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**Article**

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Energy Reports

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*Suggested Citation:* Apinan Namkanisorn; Siripan Murathathunyaluk (2020) : Sustainable drying of galangal through combination of low relative humidity, temperature and air velocity, Energy Reports, ISSN 2352-4847, Elsevier, Amsterdam, Vol. 6, Iss. 2, pp. 748-753, <https://doi.org/10.1016/j.egy.2019.11.150>

This Version is available at:

<https://hdl.handle.net/10419/243963>

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The 6th International Conference on Power and Energy Systems Engineering (CPESE 2019),  
20–23 September 2019, Okinawa, Japan

# Sustainable drying of galangal through combination of low relative humidity, temperature and air velocity

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Received 30 October 2019; accepted 23 November 2019

## Abstract

Galangal (*Alpinia galanga*) is a herb commonly grown in Southeast Asia. The galangal rhizomes contain compounds that have antimicrobial and antioxidative properties. Longer storage of galangal can be achieved by drying. In the household-based industry, farmers use tray dryers because they are relatively cheap and easy to use. However, the quality of the products is low due to inappropriate temperature and drying time. The drying process is also energy intensive. This study investigated the effects of drying conditions such as air velocity, drying temperature and relative humidity on the drying characteristics and product quality. Drying of galangal was carried out at the following conditions: air velocities 0.25 and 0.5 m/s, drying temperatures 45 and 75 °C and relative humidity at 15 and 70 %RH, respectively. The mathematical modeling of thin layer drying kinetics of galangal was performed using Page model. The active ingredients in dried galangal were best preserved using a drying condition at air velocity of 0.25 m/s, 45 °C and 15%RH, in which the highest values of inhibition of free radicals by DPPH, total phenolic content (TPC) and 1'-acetoxychavicol acetate (ACA) content were  $79.2 \pm 1.3\%$ ,  $91.9 \pm 3.9$  mgGAE/100 g and  $384.1 \pm 17.6$  mg/100 g, respectively. Switching the relative humidity from low to high while keeping both air velocity and temperature low yielded a low drying rate. Hence, a combination of low relative humidity and low drying temperature at the optimum air velocity is promising for the design of more energy efficient dryer that gives desirable drying characteristics and product quality.

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Peer-review under responsibility of the scientific committee of the 6th International Conference on Power and Energy Systems Engineering (CPESE 2019).

**Keywords:** Drying; Low humidity; Galangal extracts; Casehardening; Page model

## 1. Introduction

At present, food or drug products often contain synthetic chemicals. When the body receives excessive amounts of chemicals for prolonged periods of time, it may lead to chemical residues in the body, causing both short and long term effects. As a result, people are more interested in using herbs instead of synthetic chemicals, which have no different benefits and less side effects. They are also easily available, inexpensive, and more cost effective than

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<https://doi.org/10.1016/j.egy.2019.11.150>

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importing expensive synthetic chemical drugs from abroad. Galangal or “khaa” in Thai is a tropical plant in the ginger family and is an endemic plant in Southeast Asia. In Thailand, galangal is used for medical purposes such as carminative, stomachic, antispasmodic, antiphlogistic and antibacterial drugs [1]. Thai people use fresh galangal for cooking. The antioxidants in the galangal rhizome are in large quantities compared to other Thai herbs. The major component is phenolic compounds, which have the potential to inhibit carbohydrate degradation by  $\alpha$ -amylase and  $\alpha$ -glucosidase enzymes. It helps slow down the absorption of glucose into the bloodstream and slow down the increase in blood sugar. The substances can also be used to treat non-insulin-dependent diabetes [2]. ACA is an important substance that can be produced within the galangal rhizomes. It can be used in combination with other HIV antibiotics [3]. In addition, galangal extracts are used in the process of storage or processing of protein because galangal antioxidants can inhibit oxidation, such as lipid oxidation which causes of protein degradation [4]. The use of the extract from dried galangal also shows a promising future.

Among various processing methods for galangal preservation, drying is one of most convenient techniques. Drying is a dehumidification process in the product to prolong the shelf life of the product. This has the effect of inhibiting the microorganisms that cause spoilage. However, drying can lead to undesirable effects such as color alteration and decomposition of active ingredients and the drying process itself is often energy intensive. This research was conducted to investigate the effect of process variables, such as drying temperature, air velocity and relative humidity, on thin-layer drying behavior of galangal as well as the preservation of active ingredients. The results obtained from this study enable future design of galangal dryer in which good drying characteristics and efficient usage of energy can be achieved.

## 2. Material and methods

### 2.1. Galangal dehydration and drying curve

Old galangal rhizomes were purchased from a farm in Mahasarakham, plantation area where quantity of ACA content in galangal rhizomes was high [5]. Rhizomes were cleaned with tap water and cut into 2 cm-diameter and 2 mm-thick slices. Galangal slices were dried by thin-layer dryer in various conditions: temperature at 45 and 75 °C, air relative humidity at 15 and 70%RH, and air velocity at 0.25 and 0.5 m/s. The samples were weighed in an analytical balance every 10 min. The drying was continued until galangal moisture content was constant. After 3 h of drying, the moisture content in galangal was lower than 0.3 kg<sub>water</sub>/kg<sub>drysolid</sub> or the water activity of galangal is below 0.6. Then dried galangal was taken out of the dryer and kept at –5 °C in the package protected from light for further determination of color, antioxidant activity by DPPH radical scavenging activity, total phenolic content (TPC), 1'-acetoxychavicol acetate (ACA) content and surface morphology of dried galangal.

### 2.2. Properties of dried galangal

Color quantification of galangal samples was determined with colorimeter (Juki, Japan) using a D65 illuminant, at 10° standard observer angles. CIELAB color values, L\*(Lightness), a\*(Redness–Greenness) and b\*(Yellowness–Blueness) were measured 5 times and the average was calculated for each sample.

The dried sample was grounded to fine powder in a mortar and sieved to obtain the particle size between 40–50 mesh. 0.1 g of galangal powder was extracted with 10 ml of 95% ethanol for 24 h at room temperature. The extracts were centrifuged at 5000 rpm for 5 min and filtered to get the clear supernatant. The supernatant was stored at 4 °C in dark bottle until its use.

Free radical scavenging by using DPPH radical: Extracts (0.5 ml) were added to 0.004%DPPH in ethanol (10 ml). After a 30 min incubation period at room temperature, the absorbance was read at 517 nm. The purple color bleaching of the DPPH reagent was evaluated as positive antioxidant activity. The inhibition of free radicals by DPPH in percent (I%) was calculated by Eq. (1):

$$I\% = [(A_B - A_A)/A_B] \times 100\% \quad (1)$$

where  $A_B$  and  $A_A$  are the absorbance of blank and sample after 30 min, respectively.

Total phenolic content (TPC): Folin-Ciocalteu reagent (0.5 ml) was added to the test tube containing 3 ml of distillation water and 0.5 ml of galangal extract. The reaction was allowed to progress for 6 min, then 3 ml of 10% sodium carbonate solution was added to the test tube and the mixture was diluted with distillation water to make

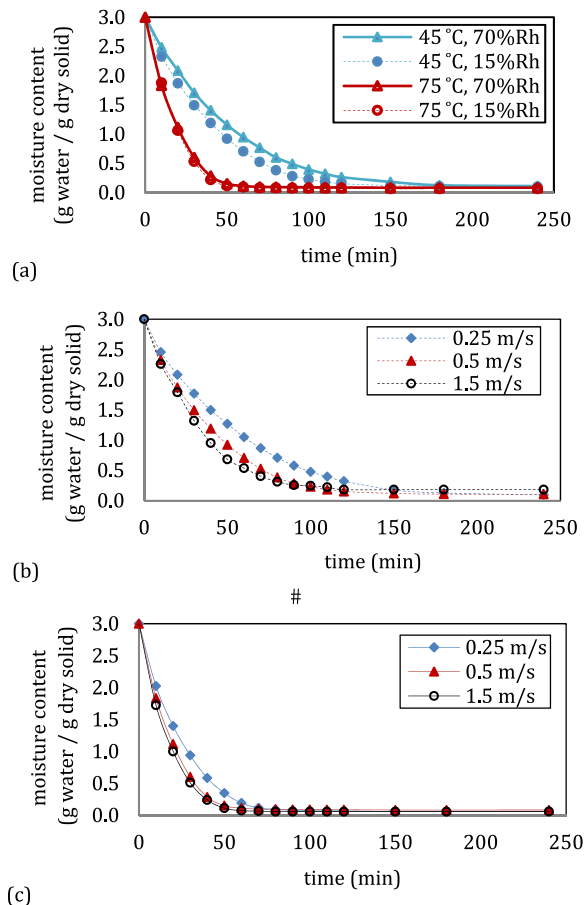
10 ml of solution. The mixture was allowed to stand for 90 min. The absorbance of the resulting solution was measured at 760 nm. The content of phenolic compounds was expressed as mg gallic acid equivalent (GAE)/100 g sample.

1'-acetoxychavicol acetate (ACA) content: Extracts (0.5 ml) were diluted with ethanol for 10 ml of solution. After a 30 min, the absorbance was read at 234 nm. The content of ACA was predicted from calibration curve of standard ACA.

### 3. Results and discussion

#### 3.1. Galangal drying curve

Drying kinetics of galangal at different drying conditions is shown in Fig. 1. Drying with high temperature, high air velocity and low relative humidity is more effective to reduce moisture content in the product than drying with low temperature, low air velocity and high relative humidity. This is because drying at high temperature has large temperature difference between the air and sample. As a result, the heat transfer rate is high. Thus, the moisture in the sample can diffuse outward faster than low temperature. High air velocity the film thickness of the air around the surface of the material is reduced. As a result, the water vapor rapidly diffuses of out the sample surface. In addition, the use of low relative humidity increases the difference in pressure of water vapor between the surface of the material and the air. Such increase in the driving force leads to more water vapor migrating out of the material to the air.



**Fig. 1.** Drying kinetics of galangal slices: (a) effect of drying temperature and air relative humidity (at air velocity of 0.5 m/s) (b) effect of air velocity (at 45 °C, 15%RH) (c) effect of air velocity (at 75 °C, 70%RH).

From Fig. 1a, it demonstrates that at high temperature, a decrease of the air relative humidity leads to smaller reduction of moisture content in the product compared to a lower temperature. As evidenced by the decrease in moisture content in the galangal at 75 °C, different air relative humidity shows no effect on the rate of drying.

From Fig. 1b, it can be seen that for low temperature and low humidity at high air velocity drying conditions, the final equilibrium moisture content is higher than value at the low air velocity. This is due to the fact that low humidity and high air velocity cause rapid evaporation of moisture from the surface of the product, creating a case-hardening which impedes heat transfer from the hot air to the product as well as prevents the movement of moisture from the product to the air. In addition, at low temperature, the diffusion coefficient of moisture content within the material is also low. Therefore, the final moisture balance is high. In contrast, drying at high air velocity, high humidity and high temperature (Fig. 1c.) shows no evidence of case-hardening.

### 3.2. Mathematical model of drying curve

In this work, the mathematical modeling of thin layer drying kinetics of galangal was performed using the Page model. The moisture ratio of galangal drying as described by Page model is expressed in Eq. (2)

$$MR = \exp(-k_p t^n) \quad (2)$$

where MR is the ratio of the moisture content at time t over the initial moisture content. The  $k_p$  and n, constants in the model, were shown in Table 1. The regression analysis was performed using the MINITAB 18 statistical software. The goodness of fit of the tested mathematical model to the experimental data was evaluated from the coefficient of determination ( $R^2$ ).

**Table 1.** Page model parameters for galangal dehydration at difference drying conditions.

T (°C)	Air velocity (m/s)	%RH	Calculated parameters		
			$k_p$	n	$R^2$
45	0.25	15	0.0172	1.0099	0.9987
		70	0.0123	1.0804	0.9980
	0.5	15	0.0157	0.9896	0.9978
		70	0.0093	1.0568	0.9978
75	0.25	15	0.0247	1.1101	0.9979
		70	0.0325	1.0623	0.9983
	0.5	15	0.0179	1.1741	0.9983
		70	0.0179	1.1429	0.9983

### 3.3. Properties of dried galangal

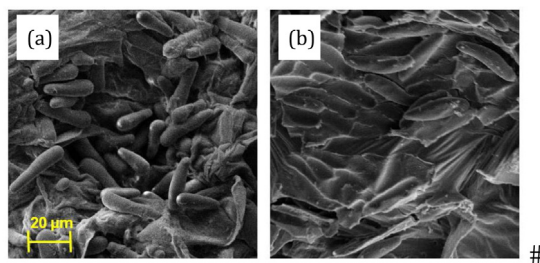
The color characteristics and values of the chemical substance, analyzed by DPPH, TPC and ACA, of the dried galangal at different conditions are shown in Table 2. It was found that, when the humidity in the air rises, the red and yellow values tend to rise. And when the drying temperature is higher, the yellow value is likely to rise. This characteristic may be due to the brown reaction product. However, the change in drying condition did not significantly affect the difference in brightness.

The results of the experiment showed that the drying condition affecting the change of important substances was the same direction. They decrease when the drying characteristics are high temperature, high humidity and high air velocity. At 45 °C, 15%RH and 0.25 m/s air velocity, the values of DPPH, TPC and ACA were  $79.2 \pm 1.3\%$ ,  $91.9 \pm 3.9 \text{ mg}_{\text{GAE}}/100 \text{ g}$  and  $384.1 \pm 17.6 \text{ mg}/100 \text{ g}$  respectively. Sequence, which is the highest value compared to other drying conditions.

Fig. 2 depicts SEM micrographs showing surface morphology of dried galangal. At high temperature, the cells are damaged by heat. The excessive heat also leads to degradation of chemical substances whose values are reported in Table 2.

**Table 2.** CIELAB color values and chemical substances of dried galangal.

T (°C)	Air velocity (m/s)	%RH	L*	a*	b*	DPPH (%)	TPC (mg <sub>GAE</sub> /100 g)	ACA (mg/100 g)
45	0.25	15	82.66 ± 0.01	7.68 ± 0.06	22.53 ± 0.02	79.2 ± 1.3	91.9 ± 3.9	384.1 ± 17.6
		70	79.62 ± 0.01	8.26 ± 0.02	24.29 ± 0.03	65.6 ± 2.1	85.9 ± 4.9	270.9 ± 23.3
	0.5	15	85.67 ± 0.01	4.25 ± 0.03	18.30 ± 0.02	51.7 ± 2.2	62.9 ± 3.7	201.8 ± 5.0
		70	85.07 ± 0.01	5.34 ± 0.04	19.99 ± 0.02	35.6 ± 1.2	43.4 ± 2.2	145.8 ± 12.5
75	0.25	15	78.85 ± 0.01	3.90 ± 0.02	23.47 ± 0.03	53.1 ± 1.5	68.6 ± 4.1	225.7 ± 30.1
		70	81.29 ± 0.01	6.94 ± 0.03	24.27 ± 0.01	51.8 ± 2.3	55.9 ± 1.0	143.3 ± 6.1
	0.5	15	80.30 ± 0.01	4.74 ± 0.02	20.17 ± 0.02	50.2 ± 1.1	55.5 ± 1.5	166.9 ± 9.6
		70	74.95 ± 0.01	8.35 ± 0.04	24.80 ± 0.04	43.8 ± 1.4	54.2 ± 2.2	160.3 ± 6.9

**Fig. 2.** SEM micrographs showing surface morphology of dried galangal after drying at 15%RH, air velocity of 0.25 m/s and temperature of (a) 45 °C (b) 75 °C.

#### 4. Conclusion

Galangal was dried at the following conditions: air velocities of 0.25 and 0.5 m/s, drying temperatures of 45 and 75 °C and air relative humidity of 15 and 70%RH, respectively. Dried galangal was characterized for its physical properties such as microstructure using Scanning Electron Microscopy (SEM) and color measurement. The analysis of chemical properties includes antioxidant activity by DPPH radical scavenging activity, total phenolic content and ACA content. The experimental results reveal that high drying rate is obtained with high temperature, high air velocity and low relative humidity. But drying at high temperature, high air velocity and high relative humidity results in degradation of chemical substances. Drying with low relative humidity of air shows potentials for good drying characteristics in terms of both preserving product quality as well as high drying rate. However, drying with too low relative humidity of air and too high air velocity causes case-hardening, leading to high final moisture content of the product. A combination of low air relative humidity and low drying temperature at the optimum air velocity is one way to increase the rate of drying, while still preserve high content of useful compounds due to minimum damage to cell structure. This drying combination offers several benefits including desirable drying characteristics, product quality as well as providing an alternative for the design of dryer which is less energy intensive.

#### Acknowledgment

The authors would like to thank Dr. Prasat Kittakoop at Chulabhorn Research Institute, Thailand, for ACA standard purification.

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