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Prediction of Carrot Reducing Sugars Based on Brix and Water Content of Carrot During Cold Storage

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Abstract: Carrot reducing sugars (RS) is often determined using difficult and time consuming laboratory tests, but it may be more appropriate and economical to develop a method which uses easily available and known quality characteristics of carrot such as brix (BX) and water content (WC). In this study, a typical two variables linear regression model for predicting RS of carrot based on BX and WC of carrot was suggested. Paired samples t-test results indicated that the difference between the RS values predicted by model and measured by laboratory tests was not statistically significant and in order to predict carrot RS based on BX and WC of carrot during cold storage the two variables linear regression model RS = 39.96 - 1.549 BX - 0.214 WC with R^2 = 0.70 can be recommended.

Key words: Carrot · Cold storage · Reducing sugars · Brix · Water content · Modeling

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, 2]. It belongs to the family Umbelliferae. The carrot is believed to have originated in Asia and now under cultivation in many countries [3, 4]. 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 [5]. It contains abundant amounts of nutrients such as protein, carbohydrate, fiber, vitamin A, potassium, sodium, thiamine and riboflavin [1, 3, 6, 7] and is also high in sugar [8]. 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 [9]. Its use increases resistance against the blood and eye diseases [3]. Fruits and vegetables contain large quantities of water in proportion to their weight. Vegetables generally contain 90-96% water while for fruits normally contain 80-90% water [10]. Carrot contains 75-88% water and 8.5-12.5% soluble solids [11-13]. Water content and soluble solids exert a profound influence on the storage period length, mechanical properties and quality characteristics of fruits and vegetables [9, 10, 12-16]. Therefore, the present study was conducted to develop a regression model for predicting carrot reducing sugar based on brix and water content of carrot during cold storage.

MATERIALS AND METHODS

Plant Materials: Carrots (cv. Imperator 408) were purchased from a local market. They were visually inspected for freedom of defects and blemishes. Carrots were washed with tap water and then air dried for approximately one hour. Then, they were placed in the polyethylene boxes and stored at cold storage.

Experimental Procedure: The experiment comprised of nine storage periods, i.e. 0, 30, 45, 60, 75, 90, 100, 110 and 120 days at temperature of 2°C and 90% relative humidity. In order to obtain required data, brix, water content and reducing sugars of 216 randomly selected carrots (24 samples for each storage period) was measured using laboratory tests. Quality characteristics of 200 randomly selected carrots were used to determine two variables linear regression model. The mean values, standard deviation (S.D.) and coefficient of variation (C.V.) of brix, water content and reducing sugars of the 200 randomly selected carrots are shown in Table 1.

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Table 1: The mean values, standard deviation (S.D.) and coefficient of variation (C.V.) of brix (BX), water content (WC) and reducing sugars (RS) of the 200 randomly selected carrots used to determine RS-(BX and WC) model

Parameter	Minimum	Maximum	Mean	S.D.	C.V. (%)
BX (%)	8.60	12.1	9.63	0.88	9.18
WC (%)	74.4	88.5	83.2	3.30	3.96
RS (%)	4.24	8.84	7.23	0.95	13.1

Table 2: The mean values, standard deviation (S.D.) and coefficient of variation (C.V.) of brix (BX), water content (WC) and reducing sugars (RS) of the sixteen randomly selected carrots used to verify RS-(BX and WC) model

Parameter	Minimum	Maximum	Mean	S.D.	C.V. (%)
BX (%)	9.00	12.2	10.7	1.13	10.6
WC (%)	73.4	84.8	79.8	3.30	4.14
RS (%)	4.75	7.34	6.09	0.88	14.4

Also, in order to verify two variables linear regression model by comparing its results with those of the laboratory tests, quality characteristics of sixteen randomly selected carrots were utilized. The mean values, S.D. and C.V. of brix, water content and reducing sugars of the sixteen randomly selected carrots are shown in Table 2.

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

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

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

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

Reducing Sugars (RS): The RS of carrots were determined using Fehling method. This method can be used as a basis for the analysis of RS. Fehling's solution contains Cu^{2+} ions that can be reduced by some sugars to Cu^{+} ions. As the Fehling's solution is added the blue Cu^{2+} ions will be reduced to Cu^{+} ions. These will precipitate out of solution as red Cu^{+} ions. The resulting solution will be colorless. A titration can be carried out to determine an equivalent amount of the sugar to the Fehling's solution. The end point would be when the blue color has just disappeared. This reaction can be used for the quantitative analysis of RS [17].

Regression Model: In order to predict carrot RS based on BX and WC of carrot during cold storage, a two variables linear regression model RS - (BX and WC) was suggested. A typical two variables 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 RS of carrot during cold storage
X_1, X_2 = Independent variables, for example BX and WC of carrot during cold storage
k_0, k_1, k_2 = Regression coefficients

Statistical Analysis: A paired sample t-test and the mean difference confidence interval approach were used to compare the RS values predicted using the RS-(BX and WC) model with the RS values measured by laboratory tests. The Bland-Altman approach [18] was also used to plot the agreement between the RS values measured by laboratory tests with the RS values predicted using the RS-(BX and WC) model. The statistical analyses were performed using Microsoft Excel 2007.

RESULTS AND DISCUSSION

Two variables 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 RS can be predicted as a function of carrot BX and WC. The p-value of independent variables (BX and WC) and coefficient of determination (R^2) of the model were 6.59E-38, 1.46E-14 and 0.70, respectively. Based on the statistical result, the model was judged acceptable.

Table 3: The two variables linear regression model, p-value of independent variables and coefficient of determination (R^2) of the model

	p-value of independent variables		
Model	BX	WC	R^2
RS = 39.96 - 1.549 BX - 0.214 WC	6.59E-38	1.46E-14	0.70

Table 4: Brix (BX), water content (WC) and reducing sugars (RS) of the sixteen randomly selected carrots used in evaluating RS-(BX and WC) model

			RS (%)	
Sample No.	BX (%)	WC (%)	Laboratory tests	RS - (BX and WC) model
1	9.10	84.7	6.84	7.72
2	11.4	79.6	6.40	5.26
3	10.5	81.5	5.26	6.24
4	12.2	76.5	4.75	4.69
5	9.00	84.8	7.10	7.86
6	10.8	80.0	6.81	6.10
7	10.2	82.0	5.40	6.60
8	11.8	76.9	5.30	5.22
9	9.20	82.4	7.02	8.06
10	11.5	77.3	6.54	5.61
11	10.6	78.8	5.42	6.67
12	12.2	73.4	4.96	5.34
13	9.00	83.4	7.34	8.17
14	10.9	79.0	7.02	6.15
15	10.3	80.9	5.88	6.68
16	11.8	75.7	5.40	5.48

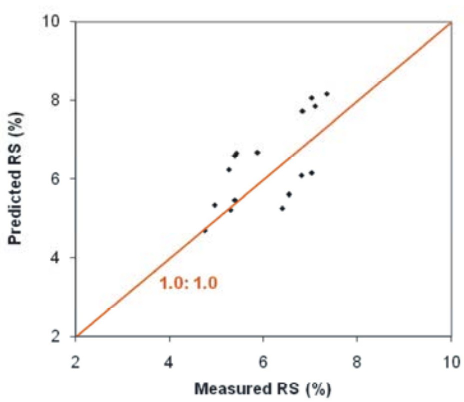

Fig. 1: Measured RS and predicted RS using the RS - (BX and WC) model with the line of equality (1.0: 1.0)

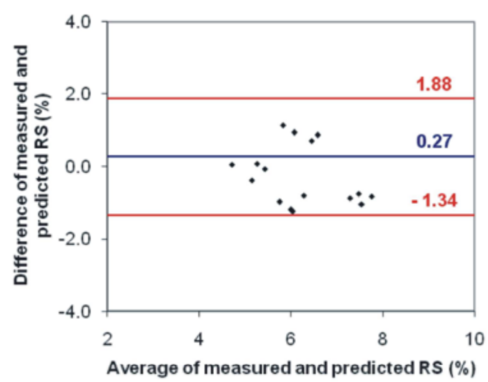

Fig. 2: Bland-Altman plot for the comparison of measured RS and predicted RS using the RS - (BX and WC) model; the outer lines indicate the 95% limits of agreement (-1.34, 1.88) and the center line shows the average difference (0.27)

Furthermore, a paired samples t-test and the mean difference confidence interval approach were used to compare the RS values predicted using the RS-(BX and WC) model and the RS values measured by laboratory tests. The Bland-Altman approach [18] was also used to plot the agreement between the RS values measured by laboratory tests with the RS values predicted using the RS - (BX and WC) model.

The RS values predicted by the RS-(BX and WC) model were compared with RS values determined by laboratory tests and are shown in Table 4. A plot of the RS values determined by the RS - (BX and WC) model and laboratory tests with the line of equality (1.0: 1.0) is shown in Fig. 1. The mean RS difference between two methods was 0.2739% (95% confidence intervals for the difference in means: -0.16284% and 0.71064%; P = 0.2012). The standard deviation of the RS differences was 0.81962%. The paired samples t-test results showed that the RS values predicted with the RS - (BX and WC) model were not significantly different than that measured with laboratory tests. The RS differences between two methods were normally distributed and 95% of these differences were expected to lie between μ-1.96ó and μ+1.96ó, known as 95% limits of agreement [11-13, 18-21]. The 95% limits of agreement for comparison of RS determined with laboratory test and the RS - (BX and WC) model was calculated at -1.34% and 1.88% (Fig. 2). Therefore, RS predicted by the RS - (BX and WC) model may be 1.61% lower or higher than RS measured by laboratory test. The average percentage differences for FIR prediction using the model and laboratory tests was 12.1%.

CONCLUSION

In order to predict carrot reducing sugars (RS) based on brix (BX) and water content (WC) of carrot during cold storage the two variables linear regression model RS = 39.96 - 1.549 BX - 0.214 WC with R^2 = 0.70 can be recommended.

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