An Instrument for Objective Measurement of Degree of Milling and Color of Milled Rice[1]

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ABSTRACT

An instrument has been developed to provide an objective method for measuring three of the important quality factors of milled rice: degree of parboiling, color (general appearance), and degree of milling. Degree of milling measurements are made by comparing the light-transmittance properties of the rice sample at two specified wave lengths, 660 and 850 nanometers. Color of white milled rice and degree of parboiling of parboiled rice are objectively evaluated by measuring the lightness, a reflectance characteristic of the rice. A special optical unit permits either measurement to be made without transferring the sample from one instrument to another. Tests of the instrument with over 500 samples of white and parboiled milled rice samples show that the instrument is highly accurate in measuring degree of milling ($r = 0.878$) and color ($r = 0.934$) of white milled rice compared to visual grades determined by official inspectors. Correlation coefficients between meter reading and visual grades were somewhat lower for parboiled rice ($r = 0.623$) because of interactions that exist between degree of parboiling and degree of milling. Rice quality control and inspection or grading are potential uses of this instrument.

Present-day emphasis on improving marketing methods requires uniform inspection of a product throughout the country, and uniform inspection requires the satisfactory use of objective quality evaluation. Three of the most important factors in determining the quality of milled rice are degree of milling, color or general appearance of white milled rice, and degree of parboiling of parboiled milled rice. Present methods used by the Inspection Service and the rice industry depend upon a visual sample appearance rating.

Milled rice, as defined by official U.S. Standards, consists of whole or broken rice kernels from which the hulls and practically all of the germ and bran layers have been removed. Milled white rice ranges in color from white to dark gray, decreasing in grade and value with darker color. Degree of parboiling is a measure of the extent of starch gelatinization; parboiling also generally tends to darken the color of the rice. Degree of milling is a measure of the extent to which the germ and bran layers have been removed from the endosperm. Complete removal of the germ and bran layers requires more extensive milling and increases the percentage of broken kernels. Percent of head (i.e., whole grain) rice is an important economic factor in rice processing or milling. The rice miller's visual estimate is relied upon for adjusting the hullers or pearlers to obtain the desired degree of milling. Errors in judgment result in undermilled or overmilled rice, with an unnecessary reduction in percent of head rice and consequent loss of market value. In the Inspection Office, the inspector's visual rating of the degree of milling determines the official grade, which is often subject to dispute.

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In research conducted at Stuttgart, Ark., Autrey *et al.* (1) showed that measurement of surface lipids was a reliable index of degree of milling up to the point at which the bran removed (percentage of rough rice) has exceeded 6% by weight. Hogan and Deobald (2) showed that accurate results can be obtained by a modified extraction procedure which uses petroleum solvents instead of diethyl ether. Other methods of determining the degree of milling employ macrocolorimetric analyses (3) or determination of the percentage loss of phosphorus (4). A rapid objective method which uses an Agtron reflectance meter was reported recently by Johnson (5). The Agtron provides reasonably good results but does not provide independent measurements of degree of milling and color, and is limited to measurement of parboiled rice.

Norris (6) has shown that the external and internal characteristics of biological materials can be measured by a light-transmittance technique which makes use of the fact that changes in various quality factors are often associated with changes in the sample spectral transmittance. For bulk samples of granular material the transmittance measurement gives a good indication of average reflectance characteristics, because the light, in passing through the sample, is reflected from one grain to another. Exploratory measurements showed that this technique could be used to measure degree of milling of rice.

Color measurements can be made with any one of several reflectance-type instruments. One of the most reliable instruments for measuring the color of a granular product such as rice is a photoelectric color difference meter with a large-area optical unit. A Hunterlab Model D-25H was found satisfactory for measuring the color of white milled rice and the degree of parboiling of parboiled milled rice. Preliminary investigations showed that such an elaborate instrument was not needed for rice color measurements.

MATERIALS, EQUIPMENT, AND METHODS

Materials

Laboratory samples of milled rice used in obtaining preliminary spectral transmission and reflectance characteristics were prepared with a McGill sample sheller and McGill miller. A wide variety of milling severities, moisture contents, and rice varieties was used to obtain a representative range in degree of milling and color. After milling, percent surface lipids (oil content) was determined with a Goldfisch extraction apparatus to give an accurate index of degree of milling. Samples were obtained from the Rice Inspection offices at New Orleans, La., and Stuttgart, Ark., for use in evaluating the experimental lightness meter, rice photometer, and Ratiospect. Commercially milled samples were furnished with official visual grades of degree of milling, color or degree of parboiling, broken contents, and variety.

Experimental Equipment and Methods

In making spectral transmission or reflection measurements of a granular material, some consideration must be given to sample size. For spectral transmission measurements, the sample should be the maximum depth which will transmit a measurable quantity of light for the particular spectrophotometer system used. This provides a more representative reading by averaging effects. It was found experimentally that a sample depth of 1¼ in. at least 2½ in. in diameter was optimum for use with a Dumont Type 6911 red-sensitive photomultiplier tube. For reflectance measurements, it is important that the area viewed be as large as possible to obtain a good average. The depth of the sample is not critical but should be sufficient to essentially eliminate the effects of reflection from the background material such as the bottom of the sample cell. It was found that an area having a diameter of 2½ in. and a depth of approximately ½ in., or four to five kernels thick, is adequate to meet the requirements. Sample cells providing for a depth of 1¼ in. and a minimum diameter of 2½ in. were subsequently constructed and used in each of the systems described below: recording spectrophotometer, d.c. rice photometer (7), and rice Ratiospect.

A laboratory-constructed recording spectrophotometer was used to obtain spectral transmission data for rice samples having various degrees of milling and the same color. The principal components of the spectrophotometer are a Bausch & Lomb grating monochromator with an electric wave length drive, a photomultiplier tube (either RCA 1P-22 or Dumont 6911, depending on spectral region being scanned), regulated d.c. power supply, and a recording millivoltmeter. Typical normalized spectral transmission curves for Bluebonnet long-grain white rice (Fig. 1) show that the greatest changes in spectral transmission due to milling occur at 660 nm.

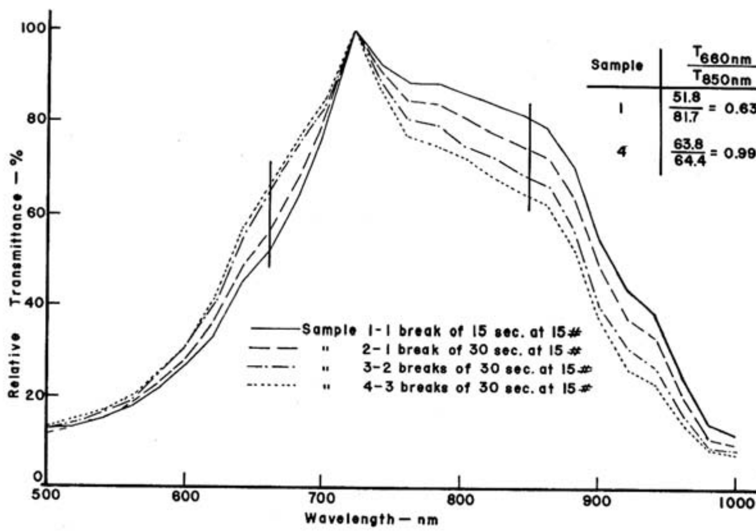

Fig. 1. Effects of degree of milling on the spectral transmission of milled rice.

(1 nanometer, nm. = 1 mμ) in the red portion of the spectrum and at 850 nm. in the near-infrared. Initially, a d.c. rice photometer (7) similar to the "smut" meter (8) was designed, constructed, and tested for measuring degree of milling of rice. This instrument provides a direct measurement of the ratio

of the transmittance at two specified wave lengths; for degree of milling measurements the ratio is $(T_{850\ nm.})/(T_{660\ nm.})$.

Studies of milled rice samples having a wide range in color with degree of milling held constant failed to show significant differences in spectral transmission or reflectance. Therefore, studies were made of the tristimulus color factors, with a Hunterlab Model D25 color difference meter equipped with a large-area optical unit. These tests showed that visual color grades are highly influenced by all of the tristimulus color factors, but lightness (Hunter "L") correlated highest ($r = 0.946$) with visual color. Various simple optical arrangements and electronic circuits suitable for measuring lightness were tested. After considerable testing, a design using 45° diffuse reflectance optics was chosen for further development (9).

Modified Ratiospect

Two additional investigations were needed to make these instruments practical for use by rice inspectors for routine grading of rice. First, the rice inspectors indicated that the instruments should be combined into a single instrument to permit measurements of any two of the quality factors; that is, the instrument should allow measurement of either degree of milling *and* color of white milled rice, or degree of milling *and* degree of parboiling of parboiled milled rice. Second, a statistical study of data was needed to develop appropriate correction factors to improve the relation between instrument readings and factors of parboiled rice where interactions exist.

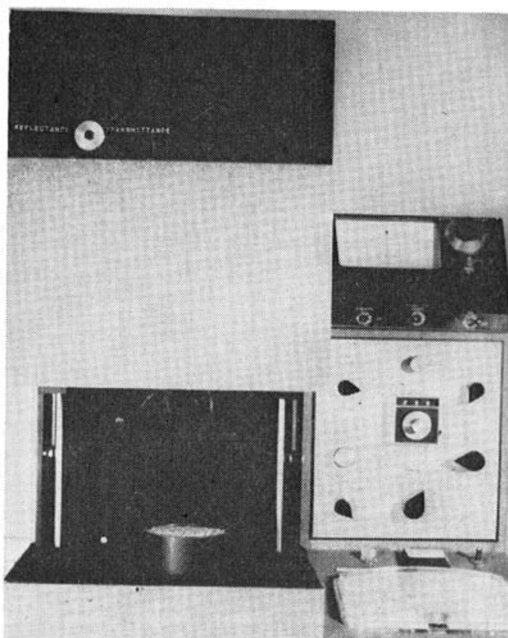

Fig. 2. The rice Ratiospect, showing a sample in place in the sample compartment.

In co-operation with a manufacturer, a basic transmittance instrument known as the "Ratiospect" was modified and tested during the past year. The modified instrument, shown in Fig. 2, employs a special optical unit which permits measurement of either light-reflectance or light-transmission properties of a granular material such as rice. This eliminates the necessity of transferring a sample from one instrument to another, since any of three quality factors can be measured by simply switching the instrument to reflectance or transmittance.

RESULTS AND DISCUSSION

Preliminary Degree of Milling Measurements

In the first test, eight lots representing five varieties were given five milling treatments. Percent surface lipids varied from 0.169 to 0.816, indicating a wide range in milling severity. The most important observation from this test was the high correlation between percent surface lipids and rice photometer reading within lots ($r = 0.995$), and the relatively low over-all correlation ($r = 0.837$). The over-all correlation indicated that differences, one of which was variety, existed between lots. Later tests showed that the difference in meter readings obtained between varieties is related to grain size. Rice surface lipids readily transmit light of 850 nm. wave length and absorb light of 660 nm. wave length. It follows that the smaller kernels would appear to have a higher lipid content, because the light would have been reflected a greater number of times from kernel to kernel in being transmitted through a sample of given thickness.

Experimental Color Investigations

As previously pointed out, initial measurements of the tristimulus color factors of rice indicated a highly significant correlation between "lightness" and rice inspectors' visual grades. An experimental lightness meter was designed, constructed, and tested for accuracy with a large number of samples of white and parboiled milled rice. The correlation of visual degree of color *vs.* meter reading was very high ($r = 0.921$) for white milled rice. The correlation coefficient was somewhat lower ($r = 0.740$) for parboiled rice, partly because of interactions between degree of milling and degree of parboiling. Also, there are only three official designations of degree of parboiling, most of the samples falling into either parboiled or parboiled light. One group of parboiled rice samples was regraded by a panel of four judges and assigned numerical values to show more closely true visual differences in degree of parboiling. The correlation between visual numerical grade and experimental lightness meter readings was much improved; the correlation coefficient was raised from $r = 0.740$ to $r = 0.935$.

Modified Ratiospect

The modified Ratiospect with reflectance attachment was tested in the laboratory to determine its accuracy in measuring the three quality factors. The Rice Inspection Service, Consumer and Marketing Service, furnished a large number of samples of officially graded white and parboiled milled rice for these tests. Simple correlation analyses were made to compare Ratiospect meter readings with visual grading values. The accuracy of the

TABLE I

CORRELATION COEFFICIENTS OF COLOR AND DEGREE OF MILLING FACTORS FOR WHITE RICE

	DEGREE OF MILLING (TRANSMITTANCE)		COLOR OR GENERAL APPEARANCE	
	D.C. Rice Photometer[a]	Combination Meter (Ratiospect)[b]	Experimental Lightness Meter[a]	Combination Meter (Ratiospect)[b]
Visual milling	0.906*	0.878*		
Visual color			− 0.931**	− 0.934**

[a] Evaluated on the basis of 300 samples.
[b] Evaluated on the basis of 500 samples.
* Probability of 91% that the two r's are significantly different.
** Probability of less than 50% that the two r's are significantly different.

modified Ratiospect compares favorably with the two individual meters described previously. The results for white milled rice are summarized in Table I.

These values show that the modified Ratiospect is capable of accurately measuring the degree of milling and color of white milled rice. Correlation coefficients (average $r = 0.623$) were somewhat lower for visual milling *vs.* meter readings for three lots of parboiled rice. The correlation of visual degree of parboiling *vs.* meter reading was also rather low. Most of the difficulty with parboiled rice is not due to error in meter reading but rather to the interactions that exist, subjectively or objectively, between measurements of degree of milling and degree of parboiling. It is believed that these difficulties can be resolved by applying proper correction factors when the instrument is used in routine grading.

CONCLUSIONS

The modified Ratiospect provides a fast, objective means of measuring three of the important quality factors determining the grade of milled rice. If adopted for official grading of rice, it would eliminate subjective measurements subject to dispute. Uniformity of grading throughout the rice industry would be accomplished automatically.

The instrument has excellent potentialities for becoming a primary or secondary control of pearlers in a rice mill for improved degree of milling. Limited field tests show that the instrument provides a much higher degree of sensitivity than is obtainable by subjective measurement.

At the present time, field tests are being conducted in an official rice inspection office to establish (a) numerical meter readings corresponding to various visual grades now used by official rice inspectors, and (b) correction factors to compensate for interactions between meter readings of degree of milling and degree of parboiling for parboiled rice. The field tests have indicated that accuracy of degree of milling measurements may be improved by adjusting sample thicknesses for various length classes and broken classes.

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