NON-DESTRUCTIVE ANALYSIS FOR CITRUS AND LANZONE FRUIT QUALITIES USING ANN

Soesiladi E. Widodo[1], Yohannes C. Ginting[1], Suroso[2] and I Dewa Made Subrata[2]

[1] *Lab. of Horticulture, Fac. of Agriculture, University of Lampung, Bandar Lampung 35145, Indonesia;* [2]*Dep. of Agricultural Engineering, Bogor Agricultural University, Bogor, Indonesia*

Abstract: The objective was to develop a non-destructive determination of physical and chemical properties of citrus and lanzone fruits as a screening method for fruit quality differentiation. The results show that although the highest correlation were shown in juice, the correlation in the whole-fruit samples were very low. Consequently, the NIRS method was judged to be inappropriate for a non-destructive determination on the chemical qualities of citrus. The tested method of visible light with the light dependent resistor system could not predict seed number and weight in citrus as two important seediness parameters, but might still be applicable to lanzone fruits.

Keywords: algorithms, neural, infrared detectors, quality, spectroscopy

1. INTRODUCTION

During selection and sortation of fruits in fruit industry, in general, a representative sample of fruit is selected and evaluated for fruit qualities such as physical and chemical qualities at maturity. Since each fruit varies in maturity at harvest, a sorting strategy to deliver a more uniform product and reduce losses to the market is needed.

Conventional destructive methods such as a penetrometer for fruit firmness and a hand refractometer for total soluble solids (°Brix) are well known to fruit industries. But even if the quality of the representative population of fruit is considered acceptable, fruit-to-fruit variation can allow a large number of low-quality fruits to be packed and sold. When dealing with a hand refractometer to represent total soluble solids, fruit quality has to be more carefully judged as it has been proven that the validity of hand refractometer is lower if more acid is present in the juice (Widodo, *et al.*, 1996). Therefore, a non-destructive analysis based on one or more quality attributes for sorting the whole population is desirable to reduce losses and improve the quality of fruit delivered to the market.

When seedless and high quality fruits are demanded, more attention has to be paid as to make sure that the fruits sorted and delivered are truly seedless, or, at least, percentage of seedlessness has to be guaranteed. This term of "high quality" has to be fully guaranteed as the perception of quality may be translated by consumers as a risk factor (Lockshin and Rhodus, 1991). In a such case, a non-destructive analysis on seedlessness is the only choice.

This research objective was to develop a non-destructive determination of physical and chemical properties of citrus and lanzone fruits as a screening method for fruit quality differentiation.

2. MATERIALS AND METHODS

2.1 Sample Preparation

Citrus (*Citrus reticulata* Blanco cv. 'Medan') and lanzone (*Lansium domesticum* Corr.) fruits purchased from the market were used as tested samples. The citrus fruits were selected as uniform as possible by rind color and diameter as they had to be fit to the fruit-case used later during seediness determination.

The citrus fruits as model samples were directly brought to laboratory and individually analyzed non-destructively with a light dependent resistor (LDR) system and a near-infrared reflectance spectroscopy (NIRS) followed by a algorithm artificial neural network (ANN) of a Backpropagation Neural Network. Lanzone fruits were also analyzed with the LDR system.

The LDR and NIRS data were correlated with physical and chemical fruit data measured conventionally (Widodo, *et al.*, 1996; Widodo and Ginting, 2000). With the LDR system 40 citrus and 61 lanzone fruits were used, while with the NIRS system 50 whole-fruits, 26 juice and 23 rind samples were used as trained/calibration data and 30 whole-fruits, 15 juice and 15 rind samples were used as validation data.

2.2 NIRS Analysis and Reflectance Measurement

The NIRS apparatus consisted of AT-100HG Shimadzu (as a source of halogen of 650 W) set at 14 Volt, AT-100AP Shimadzu (as a controlled amplifier monochromator) with set signals: chopper, detector PbS, Gain 20, and smooth 1 sec. Filters used were of 1400-2000 nm and 2000-2500 nm.

The whole-fruit sample was put on the sample port of the integrating sphere unit of SPG-100 IR to be illuminated. The spectrum was scanned from 1400–2500 nm at scanning speed of 4 nm/sec. with reading taken every 4 nm, so each spectrum contained 275 data points with each point being the average of 50 A/D conversion.

The reflectances of the samples were transformed to log (1/R) according to Williams (1990), recorded, and analyzed later with the Principle Component Analyses of PCA15, PCA10, and PCA5 (Minitab Inc., PA, USA, 1996).

The PCA scores and conventional chemical analyses of the juice were then analyzed with an algorithm artificial neural network (ANN) of a Backpropagation Neural Network. The parameters of ANN were iteration = 15000; eta = 0,7; alpha = 0,3; temp = 1; input layer = as 5, 10, or 15; output layer = as observed variables (7 for the whole-fruits and juice and 6 for rind); hidden layer = as means of output and hidden layers.

2.3 LDR Analysis and Measurement

Seediness was analyzed with the LDR apparatus equipped with a 650 W halogen lamp. Each of the whole-fruit sample was put into the fruit-case of the apparatus and illuminated with 5 V of the lamp. The volt data were correlated with physical fruit variables such as fruit weight, diameter and length, seed number and weight, rind thickness and weight, and core diameter.

3. RESULTS AND DISCUSSION

3.1 Near-Infrared Reflectance Spectrometry and Algorithm Artificial Neural Network

Results of the ANN analyses on the NIRS data of acid and sugar components of citrus fruits are shown in Tables 1 and 2. Except the correlation data of the whole fruits at PCA5, the r-values of the calibration were generally high. Unfortunately, these high r-values could not be maintained during validation as in general the r-values of the whole-fruits validation data were very low. The highest correlations were shown in juice by the acid components variables (58.27% and 51.33% by free and combined acids, respectively, of PCA10 and 44.97% by total acid of PCA15), by reducing sugar (41.50% of PCA5), and by total soluble solids (48.04% of PCA10).

Table 1 ANN analysis on the NIRS data of acid components of citrus (*Citrus reticulata* Blanco cv. 'Medan')

Sample	PCA	Calibration	Validation
		r	r
1. Free acid			
Whole-fruit	5	0.2361	0.2286
	10	0.6983	0.0743
	15	0.9096	0.2068
Juice	5	0.7378	0.4019
	10	0.8983	0.5827
	15	0.9753	–0.2781
Rind	5	0.5235	–0.0724
	10	0.9185	0.1587
	15	0.9472	–0.2505
2. Combined acid			
Whole-fruit	5	0.2095	–0.6725
	10	0.6580	–0.0831
	15	0.7554	–0.3308
Juice	5	0.8151	–0.0798
	10	0.7989	–0.5133
	15	0.9654	–0.3947
Rind	5	0.8699	–0.1729
	10	0.9852	–0.2291
	15	0.9937	–0.2550
3. Total acid			
Whole-fruit	5	0.1769	–0.0843
	10	0.7400	–0.2672
	15	0.9248	–0.3642
Juice	5	0.8534	0.1394
	10	0.9593	–0.0338
	15	0.9822	–0.4497
Rind	5	0.9151	–0.1838
	10	0.9753	–0.4087
	15	0.9818	–0.2751

Table 2. ANN analysis on the NIRS data of sugar components and soluble solids of citrus (*Citrus reticulata* Blanco cv. 'Medan')

Sample	PCA	Calibration r	Validation r
1. Reducing sugar			
	5	0.4168	−0.2759
Whole-fruit	10	0.5338	−0.0224
	15	0.8523	−0.1641
	5	0.9329	−0.4150
Juice	10	0.9670	−0.2899
	15	0.9831	−0.3553
	5	0.7622	−0.1596
Rind	10	0.9563	−0.0911
	15	0.9715	−0.2157
2. Non-reducing sugar			
	5	0.5384	−0.0808
Whole-fruit	10	0.7745	−0.1516
	15	0.7834	−0.1437
	5	0.3560	−0.0523
Juice	10	0.8370	0.2355
	15	0.8343	0.1990
	5	0.8412	−0.4105
Rind	10	0.9157	0.0512
	15	0.9900	0.0077
3. Total sugar			
	5	0.5189	−0.0010
Whole-fruit	10	0.7796	−0.1399
	15	0.8112	−0.0632
	5	0.3345	0.0148
Juice	10	0.8650	0.2258
	15	0.8747	0.1706
	5	0.7292	−0.3186
Rind	10	0.9197	−0.1777
	15	0.9778	−0.2751
4. Soluble soilds (°Brix)			
	5	0.3100	−0.0042
Whole-fruit	10	0.6020	−0.0086
	15	0.8841	−0.1647
	5	0.9529	0.1086
Juice	10	0.9326	0.4804
	15	0.9534	−0.5142

The low r-values in Tables 1 and 2 were supported by data in Tables 3 and 4. The data show that acid and sugar contents in the rind correlated very low with those in the juice. Those indicate that the NIRS data of the whole-fruits could not predict acid and sugar contents in the juice. As analyzing the whole-fruits was a must, the applied NIRS method was inappropriate to be used as a non-destructive tool for determining the chemical qualities of citrus fruits. Other thick, loose-rind fruits of the tropics such as mangosteen (*Garcinia mangostana* L.) and lanzone should show similar results. The NIRS method has been proven to be a good non-destructive tool for homogen samples (Suroso, *et al.*, 1999) or nearly homogen samples between outer and inner layers such as in very thin rind fruits (Katayama, *et al.*, 1996; Ikeda, *et al.*, 1992; Mowat, *et al.*, 1997).

Table 3 Pearson's correlation values of acid components in the rind and juice of citrus (*Citrus reticulata* Blanco cv. 'Medan')

	rFA	rCA	rTA	jFA	jCA
rCA	−0.17				
rTA	0.12	0.14			
jFA	0.19	0.27	−0.28		
jCA	0.09	0.12	0.06	−0.01	
jTA	0.20	0.29	−0.17	0.75	0.66

r = rind, j = juice, FA = free acid, CA = combined acid, TA = total acid

Table 4 Pearson's correlation values of sugar components in the rind and juice of citrus (*Citrus reticulata* Blanco cv. 'Medan')

	rRS	rNRS	rTS	jRS	jNRS
rNRS	0.11				
rTS	0.89	0.55			
jRS	0.13	−0.04	0.09		
jNRS	0.22	0.22	0.29	0.12	
jTS	0.24	0.18	0.29	0.47	0.93

r = rind, j = juice, RS = reducing sugar, NRS = non-reducing sugar, TS = total sugar

3.2 Light Dependence Resistor (LDR) System and Seediness

Correlations between the data of LDR and physical components of citrus and lanzone fruits are shown in Table 5. The LDR system predicted lanzone seed weight better than citrus seed weight (55.4% vs 20.9%) simply because lanzone fruits have smaller diameter, thinner and lighter-color rind than citrus.

Lower r-values of seed number as a primary variable on the determination of seediness (Table 5), especially those of lanzone, should be interpreted carefully because among the tested lanzone fruits, no seedless lanzone fruits were found. In addition, the seed size varied greatly (from one seed of 0.07 g to three seeds of 5.65 g in total weight, while 6 seeds of only 1.82 g in total were also present). Those variable data made the correlations low. If an enough number of seedless lanzone fruits was present, as if a fruit grouping of seedless and seeded fruits was possible, the r-values should be higher. Those indicated that the LDR system might still be applicable to lanzone fruits.

Table 5 Pearson's correlation between the LDR data (volt) and fruit physical components of citrus (*Citrus reticulata* Blanco cv. 'Medan'; n = 40) and lanzone (*Lansium domesticum* Corr.; n = 61)

Correlated variables	r-values
Citrus fruits:	
Volt vs fruit weight (g)	– 0.403
Volt vs fruit diameter (mm)	– 0.150
Volt vs fruit height (mm)	– 0.624
Volt vs normal seed number	– 0.310
Volt vs abnormal seed number	0.030
Volt vs total seed number	– 0.283
Volt vs seed weight (g)	– 0.209
Volt vs rind thickness (mm)	– 0.317
Volt vs rind weight (g)	– 0.523
Volt vs fruit core diameter (mm)	0.204
Lanzone fruits:	
Volt vs fruit weight (g)	– 0.706
Volt vs fruit diameter (mm)	– 0.659
Volt vs fruit height (mm)	– 0.689
Volt vs total seed number	– 0.207
Volt vs seed weight (g)	– 0.554
Volt vs rind weight (g)	– 0.609

4. CONCLUSIONS

The results show that (1) among the tested samples, very low correlations of validation data were shown by the whole-fruit samples. The highest correlations were shown in juice by the acid component variables (58.27% and 51.33% by free and combined acids, respectively, of PCA10 and 44.97% by total acid of PCA10); (2) As analyzing the whole fruits was a must for non-destructive analyses, the applied NIRS method was turned out to be inappropriate to be used as a non-destructive tool for determining the chemical qualities of citrus fruits; (3) The tested method of visible light with the LDR system could not predict seed number and weight in citrus as two important seediness parameters, but might still be applicable to lanzone fruits.

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