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A REVIEW OF NON-DESTRUCTIVE DETECTION FOR FRUIT QUALITY

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Abstract: An overview of non-destructive detection in quality of post-harvest fruit was presented in this paper, and the research and application were discussed. This paper elaborated the fruit quality detection methods which were based on one of the following properties: optical properties, sonic vibration, machine vision technique, nuclear magnetic resonance (NMR), electronic noses, electrical properties, computed tomography. At last, the main problems of non-destructive detection in application were also explained.

Keywords: fruit quality; non-destructive detection; research; application

1. INTRODUCTION

Fruit commercialization is adopting the scientific method and detecting, grading, packaging the fruits on the basis of comprehending the physiology metabolism law, protecting and improving the quality, and achieving the change from the elementary raw material to high added-value commodity. Nowadays, reducing the consumption of post-harvest fruit is the most concerned question for the world agricultural trade. It was reported that the consumption of post-harvest fruit in developed countries accounted for the 15-20% of the total amount. China is the world's largest fruits and vegetables production country. The breeding, culturing, and pest control was paid much attention, however, the post-harvest processing technology was neglected, the question of detecting, grading, transporting, preservation was not solved, so the lost of post-harvest fruits and vegetables in circulation was huge, the

loss ratio was 30%~40% every year(Gao Haisheng. 2003, Li Lite et al. 2003, Lu Lixin et al.2004).

With the rapid development of science and technology and computer vision technique to the development of agricultural field, new methods of non-destructive detection for fruit quality were provided. The main methods included optical properties, sonic vibration, nuclear magnetic resonance (NMR), machine vision technique, electrical properties detection, computed tomography and electronic noses technique and so on.

2. DETECTION OF FRUIT QUALITY USING OPTICAL PROPERTIES

Due to the difference of fruits internal components, fruits have different absorption and reflection properties in the light of different ray. The non-destructive measurement for fruits quality was achieving in the combination of these properties and optical detection device.

In the fruit interior quality inspecting systems and their detecting principle, Ying yibin et al. (2003) analyzed three different kinds of measuring methods, such as regular reflection, transmittance and diffuse reflection, and elaborated the research and application technology for sugar content, acidity and firmness of fruits. Liu yande et al. (2003) studied the principle of fiber sensing technique, designed a detection system for fruit quality, and investigated a fiber sensing technique in reflectance, interactance and transmittance mode. The results showed diffuse reflection was the best method for fruits internal components detection.They also established the non-destructive method using infrared spectroscopy diffuse reflection technique for determination of the sugar content in apple and intact honey peach, and attained the good results(Liu Yande et al. 2004). At the same time, Fu xiaping et al. (2004) carried out the related experiments and obtained the good results too.

Han donghai et al. (2003) demonstrated that the absorbencies of the bruised and normal parts had the same variational tendency by analyzing on color, tissue and near infrared spectrum characteristics of the Fuji apple for their normal and bruised parts, and concluded Fuji apple had the least surface color difference in 1 hour compared to Qinguan and “Golden Delicious” apples. The range of wavelength from 760 nm to 960 nm could be used to detect the superficial damaged apple. The absorbencies increased with time according to the equation $Y = aX^b$.

Tian haiqing et al. (2007) developed a measuring system for soluble solids content (SSC) of watermelon based on near infrared transmittance technique. The system mainly consisted of an available spectrometer, optic fiber

transmittance accessories, data sampling card and light source. Prediction test for SSC of 50 'Qilin' watermelons were carried out by the system. The calibration modes between the spectra (the original spectra, its first derivative, and its second derivative) and SSC were established using partial least square and principle component regression methods. The results showed that the second derivative spectra with partial least square method provided the best prediction of the SSC of watermelons with the correlation coefficient of 0.951, the root mean square error of calibration of 0.347 and the root mean square error of prediction of 0.302. The correlation coefficient between predicted and measured values was 0.910.

Some scholars in Japan developed the sensor of detection the pear and apple maturity by visible light and infrared spectroscopy, then they developed the selecting fruit device which select fruit maturity and color quickly, and applied this technology to auto-selecting fruits production line, linked the maturity, color sensor, auto-grading, package production line, achieved a highly automatized non-destructive grading fruits (He Dongjian et al. 2001).

Liu xinxin et al. in China Agricultural University discussed the non-destructive measurement of water core in the storage process of apples. They established the equation of light intensity and weight with different time by detecting the change of light intensity with self-made differential instrument. In the storage, the light intensity of water core apples decreased more sharply than apples with no water core. In the later stage of storage, the symptoms of diseased fruit with not serious disease disappeared. Meantime, the morbidity of apples with larger weight had high incidence (Han Donghai et al. 2004). In addition, Han donghai et al. (2006) detected the internal breakdowns of apples by visible-near infrared spectroscopy (650 nm~900 nm), analyzed the spectra of the apples, and selected three wave numbers, 715 nm, 750 nm, and 810 nm as the character wave numbers. The results showed that the correct probability of classification was 95.65% by using the above-mentioned three wave numbers.

As a word, the detection for fruits using optical properties is one of the most practical and most successful technique in non-destructive measurement. It has the following characteristics: high-sensitivity detection, good adaptability, lightweight equipment, flexible usage, not harmful to humans. This technique has gradually applied to the practical stage on abroad.

3. DETECTION OF FRUIT QUALITY USING SONIC VIBRATION

It was reported that energy absorption and sonic and ultrasonic vibration reflected the status of internal damage, but these two techniques were more suitable for assessing bruise susceptibility. Compared with application of fluorescence and delayed light emission to chlorophyll containing fruits and vegetables, optical absorbance to all fresh produce was widely tested to evaluate damage. However, these methods developed were essential for detection of physical damage. For researchers and industry, an exciting prospect arises from a better understanding of internal damage of fruits and vegetables during post-harvest processing and circulation. X-ray analysis, magnetic resonance imaging, and laser inspection can now be used to detect the internal damage in some limited application; but not practical for routine damage testing because the equipment is expensive. Like all other technologies, the cost of sonic vibration detection method was reduced sharply, and detection capability was improved highly(Jiang Yueming et al. 2002).

4. DETECTION OF FRUIT QUALITY USING MACHINE VISION TECHNIQUE

Machine vision technique had an earlier application in agriculture to identify plant species. With the rapid development of image processing technology and computer software and hardware, machine vision system had fast development for fruits quality auto-detection and grading. The study indicated that black-and-white image processing technology had already applied to apples surface bruise detection in U.S.A.

Ying yibin et al. (2004) explored a methodology for the maturity inspection of citrus with machine vision technology, and used the surface color information and the ratio of total soluble solid to titratable acid (TSS/TA) as maturity indexes of citrus. The results stated that at the wavelength of 700 nm, the green surface and saffron surface of citrus were of higher spectral reflection, the difference between them reached the maximum, and the image acquired at this wavelength could be of much color information for the maturity inspection. The test results showed that the identification accuracy was 91%.

A tendency of non-destructive detecting technology for quality and safety of agricultural and poultry products is a hyper-spectral imaging system, which possesses the advantages of both computer vision and spectroscopy inspecting technologies. Hyper-spectral imaging technology had higher

wavelength resolution than multi-spectral imaging, the precision was 2~3 nm. The inspecting technology of interior quality of kiwifruit by means of hyper-spectral imaging was discussed. The new process methodology of data for hyper-spectral imaging was analyzed and future research aspects were pointed out. The range of wavelength was 650~1100nm. The predict mode of SSC was established by PLS. The results showed that the predict of SSC by near-infrared spectra technique had high precision, predict error was 1.2Brix. The injury, decay, bruise and detection of soil pollution were studied by hyper-spectral imaging. Second uneven difference algorithm was designed to Separate the defects and contamination in apples. The defects and contamination regions were differentiated(Liu Muhua et al. 2005).

5. DETECTION OF FRUIT QUALITY USING NUCLEAR MAGNETIC RESONANCE(NMR)

Nuclear magnetic resonance(NMR) is a technique which detects the concentration of hydrogen nuclei and is sensitive to variations in the binding state. The researchers found that the mobility of water, oil and sugar hydrogen nuclei would change with the change of content in the maturation process of fruits. In addition, the concentration and mobility of water, oil and sugar related to mechanical injury, tissue degeneration, over maturity, decay, insect damage and frost injury. Thus different quality parameters of fruits would be detected by measuring the concentration and mobility based on these properties.

Researchers could measure many parameters of fruits quality using NMR image technique as non-destructive method. The relationship of NMR parameters and fruits quality parameters could be obtained easily, and the development of NMR technique was improved. Although NMR technique had already applied to detecting tumor and other medical fields commercially, the potential of testing fruits defects and other qualities was not totally developed. Therefore this technique has not been reported yet in China(Lu Lixin et al. 2004).

6. DETECTION OF FRUIT QUALITY USING ELECTRICAL PROPERTIES

With the drop of fruits' freshness, the equivalent impedance of spoiled or damaged apples is less than that of intact apples, but the measurement results may be affected by the excursion of frequency. The dielectric constant of

spoiled or damaged apples was more than that of intact apples. Some experts studied the relationship of frequency properties of fruits electrical properties constant and fruits quality characteristics from 0.1 kHz to 100 kHz in frequency, taking apple and pear as experiment object. The results showed that frequency properties of fruits electrical properties constant and fruits quality characteristics had close relationship. The base of non-destructive detection and auto-grading for fruits was established(Zhang Libin et al. 2000).

Guo wenchuan et al. (2007) investigated electrical and physiological properties of peaches in order to understand electrical properties of post-harvest fruitss and to explore new quality sensing methods based on electrical properties. It was observed that the relative dielectric constant varied with cosine law roughly and loss tangent decreases as peaches' aging. The maximum relative dielectric constant appeared at peak of respiration. The reasons why electrical parameters change were analyzed. Furthermore, BP neural network technology was used to identify freshness of peaches when relative dielectric constant and loss tangent were selected as input characteristic parameters. Results showed the average distinguishing rate was 82%.

7. DETECTION OF FRUIT QUALITY USING COMPUTED TOMOGRAPHY

Computed tomography (CT) is a method of examining body organs by scanning them with X rays and using a computer to construct a series of cross-sectional scans along a single axis. Xu shumun et al. used picked Fuji apples as the experiment objects. The layer of X-ray and computer scan was applied to detect the CT value of apples drop from different heights. On the same scan layer , the CT value of destructive apples decreased with increased of storage time, and the more destruction was made, the lower the CT value was. With the increasing the thickness of scan layer, the CT value of non-destructive apples decreased, while the CT value of destructive apples increased. By changing the storage time, the relation between CT value and destruction was also different(Xu Shumin et al. 2006). Zhang jingping et al. scanned the red Fuji apples with CT technology and analyzed the CT image properties of apples, obtained the significant linear relationship of sugar content of a point on fruits and CT value. Thus the sugar content would be attained from CT value, a new method of using CT image to detect sugar content distribution on line was obtained. The mode of linear relationship of sugar content of a point on fruits and CT value was established and verified by non-destructive method. The results showed that the average error rate of this mode was only 4.36%(Zhang Jingping et al.

2007). Meanwhile, the CT technique was used as the input of neural network to forecast the major components of Fuji apple. The results showed that the average forecast errors of moisture content, sugar content and acid content are 1.75%, 5.81% and 0.72% respectively, and the precision of this method could meet the requirements of Fuji apples non-destructive measurement(Zhang Jingping et al. 2008).

8. DETECTION OF FRUIT QUALITY USING ELECTRONIC NOSES

Electronic noses have been developed as systems for the automated detection and classification of odors, vapors, and gases since the end of last century. An electronic nose is generally composed of a chemical sensing system and a pattern recognition system. There was a kind of portable non-destructive detector called Sakata fruits detector in Japan. It could detect the immature, mature and spoiled fruits with 99% accuracy. Zhang libin et al. (2000) developed a set of electronic nose system which composed of metal oxide semiconductor gas sensor array by simulating the functioning of the olfactory system, and analyzed the samples with neural networks. The detection accuracy was 80%.

Zou xiaobo et al. (2005) gave a new method to classify apples by the odor of apples, and developed an electronic nose equipment to classify apples. Fifty good apples and fifty bad apples was classed. Five feature parameters were developed from every data curve of sensor arrays, and all the feature parameters were called input vectors. Principal component analysis and genetic algorithm radial based function (GA-RBF) neural network were used to combine the optimum feature parameters. Good separation among the gases of different apples was obtained using principal component analysis but a bit was overlapped. The recognition probability of the GA-RBF to the learning samples and the testing samples were 100% and 96.4%.

9. CONCLUSION

The non-destructive detection methods including optical properties, sonic vibration, machine vision technique, nuclear magnetic resonance(NMR) for fruit quality had distinctive advantage compared to other instrumental analysis and chemical analysis methods, and had broad application prospects and development potential. Traditional chemical analysis methods had following disadvantage: time-consuming, hard sledding, high cost. Many

analytical instruments had large volume and weight and high price. These instruments only were used in laboratory. It is necessarily for agricultural sector, quality inspection sector, market management sector to put in use portable non-destructive detection instruments for fruits and vegetables sampling detection. Non-destructive detection was also a development for researchers combine the research results and production practice. However, the non-destructive detection was only for one product and one item in China. The comprehensive detection methods for many internal qualities of fruits were deficient. With the development of non-destructive detection technique, data-processing technology, automatic control technology and computer technology will play an important role in non-destructive measurement for fruit quality.

The non-destructive detection methods have their strengths and weaknesses. For instance, the method of optical properties can detect the injury of fruits surface, but can not detect the internal quality. Sonic properties, NMR detection technique are still in laboratory experiment, not applying to commercial fields. The application of computer vision technique for post-harvest fruits commercialization is in practical stage at home and abroad. At the same time, with the rapid development of computer technology and specialization in many fields, the automation of fruits measurement will come true. Therefore it is essential that simple, quick, accurate and comprehensive detection methods apply to the research and application in the future. In addition, the combination of machinery and optics technology, multi-spectrum technology and machine vision technology should be strengthened. Last but not least, the combination of independent research and develop and introduction from abroad should be adopted. New techniques apply to post-harvest fruits processing, the competitiveness of China's fruits in international market will be enhanced.

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