KKU ENGINEERING JOURNAL 2016;43(S2):244-246 Research Article

KKU Engineering Journal

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# Combined effect of air temperature and velocity on drying of Thai rice cracker

P. Pintana*[1)], P. Thanompongchart[1)], K. Phimphilai[2)] and N. Tippayawong[2)]

[1)]Faculty of Industrial Technology, Uttaradit Rajabhat University, Uttaradit, Thailand.
[2)]Department of Mechanical Engineering, Chiang Mai University, Chiang Mai, Thailand.

Received April 2016
Accepted June 2016

**Abstract**

Fried glutinous rice cracker or "Khaotan" is a traditional snack of local Thai communities. Drying is one of the important steps in production of rice cracker. Hot air drying is an alternative method to direct solar drying used to reduce moisture of the rice cracker during rainy season. In this work, effect of air temperature (40, 50, and 60°C) and velocity (0.5, 1, and 1.5 m/s) in a hot air dryer was investigated. Full factorial and central composite designs of experiments were adopted. The results indicated that air temperature and velocity affected the drying time. The relationship was in second order polynomial with high correlation coefficient $R^2$ of 0.8719. Moderately good agreement in predicting drying time between experiments and the regression model was reported.

**Keywords**: Food processing, Khaotan, Drying time, Regression analysis, Hot air drying

## 1. Introduction

Thai fried glutinous rice cracker or "Khaotan" is a favorite snack for local Thais. In Lampang alone, there are more than 50 manufacturers. The snack has been well accepted by consumers domestically and abroad. Khaotan made from glutinous rice mixed with watermelon juice and molded into shapes such as rectangular, round, and oval. The production process includes steaming, molding, drying, storing, and frying. In the drying process, Khaotan obtained from 10% remaining moisture content was confirmed for the best product quality [1]. Solar energy is traditionally used in this process because it has low operating cost, which has been studied for a long time [2-4]. However, it is necessary to use hot air dryer to reduce moisture where there is no sunlight and during rainy season. For hot air drying, factors affecting time of drying were temperature and air velocity. Works on hot air drying of Khaotan have so far been in a limited number and most previously studies focused only on temperature [1, 5].

In this work, drying time of Khaotan drying process to reach 10% dry basis from combined effect of temperature and air velocity in hot air dryer was investigated.

## 2. Materials and methods

### 2.1 Rice cracker samples

The glutinous rice was obtained locally. Before experiment, it was soaked in water overnight, after which it was washed and steamed. The steamed rice was then mixed with watermelon juice and other ingredients. It was then molded into rectangular shape with volume of about 12 cm$^3$. There were 8 pieces of samples for one tray.

### 2.2 Hot air oven

After molding, the samples were loaded in a hot air oven, shown in Figure 1. The laboratory scale oven was used to study at three temperatures; 40, 50, and 60°C and three air velocities; 0.5, 1, and 1.5 m/s$^2$. The samples were weighted every 30 min until the moisture content was less than 10% dry basis.

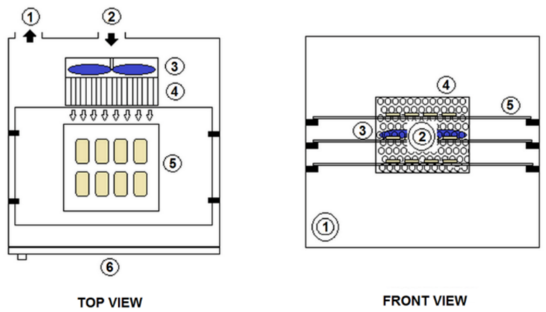


**Figure 1** Experimental setup of the hot air oven showing top and front views; (1) moisture out (2) make up air in (3) fan (4) air flow laminizer (5) sample tray (6) oven door

### 2.3 Design of experiments

Full factorial and central composite designs of experiments involving temperature and air velocity as factors and drying time as response were carried out. The

*Corresponding author. Tel.: +6685 863 3419
Email address: p.pintana@gmail.com
doi: 10.14456/kkuenj.2016.100

methodology gave a number of experimental runs of 13. The conditions of all tests with the coded values of the independent variables are shown in Table 1.

**Table1** Design of test runs

| Run | Levels of parameters (coded values) | |
|---|---|---|
| | temperature | air velocity |
| 1 | 40 (-1) | 0.5 (-1) |
| 2 | 40 (-1) | 1.0 (0) |
| 3 | 40 (-1) | 1.5 (1) |
| 4 | 50 (0) | 0.5 (-1) |
| 5 | 50 (0) | 1.0 (0) |
| 6 | 50 (0) | 1.0 (0) |
| 7 | 50 (0) | 1.0 (0) |
| 8 | 50 (0) | 1.0 (0) |
| 9 | 50 (0) | 1.0 (0) |
| 10 | 50 (0) | 1.5 (1) |
| 11 | 60 (1) | 0.5 (-1) |
| 12 | 60 (1) | 1.0 (0) |
| 13 | 60 (1) | 1.5 (1) |

Experimental data was used to perform the regression analysis for prediction of Khaotan drying time. Mathematical relationship was generalized as a second order polynomial using the equation as follows [6]:

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_{12} x_1 x_2 + \beta_{11} {x_1}^2 + \beta_{22} {x_2}^2 \quad (1)$$

where $y$ is the drying time, $\beta_0$ is the equation constant, $\beta_1$, $\beta_2$, $\beta_{12}$, $\beta_{11}$, $\beta_{22}$ are the regression coefficients of the model, $x_1$, $x_2$ are the input parameter (temperature and air velocity), respectively.

## 3. Results and discussion

Drying curves for all experiments are shown in Figure 2, moisture in dry basis as Y-axis and time as X-axis. It can be seen that the drying curves were not linear. From the observation, increasing air velocity resulted in more rapid release of moisture; hence, faster drying time. The times used to reduce the moisture content to 10% dry basis of runs 1 and 2 were found to be over 12 h. Conditions of runs 12, 13 gave drying time to within 8 h. It should be noted that the drying times in this work appeared to be longer than those previously reported for cooked rice in existing literature [1, 7]. This may be attributed to the fact that the oven used here had small outlet to discharge moist air out. The relatively high humidity atmosphere inside the oven may slow down drying process, resulting long operating time to reach targeted moisture content in the sample.

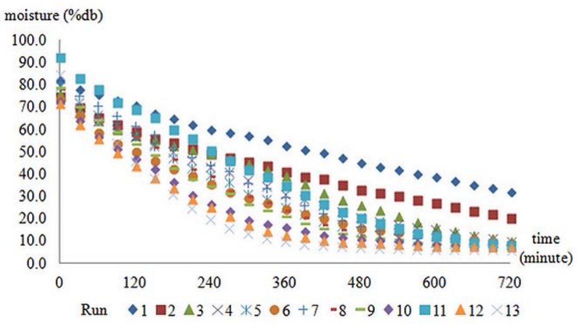


**Figure 2** Drying curves

All data was used to fit into a second order polynomial model. The regression coefficients of the model are shown in Table 2. High correlation ($R^2$ = 0.8719) was evident. The drying time of Khaotan to reach targeted moisture content of 10% was significantly affected by temperature ($\beta_1$, $\beta_{11}$), air velocity ($\beta_2$), and the interaction term ($\beta_{12}$). The term of $\beta_{22}$ appeared to have no significant effect on drying time. The resultant prediction model is illustrated in Eq. (2), where y, $x_1$ and $x_2$ are the drying time, temperature, and air velocity, respectively.

$$y = 14613.5 - 456.9x_1 - 2242.9x_2 + 43.2x_1x_2 + 3.7{x_1}^2 - 232.5{x_2}^2 \quad (2)$$

**Table 2** Regression analysis results

| Terms of model | Terms of parameter | Regression coefficients | p-value |
|---|---|---|---|
| $\beta_0$ | constant | 14613.50 | 0.001 |
| $\beta_1$ | temperature | -456.90 | 0.003 |
| $\beta_2$ | air velocity | -2242.90 | 0.092 |
| $\beta_{11}$ | temperature × temperature | 3.70 | 0.008 |
| $\beta_{22}$ | air velocity × air velocity | -232.50 | 0.576 |
| $\beta_{12}$ | temperature × air velocity | 43.20 | 0.034 |

The plot depicting comparison of drying times between experimental and model prediction is shown in Figure 3. A fairly good agreement was obtained between predicted results and experiments. For most conditions, difference within 10% was evident. Only a few runs showed difference of over 30%.

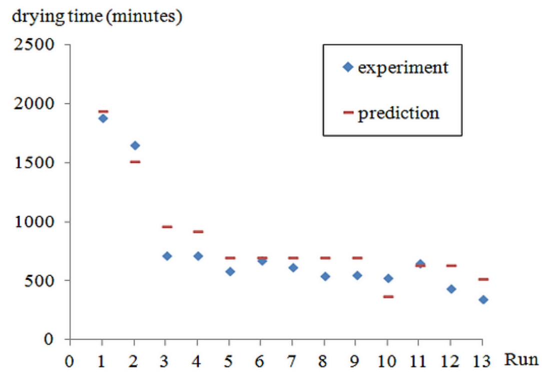


**Figure 3** Comparison of drying time between experiment and prediction

## 4. Conclusions

In this work, hot air drying was considered for processing of Thai fried glutinous rice cracker, investigating combined effect of air temperature (40, 50, and 60°C) and velocity (0.5, 1, and 1.5 m/s). It was found that use of hot air oven for drying process can help in achieving targeted moisture content of 10% dry basis for the rice cracker. A second order polynomial regression model for drying time as a function of temperature and air velocity was developed. The prediction model appeared to give approximate drying times, similar to those from experiments.

## 5. Acknowledgements

The authors wish to acknowledge the support from the National Research Council of Thailand, Uttaradit Rajabhat

University, Chiang Mai University, and Khaotan Thaweephan Partnership Limited’s staff.

## 6. References

[1] Intharapongnuwat W, Arkanit K, Wangcharoen W. Process improvement for Thai-style fried rice crackers. Asian Journal of Food and Agro-Industry 2008; 1(03):155-166.
[2] Janjai S, Intawee P, Kaewkiew J, Sritus C, Khamvongsa V. A large scale solar greenhouse dryer using polycarbonate cover: modeling and testing in a tropical environment of Lao People’s Democratic Republic. Renewable Energy. 2011;36(2):1053-1062.
[3] Janjai S. A greenhouse type solar dryer for small scale dried food industries: development and dissemination. International Journal of Energy and Environment 2012;3(3):383-398.
[4] Limpaiboon K, Wiriyaumpaiwong S. Drying kinetics of steamed glutinous rice with a free convective solar dryer. Walailak Journal of Science and Technology 2009;6(2):217-229.
[5] Saiai S, Chithep S. Estimate of energy dissipation on cabinet dryer for decreased moisture of crackers. Proceedings of the 5th endemic conference; 2004 May 20-21; Chiang Mai, Thailand.
[6] Erbay Z, Icier F. Optimization of hot air drying of olive leaves using response surface methodology. Journal of Food Engineering 2009;91:533-541.
[7] Luangmalawat P, Prachayawarakorn S, Nathakaranakule A, Soponronnarit S. Effect of temperature on drying characteristics and quality of cooked rice. LWT - Food Science and Technology 2008;41:716-723.