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Modeling of Carrot Firmness Based on Carrot Water Content

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Abstract: There are many cases in which it is desirable to determine relationships among some fruit quality characteristics. For example, fruit firmness (FIR) are often determined using laborious and time consuming laboratory tests, but it may be more suitable and economical to develop a method which uses an easily available characteristic. In this study, one linear regression model for predicting FIR of Nantes carrot based on carrot water content (WC) was suggested. The statistical results of the study indicated that in order to predict FIR of carrot based on WC the linear regression model FIR = - 1665 + 55.5 WC with R^2 = 0.84 can be recommended.

Key words: Carrot · Firmness · Water content · Prediction · Modeling

INTRODUCTION

Carrot (*Daucus carota* L.) is an important vegetable crop not only for its large yield but also for its food value [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 firmness 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 firmness 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. Again, water content and firmness of them were determined using laboratory tests (Table 2).

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

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

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 firmness (FIR) of the seventy-five carrots used to determine 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

Table 2: The mean values, standard deviation (S.D.) and coefficient of variation (C.V.) of water content (WC) and firmness (FIR) of the ten carrots used to verify 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

Firmness: The firmness (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. Based on the average firmness of carrots in 0-days (3200 N); the range of the cutting force was set to 2000-3400 N and the maximum cutting force measured during each test was considered as stiffness.

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

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

Where:

Y = Dependent variable, for example FIR of carrot

X = Independent variable, for example WC of carrot

k_0 and k_1 = Regression coefficients

In order to predict FIR 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 FIR 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 FIR values measured by laboratory tests with the FIR 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 (FIR-WC model) are shown in Table 3. In FIR-WC model FIR of carrot can be predicted as a function of carrot WC. The p-value of independent variable and R^2 of the FIR-WC model were 5.79E-21 and 0.84, respectively. Based on the statistical results, the FIR-WC model was judged acceptable.

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

The FIR values predicted by the FIR-WC model were compared with FIR values determined by laboratory tests and are shown in Table 4. A plot of the FIR values determined by FIR-WC model and laboratory tests with the line of equality (1.0: 1.0) is shown in Fig. 1. The mean FIR difference between two methods was - 19.5 N (95% confidence interval: - 90.9 N and 51.7 N; P = 0.550). The standard deviation of the FIR differences was 99.7 N. The paired samples t-test results showed that the FIR values predicted with the FIR-WC model were not significantly different than that measured with laboratory tests. The FIR 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 [12-14]. The 95% limits of agreement for comparison of FIR determined with laboratory tests and the FIR-WC model were calculated at - 215 and 176 N (Fig. 2). Thus, FIR predicted by the FIR-WC model may be 215 N lower or 176 N higher than FIR measured by laboratory test. The average percentage differences for FIR prediction using the FIR-WC model and laboratory test was 2.5%.

Table 4: Water content (WC) and firmness (FIR) of the ten carrots used in evaluating linear regression model

		FIR (N)	
Sample No.	WC (%)	Laboratory test	FIR-WC model
1	75.6	2467	2530
2	80.0	2972	2777
3	81.0	2938	2832
4	82.3	2896	2902
5	82.7	2999	2924
6	84.5	3020	3025
7	85.4	3024	3075
8	86.1	3112	3111
9	87.2	3271	3176
10	88.5	3097	3248

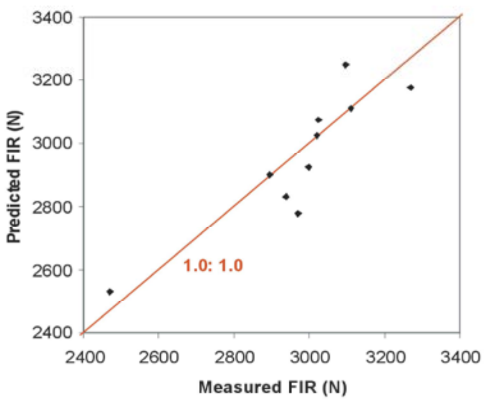

Fig. 1: Measured FIR and predicted FIR with the line of equality (1.0: 1.0).

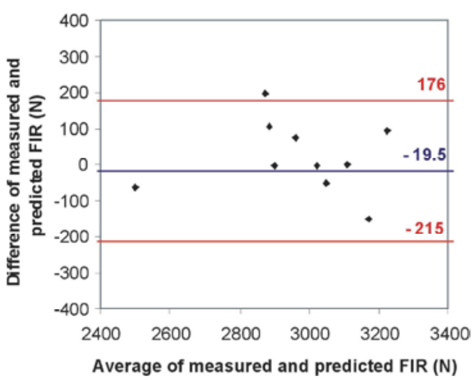

Fig. 2: Bland-Altman plot for the comparison of measured FIR and predicted FIR; the outer lines indicate the 95% limits of agreement (-215, 176) and the center line shows the average difference (-19.5).

CONCLUSION

In order to predict carrot firmness (FIR) based on water content (WC) of carrot the linear regression model FIR = - 1665 + 55.5 WC with R^2 = 0.84 can be suitably suggested.

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