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# Glycemic response to brown rice treated by different drying media

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ABSTRACT

During high-temperature treatment, starch is gelatinized and amylose can simultaneously form with lipids to be the amylose–lipid complexes. These complexes can resist to enzymatic attack and useful for decreasing risk of developing type 2 diabetes and cardiovascular disease. The effects of drying media, hot air (HA), humidified hot air (HHA) and superheated steam (SHS), and their operating conditions on drying characteristics and the glycemic index (GI) of three rice varieties i.e. Phitsanulok 2, Kao Dok Mali 105 and RD 31 was therefore investigated experimentally. Drying temperature and drying medium strongly influenced the drying rate, degree of starch gelatinization, amylose–lipid complex formation and the GI value. Rice variety also took an effect on the starch gelatinization and GI value. To obtain the GI value as low as possible, the SHS should be applied to dry rice with high gelatinization temperature while HA or HHA should be used for drying rice with low gelatinization temperature.


## 1. Introduction

Nowadays, people have increasingly demanded healthy foods. Brown rice contains nutritious compounds such as protein, minerals and vitamins (Miller et al., 1992; Heinemann et al., 2005; Ito et al., 2005). With a dietary fiber source, brown rice after consumption has a lower rate of starch digestion than the milled rice (Miller et al., 1992; Ito et al., 2005; Babu et al., 2009). The low rate of rice starch digestion results in slow release of glucose into the blood stream after consumption. The glycemic index (GI) is used to classify the carbohydrate-based foods according to their glucose response after consumption for 2 h, and is presented as a value relative to that of white bread or glucose. Beulens et al. (2007) studied the effect of consuming high glycemic foods (GI > 70) on risk of cardiovascular disease in middle-aged women during 9 years of a follow-up study and found that consumption of high glycemic diets increased the risk of cardiovascular disease by 33%, particularly with overweight women. For the risk of developing type 2 diabetes, McGonigal and Kapustin (2008) reported that the risk was increased by 37% for men and 59% for women, if the panelists usually consumed a GI food in a range of 79–82.

The HA, HHA or SHS has been intensively studied for drying many kinds of food (Taechapairoj et al., 2004; Soponronnarit et al., 2006; Jariyatontivait et al., 2007; Nimmol et al., 2007; Jaisut et al., 2008; Sa-adchom et al., 2011). Brown rice production with lowering of GI value when treated thermally is one of these studies. Jaisut et al. (2008) found that GI of treated brown rice by HA was reduced because of amylose–lipid complex formation. During high-temperature treatment, starch is gelatinized and amylose can simultaneously form with lipids present in the rice bran to be the amylose–lipid complexes (Biliaderis, 1992; Eliasson and Wahlgren, 2004). Characteristic of the complex crystalline has a V-type X-ray diffraction pattern (Gelders et al., 2004; Derycke et al., 2005). The V-type is formed at temperature of at least 90 °C and the dissociation temperature is around 130 °C (Derycke et al., 2005; Putseys et al., 2010). At this dissociation temperature, it indicates that the complexes are rather heat stable during the cooking process.

Several studies have been reported that the extent of the complex formation depends on the lipid type, quantities of lipid and amylose and the degree of starch gelatinization (Guraya et al., 1997; Kaur and Singh, 2000; Rattanamechaiskul et al., 2013). The saturated fatty acids can deeper protrude into the amylose helix than unsaturated fatty acids because the unsaturated fatty acids require a larger amylose helix cavity to form complex. In addition, the long-chain ($\geqslant C$:18) saturated fatty acids can reduce digestibility more than the short-chain ($<C$:18) saturated fatty acids (Lagendijk and Pennings, 1970; Guraya et al., 1997).

As mentioned earlier, the complex can be formed when the starch is gelatinized. Several studies have been reported that using superheated steam and humidified hot air encourage starch to be gelatinized with a higher degree than the hot air drying and this expects to have higher amylose–lipid complexes, which may lead to lower GI value (Taechapairoj et al., 2004; Soponronnarit et al.,

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2006; Jariyatontivait et al., 2007; Jaisut et al., 2008). Therefore, the drying media i.e hot air (HA), humidified hot air (HHA) and superheated steam (SHA) and their operating conditions to form the complexes are investigated on their effect on the enzymatic digestion of some selected rice varieties.

## 2. Materials and methods

### 2.1. Materials

The Phitsanulok 2, Kao Dok Mali 105 and RD 31 rice varieties obtained from the Rice Research Institute in Pathumthani province, Thailand, were used in this study. The apparent amylose contents of Phitsanulok 2, Kao Dok Mali 105 and RD 31 were 28.6%, 17.0% and 29.8%, respectively. The Phitsanulok 2 and Kao Dok Mali 105 were rewetted from the initial moisture content of 13–15% (db) to the moisture content of 33% (db) while the RD 31 was rewetted to the moisture contents of 33–43% (db). After rewetting, all rice samples were kept in cool storage at 4–6 °C for a week. Before starting the experiment, sample were taken out from the cool storage and left for a given period of time in order to allow the grain temperature to reach the ambient temperature.

### 2.2. Experimental set-up

A fluidized bed drying system, as shown in Fig. 1, consists of a 12 kW electrical heater controlled by a PID controller with accuracy of ±1 °C, a cylindrical drying chamber with diameter of 20 cm, a 1.5 kW backward-curved blade centrifugal fan and a boiler with a capacity of 100 kg/h. In the operation of HHA, the air was heated until it reached the desired drying temperature and then the saturated steam from a boiler at the absolute pressure of 106 kPa flowed through steam pipe and mixed with the hot air. When the SHS was used, a damper at air inlet tube was closed and the saturated steam was heated by electrical heaters to be a superheated steam before flowing through drying chamber. For the HA, the steam was not introduced into the air.

### 2.3. Dried sample preparation

A 2 kg batch of the rewetted rice was dried by HA, HHA and SHS in a fluidized bed dryer at temperatures of 130–150 °C, a bed depth of 0.1 m and drying medium mass flow rate of 0.08 kg/s. At this temperature range, the relative humidity (RH) was 1–2% and 6–12% for the HA and HHA runs, respectively. The exhaust air was recycled with a fraction of 0.78 for HA and HHA dryings and the remaining was delivered to the atmosphere. For SHS drying, the exhaust air was completely recycled. During the drying operation, the samples were taken out from the drying chamber at predetermined times and tempered in a closed jar for 30 min to reduce the moisture-induced stresses which had been occurred during drying (Poomsa-ad et al., 2002). Finally, the dried rice was ventilated with ambient air for 30 min until the sample moisture content reached 13–15% (db). The sample moisture content was determined using a hot air oven with a precision of ±1 °C (Memmert, model ULE500, Schwabach, Germany).

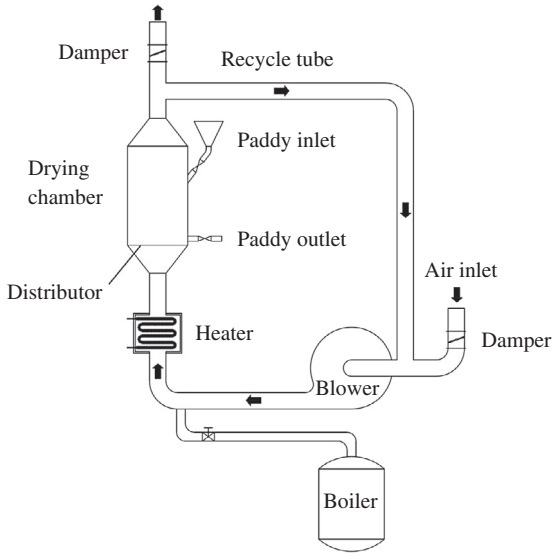


**Fig. 1.** Schematic diagram of fluidized bed dryer.

### 2.4. Fatty acid analysis

The fatty acid of Phitsanulok 2, Kao Dok Mali 105 and RD 31 brown rice flours was evaluated by Method of Department of Medical Sciences (DMSC) and National Bureau of Agricultural Commodity and Food Standards, (ACFS), (2003). The brown rice sample (500 mg) was prepared in Erlenmeyer flask with lid and 30 mL of $CHCl_3$:MeOH (2:1) was added before shaking for 30 min. The supernatant from the Erlenmeyer flasks was filtered through the sodium sulphate anhydrous and filter paper (No. 1) to round bottom flask. The filtered sample was evaporated by rotary evaporator at 40 °C. After evaporating, the remained sample was the total fatty acid ($M_1$). For determining percentage of fatty acid type, the fatty acid was prepared by following the method of DMSC and ACFS (2003) before analysing with Gas Chromatography (model no. CP-3800, Varian, California, USA). The percentage of total and type of fatty acid were calculated from the following equation:

$$\text{Percentage of total fatty acid} = [(M_1)/W] \times 100 \quad (1)$$

$$\text{Percentage of fatty acid type} = [(100 \times A_x)]/[(A_t - A_{ts})] \quad (2)$$

where $M_1$ is the total fatty acid mass (g), $W$ is the brown rice sample mass (g), $A_x$ is the area of each type of fatty acid, $A_t$ is the area of total fatty acid and $A_{ts}$ is the area of internal standard.

### 2.5. Thermal property of rice

The dried brown rice samples were ground by an ultra-centrifugal mill (Retsch, model no. ZM 100, Haan, 167 Germany) and sieved through a 0.25-mm screen. The brown rice flour was examined by Differential Scanning Calorimeter (DSC) (Perkin Elmer Co. Ltd., model DSC-7, Norwalk, USA). A 3 μg sample flour was put into an aluminium pan and 10 μL distilled water was added. The sample pan was then held for 1 h at room temperature (Normand and Mashall, 1989). The sample pan was heated up from 40 to 150 °C with a rate of 10 °C/min. The recorded parameters were: the onset temperature ($T_o$), peak temperature ($T_p$) and conclusion temperature ($T_c$). The degree of gelatinization of starch (DG) was calculated by the following equation:

$$DG = [1 - (\Delta H/\Delta H_c)] \times 100 \quad (3)$$

where $\Delta H$ is the transition enthalpy of dried brown rice (J/g dry matter) and $\Delta H_c$ is the transition enthalpy of reference brown rice (J/g dry matter).

### 2.6. X-ray diffractometry

The crystallinity of the dried brown rice flour was determined by X-ray diffractometer (Model no. D8 Discover, Bruker AXS GmbH, Karlsruhe, Germany). A 5 mg sample flour was putted into a sample holder in the machine operated at condition as follows: 40 kV