Establishment of Optimized Manufacturing Conditions for Cooked Rice

-Part I- Equilibrium Moisture Content and Latent Heat of Vaporization of Cooked Rice

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ABSTRACT The equilibrium moisture contents (EMCs) of cooked milled rice in the desorption process were measured at several temperatures (20-60 ºC) and relative humidity levels (10-86 %) by a static method. The EMC of the sample increased with increasing equilibrium relative humidity at a constant temperature and increased with a decrease in temperature at any given equilibrium relative humidity (ERH). The Chen-Clayton equation, which is a sorption isotherm, was used to express the relationship between the EMC of the sample, ERH, and absolute temperature. The latent heat of vaporization (LHV) of water for the cooked rice was calculated by using the Chen-Clayton equation and thermodynamic theory (Clapeyron equation). At a moisture content of 5-30 % (d.b.), the LHV of the sample decreased almost exponentially with an increase in moisture content. For samples at a moisture content above 50 % (d.b.), the values of latent heat of vaporization sufficiently approached that of free water.

INTRODUCTION

The development of processed food made from rice at production location is expected to lead to regional revitalization and increased income for farmers. A simply processed food made from rice is dried cooked rice or pregelatinized rice.

To determine the storage conditions and analyze the drying process, it is necessary to know the relationship between the EMC in the foodstuffs and the ERH of the drying air or aeration air at a given temperature. The LHV of water in foodstuffs is important for the design of drying equipment. Little research has been reported on the EMC and LHV for cooked rice.

OBJECTIVES

- ✓ To evaluate the relationship between the EMC, ERH, and temperature
- ✓ To estimate the LHV of water by using the thermodynamic theory

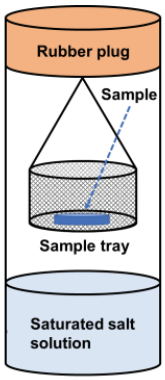
METHODOLOGY

1. Sample

The milled rice (short grain rice, japonica) was cooked with commercial rice cookers in accordance with the operation manual of the rice cooker. To obtain a single grain of cooked rice from the mass of cooked rice, the cooked rice was rinsed with tap water for 3 s, and the excess water was drained. After the rinse, the surface of the cooked rice was wiped with Kimwipes® to remove excess water.

2. EMC

The EMCs of the cooked rice in the desorption process were measured by a static method at three temperatures (20, 40, and 60 ºC) and ten relative humidity levels ranging from 10 % to 86 %. The temperature was controlled with an incubator. Ten kinds of saturated salt solutions (NaOH, LiCl, CH_3COOK, $MgCl_2$, K_2CO_3, NaBr, $NaNO_2$, $NaNO_3$, NaCl, KCl) were used to maintain the particular relative humidity in each vessel.



1 L wide-mouth bottle

Approximately 10 g of the sample was suspended in a 1 L wide-mouth bottle containing a selected saturated salt solution to maintain a constant humidity at a constant temperature. The sample was weighed on a digital balance at intervals of 2 or 3 days. Equilibrium was considered to be reached when the change in weight was less than 0.2 mg between two successive measurements. In this method, it took approximately 30 days for a sample to reach the EMC. The EMC of the sample was determined using a forced hot air oven at 135 ºC for 24 h.

RESULTS & DISCUSSION

1. EMC

The solid lines in Fig. 1 are the results calculated from the Chen-Clayton equation (Eq. (1)). The relationship between the EMC of the sample in the desorption process, ERH, and absolute temperature was expressed by Eq. (1).

$$rh = \exp\left\{-f_1 T^{g_1} \exp\left(-f_2 T^{g_2} M_e\right)\right\} \quad (1)$$

M_e : EMC (% (d.b.))
rh : ERH (-)
T : Temperature (K)
f_1 : parameter, 50.61
f_2 : parameter, 2.577x10^{-7}
g_1 : parameter, -0.3675
g_2 : parameter, 2.326

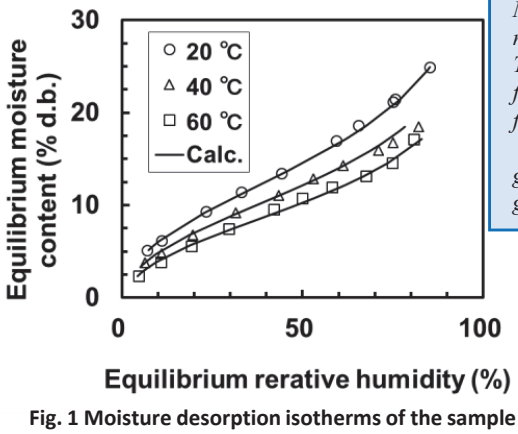


Fig. 1 Moisture desorption isotherms of the sample

The values of the parameters in Eq. (1) were estimated by using a nonlinear least squares method.

2. LHV

Using Clapeyron theory, the LHV was calculated from eq. (2) (Fig. 2). The eq. (1) was used to calculate the value of dp_{st}/dT.

$$\Delta h_v = \left(v_g - v_l\right) \times T \times \frac{dp_{st}}{dT} \quad (2)$$

Δh_v : LHV (J/kg)
p_{st} : Water vapor pressure in the sample (Pa)
v_g : specific volume of water vapor (m^3/kg)
v_l : specific volume of liquid water (m^3/kg)

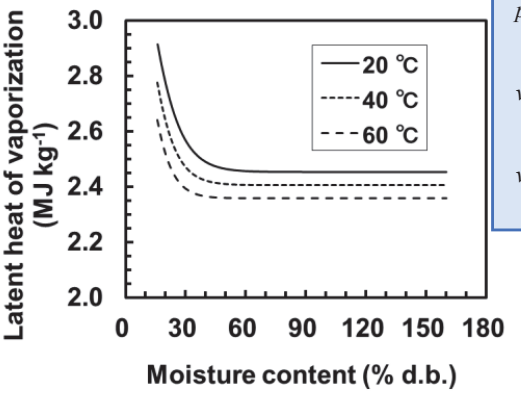


Fig. 2 LHV of water for the sample

The values of v_g and v_l in Eq. (2) were calculated by using the IFC formulation for industrial use.

CONCLUSION

The Chen-Clayton equation was used to express the relationship among the EMC of the sample in the desorption process, equilibrium relative humidity, and absolute temperature. The values of LHV decreased almost exponentially with an increase in moisture content from 5-30 % (d.b.) and sufficiently approached that of free water at a moisture content above 50 % (d.b.).