

ALTERNATIVE METHOD FOR MEASUREMENT OF WHITENESS AND TRANSPARENCY OF RICE USING MATHEMATICAL MODEL OF COLOR VALUES

*Ravipat LAPCHAROENSUK¹ and Panmanas SIRISOMBOON²

¹*Division of Agricultural Engineering, Faculty of Science and Technology, Rajamangala University of Technology Tawan-ok 43 moo 6 Bangpra, Sriracha, Chonburi, 20110, Thailand*

²*Curriculum of Agricultural Engineering, Department of Mechanical Engineering, Faculty of Engineering, King Mongkut's Institute of Technology Ladkrabang Chalongkrung Road, Ladkrabang, Bangkok, 10520, Thailand*

Corresponding author: Ravipat LAPCHAROENSUK. E-mail: ravipat@live.com

ABSTRACT

Purpose of this study was to investigate mathematical models developed using color property parameters by multiple linear regressions (MLR) for evaluating whiteness and transparency of rice. The samples of milled rice were of parboiled rice, white rice, new Jasmine rice (harvested in 2012), and aged Jasmine rice (harvested in 2006 or during 2007-2011) of 51, 23, 12, and 164 samples, respectively. The color of rice samples were recorded by color meter on tristimulus XYZ system. The whiteness and transparency were measured by the milling meter. The mathematical models were established using MLR. All models showed high prediction ability for evaluation of the whiteness and transparency of rice (i.e., "R" $_{val}^2$ between 0.81 and 0.98; standard error of prediction (SEP) between 1.00 and 2.00; bias between -0.07 and 0.09). The proposed models can be alternative method for evaluating whiteness and transparency of rice.

Keywords: Rice; Whiteness; Transparency; Color; Multiple linear regression.

INTRODUCTION

Rice (*Oryza sativa* L.) is Thailand's most important agricultural produce grown to feed both domestic and international consumers. One of the most important aspects of rice grain quality and production cost is its milling process. The main indicators of milling process assessment are whiteness and transparency of rice grain. Both indicators are observation properties that can be detected visually. Typically these are measured by milling meter. In the milling meter, a light is projected onto the rice sample, then amount of reflected light is detected by photodiodes.

Color is optical properties of material. Presently colorimetry is used to quantify and describe physically the human color perception. Since the perception of color mainly depends of the observer and other illumination conditions, an objective assessment of color requires appropriate instrumentation that follows the recommendations instituted by the CIE (International Commission on Illumination) [1]. The CIE institute have developed color measurement systems such

as tristimulus (XYZ and RGB) and CIE $L^*a^*b^*$ values. The tristimulus (XYZ) system is simulated for explaining three cone cells type in human eye. This information brings to the possible application of color measurement to evaluating the whiteness and transparency of milled rice.

One of the most interesting mathematic modeling is multiple linear regressions (MLR). In many research, MLR were used to create models from some attributes for predicting properties of agricultural product such as maturity index of mango [2], surface tension of vegetable oils [3], consumer liking of beef bouillon products [4], sensory attributes of sweet potato [5] and texture of apple [6].

The objective of the present study was to develop the MLR models that correlated the color property (XYZ) with whiteness and transparency of milled rice. It was aimed to prove the possibility of this alternative method for evaluation of whiteness and transparency of milled rice.

METHODOLOGY

Rice Samples

All samples (n = 250) of milled rice were received from the rice quality improvement plant (C.P. Rice Co., Ltd., Thailand). The rice samples were randomly garnered from three locations within the plant premises (the raw material receiving station, behind the color sorter machine, and under the storage bin). These three locations were selected for sample collection because they are the sites at which rice samples are typically collected for internal quality inspection. The samples of milled rice tested were parboiled rice (processed from white rice; n = 51), rice (from varieties other than Jasmine; n = 23), new Jasmine (Khao Dawk Mali 105 variety; n = 12; harvested in 2012 and sold to the plant where it was evaluated that year), and aged Jasmine (n = 164; harvested either in 2006 or 2007–2011; “aged” means the rice was kept for at least 1 year postharvest before processing and evaluation). The weight of each milled rice sample was approximately 200 g, and samples were retained in a plastic zipper bag until experimentation.

Color Measurement

The color of milled rice was measured by spectrophotometer (Miniscan XE Plus 45/0 LAV, Reston, USA). The color values were recorded on tristimulus (XYZ) scale with the observer angle of 2° and the light source of D65. Three replicates of milled rice sample were measured and the measurements were then averaged.

Whiteness and Transparency Measurements

The whiteness and transparency of the milled rice samples were measured by the rice milling meter (MM1D, Satake, Japan). Three replicates of each sample were measured and the measurements were then averaged.

Multiple Linear Regression Calculation and Prediction Methods

The multiple linear regressions were calculated from relationship of the color value with the corresponded whiteness and transparency of milled rice. The color values were defined independent variables and whiteness and transparency dependent variables. The formula of multiple linear regression equation represents as follows:

$$Y = aX_1 + bX_2 + cX_3 + d \quad \dots(1)$$

Then Y is the whiteness or transparency of milled rice. The X₁, X₂ and X₃ are color value (i.e. X, Y and Z, respectively). The a, b and c are regression coefficients of independent variables (i.e. X₁, X₂ and X₃, respectively). The d is the intercepts.

Eighty percent of the experimental samples (201 samples) were used in the calibration group and the remainder (49) in the validation group. The calibration group was used for model creation and the model error was calculated by the full cross-validation method. The created model was then used to predict the dependent variable of rice samples in the validation group. The optimum model was selected by coefficients of determination of the calibration and validation groups (R_{cal}² and R_{val}²), standard error of calibration (SEC), standard error of prediction (SEP), bias, The software for multivariate analysis (Unscrambler, v. 9.8, CAMO, Norway) was used in model development and prediction process.

RESULTS AND DISCUSSION

The mean, standard deviation (SD), maximum (Max), and minimum (Min) values of the whiteness and transparency of milled rice for calibration and validation groups are shown in Table 1. The range of whiteness of milled rice was 21.1 to 46.5 and the range of transparency of milled rice is 2.16 to 4.13. The SD value for calibration set of whiteness is less than prediction set but the transparency showed the opposite. The SD value was calculated for explaining the amount of variation or dispersion from the average which indicated the comprehensiveness of data in the calibration models.

The MLR models created and the results of prediction for whiteness and transparency of milled rice were showed in Table 2. Both MLR models, i.e. whiteness model and transparency model, showed a negative regression coefficients value with X₁ variable, indicating the X value inversely correlated with whiteness and transparency. On the other hand, the regression coefficients of X₂ and X₃ variables display a positive slope, thereby indicating the positive correlations.

The scatter plots of reference data with prediction data of whiteness and transparency are shown in Fig. 1. The prediction results of

whiteness and transparency of milled rice showed high ability of prediction (i.e., $R_{val}^2 = 0.863$ to 0.980 ; $SEP = 0.205$ to 1.033 and $Bias = -1.120$ to 0.008). The prediction result of whiteness model was more capable than of transparency model. Cause of high prediction capability occurred on prediction results of

whiteness was the whiteness was an indicator for explaining color of milled rice. Likewise the transparency of milled rice affects the color of milled rice. The findings showed the possible application color measurement for evaluating whiteness and transparency of milled rice.

Table 1 Minimum (Min), maximum (Max), mean, and standard deviation (SD) of whiteness and transparency of milled rice samples.

Parameter	Calibration					Prediction				
	Number of Sample	Min	Max	Average	SD	Number of Sample	Min	Max	Average	SD
Whiteness	201	21.1	46.5	36.9	7.2	49	20.8	44.6	35.3	8.3
Transparency	201	2.16	4.13	3.04	0.47	49	2.05	3.69	2.99	0.45

Table 2 MLR Models and statistical results for prediction of whiteness and transparency of milled rice

Parameter	MLR Model	R_{cal}^2	R_{val}^2	SEC	SEP	Bias
Whiteness	$Y = -3.819X_1 + 3.802X_2 + 0.731X_3 + 8.887$	0.977	0.980	1.120	1.033	-0.121
Transparency	$Y = -1.934X_1 + 1.697X_2 + 0.074X_3 + 6.569$	0.811	0.863	0.205	0.170	0.008

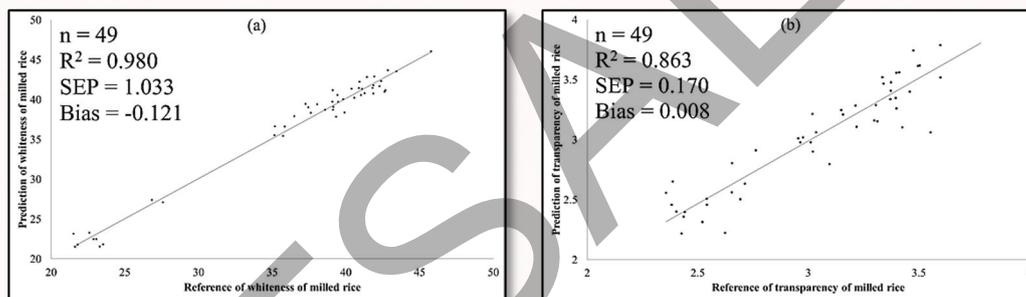


Fig. 1 The scatter plots of reference data (X) with prediction data (Y) of whiteness (a) and transparency (b)

CONCLUSION

The prediction results of whiteness and transparency of milled rice showed " R_{val}^2 " more than 0.863. The results of the whiteness model indicated its better prediction ability than that of transparency model. (i.e., " R_{val}^2 " = 0.980; $SEP = 1.033$ and $Bias = -1.120$). The study reveals that color values on tristimulus (XYZ) of milled rice can be substituted in the multiple linear equations to determine whiteness and transparency of milled rice. It could be alternative method for evaluation whiteness and transparency of milled rice. In addition the finding is important information for a development of instrument to be used in rice processing.

ACKNOWLEDGEMENTS

The authors are grateful for C.P. Rice Co., Ltd., Thailand for providing samples and assistance in sample collection.

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