KINETIC OF COOKING PARBOILED PRE-GERMINATED BROWN RICE AND TTI DEVELOPMENT

Nucharee Krongworakul[1] Onanong Naivikul[2*]

Abstract

Parboiled pre-germinated brown rice (PPGBR) is a modified rice by germinating and parboiling to improve its quality. It is considered health benefit as the results of hydrolysis of high molecular weight polymers which decreased the molecular size and produced bio-functional substances during germination. Normally, the qualities of cooked rice depend on many factors; cooking condition is one of them. The purpose of this work is to determine the activation energy (E_a) of rice cooking process and develop the time-temperature indicator (TTI) for monitoring the process. Rice cooking kinetic of PPGBR from KDML 105 was determined by measuring the hardness value of cooked rice over time. The optimum cooking time at 100°C was 20 min. The E_a of rice cooking, derived from Arrhenius plots of cooking rate constant was 16.69 kJ/mole. TTI was developed based on chemical reaction to monitor rice quality during processing. The absorbance at 420 nm was measured over time at 80°C, 90°C and 100°C. The color of TTI changed from colorless to dark brown. The E_a of TTI calculated from Arrenius equation was 94.30 kJ/mol. The color changing of TTI directly related to rice cooking at 100°C. The present results suggest that the color changing of TTI could be used as an indicator to monitor cooked rice quality by visual checking.

Keywords : Parboiled pre-germinated brown rice, rice cooking, kinetic, monitoring

---

[1] Ph.D. student, Department of Food Science and Technology, Faculty of Agro-Industry, Kasetsart University, 50 Ngam Wong Wan Rd., Lat Yao, Chatuchak, Bangkok 10900, Thailand. e-mail: manyon22@hotmail.com

[2] Associate Fellow of the Royal Society, Thailand, Department of Food Science and Technology, Faculty of Agro- Industry, Kasetsart University, 50 Ngam Wong Wan Rd., Lat Yao, Chatuchak, Bangkok 10900, Thailand. e-mail: fagionn@ku.ac.th

**Corresponding author, e-mail: fagionn@ku.ac.th*

Introduction

Rice is a staple food for most Asian people. There are many methods for cooking rice such as boiling, steaming or using electric rice cooker. All these methods use energy at a considerable level. Understanding the kinetics of rice cooking is beneficial to conserve energy consumption. There are several studies on kinetic of rice cooking at various conditions to obtain activation energy of cooking, but no information on kinetic of parboiled pre-germinated brown rice. Parboiled pre-germinated brown rice (PPGBR) is a modified rice through germinating and parboiling to improve its quality and known to be health benefit. Chemical and physico-chemical properties of PPGBR were found to change compared to brown rice as reported by Panchan and Naivikul (2009). Further study on the kinetics of PPGBR rice cooking is beneficial for the control of cooked rice quality.

Kinetic of rice cooking is used to design the optimum condition to cook rice but the controlling of optimum time is also very important in food processing. Time-temperature indicators (TTIs) are effectively used to monitor, record, and cumulatively indicate the overall influence of temperature history on the food product quality (Giannakourou et al., 2005). TTIs are developed base on different biological, chemical and physical processes. They exhibit color change with elapse time. Sun et al. (2008) developed a new amylase type TTI based on the reaction between amylase and starch. Vinicius et al. (2012) reported a colorimetric temperature indicator made from chitosan card paper system. A time–temperature indicators based on non-enzymatic browning reaction of Maillard is new. It is a reaction between amino acids and reducing sugars, which takes place in thermally processed foods. The rate of Maillard reaction are governed by its immediate chemical environment including water activity, pH and temperature. It results in the formation of complex mixtures of color and colorless reaction products.

This research focused on the kinetic rice cooking of PPGBR and development of time-temp indicator (TTI) to monitor the quality of cooking process. This new type of TTI was obtained under constant temperature and their dynamics parameters were analyzed using Microsoft office software to construct a mathematical model, which would reflect the relationship between color absorption and temperature over time. This new time–temperature indicator used sugar and amino acid which are suitable for food processing.

Materials and Methods

Kinetic of rice cooking

Parboiled pre-germinated brown rice (PPGBR) from Khaw Dok Mali 105 (KDML 105) was obtained from a supermarket in Thailand. Rice sample was cooked by weighing approximately 10 g into 75 ml glass tubes. Then, water was added and the tube was placed in a water bath at a constant temperature in various conditions (80°C, 90°C and 100°C). At time intervals of 5 min, the tubes were removed from the water bath and the cooked rice was placed on a filter sieve. Three cooked rice grains were used for hardness measurement using texture analyzer, TA-XT plus Stable Micro System. Pre-test, post-test and test speed were 0.5, 0.5 and 10 mm/second, compression was adjusted to about 70 %. Force-time graph was observed from testing. Hardness of cooked milled rice (Ho) was determined by extrapolation of the plot of In reciprocal hardness against cooking time. Mean hardness at terminal point of cooking (HL) and cooking time to terminal point of cooking were estimated from a plot of In reciprocal hardness against In cooking time. A plot was then made of In (1 - α) as a function of cooking time where α= Ht-Ho/HL-Ho where Ht = hardness at time t. The reaction rate constant was calculated from the slope of the plot of In (1-α) versus t and a plot made of Ink as a function of reciprocal cooking temperature in degrees Kelvin. The activation energy was calculated from the slope from Arrhenius equation (Juliano and Perez, 1986).

Kinetic of glucose-glycine reaction

Reaction mixtures of glucose and glycine containing concentration of 2 M were prepared in 0.1 M phosphate buffer. Final pH of mixtures were adjusted to 6.6±0.1. Reaction mixture was then distributed in vial tube, containing 20 ml solution. Samples were heated in water bath at 80°C, 90°C, 100°C. At time, the samples were drawn, immediately cooled in ice and then tested for absorbance measurement at 420 nm.

According to the indicator kinetics characterized by Taoukis and Labuza (1989), the absorbance value X = A of the indicator could be expressed in terms of a response function as follows:

$$F(X) = kt \qquad \text{Eq. 1}$$

where k is the rate constant of the reaction that is correlated with temperature, and t is the time. By plotting a curve between the response function of absorbance F(X) and time, a straight line could be obtained, and the k of different temperatures could be calculated from the slope. Taking the logarithm on both sides of the Arrhenius function:

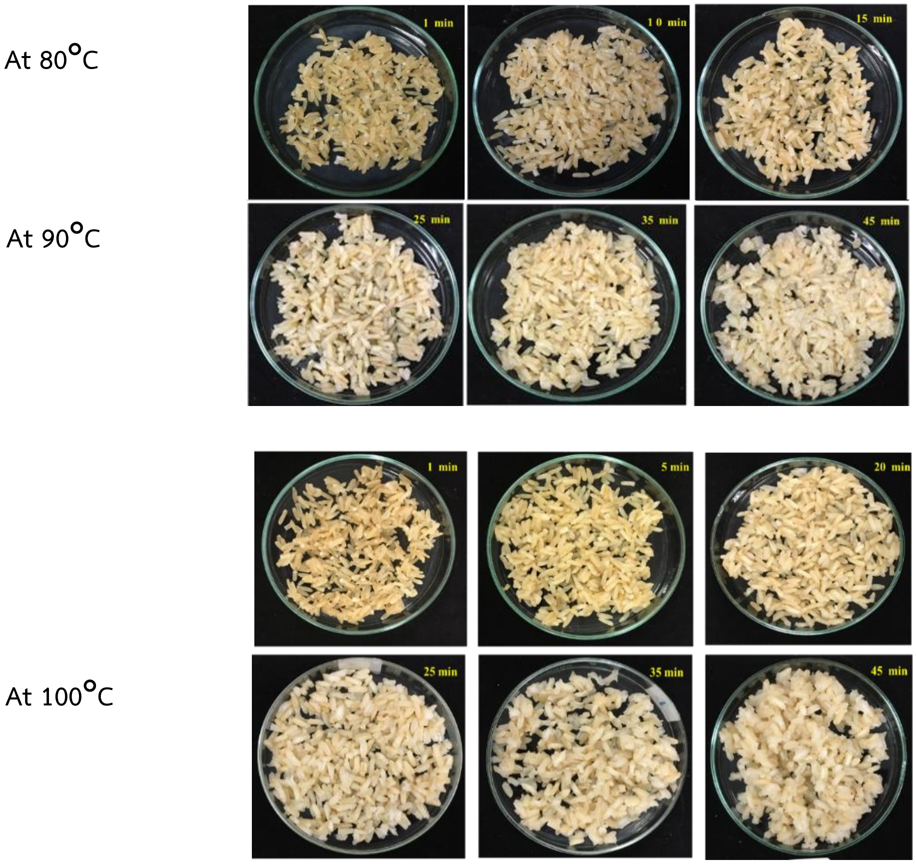
$$\log k = E_a / 2.303RT + \log A \qquad \text{Eq.2}$$

by plotting a curve of logk and 1/T, a straight line was obtained. The activation energy could be calculated from the slope, and A from the intercept directly.

Results and Discussion

Kinetic of rice cooking

In general, water absorption phenomenon occurs during cooking. Hydration of water into rice grain results in the appearance of swollen and soften texture while interval time increased. Figure 1 shows the appearance of PPGBR during cooking in water. Cooking time of PPGBR at 80°, 90°C and 100°C were 30, 25 and 20 min, respectively. Cooking time were decreased while increasing cooking temperature. PPGBR which had been cooked at 100°C gave the higher rate of water absorption than PPGBR at 80°C and 90°C. The appearance of PPGBR at 100°C more swollen and rupture than PPGBR at 80°C and 90°C. These outcome maybe the results of higher temperature induced and the interaction of hydrogen bond with water at faster rate to destroy starch granule.



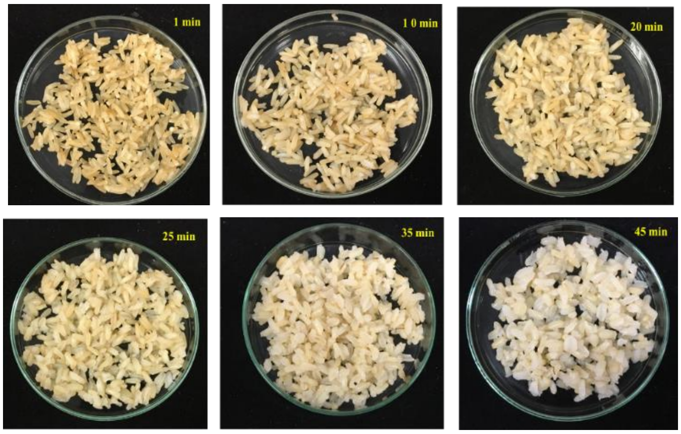


Figure 1 Appearance of PPGBR during cooking in water at 80°C, 90°C and 100°C.

Figure 2 shows the hardness value of PPGBR rice during cooking in water at 80°C, 90°C and 100°C. The hardness value was decreased while the cooking time increased due to water absorption into the rice grains. The activation energy (E_a) of PPGBR cooking calculated from Arrhenius equation was 16.69 kJ/mole or 3.98 kcal/mole. There are several reports on kinetic of hydration and energy relations. The activation energy of kinetic of rice hydration between 75°C and 150°C as reported by Parthasarathi and Nath (1953) was 13 kcal/mole (54.43 kJ/mole). Sukuzi et al. (1976, 1977) reported the activation energy was 9 kcal/mole and 19 kcal/mole below and above 102°C. In addition, Juliano and Perez (1986) also studied the hydration phenomenon in Japonica rice between 80°C and 100°C showing the activation energy to be 76 and 121 kJ/mole at temperature below 90°C and 32 and 57 kJ/mole at temperature above 90°C. The cooking PPGBR cooking with low activation energy could be the results of gelatinized starch during parboiling process and properties changing.

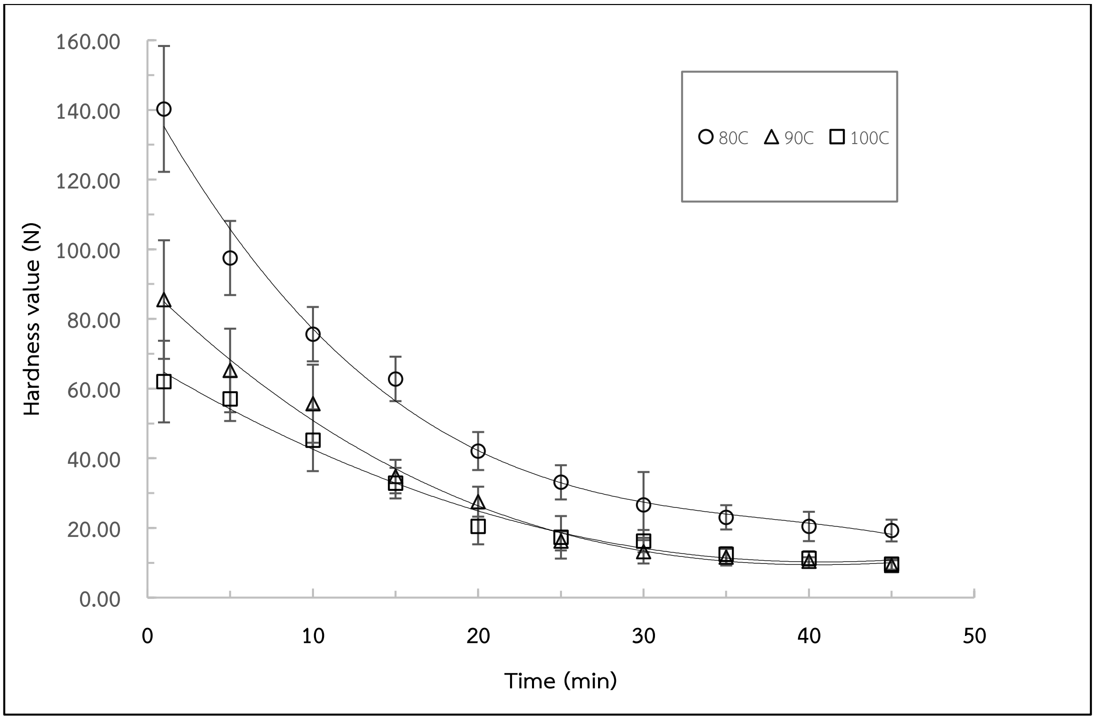


Figure 2 Hardness value of PPGBR during cooking in water at 80°C, 90°C and 100°C. Color changes of time-temperature indicator

The reaction between glucose and glycine could be the results of complex mixtures formation of colored and colorless reaction products which range from flavor volatiles to melanoidins, a series of brown pigments with high molecular weights. The color change process of time-temperature indicator (TTI) was the reaction of sugar and amino acid in solution, the color of Maillard reaction products changes from colorless to dark-brown (Figure 3).

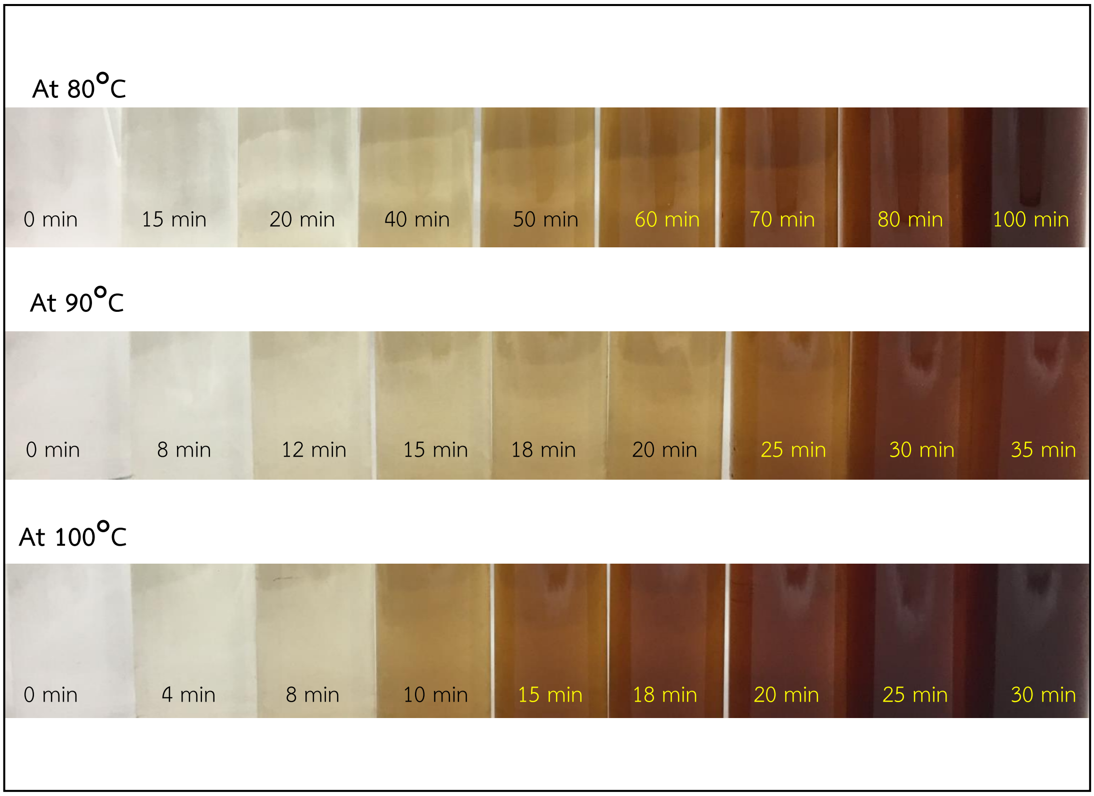


Figure 3 Color change of TTI at 80°C, 90°C and 100°C.

Figure 3 shows the color of TTI change from colorless to dark-brown while increasing time at constant temperature.

According to Eq.1 (1), the regression lines correlating the response value X and time at different temperature was obtained and presented in Figure 4 and the related coefficients R^2 of TTI in Table 1.

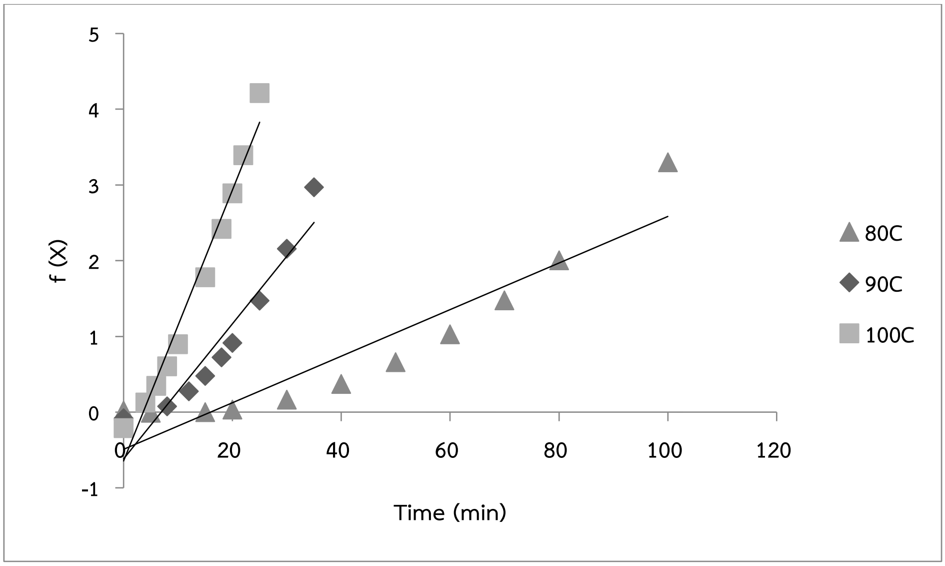


Figure 4 Plot of the response X and time of TTI at 80°C, 90°C and 100°C.

Table 1 R^2 of TTI from Arrenius plot which fit the data at 80°C, 90°C and 100°C.

Temperature (°C)	R^2
80°C	0.877
90°C	0.909
100°C	0.974

According to Eq. (2), the E_a of TTI can be calculated by plotting a curve between log k and 1/T. E_a of TTI was found to be 94.30 kJ/mol. The E_a of this new TTI was similar to the MonitorMark indicators, which were found ranging from 96.30 kJ/mol to 129.79 kJ/mol (Shimoni, Anderson, and Labuza, 2001). The system has high potential for applications to different usages such as food quality losses. The convenience of colourimetric visually detection and simple manufacturing are advantages of this temperature indicator prototype.

Figure 5 shows the relationship of rice cooking and TTI color changing at 100°C. Different color of TTI could be applied for monitoring cooked rice quality by visual checking.

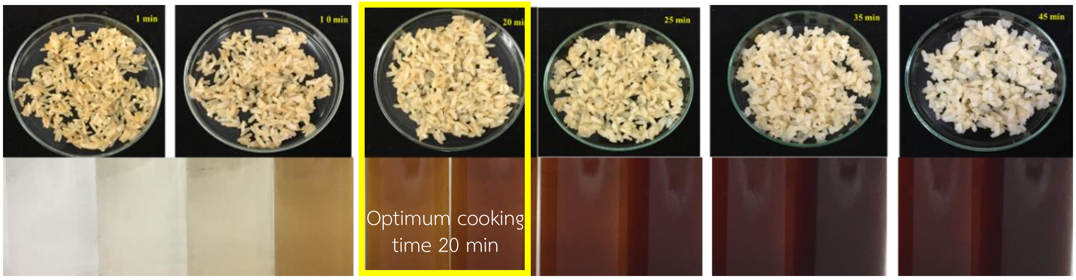


Figure 5 Relationship of rice cooking and TTI color changing 100°C.

The difference in E_a of the TTI obtained from this research and E_a of rice cooking was more than 40 kJ/mole. It means that the minimum energy required to start chemical reaction of TTI was higher than those of rice cooking process. Therefore TTI could be further developed to obtain the closest value to E_a of rice cooking process by adjusting the chemical reaction factors, such as pH, temperature, reactant concentrations and the ratio between reactants.

Conclusion

The kinetic of PPGBR cooking was shown having E_a equal to 16.69 kJ/mole. TTI was developed using glycine-glucose reaction resulting in the color changes from colorless to very dark brown after heating at temperature ranging from 80 to 100°C. The E_a of TTI was found to be 94.30 kJ/mol. TTI could be used to monitor cooking process by visual checking and could be further developed to obtain the closest value to E_a of rice cooking. Knowing the effect of Maillard reaction factors, such as buffer, pH, temperature, reactant concentrations and the ratio between reactants was suggested for better TTI development.

Reference

Giannakourou, M. C., Koutsoumanis, K., Nychas, G. J. E., and Taoukis, P. S. (2005). Field evaluation of the application of time temperature integrators for monitoring fish quality in the chill chain. **International Journal of Food Microbiology**, 102, 323-336.

Juliano, B. O., and Perez, C. M. (1986). **Kinetic studies on cooking of tropical milled rice**. Food Chemistry, 20 (2), 97–105.

Panchan, K. and O. Naivikul. (2009). Effect of pre-germination and parboiling on brown rice properties. **Asian Journal of Food and Agro-Industry**, 2 (4), 515-524.

Parthasarathi, N. V. V., and Nath. N. (1953). Cooking and energy requirements. **Journal of Scientific and Industrial Research**, 12, 224-226.

Shimoni, E., Anderson, E. M., and Labuza, T. P. (2001). Reliability of time–temperature indicators under temperature abuse. **Journal of Food Science**, 66(9), 1337–1340.

Sun, Y., Cai, H., Zheng, L., Ren, F., Zhang, L., and Zhang, H. (2008). **Development and characterization of a new amylase type time–temperature indicator**. Food Control, 19, 315–319.

Suzuki, K., Kubota, K., Omichi, M., and Hosaka, H. (1976). Kinetic studies on cooking of rice. **Journal of Food Science**, 41, 1180–1183.

Suzuki, K., Aki, M., Kubota, K., and Hosaka, H. (1977). Studies on the cooking rate equations of rice. **Journal of Food Science**, 41, 1545–1548.

Taoukis, P. S., and Labuza, T. P. (1989). Applicability of time temperature indicators as shelf-life monitors of food products. **Journal of Food Science**, 54, 783–788.

Vinicius, B. V. M., Cristiana, M. P. Y., and Telma, T. F. (2012). Development of a prototype of a colourimetric temperature indicator for monitoring food quality. **Journal of Food Engineering**, 111, 21–27.