Establishment of Optimized Manufacturing Conditions for Cooked Rice
-Part II- Moisture Transfer Kinetics of Cooked Rice when Drying and Soaking in Water

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ABSTRACT The thin-layer drying characteristics of cooked milled rice during hot air drying were measured at four temperatures (30, 40, 50, and 60 ºC) and at a relative humidity of 40 %. The hot air-drying process of the sample was composed of the first falling rate, and the exponential model was applied to predict the changes in moisture content of the sample at each temperature. The drying rate constant of the sample increased as temperature increased and was expressed as an Arrhenius-type equation. The water absorption characteristics of dried cooked milled rice when soaking in water were examined at four temperatures (70, 80, 90, and 98 ºC). The ratios of the changes in moisture content from 8 to 150 % (d.b.) were converted from the data of changes in moisture content. The first-order reaction rate equation could be applied to explain the water absorption process of samples. The water absorption rate constant had a tendency to increase with increasing soaking temperature and was expressed as a function of soaking temperature by an Arrhenius-type equation.

INTRODUCTION

The data of the drying characteristics, equilibrium moisture content, latent heat of vaporization for cooked rice, and water absorption (rehydration) characteristics of dried cooked rice are required for optimizing processing operations, designing equipment, and ensuring high quality. Optimum drying and water absorption models including the values of parameters, are particularly useful for easily predicting the changes in the moisture content of materials. Therefore, knowing the optimum model is important for practical use.

OBJECTIVES

- ✓ To examine the hot air-drying characteristics at several temperatures
- ✓ To derive a suitable mathematical drying model to describe changes in moisture content
- ✓ To evaluate the relationship between the drying rate constant and temperature

METHODOLOGY

1. Sample

Cooked milled rice was used for measuring the drying characteristics. The sample and treatment were the same as in Part I. Dried cooked milled rice was used as a sample for the water absorption test.

2. Hot air-drying test

Fig. 1 shows a schematic of the hot air-drying apparatus used in this study. The apparatus consisted of three units: a drying chamber at constant temperature and humidity, a ventilation unit, and a recording unit. The sample (approximately 10 g) was placed on the tray. The drying test was terminated when the moisture content of the sample was approximately 15 % (d.b.).

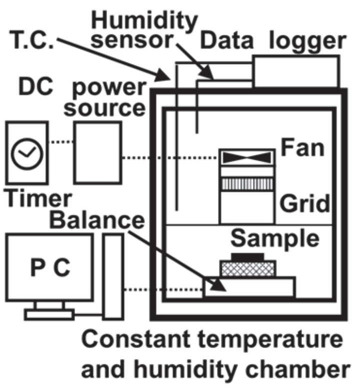

Fig. 1 Schematic of the hot air-drying apparatus

3. Measurement of water absorption characteristics

Approximately 5 g of sample was put into a sample net after weighing the sample mass with a digital balance, and soaked in a water bath. The sample net was removed from the water bath at each preset soaking time (1.0, 2.0, and 5 min intervals), and the surface of the sample was wiped with Kimwipes® to remove residual liquid. The sample was then reweighed. The increase in sample mass when soaking in water was considered to be an increase in the moisture content of the sample.

RESULTS & DISCUSSION

1. Hot air-drying characteristics

Under all measurement conditions, the changes in the moisture content of the sample caused by hot air-drying could be estimated by the exponential model (Eq. (1)).

$$\frac{M-M_e}{M_0-M_e}=\exp(-k_1 t) \quad (1)$$

M : Moisture content (% (d.b.))
M_0 : Initial moisture content (% (d.b.))
M_e : Equilibrium moisture content (% (d.b.))
k_1 : Drying rate constant (h^{-1})
k_2 : Water absorption rate constant (min^{-1})
t : time (min)
x : Ratio of the change in moisture content M from 8 to 150 % (d.b.) (-)

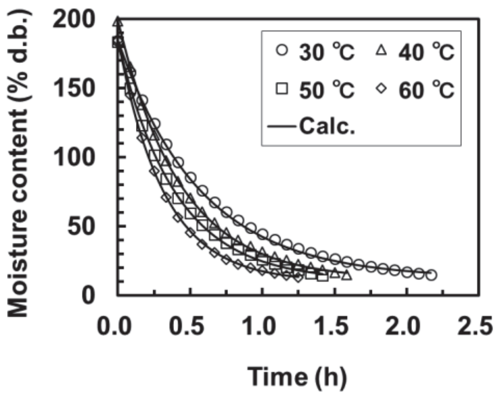

Fig. 2 Changes in the moisture content of the sample when drying

2. Water absorption characteristics

The ratios of the change in moisture content from 8 to 150 % (d.b.) were calculated from Eq. (2) and could be estimated by the first-order reaction rate equation (Eq. (3)).

$$x=\frac{M-M_0}{M_T-M_0}=\frac{M-8}{150-8} \quad (2) \qquad \frac{\mathrm{d}x}{\mathrm{d}t}=k_2(1-x) \quad (3)$$

The values of rate constant increased with an increase in soaking temperature. The rate constant was expressed as a function of temperature by using the following Arrhenius-type.

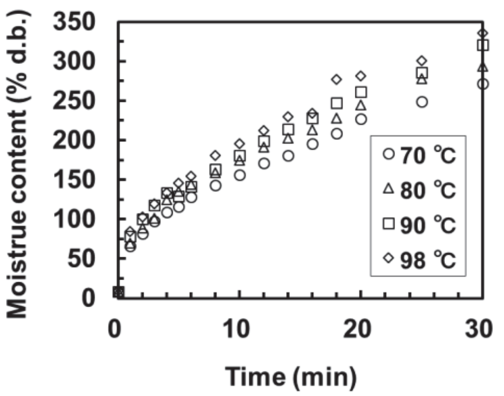

Fig. 3 Changes in the moisture content of the sample during water absorption

CONCLUSION

The exponential model was applicable to predict the changes in moisture content of the sample at each temperature when drying. The first-order reaction rate equation could be applied to explain the water absorption process of samples.