Management of mixing process in preparation of solid media used for mushroom cultivation using near infrared spectroscopy

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Introduction

Several kinds of mushrooms, such as *Lentinus edodes*, *Pleurotus ostreatus*, *Flammulina velutipes* and *Auricularia auricula* are commercially cultivated in solid media consisting of a mixture of sawdust, rice bran and wheat bran. In the cultivation of mushrooms in solid media, water and rice bran contents are very important factors that promote the growth of mushrooms. The water content in the solid media is generally adjusted in the range of 60 to 65% by the addition of water to the mixture of sawdust with rice bran and wheat bran. Although the water content of rice bran and wheat bran is almost constant, the water content of sawdust varies and the magnitude of the change is dependent on the storage conditions of sawdust. Sawdust is usually stored in an open yard. In general, the water content is determined gravimetrically by drying the medium to a constant weight. However, it is difficult to apply the dry-weight method for adjustment of the water contents in solid media because the method is time-consuming.

The rice bran content based on dry weight also varies because of the variation of the water content of sawdust. Measurement of the content of rice bran in solid media is difficult even for a skilled worker. The development of a simple method for simultaneously measuring the content of water and rice bran in solid media has been desired for a long time. Such a method could promote the development of an automatic mixer used for mixing the ingredients, which are sawdust, rice bran, wheat bran and water.

In the previous study,[1] application of near infrared (NIR) spectroscopy for the simultaneous prediction of the content of water and rice bran in the solid medium used for mushroom cultivation was studied. The solid media were prepared by addition of water to a mixture of sawdust with rice bran and wheat bran. The reflected rays in the wavelength range between 400 and 2500 nm were measured at 2 nm intervals. To obtain a calibration equation for water content, a simple linear regression was carried out on the NIR spectral data at 1450 nm and on the water content of a calibration sample set (sample number, $n = 113$) obtained using the dry-weight method. On the basis of the result of a multiple linear regression on the content of rice bran in the solid media, a calibration equation using the second-derivative reflectance data at the wavelengths of 672 and 2100 nm was obtained. The content of water and rice bran in the solid media could be analysed simultaneously by NIR spectroscopy.

In this study, assignment of the wavelength of 672 nm used for determining rice bran content was studied. NIR spectra of acetone extract of rice bran, residual of rice bran extracted with acetone, rice bran oil purchased and rice bran obtained from the rice polishing process for preparing 90, 80, 70, 60, 50, 40 and 30% yield polished rice were measured.

Materials and methods

Materials

Polished rice and rice bran used in this study were prepared from an unpolished rice breed called 'Nakatesinsenbon' harvested in 1998. The 90, 80, 70 and 30% yield rice bran were prepared from unpolished rice 90, 80 and 40% yield polished rice, using a rice polisher (DB25E, Satake Co., Higashi-hiroshima, Japan), respectively. The grain size of polished rice was measured using an image analyser (IRA1A, Satake Co.).

Authentic rice bran oil was purchased from Katayama Chemical Industry Co., Osaka, Japan.

Near infrared spectroscopy

A sample cup filled with the rice, rice bran and residual of acetone extraction with rice bran was placed in a near infrared spectrophotometer (NIRS6500SPL, Nireco Co., Tokyo, Japan), the reflectance values at wavelengths ranging from 400 to 2500 nm were measured at 2 nm intervals. NIR spectra of the authentic rice bran oil, acetone extract of rice bran and acetone were drawn with the transmittance values obtained with 2 mm light pass length at wavelengths ranging from 400 to 2500 nm measured at 2 nm intervals.

Acetone extraction

Acetone extraction of rice bran was carried out in a Soxhlet's extractor. Residual of acetone extraction with rice bran was dried at room temperature to remove acetone before measurement of the NIR spectrum. Acetone extract with rice bran was used directly for measuring NIR spectrum.

Results and discussion

In the previous study,[1] application of NIR spectroscopy for the simultaneous prediction of the content of water and rice bran in the solid medium used for mushroom cultivation was studied and the content of water and rice bran in the solid media could be analysed simultaneously by NIR spectroscopy. On the basis of the result of a multiple linear regression on the content of rice bran in the solid media, the following calibration equation using the second derivative reflectance data at the wavelengths of 672 and 2100 nm was obtained.

$$C\text{pre} = 9.50 - 3007A_1 - 590.6A_2 \quad (1)$$

Here, Cpre is the NIR-predicted value of rice bran content (%). And A_1 and A_2 are the values of $d^2\log R^{-1}$ at 672 and 2100 nm, respectively. The values of the multiple correlation coefficient and the standard error of calibration (*SEC*) were 0.978 and 1.73%, respectively.

In this study, assignment of the wavelength of 672 nm used for determining rice bran content was studied. NIR spectra of acetone extract with rice bran, residual of acetone extraction with rice bran, purchased rice bran oil and rice bran obtained from rice polishing process for preparing 90, 80, 70, 60, 50, 40 and 30% yield polished rice were measured.

Raw spectra of rice bran and residual of acetone extraction with rice bran

In Figure 1, the raw spectra of rice bran and residual of acetone extraction with rice bran are plotted for wavelengths ranging between 400 and 2500 nm. The spectrum of rice bran was uniquely characterised by five peaks at around 672, 1726, 1760, 2308 and 2348 nm, which were not observed in the spectra of sawdust and wheat bran.[1] Rice bran is a by-product of rice polishing. Unpolished rice generally contains lipids at the concentration of approximately 3%. Peaks at around 1726, 1760, 2308 and 2348 nm on the spectrum of rice bran may be assigned to the lipid components of rice bran. Though the

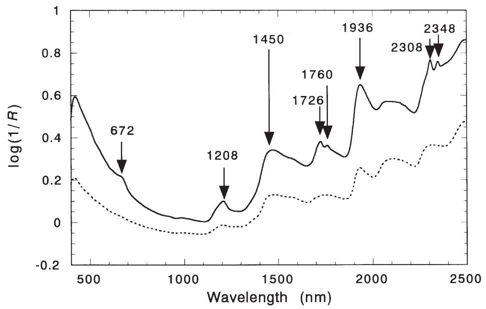

Figure 1. Raw spectra of rice bran and residual of acetone extraction with rice bran. Lines: rice bran (—) and acetone extraction with rice bran (- - - -).

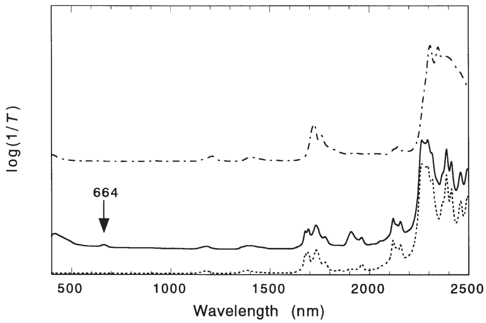

Figure 2. Raw spectra of acetone extract with rice bran, acetone and authentic rice bran oil. Lines: acetone extract with rice bran (—), acetone (- - - -) and authentic rice bran oil (— - —).

origin of the peak at around 672 nm in the spectrum of rice bran was not clear, the compound(s) may be an oleophilic red pigment.

Raw spectra of acetone extract with rice bran, acetone and authentic rice bran oil

In Figure 2, the raw spectra of acetone extract with rice bran, acetone and authentic rice bran oil are plotted for wavelengths ranging between 400 and 2500 nm. The peak observed at around 672 nm on the spectrum of rice bran (Figure 1) was observed at around 664 nm on the acetone extract with rice bran, while the peak could not be observed on the spectrum of acetone. On the spectrum of authentic rice bran oil, the peaks observed at around 1726, 1760, 2308 and 2348 nm on the spectrum of rice bran (Figure 1) were observed at the same wavelength. However, the peak at around 672 nm was not observed on the spectrum of the authentic rice bran oil. The compound which absorbed the light of around 672 nm might be removed on the purification process of rice bran oil.

Raw spectra of different yield polished rice

The 90, 80, 70 and 30% yield polished rice were prepared from unpolished rice, 90, 80 and 40% yield polished rice using a rice polisher and 90, 80, 70 and 30% yield rice bran were obtained as by-product, respectively. Figure 3 shows NIR spectra of unpolished rice and 90, 80, 70 and 30% yield polished rice. The peaks at around 1726, 1760, 2308 and 2348 nm were observed on the spectrum of unpolished rice. These peaks originated from rice bran oil as shown in Figure 1. The peak at around 672 nm was also observed on the spectrum of unpolished rice. While these five peaks could not be observed on the spectra of 90,

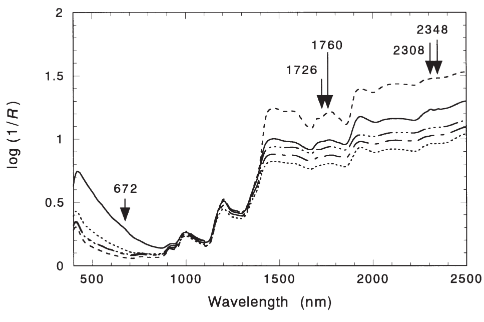

Figure 3. Raw spectra of different yield polished rice. The 90, 80, 70 and 30% yield polished rice were prepared from unpolished rice, 90, 80 and 40% yield polished rice using a rice polisher, and 90, 80, 70 and 30% yield rice bran were obtained as by-product, respectively. Lines: 100% yield (—), 90% (- - - -), 80% (–––), 70% (——–––) and 30% (– –).

Table 1. Dimensions of a grain of polished rice.

yield of polishing (%)	Length (mm)	Width (mm)	Thickness (mm)
100	5.29	2.90	2.28
90	5.04	2.95	2.27
80	4.78	2.83	2.15
70	4.35	2.67	2.05
60	3.95	2.56	2.00
50	3.51	2.47	1.96
40	3.00	2.35	1.93
30	2.57	2.22	1.89

Values of three dimensions were expressed with the average value of 150 grains.

80, 70 and 30% yield polished rice. Both rice bran oil and an unknown compound absorbed the light around at 672 nm which might mainly be contained in the surface of unpolished rice. For 90, 80, 70 and 30% yield polished rice, the spectra shifted to an upper level as the yield decreased between the wavelength from 1400 and 2500 nm. This phenomenon might be caused by the decrease in grain size. The grain size of polished rice was measured and shown in Table 1. The shape of polished rice changed from a pole to a ball as the development of the polishing process.

Raw spectra of different yield rice bran

NIR spectra of 90, 80, 70 and 30% yield rice bran were shown in Figure 4. The shoulder observed at around 672 nm on the spectrum of 90% yield rice bran became smaller on the spectrum of 80% yield rice bran, and could not be observed on the spectra of 70 and 30% yield rice bran, while the peaks observed at around 1726, 1760, 2308 and 2348 nm on the spectrum of 90% yield rice bran, which originated from rice bran oil, could not be observed on the spectra of 80, 70 and 30% yield rice bran. These results suggest that the compound(s) which absorbs the light at around 672 nm may be an oleophilic red pigment which is contained in the surface of unpolished rice.

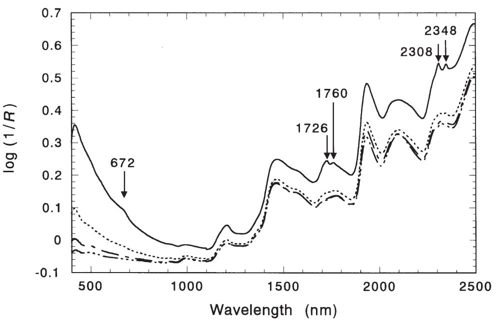

Figure 4. Raw spectra of different yield rice bran. Lines: 90% yield (—), 80% (-----), 70% (– – –) and 30% (— - - - - —).

Acknowledgement

The authors are very grateful to Mr. Koji Yamamoto and Mr. Koji Kawakami of Satake Co. (Higashi-Hiroshima, Japan) for supply of

rice bran and polished rice used in this study and for measurement of the size of rice.

Reference

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