Development of a continuous, high-speed, single-kernel brown rice sorting machine based on rice protein content

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Introduction

Recently, consumers have been purchasing rice with an increasing interest for its taste. Consequently, every agricultural research station in Japan has been conducting its breeding programme by systematically selecting rice based on taste-related constituents. To improve this process, it is desirable to be able to estimate the constituent content of rice kernel by kernel and many researchers have been conducting single-kernel estimation using commercial bench-type NIR instruments.[1] However, those estimations usually take a long time—approximately 30 seconds to 1 minute—so they are not suitable for sorting the large number of samples that have either natural distribution or have been artificially mutated in a short time. To improve sorting speed, Shizuoka Seiki (Fukuroi City, Japan) and NFRI (National Food Research Institute) of MAFF (Ministry of Agriculture, Forestry and Fisheries of Japan) have jointly developed a continuous, high-speed, single-kernel brown rice sorting machine based on rice protein content.

Instrumentation

Figures 1 and 2 show the schematic diagram of the developed instrument and sample transport/sorting mechanism, respectively. The instrument consists of several sections, which include a feeding mechanism, measuring unit, sorting mechanism and controlling PC. As shown in Figure 2, the feeding mechanism picks up single-kernel brown rice from the hopper (maximum 5 kg storage capacity) and sends it to the measuring unit. A spectrum of the brown rice is obtained in the measuring unit, which consists of a near infrared array sensor. The brown rice is then sorted in the sorting mechanism based on its protein content estimated by the controlling PC.

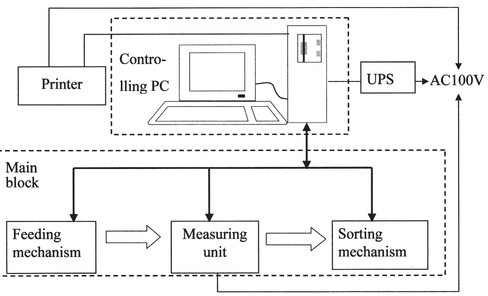

Figure 1. Schematic diagram of a continuous high-speed single-kernel brown rice sorting machine.

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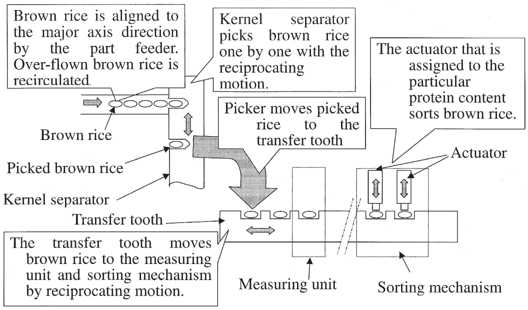

Figure 2. Schematic diagram of sample transport/sorting mechanism.

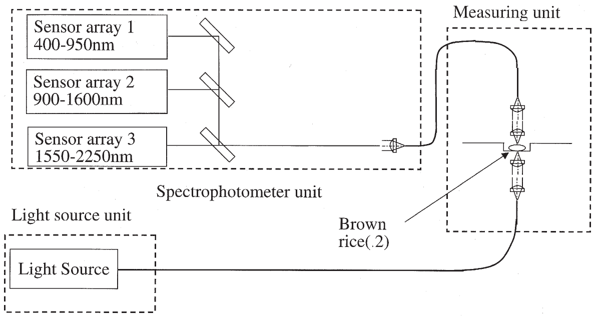

Figure 3. Optics layout (transmission).

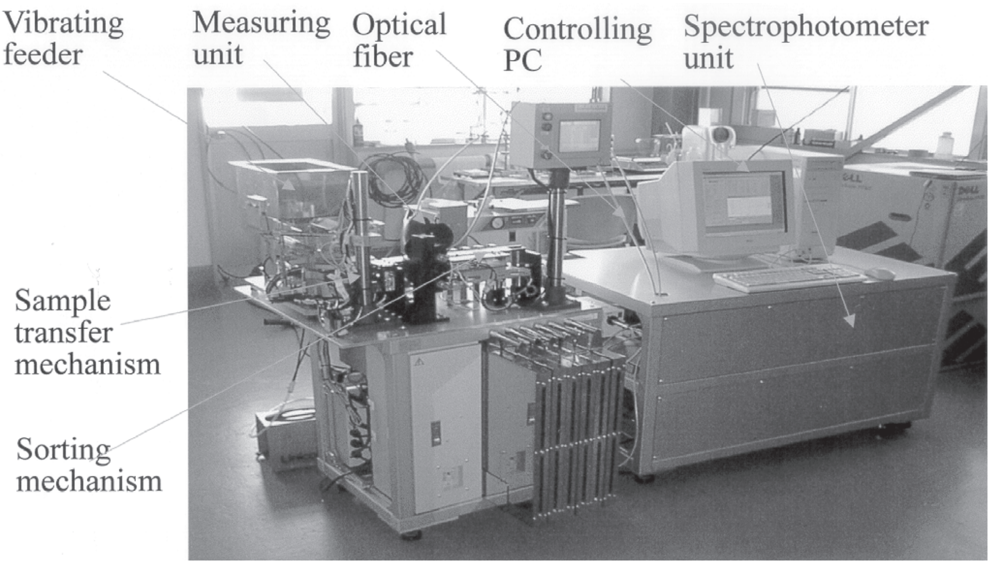

Photo 1. The developed instrument.

Figure 3 shows the optics layout. The light induced by input from the optical fibre to the measuring unit is focused approximately 2 mm diameter on the surface of brown rice. Light transmitted through the rice is then focused on an output optical fibre and is guided to a detector consisting of three array sensors, (400–950 nm Si, 900–1600 nm InGaAs and 1550–2250 nm InGaAs) after being monochromised by gratings. Measuring speed was approximately 500 ms for the full spectrum range of 400–2250 nm, 1 nm interval and overall sorting speed was approximately 2.8 s for one kernel.

Photo 1 shows the appearance and Table 1 shows the major specifications of the instrument.

Materials and methods

Samples

We used 363 brown rice samples (cultivar: Hitomebore) harvested in 1997, 1998 and 1999 provided by the Shizuoka Agricultural Experiment Station.

Spectrum measurement

Single-kernel brown rice spectra were obtained for both transmission and reflectance mode, configured to single-kernel measurement mode in the developed instrument set-up to obtain optimum S/N ratio when measurement was carried out at 500 ms. The total measuring time, including sample preparation and removal, was approximately 30 to 35 seconds.

Table 1. Major specifications of the developed instrument.

Model	CTC-3	
Feeding mechanism	Sample hopper Feeding method Transfer method	5 kg brown rice Automatic feeding using vibrating feeder Single kernel transfer mechanism
Measuring unit	Method Wavelength range Detector Measuring constituent	Transmission / Reflectance 400–2500 nm spectrum (1 nm interval) Si and InGaAs array sensors0 Protein content(DM)
Control unit	Controlling PC OS I/O	DOS/V PC Windows98 High-speed data transfer using SCSI
Sorting mechanism	Sorting Sorting method	Any given 5 classes of 0.1% pitch + NG Shutter
Power requirement	Instrument Air compressor	AC100V 10A AC100V 10A
Dimension		App. 1500 W × 700 L × 1500 H
Weight		App. 200 kg (air compressor excluded)
Spectrophotometric measuring time		App. 500 ms
Feeding speed		1 Kernel / 1.8 s
Accuracy	*SEP*	0.5% Protein content (DM)
Overall sorting speed		1 Kernel / 2.8 s

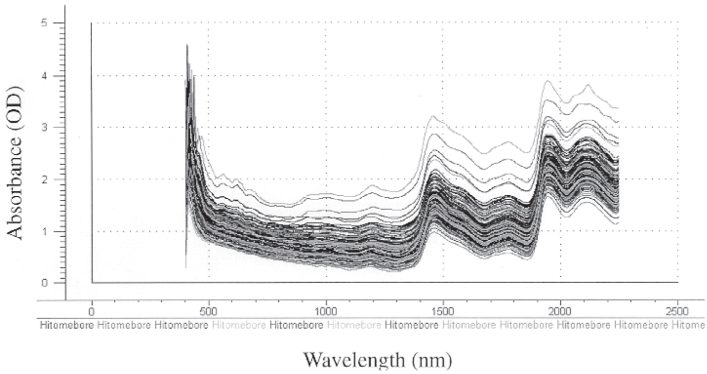

Figure 4. Brown rice spectra (transmission: 400–2500 nm.)

Chemical analysis

The spectrum-measured brown rice kernel first was dried completely by the oven method for 135°C for 24 h. Its nitrogen content was then measured using an NC-1000 (Sumika Chemical Analysis Service, Osaka, Japan) combustion nitrogen analyser and the protein content was calculated by multiplying 5.95 times the nitrogen–protein conversion factor. SDD (standard deviation of the difference) was 0.04%.

Developing calibrations

PLS regression analysis was carried out to developing calibrations using Unscrambler Version 7.5 (CAMO, Norway). Samples were randomly divided into three parts; two were used for developing calibrations and the other was used for validation.

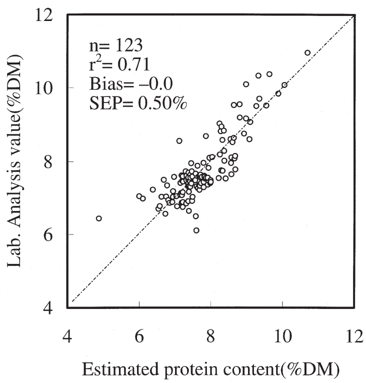

Figure 5. Scatter plot of estimated protein content *vs* laboratory analysis value (transmission 1000–2000 nm).

Results and discussion

As a consequence of examining both measuring mode and wavelength range, the best calibration was obtained when using 1000–2000 nm as the wavelength range in the transmission mode with a *SEP* value of 0.50%. Figure 4 shows the spectra of brown rice and Figure 5 shows the scatter plot. No good calibrations were obtained in the reflectance mode.

Concluding remarks

The new instrument reported here is now being used at the Shizuoka Agriculture Experiment Station. While good *SEP* results were obtained in the present study, over-all sorting speed and the consistency of measurements should be improved. These improvements and further improvement for *SEP* are currently underway.

Acknowledgement

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References

1. S. Kawano, C. Iyo, H. Abe and M. Iwamoto in *Proceedings of 8th International Conference on Near-Infrared Spectroscopy*, p. 15 Food (1997).