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FEASIBILITY STUDIES INTO NIR TECHNIQUE FOR MEASUREMENT OF INTERNAL QUALITY OF SOME TROPICAL FRUITS

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ABSTRACT

Okinawa Prefecture is located in the southernmost part of Japan and has a subtropical climate. A lot of tropical fruits such as pineapples, mangoes and papayas are produced. Pineapples were mainly supplied to the canning industry. Since April 1990, the Japanese Government released the foreign trade restriction of canned pineapples and pineapple juice in accordance with GATT. Okinawan farmers have been expanding the customers from the processing industry to the fresh market.

During the recent year, fully mature, high quality pineapples which have 15 Brix in sugar content are produced in green houses on Okinawa. Prices are 2 to 3 times those of the imported pineapples. At present, they are sorted manually, and this sorting might cause the pineapples to lose their reputation.

NIR applied fruit sorters have been developed and operated for apples and peaches in Japan. NIR applied tests were carried out to consider the feasibility into the NIR technique for measurement of internal quality of pineapples and mangoes. The results of the NIR analysis suggests adequate correlations between sugar content and NIR reflectance properties of pineapples and mangoes.

Key Words: NIR, NIR analysis, Internal Quality, Toropical Fruits

INTRODUCTION

Until now, pineapples produced in Okinawa Prefecture have been mainly raw materials used for processing. These crops reached a peak during the period of 1965 to 1970; however, since then, the crop has been declining. In 1988, the crop reached less than half of the 35,500 tons obtained during the peak season. Furthermore, the 1988 GATT decision to liberalize imports of canned pineapples beginning in 1990 brought a severe blow to the Okinawa Prefecture pineapple industry "Kohda(1990)". Since Okinawa Prefecture has a geographical advantage, which allows companies to transport pineapples faster and with less deterioration than foreign industries. Okinawan farmers have been expanding the customers from the processing industry to the fresh market. Okinawa islands were contaminated with melon flies and were restricted to exporting tropical fruits and vegetables from the islands. A lot of sterilized male flies have been spread with helicopters all the year round anywhere. In 1991 the Government released the restriction for exportation of tropical fruits without quarantine treatment. However, when tropical fruits are hand-picked and graded based on the producer's experience and intuition, the quality is uncertain. To ensure sales of high quality pineapple, it is necessary to employ a nondestructive quality detection and sorting based on the inside quality of the fruit. The possibility of sorting pineapples using the Near Infrared Spectroscopy (NIR) to determine the principal sugar and acidity content as the essential components of its quality was studied.

The variations in sugar and acidity of the pineapples when examining the basic data measured by the spectroscope were also researched.

PROCEDURE OF NEAR INFRARED SPECTROSCOPIC ANALYSIS

Near Infrared Spectroscopy was executed according to the following procedure. Generally, the procedure of the near infrared spectroscopic analysis is, (1) prepare the calibration curve, (2) evaluate the calibration curve. The calibration curve is prepared by using the regression formula on the calculated comparison values determined from the addition of absorbances found at different wavelengths "Ikegaya(1988), Maeda(1991), Kaye(1954)".

Determination of the Calibration Curve

To determine the calibration curve, measure the spectrum of the sample and determine the comparison value that corresponds to that specific spectrum. Then, process the spectrum data (averaging, differentiating, normalizing, etc.) as necessary and determine the calibration curves, according to the multiple regression analysis of the spectrum and the comparison values.

Evaluation of the Calibration Curve

To evaluate the calibration curve, estimate from the calibration curve determined in the following (1) from data of the spectrum and comparison value of a sample different from the one used to determine the first calibration curve and choose the more precise calibration curve by comparing the errors of this estimated value and the true value.

Measurement of unknown sample

To test the unknown sample, determine nondestructively the actual comparison value of the unknown sample based on the best calibration curve chosen after determining the spectrum from (2).

In order to evaluate the feasibility on the quality analysis of pineapples by using near infrared spectroscopy, we tried to determine the calibration curve this information.

EXPERIMENTAL PROCEDURE

Samples

There were 140 sound pineapples fruits(Ananas comosus, L: cv. N 67-10) harvested from Higashi-son, Okinawa Prefecture from June-July 1992 and 40 sound mango fruits(Mangifera indica, L: cv. Irwin), that were selected and transported by air at normal temperature to Hamamatsu, Shizuoka Prefecture and used for experimentation.

Table 1,2 shows the average dimensional data of measured pineapples and mangoes, respectively .

Measurement of the infrared spectrum

A Nireco model 6500 near infrared spectrophotometer was used to measure the infrared spectrum. The pineapple was placed so that the light beam on the surface of the fruit at right angle and covered with a black cloth avoiding influence of external light. A specific spectrum irradiated onto the sample, and the reflected light from the center section of the sample was sent to the detector and the absorbance was measured. 4 places were chosen along the equatorial of the fruit as the testing areas and the near infrared beam was irradiated at 2 nm intervals from 400 to 2500 nm onto the sample and the average absorbance was measured. This was repeated 50 times.

Measurement of the sample components

Hardness of peel and flesh, sugar content, and acidity were selected to be quickly measured. A fruit hardness tester was used to measure the hardness of the peel at the same area to determine the near infrared spectrum.

The flesh in the identical area used to measure the near infrared spectrum was cut out; the juices were squeezed out by hand. An Atago model PR-1 digital refractometer was used to measure the soluble solid content as sugar content. A Touwa-denpa model AT-100 fruit acid meter measured the acidity of juice as citric acid.

Determination of the calibration curve

The calibration curve was determined by using the secondary differentiated spectrum to find a correlation for each component value and each peak of wavelength. After the determination of the primary wavelength that indicated the high correlation was calculated using multiple regression analysis with the variable additional method. The calibration curve was determined from four wavelengths.

Table 1 Average Values and Standard Deviations of the Shape and Components of Pineapples

Components	Average	S.D
Mass (g)	1275.7	58.7
Width (mm)	114.2	3.5
Height (mm)	142.7	7.7
Sugar Content (Brix)	14.08	1.39
Acidity (mg/100ml)	3.02	0.12
Hardness of Peel (kg)	3.18	0.32
Hardness of Flesh (kg)	1.30	0.15

Table 2 Average Values and Standard Deviation of Shape and Components of Mangoes

Components	Average	S.D
Mass(g)	311.9	31.6
Width(mm)	68.9	2.5
Height(mm)	105.1	3.5
Sugar content(Brix)	12.3	1.8
Acidity(mg/100ml)	0.65	0.08
Hardness of peel(kg)	1.11	0.11
Hardness of flesh(kg)	0.42	0.06

A model equation of the calibration curve that estimates the S (%) of each component content is indicated as the following;

$$S\ (\%) = K0 + K1d^2OD(f1) + K2d^2OD(f2) + K3d^2OD(f3) + K4d^2OD(f4) \qquad (1)$$

where K0, K1 . . . are regression variables,
d^2OD is the secondary differentiated spectrum absorbance
f1, f2 . . . indicates each wavelength

Measurement of the distribution in internal quality of a fruit

The crown side was defined for upwards; and pineapples were divided into a upper, middle, and lower sections; and the core and peel were separated. In order to consider the distribution in internal quality of pineapples, sugar content and acidity were measured.

RESULTS AND DISCUSSION

The coefficient of multiple regression (MR) for the sugar content of pineapples, as shown in Table 3, was 0.8252 using 4 specific wavelengths, while the standard error of the estimated value was 0.882; for the acidity, the coefficient of multiple regression was 0.6858, while the standard error was 1.07. For the hardness of the peel, the coefficient of multiple regression was 0.4592 and the standard error was 0.314 and the coefficient of multiple regression was 0.5676 and the standard error was 0.135 for the hardness of the flesh.

The coefficient of multiple regression for sugar content of mango fruits, as shown in Table 4, was 0.954, while the standard error of the estimated sugar content was + 0.363. For the acidity, the coefficient of multiple regression was 0.856 and the standard error was was 0.104. For hardness of peel, the coefficient of multiple regression was 0.949 and the standard error was 0.319. The coefficient of multiple regression was 0.920 and the standard error was 0.135 for hardness of flesh.

Table 3 Results of multiple regression analysis of some quality index of the Pineapple and the Near Infrared Spectrum

Quality index	Specific wavelength(nm)				MR*	SE**
	f1	f2	f3	f4		
Sugar Content(Brix)	900	696	1200	1138	0.825	0.822
Acidity*** (mg/100ml)	526	878	2338	716	0.686	0.107
Hardness of peel(kg)	668	2134	450	664	0.460	0.314
Hardness of flesh(kg)	2280	1140	614	772	0.568	0.135

* : Coefficient of Multiple regression
** : Standard error in estimated value
*** : Acidity as citric

Table 4 Results of multiple regression analysis of some quality index of mango fruits and near infrared spectrum

Quality index	Specific wavelength(nm) f1	f2	f3	f4	MR	SE
Sugar content(Brix)	1098	876	2418	2290	0.954	0.363
Acidity (mg/100ml)	620	832	1498	1668	0.856	0.104
Hardness of peel(kg)	1728	2462	1018	690	0.949	0.319
Hardness of flesh(kg)	2298	2436	1230	1740	0.920	0.135

The regression equation for each quality index of pineapple fruit is shown in the following.

$$\text{Sugar Content}(\%) = 12.378 + (-919.882)d^2OD(900) + 5.819d^2OD(696) + (-1566.816)d^2OD(1200) + (-595.729)d^2OD(1138) \quad ..(2)$$

$$\text{Acidity Content (mg/100ml)} = 1.452 + (-5.709)d^2OD(526) + 88.512d^2OD(878) + 23.008d^2OD(2338) + 0.548d^2OD(716) \quad .... (3)$$

$$\text{Hardness of Peel (kg)} = 2.532 + 15.986d^2OD(668) + 67.313d^2OD(2138) + (-8.393)d^2OD(450) + (-18.717)d^2OD(664) \quad ... (4)$$

$$\text{Hardness of Flesh (kg)} = 0.742 + 19.836d^2OD(2280) + (-24.387)d^2OD(1140) + (-7.908)d^2OD(614) + (-6.149)d^2OD(772) \quad .... (5)$$

Table 5 Distribution of sugar content and acidity according to the portion of the pineapple

Portion	Sugar Content (Brix)	Acidity (mg/100ml)
Upper portion of the Peel	11.633	1.979
Upper portion of the Core	12.000	1.929
Middle portion of the Peel	14.300	2.097
Middle portion of the Core	14.267	2.013
Lower portion of the Peel	14.700	1.988
Lower portion of the Core	15.800	1.974
Total Average	14.0778	2.0185

The regression equation for each quality index of mango fruit is shown in the following.

$$\text{Sugar content}(\%) = 11.888 +(-1080.746)d^2OD(1098)+4148.400d^2OD(876) +150.677d^2OD(2418)+(-194.216)d^2OD(1668) \quad \ldots\ldots (6)$$

$$\text{Acidity (mg/100ml)}=0.603 +(-2.785)d^2OD(620)+218.580d^2OD(832) +(-30.085)d^2OD(1498)+(-30.979)d^2OD(1668) \quad \ldots\ldots (7)$$

$$\text{Hardness of peel(kg)}=1.281 +44.423d^2OD(1728)+(-18.739)d^2OD(2462) +97.947d^2OD(1018)+7.959d^2OD(690) \quad \ldots\ldots (8)$$

$$\text{Hardness of flesh(kg)}=0.431 +17.199d^2OD(2298)+(-13.359)d^2OD(2436) +274.830d^2OD(1230)+35.208d^2OD(1740) \quad \ldots\ldots (9)$$

From the above results, based on the method of Near Infrared Spectroscopy (NIR) of pineapples and mango fruits, there are high possibilities of determining the sugar content by nondestructive measurement of the inner quality; but as for the other components, further studies are necessary.

The distribution of inner quality depending on the portion of the fruit is shown in Table 5. It is noted that the lower portion of the core contained the highest sugar content, the lower portion of the peel contained the lowest sugar level, while the center portion showed an average level of sugar content. The center portion also showed an average acidity level.

CONCLUSION

There are adequate correlations between sugar content and NIR reflectance properties of pineapples and mangoes. The mutiple regression coefficient for sugar content of pineapple and mongoes were 0.825 and 0.954 respectively, using 4 wave bands.

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