# Advance in application of rapid non-destructive testing technology in the detection of apple mold heart disease

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**Abstract:** Apples are rich in vitamins and dietary fiber, and are one of the essential fruits and vegetables in People's Daily diet. China is a big apple consumer, and with the improvement of people's pursuit of quality of life and the improvement of nutrition and health requirements, the demand for high-quality apples has increased year by year. Apple mold heart disease is one of the main diseases affecting apple quality, this disease can not be identified from the outside, so the detection is very difficult, and spectral technology, electromagnetic technology and other non-destructive testing technology has accurate, efficient, convenient, non-destructive advantages, can greatly reduce the difficulty of detection of mold heart disease. This paper mainly analyzed the application of non-destructive testing technology in the detection of apple mold heart disease, combined with the current rapid development of AI technology to discuss the future development direction of each technology in the field of apple mold heart disease rapid detection.

## 1. Introduction

Apple is rich in dietary fiber, vitamins and a series of other nutrients, and has high nutritional value. It is one of the main fruits produced in China, and an important factor restricting the development of China's apple industry is the lack of high-quality apples[1-2]. With the continuous improvement of the quality of life of the people, as the daily consumption fruit of the people, the quality problem of apples needs to be strictly controlled, so as to provide the people with high-quality apples[3]. Apple heart disease is a major disease inside the fruit, caused by a variety of bacteria such as penicillin and patulin, which seriously affects the quality and yield of apples. The risk of carcinogenesis, teratogenesis and fertility will be greatly increased after people eat the disease fruit, which will seriously endanger human health[4-5]. The symptoms of diseased fruit mainly include fruit ventricular mildew (mildew heart type), fruit ventricular Browning (Browning type), and fruit heart rot (heart rot type)[6-7]. However, the external characteristics of apple fruit surface in the early and middle stages of mildew heart disease are not significantly different from those of normal apples, and the related symptoms are not obvious, so it is difficult to detect. After the disease enters the market, it will not only seriously damage the interests of consumers, endanger the health of consumers, but also have a huge impact on the reputation of enterprises and the apple industry. Therefore, rapid detection of apple heart disease is very important for the development of the apple industry.

At present, the detection methods for apple mold heart disease are mainly traditional detection and rapid non-destructive testing. The traditional detection is divided into subjective detection and chemical detection, both of which have the disadvantages of tedious process, long time and high cost. Non-destructive testing technologies, such as low-frequency magnetic resonance, CT imaging, spectroscopy, etc., have been favored by many experts, scholars and scientific and technological personnel for their application in food quality testing after years of practice and research. Non-destructive testing technology and its equipment have been developing rapidly, and its application prospect has great potential in various fields[8]. Many researchers use various rapid non-destructive testing techniques to identify apple mold heart disease, hoping to ensure the quality and excellent fruit rate of apples[9]. This paper is expected to provide a reference for the rapid non-destructive intelligent detection of apple mold heart disease and provide help for subsequent researchers.

## 2. Progress in the application of rapid non-destructive testing technology in the detection of apple mold heart disease

Rapid non-destructive testing technology is mainly divided into spectral technology, electronic nose technology, acoustic technology, electrical technology and magnetic technology[10]. In recent years, with the unremitting efforts of researchers, the application of non-destructive rapid testing technology and equipment has

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become more and more extensive in the field of rapid detection of fruit and vegetable quality[11].

## 2.1 Spectrum Technology

With the development of science and technology, computer technology and spectral technology have been rapidly improved. Spectral technology has been widely used, with advantages such as low cost, non-destructive detection and fast analysis speed[12-13], and has been widely welcomed by many researchers in detecting the internal quality of apple[14-15]. To establish a relationship between the spectral reflectance or absorption rate of specific wavelength peaks of apples in a certain part or several parts according to the characteristic peak of apples and apple deterioration index, so as to distinguish the quality of apples[9].

### *2.1.1 Near infrared spectroscopy*

The common nondestructive testing spectral technology is mainly near-infrared spectroscopy, which is mainly the spectrum generated by the molecular vibration transition from ground state to high energy level, and the frequency doubling and frequency sum absorption of X-H vibration of hydrogen-containing groups, which contains the composition and molecular structure information of organic compounds[16-17]. Andrea et al. designed and manufactured a low-cost innovative device for early detection based on near infrared spectroscopy technology. After multiple rounds of detection, it was found that the ANN-AP model combined with the infection growth rate showed a better correlation, with the highest accuracy and a prediction accuracy of 97%[18]. Tian et al. designed and assembled an online spectral measurement system for apple mold heart disease using near-infrared transmission spectrum technology. Data in the wavelength range of 550 to 900 nm was collected using spectrometers in three different directions of the Apple. After pre-processing the spectrum, it was found that the best transmission spectrum could be obtained in the T2 direction support vector machines (SVM) were used to build local and global models. The results show that the accuracy of global model test set is 100%, which is better than that of local model. The study shows that it is feasible to design and manufacture a non-destructive detection system for malus heart disease by using near infrared spectroscopy[19]. Lei et al. designed and manufactured a transmission energy spectrum acquisition system (as shown in Figure 1) based on near-infrared spectroscopy technology to collect the visible/near-infrared spectra of samples within the band of 200~1100 nm. Successive projections algorithm, SPA model and principal component analysis (PCA) model were established. It was found that the accuracy of PCA model training set and test set was 99.3% and 96.7%, which were better than the SPA model. The results of this study provide a basis for the development of portable apple mold heart disease detector[6].

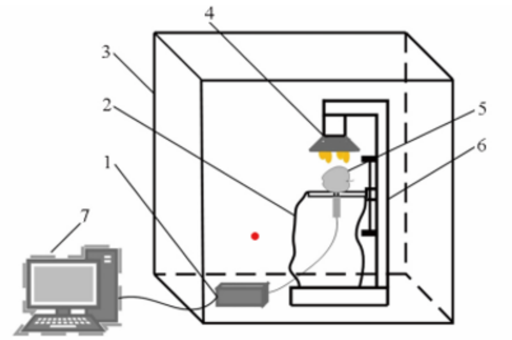


**Figure 1.** Visible/near infrared transmission energy spectrum acquisition system

Note: 1. Portable spectrometer; 2. Blackout curtain curtain; 3. Collection camera obscura; 4. Light source; 5. Apple; 6. Height adjustable stage; 7. Computers.

Zhang et al. designed and manufactured a diffuse reflection spectrum data acquisition platform and measured the data with a density meter. The platform was analyzed in combination with four models such as partial least squares discriminant analysis (PLS-DA). It was found that SVM density plus spectrum model had the best recognition effect. The overall discriminant rate was 95.56%, which was better than the other three models. Compared with the detection rate of mold heart disease based only on density or diffuse reflection spectrum, this experiment has opened up a new direction for the non-destructive detection of apple mold heart disease by integrating multiple technologies. But its disadvantage is that the addition of density meter makes the inspection process more complicated and the equipment is not easy to carry[8].

### *2.1.2 Raman spectroscopy*

Raman spectroscopy is a vibration spectrum technology based on Raman scattering, which analyzes the scattering spectra with different frequencies from the incident light, and enhances the Raman signal through the nanostructure of precious metals to obtain molecular vibration, rotation and other information. Through molecular vibration and rotation, structure and other relevant information are obtained for detection[16]. A variety of fruits and vegetables use Raman spectrum combined with different models to judge their internal quality through the detection of maturity, organic content, component ratio and other data, so as to achieve the purpose of internal quality detection[20-21] However, Raman spectroscopy has great potential in the field of detection of apple mold heart disease. Josu et al. used Raman spectroscopy technology and confocal Raman microscopy with 514 nm excitation laser wavelength to extract the main information of organic components in the sample, as shown in Figure 2[22]. Fan et al. used a portable Raman spectrometer laser source with 780 nm and 100 mW power to perform surface enhancement of Raman scattering at 200~2000 $cm^{-1}$. The sample pesticide content was measured in SERS spectrum, the sample surface enhanced Raman spectrum data was pre-processed by PCA, and the actual pesticide content was measured by partial least squares regression, combined with chemometry. PLSR and support vector regression (SVR) algorithms were used to build models respectively. The experimental results show that the SVR model has the best performance and the correlation coefficient is as high as 0.986. The research shows that Raman spectroscopy is a fast and reliable nondestructive testing technique[23]. Josu et al. built a portable Raman spectroscopic nondestructive testing system using Raman microprobe, micro camera and near-infrared laser with wavelength of 785nm and power of 350mW, and measured the internal maturity of samples within the spectrum range of 100~3000 $cm^{-1}$. The feasibility of using Raman spectroscopy to develop a portable nondestructive testing system has been proved[24].

The above studies show that the Raman spectroscopy detection effect is objective, real and efficient, and the detection technology can be used to detect the internal quality of fruits and vegetables, which has certain advantages in this aspect. The apple mold heart disease is also a representation of the internal quality of fruits, which is consistent with the detection principle of Raman spectroscopy technology. It can be concluded that Raman spectroscopy is feasible for rapid detection of apple mildew heart disease.

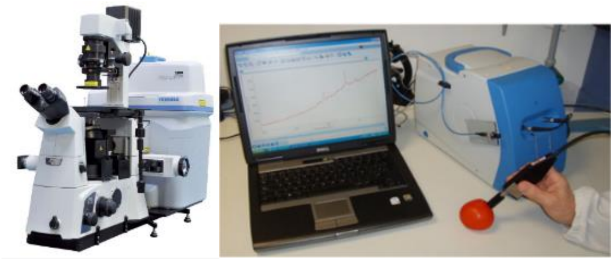

**Figure 2.** Raman spectrum detection system

The popularity of spectral technology has changed the problem of slow development of rapid nondestructive testing technology, but its disadvantages are also prominent. First of all, spectral detection is an indirect analysis technology, which requires a lot of investment in the early stage of detection and the establishment of relevant model libraries. Secondly, it is difficult to carry equipment. Therefore, the improvement of spectral nondestructive testing technology can provide ideas for future development.

## 2.2 Electronic nose technology

Electronic nose detection technology is an intelligent bionic olfactory technology with advantages of low operation difficulty and high sensitivity of detection system[25]. It consists of a gas sensor array, a signal processing unit and a pattern recognition unit, which can collect gas signals for gas composition analysis and form a feature map. Compared with the information stored in the database, it is simple to operate and easy to carry. In recent years, electronic nose is mainly applied in food and other fields, and its technology is relatively mature, which makes up for the shortcomings of manual evaluation and physical and chemical analysis, and provides great convenience for testing the quality of agricultural products[26-27].

Li used electronic nose technology to judge the internal quality of apples, and used BP neural network to establish mold heart disease prediction models for various physical and chemical quality indexes of apples, and obtained a good correlation between mold heart disease and the BP neural network model established based on apple odor, that is, $R^2$ was greater than 0.9000[28]. Gomez et al. used the electronic nose system to judge the storage time of fruits and vegetables, and combined with linear discriminant analysis (LDA) and PCA. They concluded that the discriminant effect of the former was superior to that of the latter, proving that the electronic nose system could detect whether there were abnormalities in apples through odor differences. The smell of apples with mildew heart disease is different from that of healthy apples, so it can be concluded that it is feasible to establish a non-destructive detection system of apples with mildew heart disease by using electronic nose system[29]. Zhang et al. used the difference of sensors in the electronic nose system to detect whether apples have mildew heart disease. Latent Structures Discriminant Analysis (HCA) show that volatile odor is one of the important criteria for distinguishing diseased fruit. It is found that the multi-layer perceptron neural networks (MLPNN) discriminant model constructed based on the Fisher function and neural network is superior to other models, and its discriminant rate is generally higher. The training set was 88.61%, and the test set was 88.46%. The results provide a theoretical basis for the development of Apple's internal disease and quality integrated nondestructive testing equipment based on the principle of electronic nose technology[30]. Yang et al. used electronic nose technology combined with chemometry to determine whether there was mold heart disease, and constructed three models, Fisher discrimination, MLP neural network and RBF neural network. Among them, the combination of the MLP neural network model made the electronic nose have the best discrimination effect, and the discrimination rate was 87.9% and 86.2%, respectively. The research proves that the electronic nose technique has a unique advantage in distinguishing malady heart disease, and the judgment effect is good, so it can realize the development and expansion of the non-destructive detection system of malady heart disease[31].

Electronic nose technology is widely used, but there are still many shortcomings in practical applications, such as the detection speed is not as fast as the spectral speed, easy to be disturbed by environmental noise, equipment is easy to age, gas collection is greatly affected by surrounding environmental factors, etc. Therefore, its application ability is limited to a certain extent, and the hardware performance can be improved in the future to improve the detection speed and noise reduction ability of electronic nose.

## 3. Conclusions and prospect

With the development of science and technology, the above technologies are expected to become the main force in the field of rapid non-destructive intelligent testing in the future, and different technologies can be selected according to specific application scenarios. Due to the vigorous development of AI artificial intelligence, computing power and algorithms have been unprecedently enhanced. At present, the fusion of AI and rapid nondestructive testing technology is limited to several conventional modeling algorithms, which is too restrictive. AI algorithms can be combined with existing modeling technologies and big data, and can extract important key points from massive nondestructive testing information and complete manual operations such as image recognition, feature extraction and data analysis independently. With the rapid development of technology and the country's attention to the research and development of domestic instruments, more mature rapid non-destructive testing AI technology is expected to become a powerful practical tool for researchers.

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