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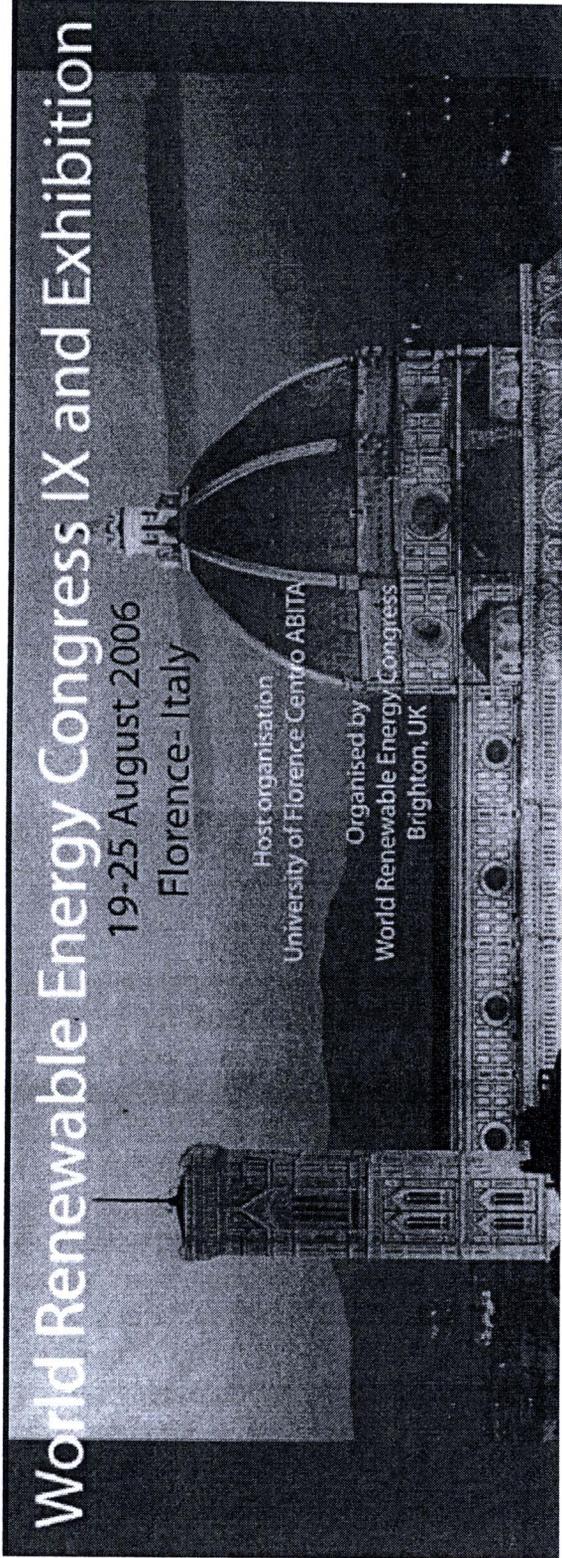
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# Techno-Economic Assessment of Ginger Drying for Essential Oil Extraction by Using Infrared Technique

C. Punlek<sup>1</sup>, R. Pairintra<sup>2</sup> and S. Chindaraksa<sup>3</sup>

<sup>1</sup>School of Energy and Materials, King Mongkut's University of Technology Thonburi, Pracha-Uthit Rd., Bangmod, Thungkru, Bangkok 10140, Thailand

<sup>2</sup>School of Bio Resource and Technology, King Mongkut's University of Technology Thonburi, Pracha-Uthit Rd., Bangmod, Thungkru, Bangkok 10140, Thailand

<sup>3</sup>Department of Physics, Faculty of Science, Naresuan University, Phitsanulok, 65000 Thailand

## Abstract

This paper presents technique and economical comparative analysis of ginger drying between infrared and HAD. A technique of ginger drying was studied the kinetic of drying and the electrical energy consumption in each levels of the temperature dryer at 50°C, 60°C and 70°C. In the other parts, the quality of ginger drying was studied by HPLC technique to analysis an important substance volume of ginger drying.

The experimental studying on quality of this research was found that the optimal temperature of ginger drying with Infrared as 60°C had an important substance volume, gingerol-6 and shogaol-6 was 56.56%, gingerol-8 and shogaol-8 was 24.52% and gingerol-10 and shogaol-10 was 18.74%. Also, we could be saved energy 7.69 kWh. Finally, economical calculations indicated that the payback period of the infrared drying is 0.34 years.

**Keywords:** Ginger, Infrared drying, HPLC technique

## 1. Introduction

Drying is the oldest method of preserving food. Water in food is eliminated during dehydration, thus achieving better microbiological preservation, as well as retarding many undesirable reactions [1]. It was removal from agricultural and food materials are very energy intensive. The efficiency of drying with respect to both energy and time is an important economic consideration. This has also revolutionized the design and development of drying systems. Dryer design is an increasingly challenging problem, which aims to select the proper type of equipment, its associated flow sheet arrangement, and its optimal construction characteristics and operating conditions [2].

Low thermal efficiencies are common in many types of process heating equipment, making process heating a prime candidate for energy saving improvements. In this research, we focus on opportunities within drying and curing operations to improve energy use, product quality, and overall productivity [3]. In many cases, infrared heating or hybrid system that combine infrared and convection technology offer several advantages over convection heating alone.

The interest for the far infrared radiation (FIR) technology upsurges because it results the healthful food as well as its higher efficiency for drying process. [4] showed that the critical moisture content of paddy after the fluidized bed drying was around 23% d.b. where as the infrared

irradiation could continuously reduced the moisture content to 21% d.b. without affecting. All the same it is suitable to combine with convection drying for barley [5]. As vegetables had been also tested to apply the combined infrared HAD, the result of carrot and potato showed that it is able to reduce the drying time by 48% and consuming less energy 63% compared to hot air heating [6]. The choice of particular for energy consumption and quality of product must be adjust to the specific application. The use combined infrared with hot air for the drying of agriculture material has not been subjected to optimization. For an economic optimum, it is obvious that the combination of different forms of energy needs to be investigated. Although, this kind optimization would have to be carried out independently for each material, due to the large variations in properties, quantitative products requirements, some general trends can be establish.

The objective of this study was to compare the specific energy consumption, quality of ginger dried for essential oil extraction and economic by convection and combined IR-HAD.

## 2. Infrared Irradiation and technique combine with hot-air drying

Infrared (IR) radiation heating has appeared as a one of the potential addition to the traditional heating method because of its some intrinsic advantages such as simplicity of the required equipment, easy accommodation of IR heating with convective, conductive and microwave heating, fast transient response and significant energy saving [7,8]. IR heating involves the exposure of the material to electromagnetic radiation in the wavelength range of 0.8–1000  $\mu\text{m}$  [9].

The combination of infrared with hot air provides the synergistic effect, resulting in an efficient drying process. Fig. 2 gives the conceptual representation of the mechanism

of combination drying. When the material is exposed to infrared radiation, it impinges on the material surface and penetrates it. The increased molecular vibration [10] due to absorption of radiation generates heat in the material both at surface and inner layers simultaneously. The rapid heating of the material increases the rate of moisture movement towards the surface. The convective flow of air removes the moisture from the surface, besides lowering its temperature, which results in increased mass transfer.

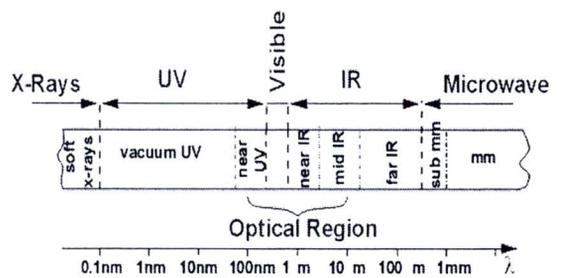


Fig 1. Electromagnetic Spectrum

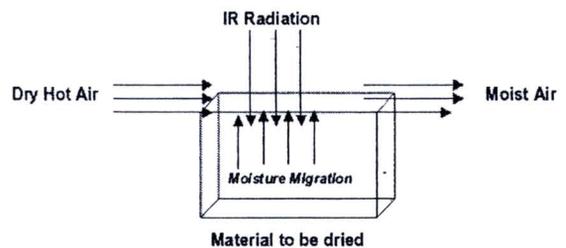


Fig 2 Conceptual representation of combined infrared and hot air heating.

## 3. Experimental set up and method

### 3.1 Description of infrared dryer combine with hot air

The infrared dryer combine with hot air is composed of infrared heater (1000 Watt) and electric heater (1000 Watt). The dryer has a capacity of 1000 g of raw ginger. The major specifications of the infrared combined with hot air dryer are provided in Table 1.

Table 1 Specification of the infrared combine with hot air dryer

Description	Specification
Dimension of drying chamber	0.52 x 0.5 x 0.5 m <sup>3</sup>
No. of heating chambers	1
Infrared heat source	Ceramic black surface
Wavelength of radiation	Far Infrared: FIR 4 – 1000 μm
Power input for IR heating	Varying 3 step; 200, 400 and 550 Watt
Residence time	2 - 7 hour
Hot air unit	1000 Watt
Blower	1 HP centrifugal blower

The schematic representation of the dryer is given in Fig 3. The dryer has recycle air system for use in drying chamber.

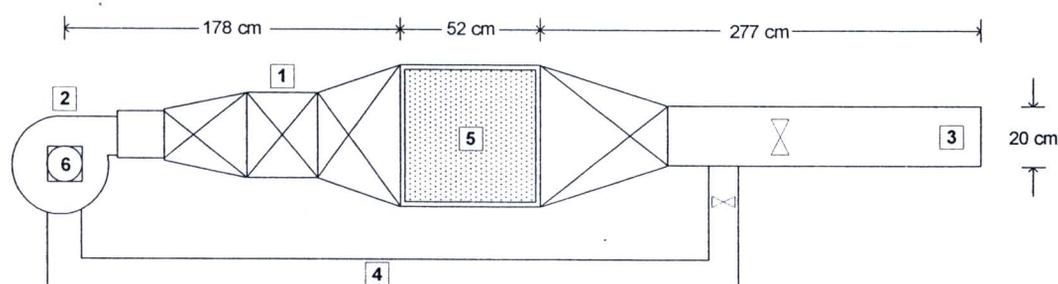


Fig 3 An infrared dryer combine with hot air (side view)

The drying conditions investigated varied in infrared radiation 200, 400 and 550 Watt temperature control in drying chamber 50, 60 and 70°C and thickness levels of about 3 mm of ginger slices. The inlet air velocity and relative humidity was 1.13 m/s and 60%, respectively. The control of drying air conditions was maintained within + 1.5°C for drying chamber. The initial moisture content of ginger rhizomes used in this study an initial moisture content of 80% db to a final moisture content of 11% db.

### 3.2 Operational modes

The efficiency of any infrared based heating system mainly depends on the type of heat source used. Operation flexibility was provided in the system so that it could be used independently in two different modes that's convective and combined mode independently. Through-flow hot air heating was provided at the desired temperature for

both convective and combination mode drying. During infrared drying, the hot air generation system was switched off to have only the infrared effect.

### 3.3 High Pressure Liquid Chromatography Analyse (HPLC)

Ginger (*Zingiber officinale* Roscoe) is grown commercially in most tropical regions for its rhizomes. The rhizome has been valued since antiquity for its flavour and pungency [11]. The ginger rhizome has two main pungent principles: gingerols and shogaol.

High Pressure Liquid Chromatography (HPLC) analyse the extracted main pungent principles. HPLC was used to analyse the main pungent principles in the extracted ginger oleoresin.

The chromatography conditions of the analysis main pungent principles by dried ginger are provided in Table 2.

Table 2 the conditions of chromatography analyse

Chromatographic Condition	
<b>Column:</b> Selectosil C18, 250x4.6 mm, 5 μm	<b>Flow Rate:</b> 1.2 ml/min
<b>Column Temperature:</b> 30°C	<b>Injection Volume:</b> 20 μl
<b>Detector:</b> UV at 282 nm	<b>Mobile Phase:</b> Methanol : water (7:3)

### 3.4 Economic Analyse

The selected economic indicators are: the net present value (NPV), pay back period (PBP) and internal rate of return (IRR) of infrared combine with hot air dryer [12]

$$PBP = \frac{A_i}{A_s}$$

$$NPV = A_o - A \frac{(1+i)^n - 1}{i(1+i)^n} - \frac{A}{(1+i)^n}$$

The internal rate of return can also be defined as discount rate that causes the net present value of a cash flow to equal zero.

where  $A_s$  is the annual income (energy saving),  $A_i$  is the initial cost,  $A_m$  is the maintenance cost,  $i$  is the discount rate and  $n$  is life-cycle.

The initial cost, life times and maintenance cost of infrared combine with hot air dryer (IR-HAD) and commercial drying (heater or hot air dryer; HAD) are given in Table 3. The energy costs were calculated for the following parameter:

- Operating 3 batch per day (drying time of IR-HAD 3 hour per batch and 7 hour for HAD)
- The material cost reference as the Ministry of Commerce Thailand as of February, 2006
- The interest rates reference as the Krung Thai Bank Public Company Limited effective data on February, 2006

### 4. Results

#### 4.1 The change in drying rate with moisture content and drying time

Samples were withdrawn at regular intervals to measure the moisture content. A typical moisture reduction show in Fig 4 the moisture content in the sample at different time intervals was plotted against time as moisture curves of ginger at temperature dried 50, 60 and 70°C by hot air and combination mode, respectively. The curves indicate the higher drying rate with combination mode over HAD at any given time. Combined mode at 70°C had a higher falling rate indicating a higher rate of mass transfer.

The drying time required or different modes. The drying time was reduced by nearly 58% with the combination mode compared to HAD. Infrared drying also reduced the drying time considerably over HAD in both the cases.

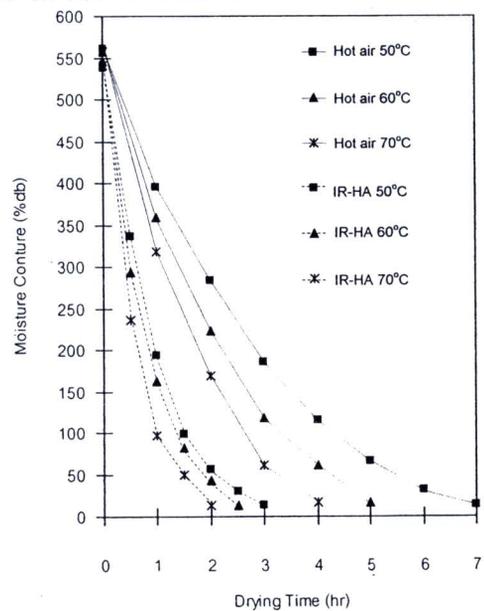


Fig. 4. Moisture curve for hot air and combined drying mode of ginger.

The conventional convective drying (hot air) is a slow process relying on heat conduction from the outer surface towards the interior. It is clear that drying rate are higher and drying time is substantially lower under combined IR-convection drying than convection alone. For example at dried with hot air 70°C and IR-HA 70°C, the drying time reduce 58% compare with the 7 hour require to achieve the same results if only hot air is used. The use of combined mode provides necessary heat of vaporization from deep inside the kernel and slightly hot air to carry away the evaporated moisture.

#### 4.2 Specific energy requirement

The infrared energy input for drying was estimated based on the power input and duration of infrared exposure. The energy required for heating the air and infrared energy input was computed for given drying conditions. The results are given in Table 3. The specific energy consumption for the combined mode drying was reduced nearly by 62% over hot air heating. Also, it was observed that infrared drying required much less energy than hot air heating when it was used individually.

Table 3 compares specific energy consumption in convection drying of ginger. Further reduction in specific energy consumption with combination drying could be achieved with the recirculation of hot air

and optimizing drying temperature and air velocity.

Table 3 Specific energy consumption during hot air, infrared and combined drying of ginger.

Mode of drying	Specific energy consumption of MJ/kg H <sub>2</sub> O evaporation		
	50°C	60°C	70°C
HAD	0.066	0.051	0.044
IR-HAD	0.029	0.020	0.017

#### 4.3 Quality of product by HPLC analyse

For the qualitative and quantitative analysis of the main pungent principles of ginger (*Zinyiber officinale* Roscoe) rhizomes, namely, gingerol and shogaol, these standards must be obtained in a pure form. There are two methods: (1) HAD and (2) IR-HAD. The results are cited in table 4. It can be seen the 6-gingerol and 6-shogaol by IR-HAD had a main pungent 56.56% when compared with that HAD.

#### 4.4 Economic results

Table 4 shows that the comparisons of the energy saving and economical analysis between IR-HAD and HAD. It can be seen that the initial cost of IR-HAD is higher than HAD about 1,600 baht for infrared part. But drying time of IR-HAD are lower than HAD about 3 hour per batch. However, the IR-HAD is can save energy about 4.5 kW per batch.

Table 4 Comparison of the main pungent principle of ginger extracted under different conditions and analyzed by High Pressure Liquid Chromatography

The main pungent principles	Area%					
	HAD			Infrared Drying		
	50°C	60°C	70°C	50°C	60°C	70°C
Gingerol-6, Shogaol-6	34.89	51.46	34.39	37.42	56.56	48.04
Gingerol-8, Shogaol-8	45.38	17.97	38.62	14.11	24.52	11.53
Gingerol-10, Shogaol-10	19.63	24.55	16.98	48.46	18.74	40.42

Table 4 Comparisons of the initial cost, energy saving and economical analysis.

Items	Added	Drying time	Energy used	Energy used *	Energy saving	PBP
	Cost (baht)	(hr/batch)	(kW)	(kWh/Yr)	(baht/Yr)**	(Yr)
HAD	-	7	1.43	7927.92	-	-
IR-HAD	3,000	3	1.83	4848.08	8931.54	0.34

\* Drying 3 batch per day and 792 batch per year

\*\*Electricity costs 2.9 baht/kWh

## 5. Conclusion

A infrared combined with hot air dryer (IR-HAD) was developed for herb and other agricultural products. The drying system was tested under hot air and combined infrared. The combined mode drying reduced the processing time dramatically (58%), in addition to consuming less energy (62%) for water evaporation compared to hot air drying. The product quality observed in terms of essential oil by extraction quality also better in combined mode at 60°C drying temperature compared on hot air and infrared drying.

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