Evaluation of a Non-Destructive Dry Matter Sensor for Kiwifruit

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Abstract

In this work we studied the relationship between kiwifruit dry matter (DW) measured using the destructive method with a fruit dehydrator (Nesco/American Harvest®, Wisconsin, USA) and a non-destructive Kiwi meter sensor (Turoni Inc., Forli, Italy). This was an approach to develop a reliable non-destructive method to predict harvest and postharvest quality based on dry matter. There was a significant, but low correlation between DM determined non-destructively using the Kiwi meter and destructively using the fruit dehydrator (industry standard). Classification models with discriminant analysis were used to segregate kiwifruit into groups according to DM. Using this statistical approach rather than the relationship between the two methods, kiwifruit were consistently segregated into two DM groups, but classification into three groups yielded lower scores. These results indicate that the Kiwi meter is a reliable and fast sensor to segregate kiwifruit according to their DM content that could be considered as a consumer quality at harvest and/or postharvest index. Further work on the optimization of this non-destructive sensor as a tool to define consumer kiwifruit quality is being carried out by our group.

INTRODUCTION

Currently, kiwifruit is marketed worldwide. This globalization has created economic advantages for early and late harvest kiwifruit sales, when commodity availability is low and prices are high. This situation has created an incentive for early harvest, which can result in low consumer-quality kiwifruit in the market, reducing repeat purchases of kiwifruit and overall demand (Woodward and Clearwater, 2008). Therefore, a more reliable, fast, and simple quality index that assures taste quality, protecting consumers, is needed. Because dry matter (DM) includes starch concentration, and is highly correlated with ripe SSC and final soluble sugars after ripening (Harker et al., 2009; Hopkirk et al., 1986; Jordan et al., 2000), researchers from various countries have proposed the use of DM concentration as a quality index. As a result, some industries have started its use for trading.

Non-destructive sensor methods, such as near infrared spectroscopic (NIR) analysis or density, can be used to assess kiwifruits in terms of their dry matter content and/or ripened soluble solids content (SSC) (Crisosto et al., 2009; McGlone et al., 2002; Moghimi et al., 2010; Nicolai et al., 2007). The commercial motivation underlying these methods is the desire for fast grading, according to optimum, consumer-defined quality. The taste of ripe ready-to-eat kiwifruit is largely determined by the fruit SSC, and this final SSC is highly correlated with the DM of unripe fruit.

The research objective of this study was to assess the accuracy of the Kiwi meter non-destructive sensor to determine kiwifruit quality, compared with destructive, traditional methods. The main goal of this study is the non-destructive prediction of the DM of kiwifruit, in order to provide a fast and non-destructive parameter to decide the correct time of harvest based on consumer acceptance.

MATERIALS AND METHODS

For this study, kiwifruits (‘Hayward’) were evaluated for destructive and non-destructive dry matter content. Fruit was harvested from experimental and commercial fields in California and Chile at its commercial maturity. Fruit was transported to UC

Davis, California, where each fruit was labeled at two equatorial positions for destructive and non-destructive dry matter measurements. The traditional destructive method (Nesco/American Harvest®, Wisconsin, USA) was used as a control method to compare with the non-destructive sensors.

Comparing Non-Destructive Technologies

In order to compare the ability of the Kiwi meter non-destructive sensor to predict the quality traits of kiwifruit, we measured fruit quality on kiwifruit ('Hayward') from 10 different origins. Six pieces of fruit per origin were measured with both destructive and non-destructive methods, at two different ripening stages (harvest and ready-to-eat). For each fruit, the following quality parameters were measured at each ripening stage:

- DM (%).
- Non-destructive sensor (two equatorial positions).
- SSC (measured in a composite sample for each origin).
- TA (measured in a composite sample for each origin).

Statistical Analysis

Linear regression models between the Kiwi Meter values and the destructive DM values were calculated using regression analysis (SPSS, Inc.).

In order to develop classification models, two different methods were used. First, the population was grouped into several ranges of Kiwi Meter values, using cluster analysis. A second approach to pre-sort samples was to set the limits between groups using a discriminant analysis. Thresholds were set between clusters according to consumer acceptance data (unpublished) and commercial harvesting standards followed by the California kiwifruit industry. The thresholds were established in a way that the final application of the non-destructive device could be of help for the industry. Discriminant functions were calculated using discriminant analysis (DA) techniques, with the Kiwi Meter values as an independent variable and class membership based upon previously identified dry matter thresholds. Trials were performed with one boundary dry matter level (classification of samples into two clusters), and two boundary levels (classification of samples into three clusters). A variation in the thresholds was studied, to search for different sensitivity of the non-destructive system across the dry matter range. Once the samples were pre-sorted and the clusters were established, discriminant function analysis was applied. Discriminant analysis provides segregation of each fruit into a category and the percentage of correct classification. The percentage of correctly classified samples was used as an indicator of a reliable model.

RESULTS AND DISCUSSION

Correlation between the Kiwi Meter non-destructive sensor values and destructively measured dry matter was significant when all the kiwifruit samples were mixed together (n>35), but the relationship was relatively low (Table 1). Non-significant correlation was found for most of the sample origins when taken individually, with the exception of sample 3360a (r^2=0.728). These results show that the non-destructive sensor tested in this study is not reliable enough for the modeling of a direct prediction equation of destructive dry matter content.

The first approach to develop a classification model for the kiwifruit samples was to group the samples into different clusters of Kiwi Meter values (Figs. 1 and 2). This approach showed much better results than the correlation of individual measurements for both dry matter (Fig. 1) and soluble solids content (Fig. 2). A significant and high linear correlation (r^2=0.916) was obtained between Kiwi Meter values and destructively measured dry matter when the samples were grouped into six different clusters based on the Kiwi Meter values. Also, a significant correlation (r^2=0.745) between Kiwi Meter readings and destructively measured soluble solids content (SSC) was obtained when the samples were sorted in clusters based on the Kiwi Meter values (Fig. 2). These results show that the Kiwi Meter can provide a reliable way to sort samples into different ranges of dry matter content, based on the non-destructive reading. Future efforts should be made to assess the consumer acceptance of the different ranges of Kiwi Meter readings.

The classification of samples into three classes (Table 2), based on their dry matter content, resulted in a percentage of correctly classified fruits between 17.9 and 69.0%, depending on the dry matter thresholds. Therefore, classification of kiwifruit with this non-destructive device into three dry matter classes is not accurate enough for an industrial application. However, better percentages of correctly classified fruits were found with just one boundary dry matter level (Tables 3 and 4). Percentages of correctly classified fruits were between 86.3 and 100%, depending on the dry matter thresholds selected. Using the threshold of 16% DM, 95.7 to 98% of the fruits were correctly classified. Since this is the recommended dry matter value to assure a high quality kiwifruit, the Kiwi Meter can be a promising tool for the fast and reliable segregation between those two classes. According to our results, the Kiwi Meter sensor seems to be industrially applicable for segregation of two dry matter content clusters, with an acceptable error in the classification.

Literature Cited

Crisosto, C.H., Valero, C. and Slaughter, D. 2009. Evaluation of a kiwifruit non-destructive sensor. Proc. 8th Fruit, Nut and Vegetable Production Engineering Symposium, Progap-INIA´s National Precision Agriculture Program, Concepción, Octava Región del Bío Bío, Chile. p.443-448.

Harker, F.R., Carr, B.T., Lenjo, M., MacRae, E.A., Wismer, W.V., Marsh, K.B., Williams M., White, A., Lund, C.M., Walker, S.B., Gunson, F.A. and Pereira, R.B. 2009. Consumer liking for kiwifruit flavour: A meta-analysis of five studies on fruit quality. Food Qual. Preference 20:30-41.

Hopkirk, G., Beever, D.J. and Triggs, C.M. 1986. Variation in soluble solids concentration in kiwifruit at harvest. New Zealand J. Agri. Res. 29:475-484.

Jordan, R.B., Walton, E.F., Klages, K.U. and Seelye, R.J. 2000. Postharvest fruit density as an indicator of dry matter and ripened soluble solids of kiwifruit. Postharvest Biol. Technol. 20:163-173.

McGlone, V.A., Jordan, R.B., Seelye, R. and Martinsen, P.J. 2002. Comparing density and NIR methods for measurement of Kiwifruit dry matter and soluble solids content. Postharvest Biol. Technol. 26:191-198.

Moghimi, A., Aghkhani, M.H., Sazgarnia, A. and Sarmad, M. 2010. Vis/NIR spectroscopy and chemometrics for the prediction of soluble solids content and acidity (pH) of kiwifruit. Biosystems Engineering 106:295-302.

Nicolai, B.M., Beullens, K., Bobelyn, E., Peirs, A., Saeys, W., Theron, K.I. and Lammertyn, J. 2007. Nondestructive measurement of fruit and vegetable quality by means of NIR spectroscopy: A review. Postharvest Biol. Technol. 46:99-118.

Woodward, T.J. and Clearwater, M.J. 2008. Relationships between ‘Hayward’ kiwifruit weight and dry matter content. Postharvest Biol. Technol. 48:378-382.

Tables

Table 1. Correlation (Pearson's coefficient) between Kiwi Meter non-destructive measurements and dry matter (%) measured destructively with the Nesco dehydrator, for different kiwifruit samples.

Sample	N	R2
3319 a	15	0.126
3360 a	15	0.728 **
3703 a	15	0.175
2400 a	15	0.524
All samples a	60	0.445 **
3319 b	9	0.530
3360 b	9	0.628
3703 b	7	0.280
2400 b	10	0.129
All samples b	35	0.556 **
All samples a and b	95	0.500 **

**Correlation is statistically significant at $p<0.01$.

Table 2. Classification matrices of kiwifruit into three different classes based on percentage of dry matter (DM). Percentage of fruit correctly classified into each class by the Kiwi Meter sensor is shown in bold.

Observed	Predicted classification (%)		
group	DM<15	15<DM<17	DM>17
DM<15	64.9	10.8	24.3
15<DM<17	46.2	17.9	35.9
DM>17	20.7	10.3	69.0

Table 3. Classification matrices of kiwifruit into two different classes (lower or higher than 15% DM) based on percentage of dry matter (DM). Percentage of fruit correctly classified into each class by the Kiwi Meter sensor is shown in bold.

Observed	Predicted	
group	DM<15	DM>15
DM<15	100.0	4.3
DM>15	16.7	86.3

Table 4. Classification matrices (calibration set) of kiwifruit into two different classes (lower or higher than 16% DM) based on percentage of dry matter (DM). Percentage of fruit correctly classified into each class by the Kiwi Meter sensor is shown in bold.

Observed	Predicted	
group	DM<16	DM>16
DM<16	**95.7**	4.3
DM>16	2.0	**98.0**

Figures

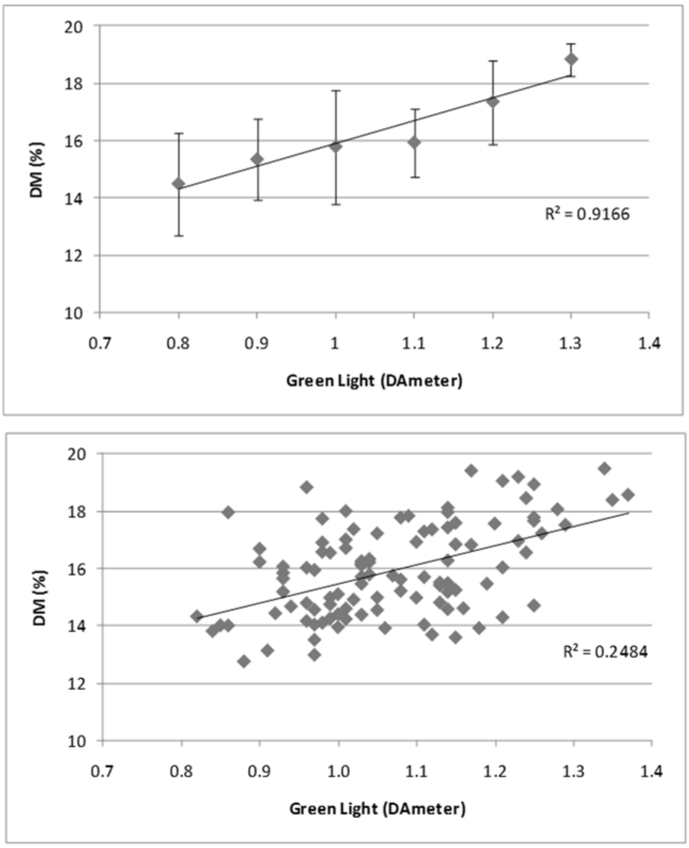

Fig. 1. Correlation between destructively-measured (Nesco dehydrator) dry matter (%) and Kiwi Meter predicted values on kiwifruit. In the first chart, the data has been organized in different clusters based on the Kiwi Meter value (cluster analysis). In the second chart, individual data are shown.

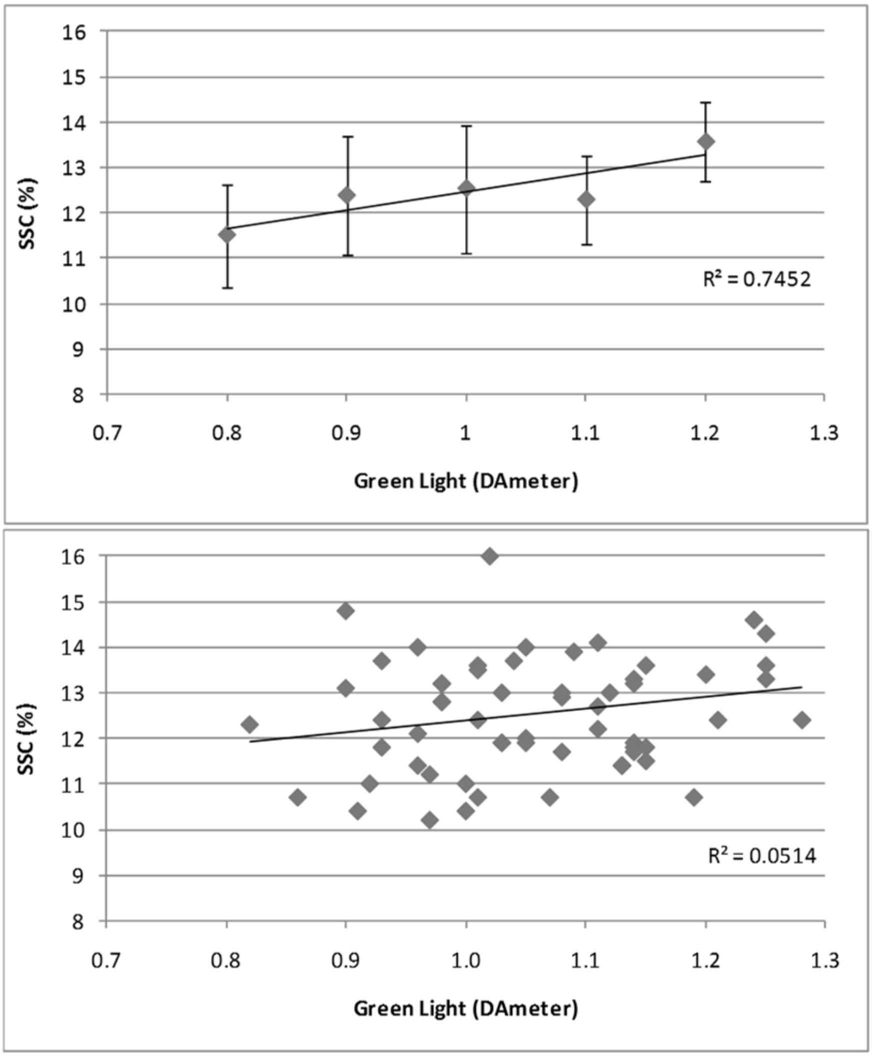

Fig. 2. Correlation between destructively measured (Atago digital refractometer) soluble solids content (%) and Kiwi Meter predicted value on kiwifruit. In the first chart, the data has been organized in different clusters (cluster analysis) based on the Kiwi Meter value. In the second chart, individual data are shown.