficient of determination (R^2)

Model	p-value of independent variables		R^2
	WC	FIR	
TSS = 36.94 - 0.368 WC + 0.001 FIR	5.13E-11	0.09212	0.87

Table 4: Water content (WC), firmness (FIR) and total soluble solids (TSS) of the ten randomly selected carrots used in evaluating two-variable linear regression model

Sample No.	WC (%)	FIR (N)	TSS (%)	
			Laboratory test	Model
1	75.6	2467	12.2	12.1
2	80.0	2972	11.0	11.1
3	81.0	2938	10.4	10.7
4	82.3	2896	10.9	10.2
5	82.7	2999	9.70	10.2
6	84.5	3020	9.20	9.50
7	85.4	3024	8.80	9.20
8	86.1	3112	8.80	9.10
9	87.2	3271	8.70	8.80
10	88.5	3097	8.60	8.20

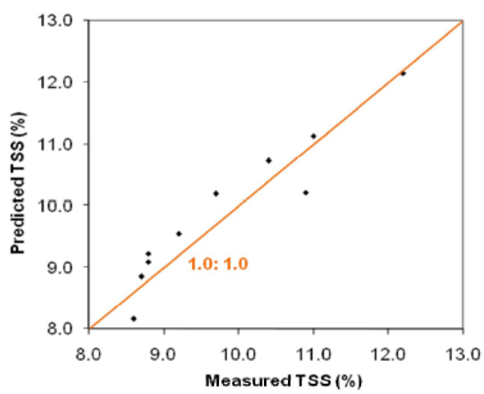

Fig. 1: Measured TSS and predicted TSS using the two-variable linear regression model with the line of equality (1.0: 1.0)

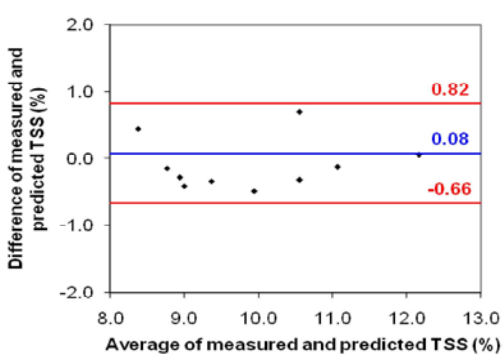

Fig. 2: Bland-Altman plot for the comparison of measured TSS and predicted TSS using the two-variable linear regression model; the outer lines indicate the 95% limits of agreement (-0.66, 0.82) and the center line shows the average difference (0.08)

of equality (1.0: 1.0) is indicated in Fig. 1. The mean TSS difference between two methods was 0.08% (95% confidence interval: -0.19% and 0.35%; P = 0.5217). The standard deviation of the TSS differences was 0.38%. The paired samples t-test results indicated that the TSS values predicted with the 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 model was calculated at -0.66% and 0.82% (Fig. 2). As a result, TSS predicted by the model may be 0.74% lower or higher than TSS measured by laboratory test. The average percentage difference for TSS prediction using the model and laboratory test was 3.5%.

CONCLUSION

In order to predict carrot total soluble solids (TSS) based on water content (WC) and firmness (FIR) of carrot the two-variable linear regression model TSS = 36.94 - 0.368 WC + 0.001 FIR with R^2 = 0.87 can be suggested.

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