Effect of Drying Condition on Shatavari (*Asparagus racemosus* Willd) Root Quality and Energy Consumption

Phattharanan Thiangma[1,*], Woranan Nakbanpote[2], Nattapol Poomsa-ad[3] and Lamul Wiset[1]

[1] Postharvest Technology and Agricultural Machinery Research Unit, Faculty of Engineering, Mahasarakham University, Khamriang, Kantarawichai, Maha Sarakham 44150, Thailand

[2] Department of Biology, Faculty of Science, Mahasarakham University, Khamriang, Kantarawichai, Maha Sarakham 44150, Thailand

[3] Drying Technology Research Unit, Faculty of Engineering, Mahasarakham University, Khamriang, Kantarawichai, Maha Sarakham 44150, Thailand

phattharanan.thi@gmail.com*(corresponding author), woranan.n@msu.ac.th, nattapol.p@msu.ac.th and lamul.w@msu.ac.th

Abstract. *The aim of this study was to investigate the effects of drying method on shatavari quality and energy consumption. In this study, microwave powers of 1,000 and 1,500 W were used in combination with hot air at 60 °C. Drying on a tray at 60 °C was used as the traditional drying method. Fresh and blanched Shatavari roots with a sliced thickness of 3 mm were used for drying. The sample was dried until the free water content was less than 0.6. Then, the quality was analyzed, i.e., color values L* a* b* hue angle and chroma, and total phenolic content and total flavonoid content. The result showed that fresh Shatavari dried with a 1,000-W microwave dryer had the highest L* value, while the a* value and b* value were the lowest. The total phenolic content (TPC) and total flavonoid content (TFC) were highest in the drying without blanching and in the 1,000-W drying. When considering energy consumption, only the hot air dryer consumed the highest specific energy consumption (SEC) (0.30 MJ/g), and increasing the microwave power resulted in a decrease in energy consumption. In addition, energy consumption was lower with blanching than without blanching. In terms of energy and quality, drying fresh Shatavari at a microwave power of 1,000 W combined with hot air at 60 °C was the appropriate condition.*

Received by	17 June 2022
Revised by	9 July 2022
Accepted by	30 September 2022

Keywords:

shatavari, drying, microwave drying, phenolic content

1. Introduction

Shatavari (*Asparagus racemosus* Willd) belongs to the family Asparagaceae. It is a kind of herb with an economic importance due to the use of various parts for various medicinal purposes, especially the root part, which has a cool, sweet taste, as a diuretic, expectorant, nourishes the unborn child, nourishes the liver, cures liver disease and nourishes. Shatavari root can be boiled to drink water to cure bleeding and goiter. The fruit has a cool taste and is boiled as an antidote for lethargy [1]. Therefore, it has been processed into a variety of health products such as Shatavari powder [2], Shatavari health drink [3] and Shatavari capsule [4]. There are many options to produce the product from Shatavari. Drying is an interesting method to remove the excess water from fresh shatavari before further process or storage.

Shatavari has been dried using different methods such as fluidized bed drying, hybrid solar drying, vacuum drying, solar drying, hot air drying in the temperature range of 40-70 °C [5,6]. Sample preparation, i.e. sliced, split, blanched, before drying had a significant effect on drying time. Sliced samples showed the faster drying time [5,6]. However, there is no report of bioactive compounds in shatavari after drying.

Drying using microwave techniques, such as microwave-assisted hot air dryers, can shorten the drying time compared to hot air drying alone and also reduce the energy consumption of drying [7]. The quality of the product is also an important parameter. In particular, it was found that products treated with microwaves and hot air were in good condition in terms of texture, appearance, odor, and color of products such as mushrooms [8]. This technique could maintain bioactive compounds and antioxidant activity which was better than only hot air drying [9]. Also, there has been reported that phenolic compounds of dried saskatoon berries with microwave vacuum drying was not significantly different with freeze drying [10]. In addition, the postharvest drying method may have an impact on the quality and quantity of the bioactive compound from plant materials. Phenolic compound recovery has been variable depending on the drying method [11,12]. An appropriate process for recovering active phenolic compounds from a plant is an important consideration.

Therefore, this research aims to study drying processes of shatavari root with microwave-assisted hot air drying compared to tray drying with blanching and fresh shatavari. The energy consumption, quality determination, and chemical properties of TPC and TFC were investigated to obtain a suitable drying process.

2. Materials and Methods

2.1 Microwave-hot Air Dryer

The pilot scale microwave assisted hot air dryer was constructed at Faculty of Engineering, Mahasarakham University, Thailand. The dryer is shown in Fig. 1. Drying chamber size was 80 (L) x 80 (W) x 80 (H) cm and manufactured with stainless steel No. 304. The four of 1,000 W magnetrons were used to generate microwave with the frequency of 2,455 MHz. Hot air generator and circulator used 9 kW electric heater and 1.5 kW centrifugal fan with electric motor. The air flow is shown in Fig. 2. Hot air duct was connected to drying chamber with flange and perforated plate was installed for microwave shielding. The circular tray is shown in Fig. 2 with driving system was mounted to the bottom of the drying chamber.

Fig. 1 The pilot scale microwave assisted hot air dryer

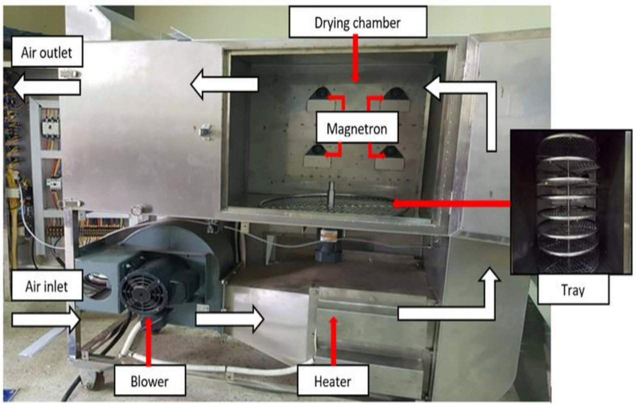

Fig. 2 The air flow and drying tray

2.2 Shatavari Preparation

Shatavari roots were harvested from Ban Phon Sim, Hua Na Kham Sub-district, Yang Talat District, Kalasin Province, Thailand (16° 23′ 52.5″ N, 103° 16′ 46.6″ E) in December 2021. The root was cleaned and sliced with a slicer to obtain a sample with a thickness of 3 mm. It was divided into 2 parts. Part 1 was the fresh sample. Part 2 was blanched at 80 °C for 5 minutes [5,6] and immersed in normal water to cool. Then, it was placed on a tray as shown in Fig. 3. A sample of 1,000 g was used for each drying.

Fig. 3 tray sample and arrangement

2.3 Drying Conditions

Microwave power of 1,000 and 1,500 watts combined with hot air at a drying temperature of 60 °C and a tray dryer at 60 °C were the drying conditions. The roots were dried to an a_w value of less than 0.6 to prevent microbial growth [13]. Drying was performed in 2 runs for each treatment. After drying, the sample was ground until it passed a 60-mesh sieve to obtain a homogeneous sample before analysis, i.e., color values, TPC, and TFC.

2.4 Quality Determination

2.4.1 Moisture Content

Shatavari root was chopped to small piece before determining moisture content. It was used an oven method at a temperature of 103 °C for 24 hr. Moisture was calculated from the water evaporation divided by the fresh weight [14].

2.4.2 Water Activity (a_w)

The dried samples were measured for a_w using an AquaLab water activity meter (Aqua-Link 3.0, Pullman, WA) which was calibrated with distilled water to obtain a_w in the range of 1.000 ± 0.003.

2.4.3 Color Values

The color of the samples was measured by a Hunter Lab Colorimeter (type Color Flex, USA). The Hunter L* a* b* scale gave a measurement of colors in units of approximate visual uniformity throughout the solid. The L* value measures lightness and varies from 100 for a perfectly white and 0 for black, a* and b* when positive measure redness and yellowness, respectively. For Chroma)C(and Hue angle)h (it was calculated as following the equation (1) and (2), respectively [15].

$$C = (a^{*2}+b^{*2})^{1/2} \quad (1)$$

$$h = \arctan(b^*+a^*) \quad (2)$$

2.4.4 Chemical Analysis

An extraction was performed with a heated ultrasonic bath at 50 °C for 1 hour. The ratio of root powder to 70% (v/v) methanol was 0.125: 4 (w/v). TPC was determined by a modified Folin-Ciocalteau method [16]. A 100 µL root extract was mixed with 500 µl of 10% (v/v) Folin-Ciocalteau reagent. The mixture was kept in the dark for 3 min before the addition of 100 µl of 7.5% (w/v) Na_2CO_3 and 300 µl of deionized water. The mixture was incubated in the dark for 2 hours, and the absorbance was measured at 731 nm. using a Vis-spectrometer. A standard curve was prepared from 5, 10, 20, 40, 60, 80, and 100 mg/l Gallic acid (GA). The TPC was expressed in terms of a GA equivalent (mg GAE/g dry wt.).

TFC was determined using a colorimetric assay [17]. A 100 µl extract was mixed with 500 µl of deionized water. Then, 30 µl of 5% (w/v) $NaNO_2$ was added. The mixtures were left in the dark for 5 min before adding 60 µl of 10% (w/v) $AlCl_3$. It was left for 6 min before the addition of 200 µl of 1 M NaOH and 110 µl of deionized water and mixed. After the mixture was placed in the dark for 5 min, the absorbance was measured immediately at 510 nm. A standard curve was prepared with 5, 10, 20, 40, 80, and 100 mg/l of epicatechin (EC). The TFC was expressed in terms of an EC equivalent (mg ECE/ g dry wt.).

2.4.5 Energy Consumption

Energy consumption from 3 phases was determined using digital electric meter (Brand Eastron model sdm 230-8i) with 5% less error. The energy consumption was from different sources i.e. blower, heater, motor and microwave power.

3. Results and Discussions

Table 1 presents the drying time, initial moisture content, final moisture content and a_w of shatavari drying. The results indicates that blanched Shatavari can be dried faster than fresh material. This is due to the blanching make the tissue softens leading the water migrates easier which corresponded with previous study that blanching could reduce drying time [18]. Moreover, the drying time is decreased when the microwave power increased. This due to the microwave power could accelerate the moisture evaporation from inside to the environment. This finding is agreed with the previous report that drying time of using microwave combined with hot air was reduced in particular increasing microwave power [19]. The a_w in all treatments was lower than 0.6 which is safe for further process and longer storage [13].

Pre-treatment	Condition	Drying time (hr)	Initial moisture content (% w.b.)	Final moisture content (% w.b.)	a_w
Fresh	Tray dry 60 °C	7	79.84±0.68	6.87±0.52	0.339±0.004
	MW 1000W +60 °C	6	79.83±0.54	7.23±0.35	0.378±0.002
	MW 1500W +60 °C	5	80.15±0.56	7.16±0.43	0.339±0.016
Blanching	Tray dry 60 °C	6	87.47±0.17	7.07±0.17	0.328±0.007
	MW 1000W +60 °C	5	87.56±0.47	7.86±0.03	0.356±0.006
	MW 1500W +60 °C	4	87.24±0.15	7.62±0.24	0.333±0.028

Table 1 Drying time, moisture content and aw of shatavari drying

Fig. 4 presents the product from different conditions, by visual assessment. In which, blanching caused the more shrinkage of dried product in particularly microwave drying.

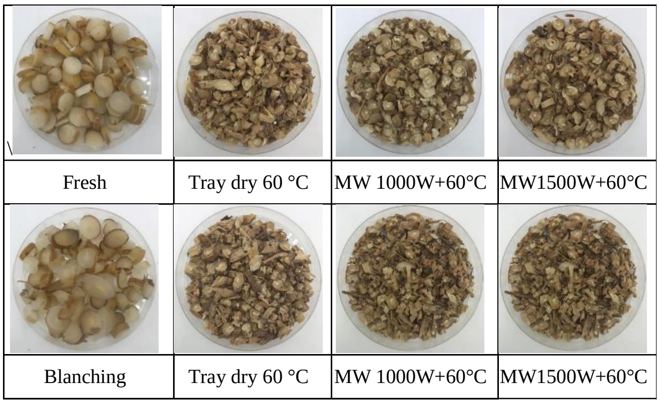

Fig.4 Samples of dried Shatavari

Pre-treatment	Condition	L*	a*	b*	hue angle	Chroma
Fresh	Tray dry 60 °C	87.60±0.37^{bc}	2.79±0.34^{a}	16.79±1.09^{a}	80.57±0.58^{b}	17.02±1.13^{a}
	MW 1000W +60 °C	90.90±1.16^{a}	1.73±0.38^{b}	13.81±0.82^{b}	82.91±1.12^{a}	13.92±0.86^{b}
	MW 1500W +60 °C	88.24±0.63^{b}	2.29±0.15^{a}	15.51±0.59^{ab}	81.60±0.22^{ab}	15.68±0.61^{ab}
Blanching	Tray dry 60 °C	84.53±0.58^{de}	2.58±0.11^{a}	16.71±1.68^{a}	81.19±0.51^{b}	16.91±1.68^{a}
	MW 1000W +60 °C	85.99±0.51^{cd}	2.27±0.01^{a}	15.78±0.25^{ab}	81.80±0.09^{ab}	15.94±0.25^{ab}
	MW 1500W +60 °C	83.76±0.83^{e}	2.85±0.07^{a}	17.65±0.65^{a}	80.83±0.12^{b}	17.88±0.65^{a}

Means with the different letter within a column are significantly different ($p \leq 0.05$) by DMRT

Table 2 the color values of dried Shatavari

After drying, the product was ground to make it homogeneous before measuring the color. Table 2 shows that Shatavari without blanching and dried at MW 1000W+60°C had the highest L* value. This is due to the fact that hot air drying takes a longer time, making Shatavari exposed to heat for a long time, and thus Shatavari roots are dark [20], and products dried at higher microwave powers cause product burns, which decreases the lightness value. However, this condition provides the lowest a* value and b* value. Hue angles are in the range of 80.57-82.91, which means that the product has a yellow direction and a chroma value are low color saturation.

Pre-treatment	Condition	TPC (mg GAE/g dry wt.)	TFC (mg ECE/ g dry wt.)
Fresh	Tray dry 60 °C	1.558±0.122[bc]	0.641±0.078[ab]
	MW 1000W+60 °C	1.956±0.006[a]	0.689±0.083[a]
	MW 1500W+60 °C	1.630±0.011[b]	0.610±0.144a[b]
Blanching	Tray dry 60 °C	1.260±0.130[d]	0.463±0.057[b]
	MW 1000W+60 °C	1.345±0.147[cd]	0.519±0.086[ab]
	MW 1500W+60 °C	1.187±0.14[d]	0.425±0.011[b]

Means with the different letter within a column are significantly different ($p \leq 0.05$) by DMRT

Table 3 The contents of total phenolic compounds and total flavonoids of dried Shatavari

Table 3 clearly shows that blanching reduced TPC and TFC. In addition, a high blanching temperature of 80 °C for 5 min may completely destroy the non-heat resistant compounds, making the different drying methods have no significant effect on the TPC and TFC values. In case of fresh root, some easily volatile phenolic can be lost by volatilizing during longer time of oven drying and certain phenolics (e.g. polyphenolic condensed tannin) may simply decompose or combine with other plant components that cause difficulty in getting free during extraction [21]. The highest TPC and TFC was found at MW 1000W+60°C. The use of microwaves may assist hot air to release of captured phenolic compounds [22]. Interestingly, the increasing microwave power of MW 1500W+6 0 °C resulted in a decrease in the amount of phenols and flavonoids. In this case, high-power microwaves can induce polymerization or degradation of thermolabile phenolics should be studied in more detail by ICP-MS/MS analysis [11, 23].

Table 4shows that blanched shatavari drying consumes less drying energy than without blanching Shatavari. Considering the drying conditions, it was found that hot air dryers consume the highest energy. The increase in microwave power resulted in less energy consumption because the drying time is shorter, which also reduces the energy consumption of fan, motor and heater, thus saving more energy.

Pre-treatment	Condition	Drying time (hr)	E_{blower} (kW-h)	E_{motor} (kW-h)	E_{heater} (kW-h)	$E_{microwave}$ (kW-h)	E_{total} (kW-h)
Fresh	Tray dry 60 °C	7	5.99	-	57.31	-	63.30
	MW 1000W +60 °C	6	1.41	0.84	15.33	6.00	23.58
	MW 1500W +60 °C	5	1.17	0.70	12.77	7.50	22.15
Blanching	Tray dry 60 °C	6	5.14	-	49.12	-	54.26
	MW 1000W +60 °C	5	1.17	0.70	12.77	5.00	19.65
	MW 1500W +60 °C	4	0.94	0.56	10.22	6.00	17.72

Table 4 energy consumption of drying with different conditions

Table 5 shows the calculation of SEC, it reveals that blanched Shatavari had lower SEC than fresh Shatavari. Since drying involves greater weight loss by evaporation and shorter drying time. It was found that the average SEC was lower for microwave assisted hot air drying. This due to hot air drying alone requires a relatively large amount of electrical energy for drying. Consequently, the average SEC for drying is high.

Pre-treatment	Condition	E_{total} (kW-h)	evaporated water (g)	SEC (MJ/g)
Fresh	Tray dry 60 °C	63.3	758.33	0.30
	MW 1000W+60 °C	23.58	770.02	0.11
	MW 1500W+60 °C	22.15	760.26	0.10
Blanching	Tray dry 60 °C	54.26	856.98	0.23
	MW 1000W+60 °C	19.65	841.06	0.08
	MW 1500W+60 °C	17.72	834.39	0.08

Table 5 Specific energy consumption for Shatavari drying (SEC)

4. Conclusions

Drying of Shatavari from fresh and blanching was studied at a microwave dryer of 1,000 and 1,500 W combined with hot air at 60 °C compared with a tray dryer at 60 °C. It can be concluded as followings:

-Blanching Shatavari could shorten the drying time. The shortest drying time was 4 hours from drying by microwave at 1,500 W.

-Blanching Shatavari before drying resulted in a decrease in L*. The drying by microwave at 1000 W assisted hot air at 60 °C, had the highest L* and lowest a* and b* values.

-Shatavari without blanching dried by microwave dryer with hot air at 1000 W provided the highest TPC and TFC of 1.956 mg GAE/g dry wt. and 0.689 mg ECE/ g dry wt., respectively.

- The increase in microwave power resulted in a decrease in energy consumption and SEC.

- Considering the quality, TPC, TFC and energy consumption, drying with microwave power of 1, 000watts combined with hot air of 60 °C is recommended for drying fresh Shatavari.

Acknowledgements

This research project was financially supported by Thailand Science Research and Innovation (TSRI) year 2022.

References

[1] S. Alok, K. Jain, A. Verma, M. Kumar, A. Mahor, and M. Sabharwal, "Plant profile, phytochemistry and pharmacology of Asparagus racemosus (Shatavari): A review," *Asian Pacific Journal of Tropical Disease*, vol. 3, no. 3, pp. 242-251, 2013.

[2] D. S. Gaikwad, R. N. Bhise, K. Sumeet, S. Arshdeep, J. Anita, and G. N. Ghadage, "Effect of dietary supplementation of Shatavari root powder (Asparagus racemosus) on growth performance and meat quality of broilers," *Annals of Biology*, vol. 34, no. 2, pp. 215-217, 2018.

[3] A. C. Serrao, L. Kukanoor, K. Gorabal, and M. Karadiguddi, "Development of karonda, shatavari and aloevera based blended health drink," *Journal of Pharmacognosy and Phytochemistry*, SP3: pp. 372-375, 2018.

[4] P. Kruti, B. Solanki, K. Maniar, N. Gurav, and S. Bhatt, "Natural herbal supplements an assessment of their nutritional value and their phytochemical constituents," *International Journal of Pharmacology and Biological Sciences*, vol. 2, no. 2, pp. 420-431, 2011.

[5] B. K. Bala, M. A. Hoque, M. A. Hossain, and M. B. Uddin, "Drying characteristics of asparagus roots (*Asparagus racemosus* Wild.," *Drying Technology*, vol. 28, no. 4, pp. 533-541, 2010.

[6] D. Kohli, N. C. Shahi, and A. Kumar, "Drying kinetics and activation energy of Asparagus root (*Asparagus racemosus* Wild.) for different methods of drying," *Current Research in Nutrition and Food Science Journal*, vol.6, no. 1, pp. 191-202, 2018.

[7] J. Dehghannya, S. Kadkhodaei, M. K. Heshmati, and B. Ghanbarzadeh, "Ultrasound-assisted intensification of a hybrid intermittent microwave-hot air drying process of potato: Quality aspects and energy consumption," *Ultrasonics*, vol. 96, pp. 104-122, 2019.

[8] S. G. Walde, V. Velu, T. Jyothirmayi, and R. G. Math, "Effects of pretreatments and drying methods on dehydration of mushroom," *Journal of food engineering*, vol. 74, no. 1, pp. 108-115, 2005.

[9] E. Horuz, H. Bozkurt, H. Karatas, and M. Maskan, "Effects of hybrid (microwave-convectional) and convectional drying on drying kinetics, total phenolics antioxidant capacity vitamin C, color and rehydration capacity of sour cherries," *Food Chem*, vol. 230, pp. 295-305, 2017.

[10] S. Lachowicz, A. Michalska, K. Lech, J. Majerska, J. Oszmianski, and A. Figiel, "Comparison of the effect of four drying methods on phenols in saskatoo berry," *LWT –Food Sci Techno*, vol. 111, pp. 727-736, 2019.

[11] K. Sukadeetad, W. Nakbanpote, M. Heinrich, and N. Nuengchamnong, "Effect of drying methods and solvent extraction on the phenolic compounds of *Gynura pseudochina* (L.) DC. leaf extracts and their anti-psoriatic property," *Industrial Crops & Products*, vol. 120, pp. 34–46, 2018.

[12] E.W.C. Chan, Y.Y. Lim, S.K. Wong, K.K. Lim, S.P. Tan, F.S. Lianto, and M.Y. Yong, "Effects of different drying methods on the antioxidant properties of leaves and tea of ginger species," *Food Chemistry*, vol. 113, pp. 166–172, 2009.

[13] Thai Agricultural Standard, "Dried herbs, Part 1: Bulbs, Rhizomes and root," *TAS* 3005 Part 1-2020 (In Thai)

[14] AOAC, "Official Methods of Analysis of the AOAC," 1995.

[15] P. B. Pathare, U. L. Opara, and F. A. J. Al-Said, "Colour measurement and analysis in fresh and processed foods: a review," *Food Bioprocess Technol*, vol.6, pp. 36–60, 2013.

[16] N. Cicco, M.T. Lanorte, M. Paraggio, M. Viggiano, and V. Lattanzio, "A reproducible, rapid and inexpensive Folin-Ciocalteu micro-method in determining phenolics of plant methanol extracts," *Microchem*. J, vol. 91, pp. 107–110, 2009.

[17] K.M. Yoo, C.H. Lee, H. Lee, B.K. Moon, and C.Y. Lee, "Relative antioxidant and cytoprotective activities of common herbs," *Food Chem.*, vol.106, pp. 929–936, 2008.

[18] H. W. Xiao, X. D. Yao., H. Lin, W. X. Yang, J. S. Meng, and Z. J. Gao, "Effect of SSB (Superheated Steam Blanching) Time and Drying Temperature on Hot Air Impingement Drying Kinetics and Quality Attributes of Yam Slices," *Journal of Food Process Engineering*, vol. 35, pp. 370–390, 2012.

[19] Q. Guo, D. W. Sun, J. H. Cheng, and Z. Han, "Microwave processing techniques and their recent applications in the food industry," *Trends in Food Science & Technology*, vol. 67, pp. 236-247, 2017.

[20] N. Therdthai, and W. Zhou, "Characterization of microwave vacuum drying and hot air drying of mint leaves (Mentha cordifolia Opiz ex Fresen)," *Journal of Food Engineering*, vol. 91, no. 3, pp. 482-489, 2009.

[21] R. Julkunen-Tiitto, "Phenolic constituents in the leaves of northern willows: methods for the analysis of certain phenolics," *Journal of Agricultural and Food Chemistry*, vol. 33, pp. 213–217, 1985.

[22] E.W.C. Chan, Y.Y. Lim, S.K. Wong, S.P. Tan, F.S. Lianto, M.Y. Yong, "Effects of different drying methods on the antioxidant properties of leaves and tea of ginger species," *Food Chemistry*, vol. 113, pp. 166–172, 2009.

[23] V.R. Sagar, K.P. Suresh KP, "Recent advances in drying and dehydration of fruits and vegetables: a review," *Journal of Food Science and Technology*, vol. 47, pp. 15–26, 2010.

Biographies

Phataranan Thiangma graduated with a bachelor's degree in biological engineering from Mahasarakham University, Thailand, in 2020. He has been studied for a master's degree in mechanical engineering in Mahasarakham University, Thailand, since 2020.

Woranan Nakbanpote graduated D Sc. (Biotechnology) from King Mongkut's University of Technology Thonburi, Bangkok, and Postdoc from Vienna University and Seibersdorf Research Centers, Vienna, Austria. Her research fields are phytoremediation, microbiology, phytochemical and sustainable development.

Nattapol Poomsa-ad has worked as a lecturer in biological and mechanical engineering in Mahasarakham University, Thailand, since 2002. He received his B.Eng, M.Eng and Ph.D from King Mongkut's University of Technology Thonburi, Bangkok. His Ph.D. degree was energy technology. His research interest includes thermal processing for food and agricultural product drying technology and energy conservation and management.

Lamul Wiset received her Ph.D in Food Science and Technology from University of New South Wales, Sydney, Australia, in 2007. At present, she is a lecturer in biological engineering in Mahasarakham University, Thailand. Her research interests include drying technology in particular quality of agricultural products such as rice, herbs, fruit and nut.