The Characteristic of Hyperspectral Image of Wheat Seeds during Sprouting

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THE CHARACTERISTIC OF HYPERSPECTRAL IMAGE OF WHEAT SEEDS DURING SPROUTING

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Abstract. The pre-harvest sprouting of wheat have significant influence for its quality and yield, therefore the fast detection of sprouting extent of wheat is very important for breeding and producing. In this study, the hyperspectral images of these seeds were collected by a near infrared hyperspectral imaging system, the wavelength of which was 850-1700 nm after wheat germination experiment at 0h, 12h, 24h, and 48h. The original light intensity of embryo and endosperm were extracted, and were then changed to reflectivity for later analysis. The image and spectral information of wheat with different parts, different varieties and different sprouting extent were compared. The results showed that after 12h sprouting, the reflectivity of embryo was lower than that of endosperm for the same seed, this is mainly due to the water and fat content of embryo was higher than the endosperm portions. For the same varieties of wheat seed at the germination of 12h, 24h and 48h,in the wavelength range of 870-1300 nm, the reflectivity increased with the increase of sprouting time, it was related to the changes of its internal content of fat in the seed germination process. At 1400nm, the reflectivity of sprouted wheat seeds were all lower than that of dry seeds, it was related to the rise of internal water content in the process of seed germination. Due to differences in seed water absorption and sprouting résistance, for different varieties of wheat seeds ,its spectral characteristics are also different. The presented indicated that hyperspectral imaging could reflect the characteristics of sprouted wheat seeds, which provide some basis for explore the sprouting index by hyperspectral imaging.

Keywords: hyperspectral imaging, pre-harvest sprouting, wheat, seed

1 Introduction

Pre-harvest Sprouting (Shorted for PHS) refers to the sprouting phenomenon if encountered rainy days or in a humid environment before harvest, and is mainly occurs in the drippy regions in the harvest season(Xiao et al., 2004). There are two main pre-harvest sprouting endanger frequent and severe areas in China: one includes Jiangsu and Anhui provinces which is south of the Huai River, most place of Hubei province and middle gluten and weak gluten wheat in the middle and lower reaches of the Yangtze River area of the south of Henan Province. the other includes strong gluten wheat area in northeast involved North, East of Heilongjiang province, Neimenggu Daxinganling and other regions (Zhu et al., 2010).Wheat pre-harvest sprouting is a climate disasters around the world-wide, it will cause a series of physiological processes, such as the increasing of α-amylase and other hydrolyses activity, cause the kernels internal storage material decompose in advance, severely affected the quality of the kernels(Zhao et al., 2009).Besides, pre-harvest sprouting also affect wheat yield and breeding value, cause large losses to agricultural production. So, achieving the detection of pre-harvest sprouting characteristics, cultivating wheat varieties with resistance to preharvest sprouting characteristics, improving the quality of wheat is an important task of the current breeding work.

There are three traditional methods to det ‘ect the resistance of wheat pre-harvest sprouting: the field natural identification method of extended harvesting, whole ear germination experiments and seed germination experiments, of which the main methods to detect the resistance of wheat pre-harvest sprouting are whole ear germination experiments and seed germination experiments. Currently, there are three technical means of wheat pre-harvest sprouting resistance detection, of which are biochemical measurement method, molecular detection method and visual method(Yang et al., 2007). Biochemical measurement method and molecular detection have flaws of complex operation, labor-intensive, costly and time consuming, destructive , visual method is susceptible to subjective factors and is difficult to detect status of early germination.

With the development of photovoltaic technology, try to take advantage of the various photoelectric detection technology to achieve the rapid detection of pre-harvest sprouting. Cheng Fang use machine vision technology to get the image of germinated rice seeds, and then use the corresponding image processing algorithm to obtain rice contour characteristic parameters, establish BP neural network model to achieve the recognition of healthy rice and buds valley rice. This method can identify germinated seeds which has the obvious appearance changes, but it is difficult to extract effective features of spike germinating seeds which are small opening(Cheng et al., 2007). Neethirajan and others get the X-ray images of healthy and sprouted kernels at the same time using Soft X-ray technology, extract 55 image features including gray level modeling and histogram from the scanned images, use neural network model to identify healthy and sprouted kernels with the recognition rate of 95% and 90% (Neethirajan et al., 2007). But the X-ray technology has a certain amount of radiation hazards to the human body, so, explore a fast and non-destructive method to detect pre-harvest sprouting imperative.

Hyperspectral imaging technology is the integration of spectroscopic techniques and imaging technology , it can obtain spectral information and image information at the same time. Hyperspectral image contains a lot of information, it can not only get its external morphology information using image information but also can get their internal composition information with spectral information. In terms of agricultural applications, hyperspectral imaging technology has been widely used in the diagnosis of crop information(Wang et al., 2011), non-destructive testing of fruit quality(Hong et al., 2007)and other aspects. The application of hyperspectral imaging technique for seed testing, scholars have conducted a lot of exploration. Cogdill and others using Near-infrared spectral images to predict the moisture and oil content of a single corn kernels. Partial least squares(PLS)regression and principal components regression(PCR)were used to develop predictive calibrations for moisture and oil content, the moisture calibration achieved a best standard error of cross-validation(SECV)of 1.20%,the best oil calibration achieved an SECV of 1.38% (Cogdill et al., 2005). Xing and others use hyperspectral imaging system(1000–2500 nm) to collect single kernel map information, use Partial Least Square regression to predict the a-amylase activity of individual wheat kernels, the correlation coefficient can be 0.73, this method to separate wheat kernels with high a-amylase activity level from those with low a-amylase activity giving an accuracy of above 80%(Xing et al., 2009).Singh and others collect the map of healthy wheat seeds and germination of wheat seeds in the range of 1000-1600nm using NIR hyperspectral imaging system, develop the discriminant classifier model to identify healthy and germinated seeds, the discriminant classifiers gave maximum accuracy of 98.3%(Singh et al., 2009).The above research have shown the feasibility of hyperspectral imaging technology in wheat germination test, this study aims to collect the map of seeds in different parts, different germination periods, different varieties of wheat seeds using the hyperspectral imaging system, analyze of the changes in the spectral characteristics in depth, laying the foundation for selection of pre - harvest sprouting resistance.

2 Materials and Methods

2.1 Sample preparation and processing

Select eight different varieties of winter wheat, respectively Jingdong 8, Jing411, Zhongmai175, Nongda211,Zhongmai16, Jingdong 18, Nongda3432 and Nongda3291. Retrieve ten wheat ears of each species from the field, and hand-strip them for wheat grains after washing, air drying and burr picking. Each variety of 120 wheat seeds and divided into four parts, each part of 30 wheat seeds for the germination experiment. The seed germination time of four parts respectively are 0h, 12h, 24h, 48h, which 0h for the original dry seeds. The specific germination method is: repeatedly wash the wheat grains with tap water and put them in the 5% NaClO solution to conduct the disinfection for 5 minutes; then repeatedly wash them again by distilled water, enchase them into the Petri dish lined with two layers of filter paper, and then add an appropriate amount of distilled water for the sprouting experiment. The seed germination hyperspectral information should be acquired after a certain period of time of the sprouting experiment. First, use absorbent paper to suck the excess water on the seed surface, to reduce the impact of water on the experimental data. At the same time to collect hyperspectral image of seed, using a color camera to obtain seed RGB image for subsequent comparative analysis between machine vision imaging results and spectrometer imaging results.

2.2 Hyperspectral imaging system

The hyperspectral imaging acquisition system used in this study is mainly composed of Near-infrared imaging spectrometer, halogen light source, guides, sample platform, motion controller and computer. The experimental apparatus shown in Fig1. This Near-infrared imaging spectrometer was the InGaAs array of near-infrared spectrometer, which size is 250×190×160 mm, spectral range was 850-1700nm, spectral resolution was 2.7nm, spatial resolution was 0.25 mm. The power of the halogen light source is 50W, spectral range was 400-3000nm.

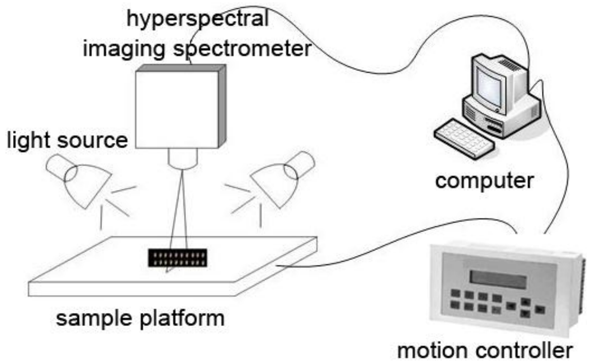


Fig. 1 Diagram of the experimental apparatus

2.3 The acquisition of wheat seed hyperspectral image

Before the data acquisition, use the black cotton cloth to cover the sample stage of the hyperspectral imaging system in order to reduce the impact of the background noise. Take 30 germinated wheat seeds each time, make the ventral furrow downward, and uniformly tile on a black background sample stage in single-layer. Ensure the Interior for the darkroom environment and avoid interference from other light sources when do the experiment. Using halogen light source irradiation on germination of seed samples, and collected the hyperspectral image information of seed germination at 0h, 12h, 24h, 48h respectively. The vertical height of the sample to the spectrometer lens is 31cm, motor speed is 28.264mm/s, the height of the halogen light source is 24cm,integration time of imaging spectrometer is 18ms,the frame rate is 50fps. when setting up various other parameters of hyperspectral imaging system, collecting the data. Use the BaSO4 Board as a standard reference Board.

2.4 Data processing

Hyperspectral data collected was the original intensity value of the point for each pixel, using ENVI software to extract the average intensity value of image for the region of interest, compare with the simultaneous determination of the whiteboard spectrum, calculate a spectral reflectance of the object, as follows:

$$\text{Ref}_{\text{object}} = (\text{Rad}_{\text{object}}/\text{Rad}_{\text{whiteboard}}) \times \text{Ref}_{\text{whiteboard}} \times 100\% \quad (1)$$

Where, $\text{Ref}_{\text{object}}$ represented spectral intensity data of object obtained by whiteboard reflectance; Rad object represented measured by spectrometer; $\text{Rad}_{\text{whiteboard}}$ represented radiance of whiteboard measured by spectrometer; $\text{Ref}_{\text{whiteboard}}$ represented known reflectance ratio of whiteboard.

3. Results and analysis

3.1 Comparative analysis between hyperspectral image and machine vision image of the germinated wheat seed

Extract the hyperspectral image of seeds at 1300nm (see in Fig.2),compared with RGB color image which was taken with the use of machine vision. As can be seen from figure 2: The picture of germination seed which was acquired using machine vision has higher resolution, the area of the protrusion, can be more clearly seen. The pictures taken using hyperspectral imaging spectrometer are grayscale image, have low resolution ,but to seeds which were germinate more obvious, was able to identify the germinated part from hyperspectral image with naked eye. Therefore, as to seed morphology, the hyperspectral imaging systems generally had low resolution, so the identification was not as good as the machine vision. But, in the process of seed germination, especially early germination the morphological change of the seed is small at the same time there are more internal changes of biochemical composition, therefore, using spectral information is expected to be a more accurate analysis of seed germination characteristics. Hyperspectral image data contains spectral information and image information at the same time, use the image processing technology to extract reflectance spectra of specific area of the seed, then use the spectroscopic techniques to analyze the spectral differences, can achieve the map effect, get more refined analysis of the characteristics of seed germination.

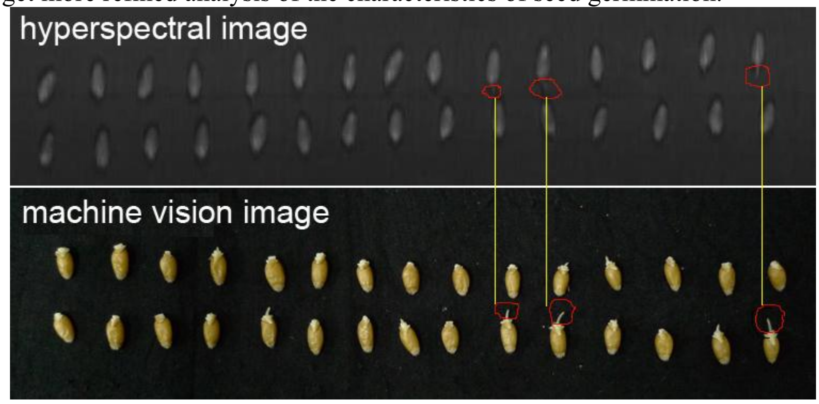


Fig. 2 hyperspectral image and machine vision image of germination wheat seeds

3.2 The analysis of spectral characteristics of the region of germinated wheat seed embryo and endosperm

Wheat seed is mainly composed of the embryo and endosperm, there are mainly three large storage material in the endosperm: carbohydrates, proteins and lipids, although the embryo part was a small part of the wheat, it were rich in protein, lysine, soluble sugar, fat and vitamins. In this study, we extracted the average spectrum of the embryo and endosperm of wheat kernel which was at the germination of 12h,and then fine analyzed the spectral absorption characteristics of the different regions. In the wavelength range of 870-1700 nm, the endosperm reflectance spectra was higher than that of the embryo portion(see in Fig.3). This band contains three characteristic reflection valley, respectively are 885 nm, 1149nm and 1381nm, These three wavelengths respectively corresponding to the characteristic absorption wavelength of the water of 970nm、1450nm and characteristic absorption wavelength of the fat at 1200nm, but the occurrence of the offset, this is mainly because that the wheat kernel is mixture, its various components within the spectral absorption occurs superimposed, therefore may lead to a spectral absorption peak position offset. As the water and fat content in the embryo is higher than the endosperm portions and therefore the spectral reflectance is lower than the reflectance of the endosperm.

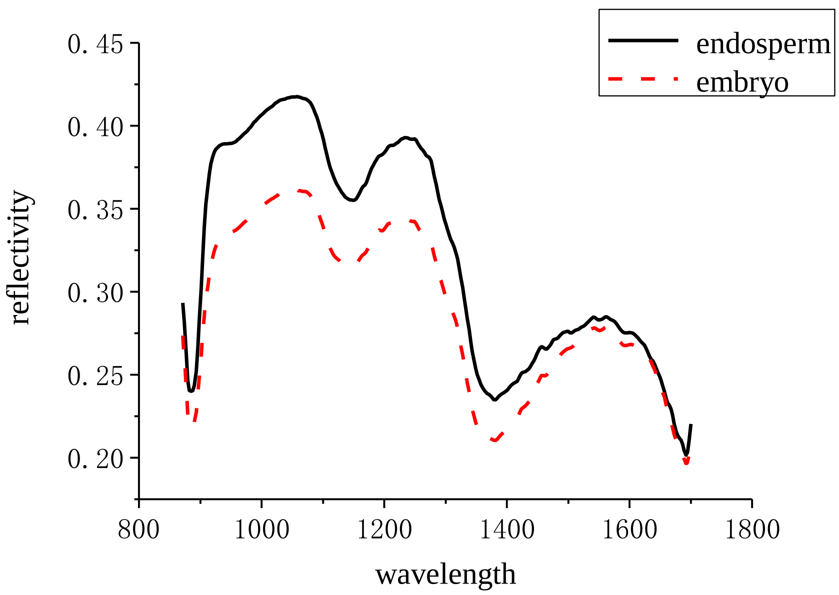


Fig. 3 the spectrum wheat seed in the germination of embryo and endosperm at 12h

3.3 Average spectrum analysis of wheat embryo at different germination period

Collect the hyperspectral image after wheat germination experiment at 0h, 12h, 24h, 48h of 8 species, extract the original average intensity value of all varieties of wheat germ region, and then change it to reflectivity, calculate the average spectrum of different germination period of wheat germ(see in Fig.5). It can be seen from the figure, at the germination of 12h, 24h and 48h,in the wavelength range of 870-1300 nm, the reflectivity increased with the increase of sprouting time, this band contains a reflection valley at 1149 nm which is the characteristic absorption of fat. So, the spectral reflectance within the range of this band change with time of germination may be related to the breakdown of fat, the embryo contains a lot of fat, with the increase in the degree of germination, fat gradually break down and reduced, causing the reflectivity increased gradually.

At 1400nm, the reflectivity of sprouted wheat seeds embryo at 12h, 24h, 48h were all lower than that of dry seeds, the main reason is that the band was in the vicinity of the water absorption band, in the germination process, the seed will absorb water, so the water content of the dry seed embryo is lower than the water content of the seed which is germinated. Furthermore, the reflectivity of sprouted wheat seeds embryo at 12h is lower than that of 24h and 48h,it may be due to before radicle grow, as a result of seeds imbibition of water, the water content is gradually increasing, so the reflectivity is at lowest. When the seed germinate arrive a certain state, rupture occurred because of embryos protrusion,, water overflows which lead to water content gradually reduce, so ,the reflectivity gradually increased.

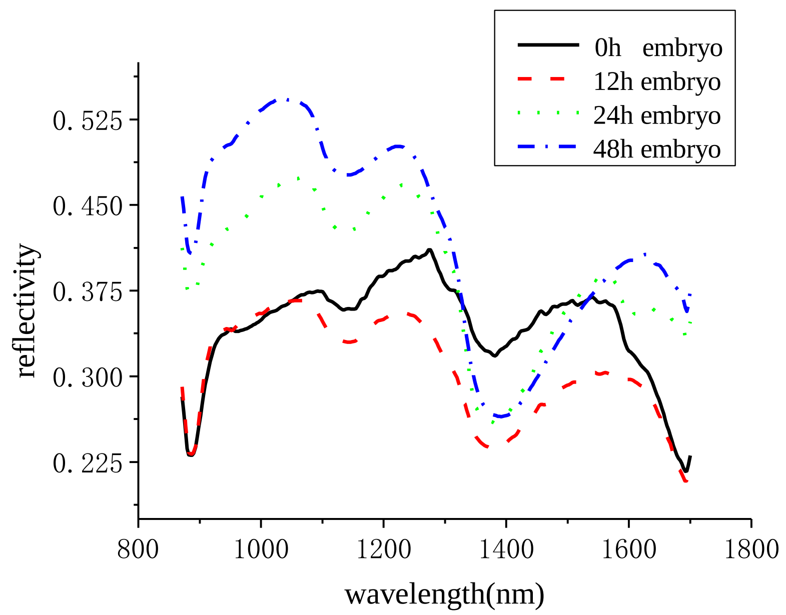


Fig. 4 The average spectrum of the embryo of 8 varieties of wheat at the same period

3.4 Average spectrum analysis of wheat embryo of different varieties in the germination process

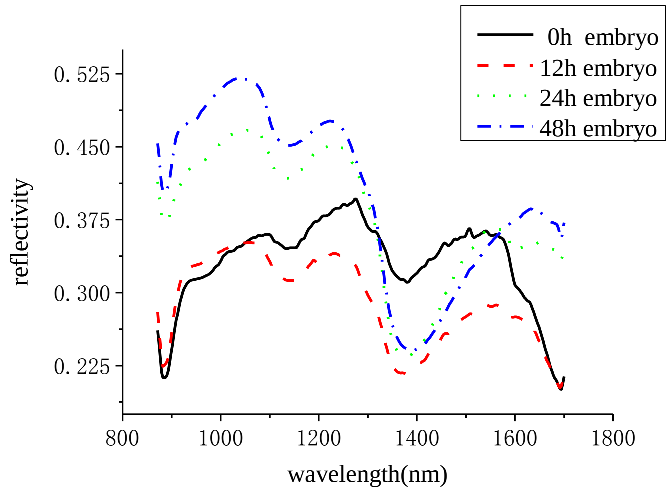
With hyperspectral images collected of wheat seed in different varieties, different times , extract the average spectrum of 30 wheat seed kernels of each variety to analyze the spectrum variation of the different varieties of wheat kernel embryo after the wheat seed germination experiment at 0h, 12h, 24h and 48h (see in Fig.5). It can be seen from the figure:

From 12h,24h to 48h， with the increase of germination time, at the wavelength range of 870-1300 nm, the reflectivity increased with the increase of sprouting time of all varieties except Nongda 3291. There are two reasons for this phenomenon: One is, the wavelength of 970nm is the water characteristic absorption, at the beginning of germination, mainly by imbibition of water, the water content is in a gradually increasing trend, when the seed germinate arrive a certain state, for embryos rupture, water overflows which lead to water content gradually reduce. So the germination time is longer, the reflectivity is higher. The second is the wavelength of 1200nm is the fat characteristic absorption, the embryo contains a lot of fat, with the increase of sprouting time, its internal fat hydrolysis under the action of the lipase, the fat content reduced, so, the reflectivity is higher.

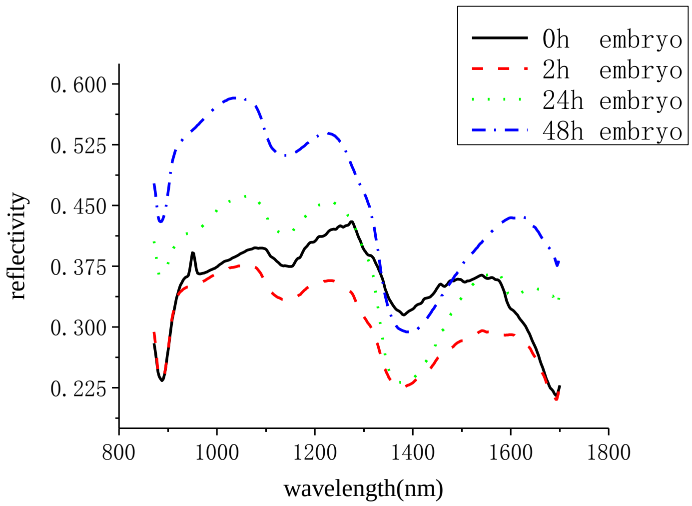
At 1400nm, the reflectivity of sprouted wheat seeds embryo at 12h is lower than that of 24h and 48h, but the reflectivity difference of sprouted wheat seeds embryo of Jing411and Zhongmai175 at 12h and 24h is less than other varieties, illustrate that the water content of the two species in this two periods have little changes.

In the wavelength range of 870-1300 nm, not all the varieties reflectivity increases with the germination time prolonged, it mainly because it contains 1450nm for the center of the strong absorption band of water, this band of water absorption is stronger than 970nm for other components vulnerable influence the water absorption at 970nm, the band of 1450nm have absolute advantage of water absorption For different varieties of seeds, due to different degrees of embryos ruptured, seed germination of spectral reflectance and gradual change of time with no obvious change with the seed germination time in the wavelength range of 1300-1700nm. Besides, the maximum reflectivity of Nongda3291 is 0.5, but other varieties of maximum reflectivity is larger than 0.52.

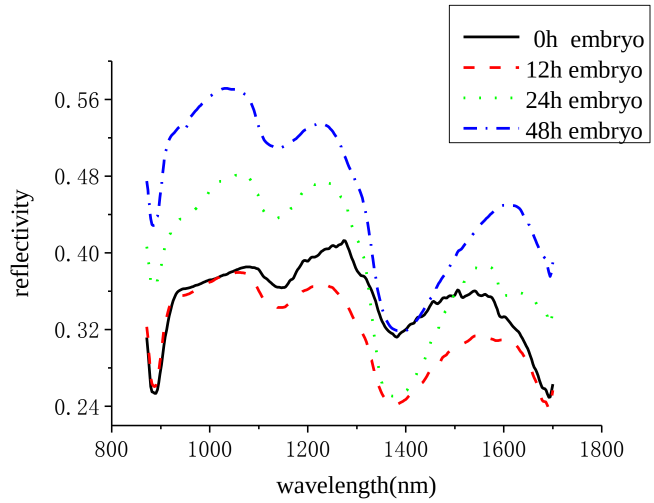
At 1400nm, the reflectivity of 12h sprouted wheat seeds were all lower than that of dry seeds. Further analysis revealed that: the reflectivity difference of 12h sprouted wheat seeds and dry seeds of Jingdong8, Jing411, Zhongmai175, Nongda211, Zhongmai16, Jingdong18, Nongda3432 and Nongda3291 respectively are 0.09627, 0.09095, 0.0727, 0.08479, 0.09405, 0.08849, 0.06057, 0.08739, but the difference of Zhongmai175 and Nongda3432 is smaller, it may be due to the capacity of water absorption is weaker than other varieties of the two varieties in the initial germination.



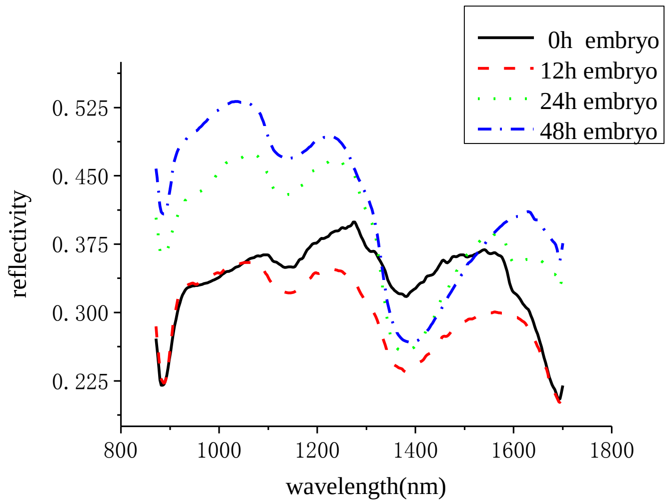
(a) Comparison chart of the average spectral reflectance of Jingdong8, different periods of wheat embryo



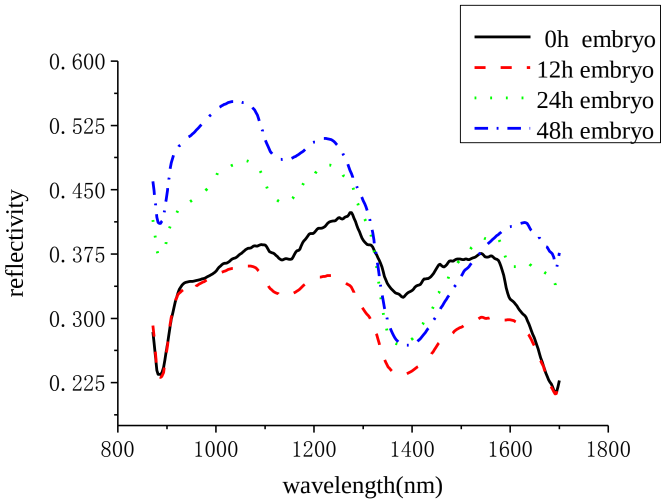
(b) Comparison chart of the average spectral reflectance of Jing411, different periods of wheat embryo



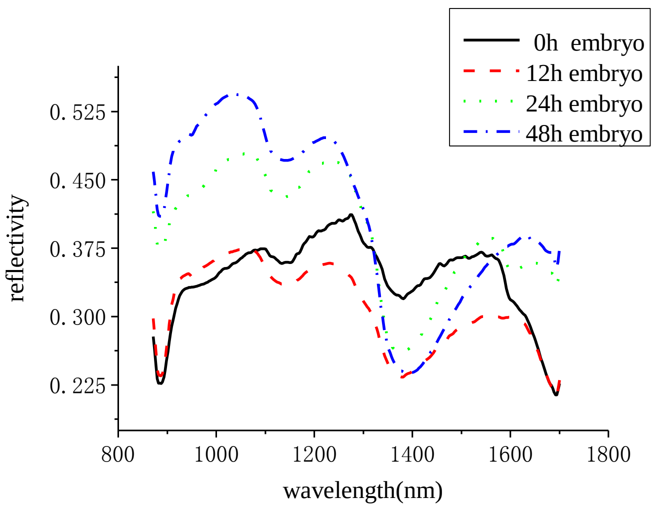
(c) Comparison chart of the average spectral reflectance of Zhongmai175, different periods of wheat embryo



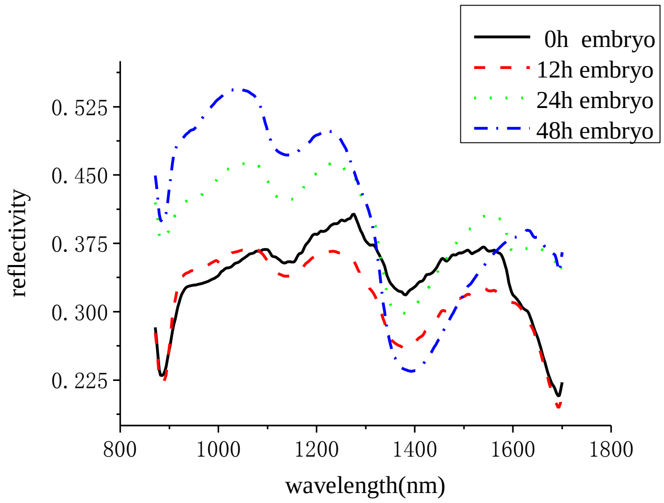
(d) Comparison chart of the average spectral reflectance of Nongda211, different periods of wheat embryo



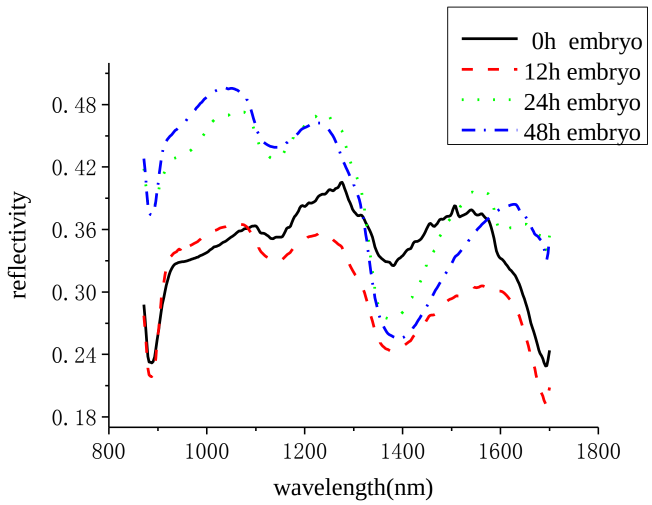
(e) Comparison chart of the average spectral reflectance of Zhongmai16, different periods of wheat embryo



(f) Comparison chart of the average spectral reflectance of Jingdong18, different periods of wheat embryo



(g) Comparison chart of the average spectral reflectance of Nongda3432, different periods of wheat embryo



(h) Comparison chart of the average spectral reflectance of Nongda3291, different periods of wheat embryo

Fig. 5 Comparison chart of the average spectral reflectance of the same species, different periods of wheat embryo

4 Conclusions

In this study, the hyperspectral images of these seeds were collected by a near infrared hyspectral imaging system after wheat germination experiment at different times, select a region of interest and extract its average original light intensity values, and were changed to spectral intensity for later analysis The results showed that after 12h sprouting, the reflectivity of embryo was lower than that of endosperm for the same seed, this is mainly due to the water and fat content of embryo was higher than the endosperm portions. For the same varieties of wheat seed at the germination of 12h, 24h and 48h,in the wavelength range of 870-1300 nm, the reflectivity increased with the increase of sprouting time, it was related to the changes of its internal content of fat in the seed germination process. At 1400nm, the reflectivity of sprouted wheat seeds were all lower than that of dry seeds, it was related to the rise of internal water content in the process of seed germination. Due to differences in seed water absorption and sprouting resistance, for different varieties of wheat seeds ,its spectral characteristics are also different. Therefore，using hyperspectral imaging technology can reflect the spectral characteristics and internal changes of wheat germination process.

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