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Prediction of Carrot Water Content Based on Carrot Firmness

Majid Rashidi and Fereydoun Keshavarzpour

Department of Agriculture, Shahre-Rey Branch,
Islamic Azad University, Tehran, Iran

Abstract: Carrot water content (WC) is often determined using lengthy laboratory tests, but it may be more suitable to develop a model which uses a determined quality characteristic. In this study, one linear regression model for predicting carrot WC based on carrot firmness (FIR) was suggested. Paired samples t-test results showed that the difference between the WC values predicted by model and measured by laboratory tests were not statistically significant and to predict carrot WC based on carrot FIR the linear regression model WC = 38.38 + 0.015 FIR with R^2 = 0.84 can be employed.

Key words: Carrot % Prediction % Modeling % 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]. Therefore, the present investigation was undertaken to develop a model for predicting carrot water content based on carrot firmness.

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 linear regression model, two quality characteristics of carrot, i.e. firmness and water content 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, firmness and water content of them were determined using laboratory tests (Table 2).

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

Corresponding Author: Dr. Majid Rashidi, Ph.D., Department of Agriculture, Shahre-rey Branch, Islamic Azad University, Tehran, Iran.

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

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

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

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

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.

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

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

Where:

WC = Water content,%

M_1 = Mass of sample before drying, g

M_2 = Mass of sample after drying, g

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

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

Where:

Y = Dependent variable, for example WC of carrot

X = Independent variable, for example FIR of carrot

k_0 and k_1 = Regression coefficients

In order to predict carrot WC based on carrot FIR 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 WC values predicted using model with the WC values measured by laboratory tests. The Bland-Altman approach [12] was also used to plot the agreement between the WC values measured by laboratory tests with the WC values predicted using model. The statistical analyses were performed using Microsoft Excel 2007.

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

Model	p-value of independent variable	R^2
WC = 38.38 + 0.015 FIR	5.79E-21	0.84

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

		WC (%)	
Sample No.	FIR (N)	Laboratory test	WC-FIR model
1	2467	75.6	75.9
2	2972	80.0	83.5
3	2938	81.0	83.0
4	2896	82.3	82.4
5	2999	82.7	83.9
6	3020	84.5	84.3
7	3024	85.4	84.3
8	3112	86.1	85.7
9	3271	87.2	88.1
10	3097	88.5	85.4

RESULTS AND DISCUSSION

Linear regression model (WC-FIR model), p-value of independent variable and coefficient of determination (R^2) of the model are shown in Table 3. In this model carrot WC can be predicted as a function of carrot FIR. The p-value of independent variable and R^2 of the WC-FIR model were 5.79E-21 and 0.84, respectively. Based on the statistical results, the WC-FIR model was judged acceptable.

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

The WC values predicted by the WC-FIR model were compared with WC values determined by laboratory tests and are shown in Table 4. A plot of the WC values determined by WC-FIR model and laboratory tests with the line of equality (1.0: 1.0) is shown in Fig. 1. The mean WC difference between two methods was 0.32% (95% confidence interval: -0.96% and 1.60%; P = 0.584). The standard deviation of the WC differences was 1.09%.

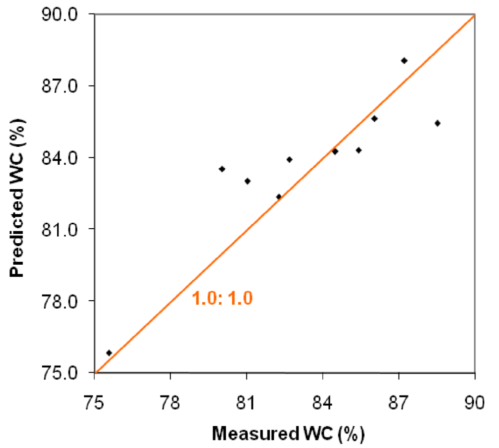

Fig. 1: Measured WC and predicted WC using the WC-FIR model with the line of equality (1.0: 1.0)

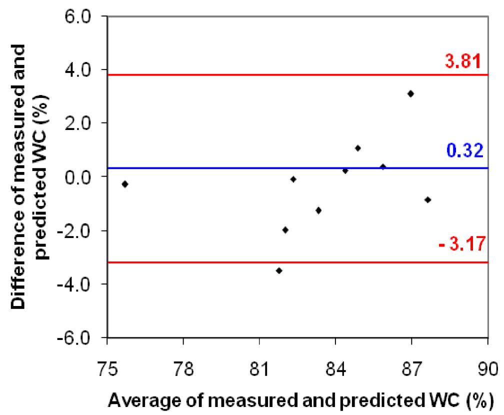

Fig. 2: Bland-Altman plot for the comparison of measured WC and predicted WC using the WC-FIR model; the outer lines indicate the 95% limits of agreement (-3.17, 3.81) and the center line shows the average difference (0.32)

The paired samples t-test results showed that the WC values predicted with the WC-FIR model were not significantly different than that measured with laboratory tests. The WC differences between these two methods were normally distributed and 95% of these differences were expected to lie between μ+1.96F and μ-1.96F, known as 95% limits of agreement [12-15]. The 95% limits of agreement for comparison of WC determined with laboratory tests and the WC-FIR model was calculated at -3.17% and 3.81% (Fig. 2). Thus, WC predicted by the WC-FIR model may be 3.49% lower or higher than WC measured by laboratory test. The average percentage difference for WC prediction using the WC-FIR model and laboratory test was 1.3%.

CONCLUSION

In order to predict carrot water content (WC) based on carrot firmness (FIR) the linear regression model WC = 38.38 + 0.015 FIR with R^2 = 0.84 can be utilized.

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