

## Effect of Drying Methods on Chemical Composition, Color and Antioxidant Properties of Thai Red Curry Powder

Sudathip Inchuen<sup>1\*</sup>, Woatthichai Narkrugsa<sup>1</sup>  
and Pimpen Pornchaloempong<sup>2</sup>

---

### ABSTRACT

Thai red curry pastes were transformed into powder by two different drying methods: microwave and hot-air drying. The microwave drying was carried out in a microwave oven with output powers of 180, 360 and 540 W and the hot-air drying was carried out at air temperatures of 60, 70 and 80°C. The quality attributes of Thai red curry powder were evaluated for proximate composition, color (Hunter *L*, *a* and *b*) and antioxidant properties (total phenolic content and antioxidant activities). The Folin-Ciocalteu method was used to determine total phenolic content, while 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging and ferric reducing antioxidative power (FRAP) assays were used to elucidate antioxidant activities. The drying methods showed no significant effects on the chemical compositions of the red curry powder, whereas color and antioxidant properties were all affected by the two methods to different extents. Microwave drying resulted in darker and less yellow color than the hot-air drying. Almost all red curry powder in the microwave-dried samples had a greater phenolic content and antioxidant activity than hot-air dried samples.

**Key words:** antioxidant activity, phenolic content, hot-air drying, microwave drying, Thai red curry powder

### INTRODUCTION

Thai red curry paste is one of the most famous kinds of curry paste used to enhance several spicy Thai dishes. The paste is prepared from some herbs, i.e. dried red chili, garlic, shallots, lemon grass, kaffir lime, galangal, spices and additives, such as salt and sugar, all blended together to obtain a homogeneous orange-red paste. It provides the colorful, spicy and authentic fragrance of certain dishes. It has been reported that the major ingredients of this product are good

sources of phenolic compounds, such as chili (Materska and Perucka, 2005), garlic, shallots (Leelarungrayub *et al.*, 2006), lemon grass and galangal root (Juntachote *et al.*, 2006). Fresh, Thai red curry paste in a semi-solid form has a short shelf life due to its high moisture content (more than 40%). The growing popularity of Thai food around the world has created the need to preserve this product. Drying is one of the preservation methods that can extend the shelf life of the red curry paste.

---

<sup>1</sup> Faculty of Agro-Industry, King Mongkut's Institute of Technology Ladkrabang, Bangkok 10520, Thailand.

<sup>2</sup> Department of Food Engineering, Faculty of Engineering, King Mongkut's Institute of Technology Ladkrabang, Bangkok 10520, Thailand.

\* Corresponding author, e-mail:sudathip4@hotmail.com

Drying, as a preservation method, is a very important aspect of food processing. Drying can be defined as a simultaneous heat and mass transfer operation in which the water activity of the material is lowered by the evaporation of water into an unsaturated gas stream (Khraiseh *et al.*, 1997). The main function of drying is to lower the water activity of the product and consequently, to inhibit the growth of microorganisms and decrease chemical reactions in order to prolong the shelf life of the product at room temperature. It also results in less space needed for storage and lighter weight for transportation.

Hot-air drying is the most widely used method to produce dried foods and agricultural products (Vega-Mercado *et al.*, 2001) due to the low investment and operating cost. However, a disadvantage of hot-air drying is that it takes a long time, even at high temperature, which in turn may cause serious damage to the product's quality attributes, such as flavor, color, texture, nutrient status and beneficial substances to health (Nijhuis *et al.*, 1998; Tsami *et al.*, 1999). Therefore, there is a need to optimize the conditions to produce high-quality dried products.

The drying time can be reduced by microwave energy (Inchuen *et al.*, 2008), which is rapidly absorbed by the water molecules in the product, resulting in rapid evaporation of the water and thus a higher drying rate. Moreover, microwave application has been reported to improve product qualities, such as aroma and to result in faster and better rehydration compared with hot-air drying alone (Maskan, 2000). However, it may result in a poor quality product if not properly applied (Nijhuis *et al.*, 1998; Zhang *et al.*, 2006).

The quality of a dried product is strongly dependent on the conditions in the drying process. It is of interest to investigate the effects of different drying methods (microwave drying and hot-air drying) on the quality of red curry powder and especially the beneficial antioxidant activity of the

powder. Thus, the objective of the present study was to explore the effects of drying methods on the chemical composition, color, total phenolic content and antioxidant activities of Thai red curry powder.

## MATERIALS AND METHODS

### Chemicals and instruments

Folin-Ciocalteu phenol reagent, DPPH (2,2-diphenyl-1-picrylhydrazyl), TPTZ (2,4,6-tripyridyl-S-triazine), gallic acid, Trolox (6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid), sodium carbonate and ferric chloride were sourced from the Sigma-Aldrich Chemical Co., USA. Other common reagents were of analytical grade. A microwave oven (Hitachi, MR-30A, Thailand) and a hot-air oven (Path OV663, Thailand) were used for the experiments.

### Raw materials

Fresh, Thai red curry paste was obtained from Namprick Maesri Ltd, Part. (245 Petkasem road, Nakornpathom, Thailand) and stored at -60°C until used. The ingredients of this product are: 35% dried red chili, 23% garlic, 20% shallots, 7% salt, 6% lemon grass, 3% sugar, 2% kaffir lime, 1% galangal and 1% spice (coriander seed, cumin and cardamom). The initial moisture of the red curry paste was determined as 258% of the dry matter.

### Sample preparation

The paste samples were dried using either microwave or hot-air drying. Prior to each drying experiment, the paste samples were taken out of storage and thawed to 20°C, then 55±1 g of paste material was uniformly spread on a translucent polyethylene sheet, with 1 mm thick and dimensions of 180 × 180 mm. The microwave-dried paste samples were dried at three different microwave output powers: 180, 360 and 540 W to a final moisture content of approximately 8% dry

matter. The drying time for the microwave drying at 180, 360 and 540 W was 23, 12 and 8 min, respectively. The final temperature of the dried curry paste was measured by an infrared thermometer (Chino, Japan). The hot-air-dried paste samples were dried at three different drying air temperatures: 60, 70 and 80°C using the hot-air oven to final moisture content as stated earlier. The drying time for the hot-air drying at 60, 70 and 80°C was 240, 180 and 130 min, respectively. The dried products were blended into small pieces and milled, using an analytical mill (Retsch, ZM1000, Germany) to a powder particle size of 0.25 mm. The prepared Thai red curry powder was sealed in an aluminum foil bag to prevent moisture absorption and stored at -4°C for further studies.

### Proximate composition analysis

Moisture, crude protein (N X 6.25), crude fat, ash and crude fiber content of Thai red curry powder were analyzed by the AOAC (1990) method. The nitrogen free extract (NFE) was obtained by subtraction, i.e. 100 - (moisture + crude protein + crude fat + crude fiber + ash) (Hsu *et al.*, 2003).

### Phenolic extraction

Thai red curry powder (250 mg dry matter) was extracted with 25 mL of 80% ethanol for 24 h at room temperature and then centrifuged with a benchtop centrifuge (Allegra X-12R, Beckman Coulter, Inc. USA) at 6000 rpm at 4°C for 15 min, after which the supernatant was separated from the residue and stored at -4°C until analysis.

### Total phenolic content determination

Total phenolic content (TPC) in the Thai red curry product extracts was determined using the Folin-Ciocalteu method described by Choi *et al.* (2006) with some modifications.

The extracts (0.5 mL) were added to test tubes followed by 9.5 mL of distilled water, 0.5

mL of Folin-Ciocalteu reagent and 2 mL of 10% sodium carbonate solution. The contents of the test tubes were mixed thoroughly. After standing for 1 h at room temperature, the absorbance was measured at 730 nm with a UV-visible spectrophotometer (Shimadzu 1700, Japan). The results were expressed as mg gallic acid equivalents per gram dry matter.

### Antioxidant activity assays

#### DPPH radical scavenging

The radical scavenging activity (RSA) of the extracts of the DPPH radical was measured according to the method described by Choi *et al.* (2006) with some modifications. The extract (0.4 mL) was mixed with 5 ml of 40% ethanol solution and 0.6 mL of 0.8 mmolL<sup>-1</sup> of DPPH solution. The mixture was vigorously shaken and left to stand for 30 min under subdued light. The absorbance was measured at 517 nm with the UV-visible spectrophotometer. The results were expressed as mg Trolox equivalents per gram dry matter.

#### Ferric reducing antioxidative power (FRAP)

The FRAP of the extracts was measured according to the method of Wong *et al.* (2006) with some modifications.

FRAP reagent consists of 10 mmolL<sup>-1</sup> TPTZ in 40 mmolL<sup>-1</sup> HCl, 20 mmolL<sup>-1</sup> FeCl<sub>3</sub>.6H<sub>2</sub>O and 0.1 mmolL<sup>-1</sup> sodium acetate buffer, pH 3.6 in the ratio of 1:1:10. The extracts (0.1 mL) were added to 3 mL of FRAP reagent and mixed thoroughly. After standing for 8 min at room temperature, the absorbance was measured at 593 nm with the UV-visible spectrophotometer. The results were expressed as mg Trolox equivalents per gram dry matter.

### Color measurements

The color of Thai red curry powder was measured using a Minolta CR300 colorimeter (Konica-Minolta, Japan). The color meter was calibrated against a standard calibration plate of a

white surface. Hunter *L*, *a* and *b* values were averaged over three readings. The color brightness coordinate, *L*, measures the whiteness value of a color and ranges from black at 0 to white at 100. The chromaticity coordinate, *a*, measures red when positive and green when negative, and the chromaticity coordinate, *b*, measures yellow when positive and blue when negative (Arslan and Özcan, 2008).

### Statistical analysis

The data were derived from average measurements of three replicates per treatment. The statistical analysis of data was carried out using SPSS software for the analysis of variance (ANOVA) in determining significant differences between drying methods at a confidence level at 95% ( $P < 0.05$ ). Variable means were compared using Duncan's multiple range test. The bivariate correlations between total phenolic content and antioxidant activity assays were analyzed.

## RESULTS AND DISCUSSION

### Proximate composition

The proximate composition of Thai red curry powder samples obtained from microwave and hot-air drying are presented in Table 1. The drying methods showed no significant effects ( $P > 0.05$ ) on the moisture, crude protein, crude fat,

crude fiber, ash and nitrogen-free extracts (NFE) of the red curry powder. Similar results were obtained by Hsu *et al.* (2003) from freeze, hot-air and drum drying of yam flour. The largest component in the red curry powder was the fiber, followed by NFE, ash, protein and fat, respectively. The NFE were mainly contributed by sugar in the red curry paste. In the proximate analysis, the NFE content of red curry powder was obtained by subtraction, i.e.  $100 - (\text{moisture} + \text{crude protein} + \text{crude fat} + \text{crude fiber} + \text{ash})$ .

### Color measurement

From a consumer-acceptance viewpoint, color is an important attribute of the dried product. A mix of red and yellow makes up the major color of Thai red curry powder due to the presence of carotenoid from the red chili. Color components are represented by Hunter *a* and *b* values, while any change in *a* and *b* values is accompanied by a simultaneous change in *L* values (Ahmed *et al.*, 2002). Hence, color measurement (Hunter *L*, *a* and *b*) should be used to evaluate the effect of drying methods on the color quality of Thai red-curry powder.

Color measurement results for the red curry powder were: *L* value in the range of 56.827 to 59.364, *a* value in the range of 23.072 to 24.103 and *b* value in the range of 30.432 to 31.652. According to the results of the ANOVA analysis,

**Table 1** Proximate composition (% dry matter) of Thai red-curry powder.

Drying methods	Moisture	Crude protein	Crude fat	Crude fiber	Ash	NFE
Microwave drying						
180 W, 23 min	8.37±0.17 <sup>a</sup>	10.94±0.12 <sup>a</sup>	3.34±0.07 <sup>a</sup>	29.41±0.23 <sup>a</sup>	27.96±0.11 <sup>a</sup>	28.36±0.31 <sup>a</sup>
360 W, 12 min	8.23±0.12 <sup>a</sup>	11.17±0.39 <sup>a</sup>	3.24±0.09 <sup>a</sup>	29.50±0.14 <sup>a</sup>	27.95±0.25 <sup>a</sup>	28.15±0.15 <sup>a</sup>
540 W, 8 min	8.37±0.12 <sup>a</sup>	10.81±0.25 <sup>a</sup>	3.28±0.10 <sup>a</sup>	29.37±0.26 <sup>a</sup>	27.93±0.31 <sup>a</sup>	28.61±0.65 <sup>a</sup>
Hot-air drying						
60 °C, 240 min	8.46±0.10 <sup>a</sup>	11.01±0.23 <sup>a</sup>	3.46±0.23 <sup>a</sup>	29.80±0.18 <sup>a</sup>	27.66±0.27 <sup>a</sup>	28.08±0.42 <sup>a</sup>
70 °C, 180 min	8.34±0.10 <sup>a</sup>	11.36±0.43 <sup>a</sup>	3.54±0.14 <sup>a</sup>	29.83±0.24 <sup>a</sup>	27.53±0.29 <sup>a</sup>	27.73±0.08 <sup>a</sup>
80 °C, 130 min	8.61±0.17 <sup>a</sup>	11.26±0.34 <sup>a</sup>	3.22±0.10 <sup>a</sup>	29.72±0.17 <sup>a</sup>	28.05±0.26 <sup>a</sup>	27.75±0.39 <sup>a</sup>

Means (± standard deviation) with different superscripts in each column are significantly different ( $P < 0.05$ ).

the overall color parameters of red curry powder are affected by the different drying methods. The *L* and *b* values of red curry powder from the microwave drying were slightly lower than the hot-air drying (Table 2), which indicated that red curry powder from the microwave drying was slightly darker in color and less yellow than the hot-air drying. The *a* value of red curry powder from microwave drying at a microwave power of 540 W was not significantly different from hot-air drying at air temperature 60°C, but had significantly more red color than from hot-air drying at air temperatures of 70 and 80°C.

The color became darker and redder, implying that more browning of the product occurred while less yellow color could imply that pigment destruction had occurred. These results indicated that the microwave-dried products were more influenced by the browning reaction, causing more pigment destruction than for the hot-air dried products. Similar results were obtained by Funebo and Ohlsson (1998) when drying mushrooms and apples. However, Arslan and Özcan (2008) and Sumnu *et al.* (2005) found that microwave drying prevented color damage during drying of rosemary leaves and carrots.

Sharma and Prasad (2001) reported that browning and carotenoid pigment destruction increased with an increase in the drying temperature and/or time. Therefore, the undesirable browning and reduced yellow color

of the microwave-dried product occurred in samples because of the high temperature generated by the microwaves (Drouzas *et al.*, 1999). The final temperature of the microwave-dried paste was 83.8, 95.4 and 96.6°C at a microwave output power of 180, 360 and 540 W, respectively. In contrast, hot-air drying was performed at lower drying temperatures than the microwave drying, resulting in a lighter and yellower color in the red curry powder. These results revealed that the microwave-drying technique strongly affected the color quality of red curry powder and produced more brown compounds.

The differences among color *L*, *a* and *b* values of microwave dried samples were not significant, which indicated that the change in color values was not dependent on the microwave output power. The results are in agreement with Maskan (2000) who studied microwave-dried banana, Soysal (2004) for microwave-dried parsley and Pereira *et al.* (2007), for microwave/hot-air-dried, osmotically dehydrated banana. Hot-air dried samples at an air temperature of 60°C had slightly higher *a* values than other hot-air dried samples but were significantly different, especially for a long time process while *L* and *b* values were not significantly different.

#### Total phenolic content (TPC)

In addition to color, health benefit is an important attribute which enhances the quality of

**Table 2** Color measurements of Thai red curry powder.

Drying methods	Color		
	<i>L</i>	<i>a</i>	<i>b</i>
Microwave drying			
180 W, 23 min	57.114 ± 0.280 <sup>b</sup>	23.636 ± 0.348 <sup>b</sup>	30.442 ± 0.455 <sup>b</sup>
360 W, 12 min	57.171 ± 0.752 <sup>b</sup>	23.950 ± 0.346 <sup>ab</sup>	30.550 ± 0.997 <sup>b</sup>
540 W, 8 min	56.827 ± 0.146 <sup>b</sup>	24.103 ± 0.077 <sup>a</sup>	30.432 ± 0.313 <sup>b</sup>
Hot-air drying			
60 °C, 240 min	58.687 ± 1.050 <sup>a</sup>	23.653 ± 0.040 <sup>b</sup>	31.570 ± 0.445 <sup>a</sup>
70 °C, 180 min	59.324 ± 0.318 <sup>a</sup>	23.072 ± 0.259 <sup>c</sup>	31.652 ± 1.092 <sup>a</sup>
80 °C, 130 min	59.364 ± 0.243 <sup>a</sup>	23.168 ± 0.246 <sup>c</sup>	31.429 ± 0.278 <sup>a</sup>

Means (± standard deviation) with different superscripts in each column are significantly different (P<0.05).

Thai red-curry powder. The ingredients of Thai red-curry product are a mixture of herbs and spices, which are good sources of phenolic compounds. Therefore, it is important to consider the effect of the drying methods on the TPC of red curry powder extracts. Folin-Ciocalteu reagent is used to obtain a crude estimate of the amount of phenolic compound present in an extract. The principle of this assay is the reduction of the Folin-Ciocalteu reagent in the presence of phenolates, resulting in the production of molybdenum-tungsten blue, which absorbs at 730 nm. Generally, the outer layers of a plant such as the peel, shell and hull, contain large amount of phenolic compounds to protect the inner material. A number of phenolic acids are linked to various cell wall components, such as arabinoxylan and protein (Lee *et al.*, 2006). Choi *et al.* (2006) and Jeong *et al.* (2004) reported that heat treatment might disrupt the cell wall and liberate phenolic compounds from the insoluble portion of the plant.

The TPC in almost all microwave-dried products was significantly ( $P < 0.05$ ) higher than in hot-air dried products (Table 3). Microwave heating is based on the transformation of alternating electromagnetic field energy into thermal energy by affecting the polar molecules of a material. The materials can absorb microwave energy directly and internally and convert it into

heat. Kratchanova *et al.* (2003) found that microwave heating led to the destruction of parenchyma cells in orange peel, while Garau *et al.* (2007) found that hot-air drying of orange peel around 50-60°C apparently promoted the minor disruption of cell wall polymers. The intense heat generated from the microwaves creates a high vapor pressure and temperature inside plant tissue, resulting in the disruption of plant cell wall polymers. Consequently, cell wall phenolics or bond phenolics can be released, thus causing more phenolics to be extracted. In contrast to the results obtained in this investigation, Lim and Murtijaya (2007) reported that microwave drying caused a greater decrease in the TPC of *Phyllanthus amarus* than hot-air drying. Thus, the effect of drying methods on phenolic compounds from different materials may not be the same.

Among microwave-dried samples, an increase in microwave power significantly ( $P < 0.05$ ) increased the TPC, which indicated that the disruption to plant tissue increased with a rise in the intensity of the microwave field, causing more phenolic compounds to be liberated and released. Hot-air-dried samples showed no statistical difference ( $P > 0.05$ ) with respect to drying temperatures. This might be attributed to a minor disruption of cell wall polymers during hot-air drying.

**Table 3** Total phenolic content and antioxidant activity of Thai red-curry powder.

Drying methods	TPC*	RSA**	FRAP**
Microwave drying			
180 W, 23 min	7.377 ± 0.157 <sup>c</sup>	1.065 ± 0.010 <sup>c</sup>	5.017 ± 0.059 <sup>c</sup>
360 W, 12 min	7.818 ± 0.069 <sup>b</sup>	1.183 ± 0.011 <sup>b</sup>	5.297 ± 0.025 <sup>b</sup>
540 W, 8 min	8.333 ± 0.067 <sup>a</sup>	1.415 ± 0.032 <sup>a</sup>	6.108 ± 0.120 <sup>a</sup>
Hot-air drying			
60 °C, 240 min	6.963 ± 0.153 <sup>e</sup>	0.822 ± 0.032 <sup>e</sup>	4.918 ± 0.057 <sup>c</sup>
70 °C, 180 min	7.252 ± 0.164 <sup>cd</sup>	0.810 ± 0.014 <sup>e</sup>	4.916 ± 0.140 <sup>c</sup>
80 °C, 130 min	7.035 ± 0.100 <sup>de</sup>	0.865 ± 0.027 <sup>d</sup>	4.943 ± 0.119 <sup>c</sup>

\*mg gallic acid equivalents per gram dry matter

\*\*mg Trolox equivalents per gram dry matter

Means (± standard deviation) with different superscripts in each column significantly different ( $P < 0.05$ ).

### Antioxidant activities; DPPH radical scavenging and FRAP assays

Several analytical methods have been developed to determine the antioxidant capacity of natural substances *in vitro*. However, the antioxidant activity of plant extracts can't be evaluated using only one method, due to the complex composition of the phytochemical and oxidative processes. Therefore, at least two methods should be employed in order to evaluate the total antioxidant activity. In this study, DPPH radical scavenging and FRAP methods were used to evaluate the antioxidant activity. Both methods, which have been established and widely used to measure the antioxidant activity of fruit and vegetable juices or extracts, are simple assays that give fast, reproducible results (Kaur and Kapoor, 2001). The DPPH radical scavenging assay is based on the reduction of DPPH radicals in ethanol, which causes an absorbance drop at 517 nm. In this study, the radical scavenging activity (RSA) was expressed as Trolox equivalents per gram dry matter as it is a more meaningful and descriptive expression than expressing antioxidant activity as the percentage decrease in absorbance (Wong *et al.*, 2006). As such, the results provide a direct comparison of the antioxidant activity with Trolox. The FRAP assay determines the ability of the extracts to reduce ferric ions. An antioxidant capable of donating a singlet electron to the ferric-TPTZ (Fe(III)-TPTZ) complex causes the reduction of this complex into the blue ferrous-TPTZ (Fe(II)-TPTZ) complex which absorbs strongly at 593 nm.

The antioxidant activities of red curry powder determined using the DPPH radical

scavenging and FRAP assays are shown in Table 3. Microwave drying resulted in higher DPPH radical scavenging activity than hot-air drying. The reduction of DPPH radical potential depended on microwave output power and air-drying temperature. The RSA values increased as the microwave output power and air-drying temperature increased. Almost all of the microwave-dried samples possessed stronger ferric ion-reducing activity than hot-air-dried samples. The FRAP values of microwave-dried samples depended on the microwave output power, while the air-drying temperature did not have a significant effect on the FRAP values among hot-air-dried samples.

### Correlation between total phenolic contents and antioxidant activities

The correlations between results of TPC and antioxidant activity analysis were highly significant ( $P < 0.01$ ) as shown in Table 4. These correlations indicated that the level of TPC contributed to the antioxidant activity of Thai red-curry powder. Phenolic compounds have been reported to be responsible for the antioxidant activities of botanical extracts (Karakaya, 2004). Velioglu *et al.* (1998) indicated that the relationship between TPC and the antioxidant activity of plant materials, such as flaxseed products and cereal products, was positive but the relationship between phenolic and antioxidant activity for anthocyanin-rich materials and for medical plants was not significant.

Ambiguous connections between the content of particular antioxidants and antioxidant activity are difficult to explain based on only

**Table 4** Bivariate correlation coefficients for relationship between total phenolic content and antioxidant activity.

Results	Correlation coefficients	Sign (2-tailed)
TPC	1.000	-
RSA	0.949	<0.01
FRAP	0.920	<0.01

quantitative analysis. Zheng and Wang (2001) suggested that not only the level of antioxidants, but also a synergy occurring between them and the other plant constituents, might influence the difference in the antioxidant ability of plant extracts. Another reason for the improved antioxidant activity of the red curry powder could be the formation of novel compounds having antioxidant activity during drying (Nicoli *et al.*, 1999). In this study, non-enzymatic browning reaction products might have been formed.

The FRAP values were consistently higher than those obtained for the RSA. A similar result was reported by Wong *et al.* (2006), who found that the DPPH radical scavenging activities of 25 edible tropical plants, expressed as Trolox equivalents, were lower than their corresponding ferric-reduction activities. They suggested that the lower RSA values of plant extracts could be due to the presence of antioxidant compounds not reactive towards DPPH. Antioxidant compounds, such as polyphenols, may be more efficient as reducing agents for ferric ions but some may not scavenge DPPH radicals as efficiently due to steric hindrance.

## CONCLUSIONS

The effects of microwave and hot-air drying methods on the chemical composition, color (Hunter *L*, *a* and *b*), and antioxidant properties (TPC, RSA and FRAP) of Thai red curry powder were examined. It was found that the effect of both drying methods on chemical composition was not significant. However, the color and antioxidant properties were affected by the drying method. Microwave drying resulted in darker and less yellow color than hot-air drying. The change in color *L*, *a* and *b* values of microwave-dried samples was not dependent on the microwave output power but the change in the *b* value among hot-air dried samples depended on the air-drying temperature. The TPC, RSA and FRAP values for

almost all microwave-dried samples were higher than for hot-air-dried samples. These values increased with an increase in microwave output power. However, there was no significant difference between the TPC and FRAP values from hot-air drying at various air-drying temperatures. The level of TPC contributed to RSA and FRAP of red curry powder.

## ACKNOWLEDGEMENT

The authors would like to thank Namprick Maesri Limited Partnership for supplying the Thai red-curry paste used in this study.

## LITERATURE CITED

- Ahmed, J., U.S. Shivhare and H.S. Ramaswamy. 2002. A fraction conversion kinetic model for thermal degradation of color in red chilli puree and paste. **Lebensm. Wiss. U. Technol.** 35: 497-503.
- AOAC. 1990. **The Official Methods of Analysis of the Association of Official Analytical Chemists.** 15th ed. The Association of Official Analytical Chemists. Arlington, Virginia. 1298 p.
- Arslan, D. and M.M. Özcan. 2008. Evaluation of drying methods with respect to drying kinetics, mineral content and colour characteristics of rosemary leaves. **Energy Convers. Manage.** 49: 1258-1264.
- Choi, Y., S.M. Lee, J. Chun, H.B. Lee and J. Lee. 2006. Influence of heat treatment on the antioxidant activities and polyphenolic compounds of shitake (*Lentinus edodes*) mushroom. **Food Chem.** 99: 381-387.
- Drouzas, A.E., E. Tsami and G.D. Saravacos. 1999. Microwave/vacuum drying of model fruit gels. **J. Food Eng.** 39: 117-122.
- Funebo, T. and T. Ohlsson. 1998. Microwave-assisted air dehydration of apple and



- mushroom. **J. Food Eng.** 38: 353-367.
- Garau, M.C., S. Simal, C. Rosselloó and A. Femenia. 2007. Effect of air-drying temperature on physico-chemical properties of dietary fibre and antioxidant capacity of orange (*Citrus aurantium* v. *Canoneta*) by-products. **Food Chem.** 104: 1014-1024.
- Hsu, C.-H., W. Chen, Y.-M. Weng and C.-Y. Tseng. 2003. Chemical composition, physical properties, and antioxidant activities of yam flours as affected by different drying methods. **Food Chem.** 83: 85-92.
- Inchuen, S., W. Narkrugsua, P. Pornchaloempong, P. Chanasinchana and T. Swing. 2008. Microwave and hot-air drying of Thai red curry paste. **Mj Int J. Sci. Tech.** 1(Special Issue): 38-49.
- Jeong, S.-M., S.-Y. Kim, D.-R. Kim, S.-C. Jo, K.-C. Nam, D.-U. Ahn and S.-C. Lee. 2004. Effect of heat treatment on the antioxidant activity of extracts from citrus peels. **J. Agri. Food Chem.** 52: 3389-3393.
- Juntachote, T., E. Berghofer, F. Bauer and S. Siebenhandl. 2006. The application of response surface methodology to the production of phenolic extracts of lemon grass, galangal, holy basil and rosemary. **Int J. Food Sci Tech.** 41: 121-133.
- Karakaya, S. 2004. Bioavailability of phenolic compounds. **Critical Reviews Food Sci. Nutr.** 44: 453-464.
- Kaur, C. and H.C. Kapoor. 2001. Antioxidant in fruits and vegetables - the millennium's health. **Int J. Food Sci Tech.** 36: 703-725.
- Khraiseh, M.A.M., T.J.R. Cooper and T.R.A. Magee. 1997. Microwave and air drying I. Fundamental considerations and assumptions for the simplified thermal calculations of volumetric power absorption. **J. Food Eng.** 33: 207-219.
- Kratchanova, M., E. Pavlova and I. Panchev. 2003. The effect of microwave heating of fresh orange peels on the tissue and quality of extracted pectin. **Carbohydr. Polym.** 56: 181-185.
- Lee, S.-C., S.-M. Jeong and S.-Y. Kim. 2006. Effect of far-infrared radiation and heat treatment on the antioxidant activity of water extracts from peanut hulls. **Food Chem.** 94: 489-493.
- Leelarungrayub, N., V. Rattananone, N. Chanarat and J.M. Gebicki. 2006. Quantitative evaluation of the antioxidant properties of garlic and shallot preparation. **Nutrition.** 22: 266-274.
- Lim, Y.Y. and J. Murtijaya. 2007. Antioxidant properties of *Phyllanthus amarus* extracts as affected by different drying methods. **LWT.** 40: 1664-1669.
- Maskan, M. 2000. Microwave/air and microwave finish drying of banana. **J. Food Eng.** 44: 71-78.
- Materska, M. and I. Perucka. 2005. Antioxidant activities of the main phenolic compounds isolated from hot pepper fruit (*Capsicum annuum* L.). **J. Agri. Food Chem.** 53: 1750-1756.
- Nicoli, M.C., M. Anese and M. Parpinel. 1999. Influence of processing on antioxidant properties of fruit and vegetables. **Trends Food Sci. Technol.** 10: 94-100.
- Nijhuis, H.H., H.M. Torringa, S. Muresan, D. Yuksel, C. Leguijt and W. Kloek. 1998. Approaches to improving the quality of dried fruit and vegetables. **Trends Food Sci. Technol.** 9: 13-20.
- Pereira, N.R., A. Marsaioli JR. and L.M. Ahrne. 2007. Effect of microwave power, air velocity and temperature on the final drying of osmotically dehydrated bananas. **J. Food Eng.** 81: 79-87.
- Sharma, G.P. and S. Prasad. 2001. Drying of garlic (*Allium sativum*) cloves by microwave-hot air combination. **J. Food Eng.** 50: 99-105.
- Soysal, Y. 2004. Microwave drying characteristics of parsley. **Biosystems Eng.** 89: 167-173.

- Sumnu, G., E. Turabi and M. Oztop. 2005. Drying of carrots in microwave and halogen lamp-microwave combination ovens. **LWT**. 38: 549-553.
- Tsami, E., M.K. Krokida and A.E. Drouzas. 1999. Effect of method drying on sorption characteristics of model fruit powders. **J. Food Eng.** 38: 381-392.
- Vega-Mercado, H., M.M. Góngora-Nieto and G.V. Barbosa-Cánovas. 2001. Advances in dehydration of foods. **J. Food Eng.** 49: 271-289.
- Velioglu, Y.S., G. Mazza, L. Gao and B.O. Oomah. 1998. Antioxidant activity and total phenolics in selected fruits, vegetables, and grain products. **J. Agri. Food Chem.** 46: 4113-4117.
- Wong, S.P., L.P. Leong and J.H. William Koh. 2006. Antioxidant activities of aqueous extracts of selected plants. **Food Chem.** 99: 775-783.
- Zhang, M., J. Tang, A.S. Mujumdar and S. Wang. 2006. Trends in microwave-related drying of fruits and vegetables. **Trends Food Sci. Technol.** 17: 524-534.
- Zheng, W. and S.Y. Wang. 2001. Antioxidant activity and phenolic compounds in selected herbs. **J. Agri. Food Chem.** 49: 5165-5170.