



The Microwave Processing of Banana Sliced by Using Multi-Feed Microwave Continuous Belt Drier

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Abstract

In this study, the drying of banana sliced by microwave energy using multi-feed microwave continuous belt drier was compared to that by hot air, combined, hybrid method. By using multi-feed microwave continuous belt drier, the microwave power was generated by means of 12 compressed air-cooled magnetrons of 800W each that gives a maximum of 9.6 kW. The power setting could be adjusted individually in 800W steps. Hot air is generated by heater in the system. Most importantly, this work focuses on the investigation of drying phenomena under microwave environment. In this analysis, the effects of the irradiation time and drying method on overall drying kinetics and electrical power consumption were studied. The results showed that using the continuous microwave applicators technique has several advantages over the conventional method such as shorter processing times, volumetric dissipation of energy throughout a product, high energy efficiency as well as improvements in product quality. The results presented here provide a fundamental understanding of microwave-heating of various kinds of dielectric materials.

Keywords: Microwave, Processing, Banana sliced, Drying, Hybrid

1. Introduction

In general, the dielectric materials contain solids, liquids and gases, which is a kind of dispersed system. The mechanical properties are multi-phase by nature. The dielectric materials vary from the very solid, which are called the non-hygroscopic. However, the dielectric materials vary from the very liquid, which are called the hygroscopic. The example of these materials is the agricultural products that are the most important products of Thailand; so, the objective

of drying is simply to study the banana sliced under the influence of microwave by using the multi-feed microwave continuous belt drier system. The knowledge of this study will be adapted to dry the agricultural products after post harvest. The good review has been illustrated by Mujumda [1], Metaxas [2], Datta and Anantheswaran [3], and Schubert and Regier [4].

Normally, the drying process is simply to remove water from the dried simple without

causing any damage. The process must be done both efficiently and economically. Water can leave the surface of the banana sliced at a given rate depending on many parameters, such as microwave power level and air temperature, etc. In order to accomplish good drying of product, it requires a method that removes the water from the inside of the dried sample to the outside surface at the same rate as the evaporation of surface water.

The reasons for the interest in the interaction of microwaves with porous materials are reported by several investigators in the recent literatures [5-10]. The microwave energy can lower the drying temperature in several porous materials by several hundred degrees; shorten drying times; reduce drying defects; provide greater throughput; increase energy efficient and lessen floor-space requirements in comparison with conventional drying methods. ⁸⁹ It is also environmentally friendly and easily integrates into flexible, automated manufacturing systems. It appears that microwaves increase the heating efficiency by concentrating the heating process within porous material rather than in the cavity in which the porous material is placed.

2. Experimental procedure

Microwave - convective air drying is carried out using a combined multi-feed microwave-convective air and continuous belt system drier (Figure1(a)). The shape of microwave cavity is rectangular with a cross sectional area of 90cm × 45cm × 270cm. The drier is operates at a frequency of 2.45 GHz with maximum working temperature of 180 °C. The microwave power is generated by means of 12

compressed air-cooled magnetrons. The maximum microwave capacity is 9.6 kW with a frequency of 2.45 GHz. The power setting could be adjusted individually in 800W steps. In the continuous processing equipment, two open ends are essential, through which the material to be heated up on the belt conveyer is put in and taken out. In this equipment, leakage of microwaves is prevented by the countermeasure in double with a combination of mechanical blocking filter (corrugate choke) and microwave absorber zone filter is provided at each of the open ends. The microwave leakage is controlled under the DHHS (US Department of Health and Human Services) standard of 5 mW/cm². The multiple magnetrons (12 units) are installed in an asymmetrical position on the rectangular cavity (Figure1(b)). The microwave power is then directly supplied into the drier by using waveguides. An infrared thermometer (located at the opening ends) is used to measure the temperature of the specimens.

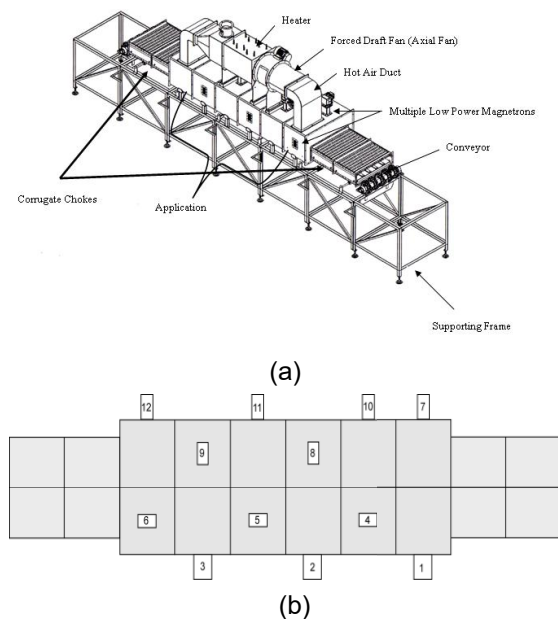


Figure1 Schematic diagram of experimental set up

- (a) A combined multi-feed microwave-convective air and continuous belt system
- (b) Feeds magnetrons positioned of 12 units

The hygroscopic dielectric material that use in this work is a banana then sliced it. Figure2 shows the banana sliced and the banana sliced in containers that waiting for feeding into the drying system.

The moisture is the crucial parameter in the drying process because it refers to the quality of the dried product. Therefore, the moisture content (mc) is the monitoring parameter. It is measured in every round of the drying cycle (from inlet of cavity to outlet of cavity), also the criteria to stop the drying process is the moisture content equal to 25% dry basis when the moisture content of dry basis can be calculated from Eq.(1)

$$mc = \frac{m_w - m_d}{m_d} \times 100 \quad (1)$$

Where m_w is wet mass of sample; m_d is dried mass of sample.



Figure2 The banana sliced

The drying samples were hygroscopic materials. A sample container was made from polypropylene with a thickness of 2 mm (with dimension of 14.5cm × 21cm × 5cm). The polypropylene did not absorb microwave energy. In this study, the samples is contain of 22 containers had total weight of 6.6 kg which had the initial moisture content of 270 % dry basis and the initial temperature was equal to the ambient temperature

Table1 The various conditions of experiments

Case	Process	Power of Magnetron (W)	Air Temperature (°C)
1	hot air	-	Ambient Air (30)
2	hot air	-	Hot Air (60)
3	hot air	-	Hot Air (70)
4	combined	6x800 W	Ambient Air (30)
5	combined	6x800 W	Hot Air (60)
6	combined	6x800 W	Hot Air (70)
7	hybrid	6x800 W	Ambient Air (30)
8	hybrid	6x800 W	Hot Air (60)
9	hybrid	6x800 W	Hot Air (70)

3. Results and discussions

Experimental data were analyzed to obtain the drying kinetics for different drying cases and conditions as listed in Table1. The details of analysis are as below

3.1 Drying kinetics of hot air process.

Figure 3-5 show the temperature and moisture variations versus elapsed times for banana sliced with constant initial moisture content of 270% (dry basis) in hot air process. It found the moisture profile of the banana sliced decreased slowly. This is because the effects of conduction from the surface to the center of

samples. Then the temperature of sample is increased to approximately 35-40°C. The drying times are used 1,200 min, 480 min and 420 min for the case 1, 2 and 3, respectively. Drying time in the microwave belt drier can be varied over a wide range by adjusting hot air temperature. In this research, drying characteristics of banana sliced are studied using hot air temperature of 30°C, 60°C and 70°C.

As expected, hot air temperature affects the drying time of banana sliced. Hot air drying at 70°C ensured the shortest drying time. This is because the convective heat transfer increases with hot air temperature.

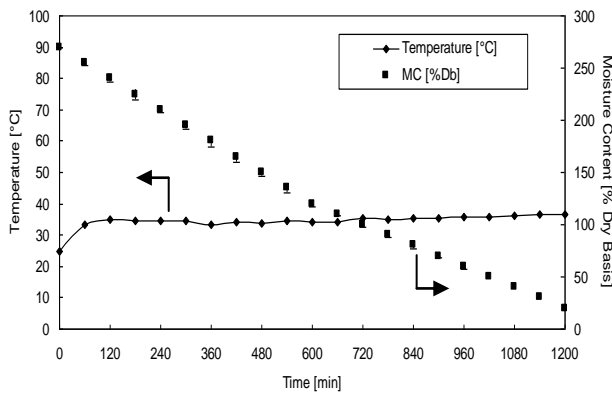


Figure3 Temperature and moisture variations versus elapsed times in case drying (Case1)

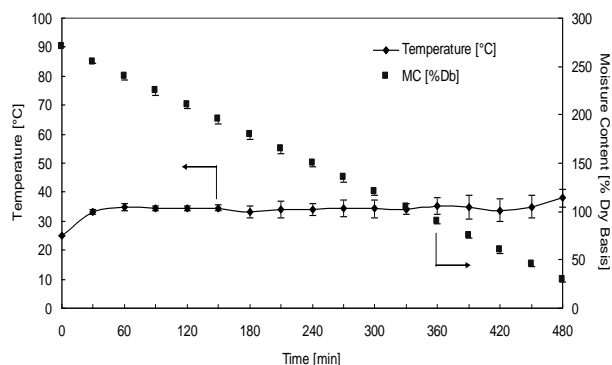


Figure4 Temperature and moisture variations versus elapsed times in case drying (Case2)

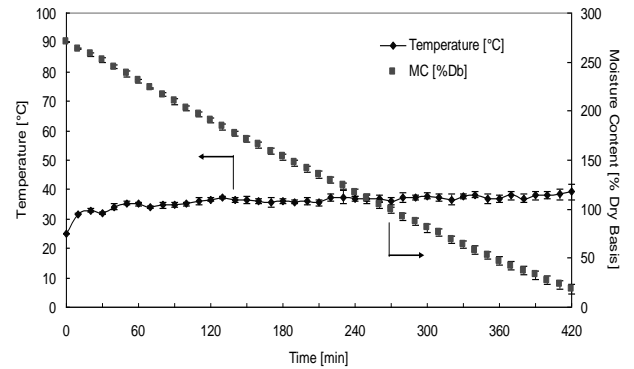


Figure5 Temperature and moisture variations versus elapsed times in case drying (Case3)

3.2 Drying kinetics of combined process.

Figure6-8 show the temperature and moisture variations versus elapsed times for banana sliced with constant initial moisture content of 270% (dry basis) in combined process. It is clearly found that the combined process is more effective in reducing drying time. In the first stage, the banana has high moisture content which corresponds to the great dielectric loss factor. In this stage the majority part of microwave can be absorbed within sample and the microwave is converted into heat inside the banana sliced. Nevertheless, near the end of drying process the moisture content is reduced continuously since the water content inside the sample is removed. This decreases the microwave power absorption within the sample. Thus, equilibrium is reached between microwave drying and convective losses by lowering sample temperature. In comparison, it is found that the case 6 has shortest drying time because its highest hot air temperature that increased the convective heat transfer coefficient in the surface of sample.

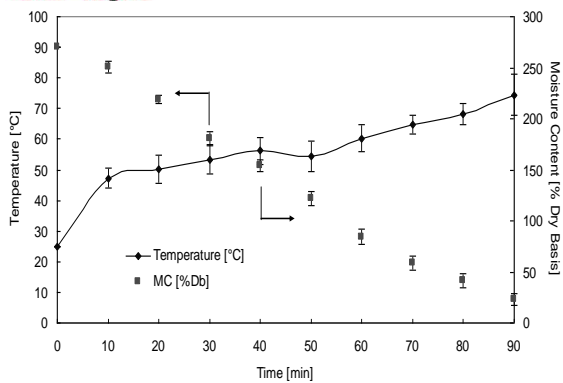


Figure6 Temperature and moisture variations versus elapsed times in case drying (Case4)

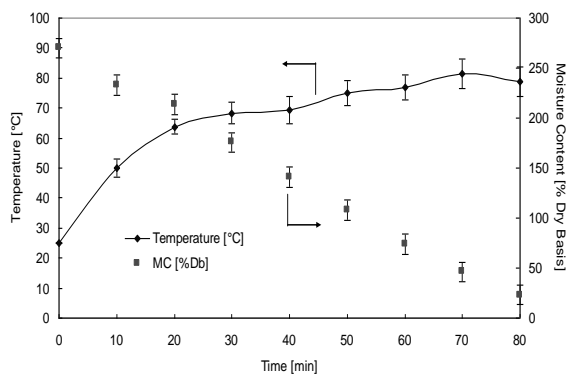


Figure7 Temperature and moisture variations versus elapsed times in case drying (Case5)

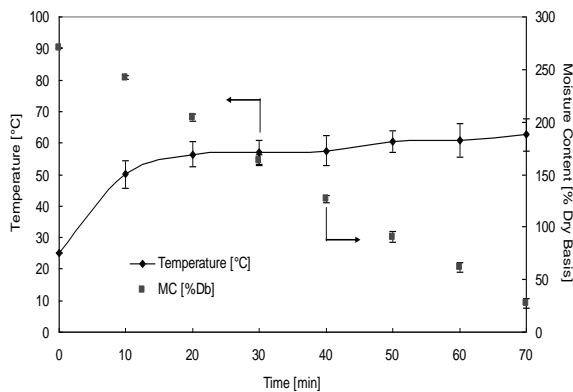


Figure8 Temperature and moisture variations versus elapsed times in case drying (Case6)

3.3 Drying kinetics of hybrid process.

Figure9-11 show the temperature and moisture variations versus elapsed times for banana sliced with constant initial moisture content of 270% (dry basis) in hybrid process. In

the first state, between 0-30 min, (in the case 7, 8 and 9) the banana sliced is dried using hot air, and the next stage, the banana sliced is dried using the combined process. In the first stage, the moisture profile decreased slowly and the temperature increased because the effect of convective drying. In the next stage the combined process is used, the moisture profile is decreased rapidly and the temperature profile is increased rapidly to the end process. The hot air is used in the early stage because the convective dried is needed for the surface drying, and in the final stage, in the final stage the combined process is needed to remove the moisture inside the material. This technique is valid for drying industry.

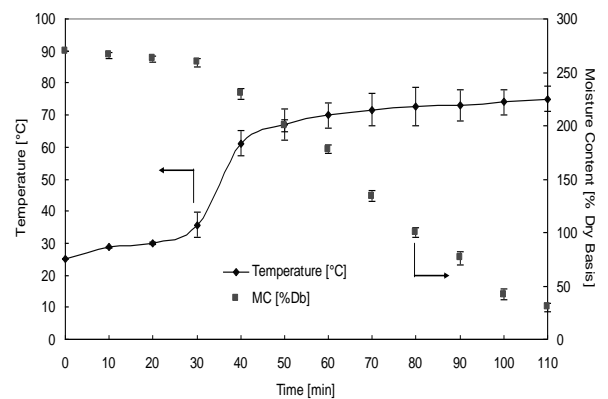


Figure9 Temperature and moisture variations versus elapsed times in case drying (Case7)

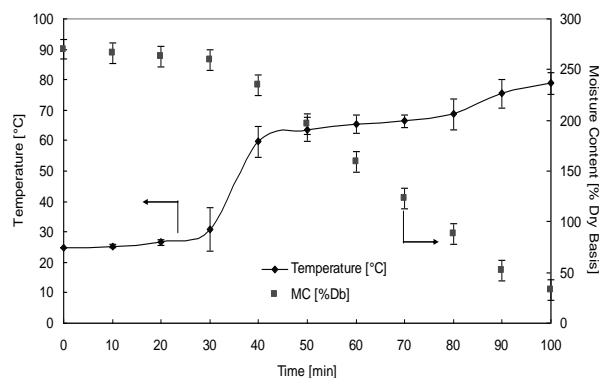


Figure10 Temperature and moisture variations versus elapsed times in case drying (Case8)

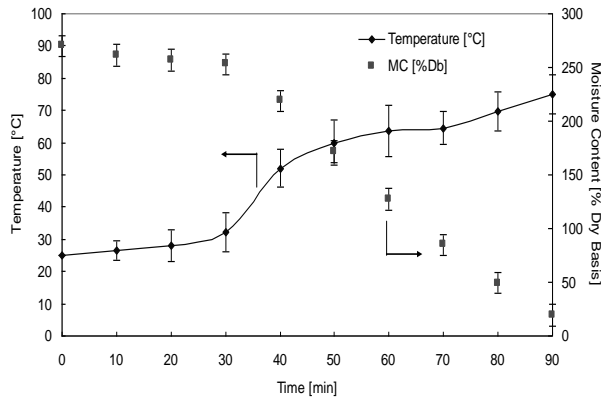


Figure 11 Temperature and moisture variations versus elapsed times in case drying (Case9)

3.4 Electric energy consumption and drying time

In this Table 2, the conventional hot air drying processes in the case 1, 2 and 3 took a long drying time and consumed more electrical power than the drying process that combined the microwave power in case 4 – 9. Therefore, the results in this table show the interesting cases which included the microwave power to the

process. The interesting cases are the combined process and the hybrid process because they have the potential to reduce the drying time rapidly and save the electrical power consumption ; however, to examine the suitable process for drying the banana sliced is short drying time and consumed low electrical power.

4. Conclusions

Microwave drying using multi-feed microwave continuous belt drier provides uniformity heat pattern, so it is suitable and convenient for drying banana sliced. The various drying process are applied to the hygroscopic material. It found that the hybrid process, which is ambient air temperature combined with microwave energy, is the best process for drying banana sliced when consider in the case of short drying time, low electrical power consumption, and good quality of product.

Table 2 Drying time and electrical power under various drying conditions

Case	Process	Power of Magnetron (W)	Air Temperature (°C)	Drying Time (min)	Electrical Power (Kw-hr)
1	hot air	-	Ambient Air (30)	1200	24
2	hot air	-	Hot Air (60)	480	33.7
3	hot air	-	Hot Air (70)	360	40
4	combined	6x800	Ambient Air (30)	90	11.1
5	combined	6x800	Hot Air (60)	80	13.5
6	combined	6x800	Hot Air (70)	70	14
7	hybrid	6x800	Ambient Air (30)	110	10.7
8	hybrid	6x800	Hot Air (60)	100	14.5
9	hybrid	6x800	Hot Air (70)	90	16.8



Furthermore, by overall when handling a multi-feed microwave continuous belt drier correctly, we can conclude that it will realize the following advantages, compared to other heating systems:

- Faster, reproducible and more homogeneous heating (high product quality)
- Faster heating of thicker layers because the multiple magnetrons are arranged around the cavity, the microwaves can penetrate further into the multi-plane of material
- Immediately ready for operation and control of heat capacity without delay

5. Acknowledgement

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6. References

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