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Characteristics of Several Foodstuff Drying by Microwave: A Review

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ABSTRACT
One of technology that used for food drying is microwave. The use of microwave drying has resulted in sensory and physical characteristics changes of food. The objective of this article is to review the use of microwave drying on several foodstuff. Microwave drying has a significant difference as compared to the other drying method. As a result of microwave drying, turmeric and giant turmeric had a darker colour as compared to the fresh one. Moreover, black sticky rice processed by microwave drying showed higher moisture content (6.35%) than that using oven drying. An increase in drying rate using a microwave drying was also reported along with the power level used for potato drying (0.18 kg/s in 100 Watt, 0.28 kg/s in 160 Watt, and 0.36 kg/s in 240 Watt). Similar result was also shown on the peanuts drying with various microwave power level, namely 113.93 g/h in 450 W, 168.12 g/h in 674 W, and 225.18 g/s in 900 W (efficiency of 98,87%). The water absorption on various dried foodstuff processed using microwave drying showed the highest valuewhen the highest microwave power level used. Based on microwave drying of pumpkin, edamame, and giant ginger showed that the bulk density with the highest value was found in the highest power treatment. Moreover, study on edamame and giant ginger microwave drying showed and the decrease of oil absorption on the dried product. It can be concluded, microwave drying can increase the drying rate, preserve colour, increase the bulk density, and lower oil absorption as the use of higher power level.

Keywords: *Bulk Density, Drying Rate, Microwave Drying, Water Content.*

1. INTRODUCTION

Microwave food drying process

Drying is one of reducing water content processes in food ingredient. During the drying process, there is a mass transfer of water from solid material to its environment to the lowest level. The drying process aims to reduce the moisture content of the material so that the material is more durable. The drying process reduce the moisture content of the material to the limit of the development of organisms and enzyme activities that can cause decay to be inhibited or completely stopped, so that the dried material has a longer shelf life. In addition to preserving foodstuffs, drying can reduce weight and reduce the size of foodstuffs so that it can facilitate storage and distribution [1]. Drying is an alternative, which is popular in food preservation. Drying is not simple preservation because during the drying process unwanted changes occur in the quality of the product being dried. High temperatures and long drying times can cause serious damage to the taste, coluor, nutrition, decrease in density, and rehydration capacity of dry products [2].

During the drying process, there is an opportunity to lose some of the nutritional value of food due to exposure to high temperatures for a long time [3]. Fruit and vegetable drying can generally be done by conventional drying methods, newer drying techniques have been developed to reduce drying times, increase energy efficiency and reduce deterioration of fruit and vegetable quality [4]. Conventional drying can utilize sunlight, hot air, radiation, convection, and conduction limited by the thermal gradient, cross-section, and physical properties, especially thermal conductivity, of the material to be dried [5]. Drying is also a common postharvest processing method that can extend shelf life, save transportation costs, and preserve nutrition [6].

One of the most drying technology is oven drying. An oven dryer is a tool or machine in the form of an isolated thermal chamber that is used for heating, baking, or drying a material at a certain temperature, and is generally used to reduce the moisture intensity of food so that it is more durable. In general, oven dryers are used in the food industry. Ovens as a substitute for sunlight are often used as conventional drying media which have had many shortcomings, namely low product hygiene because the product is placed in direct sunlight so that it is easily contaminated by microbes in the wild, the drying time is very dependent on intensity. Sunshine and very dependent on the climate. In the drying process, the oven dryer is an artificial drying method that uses a heater and artificial air to circulate the air in the oven so that it can reduce the water content in the ingredients. The advantage of oven drying compared to conventional sun drying is that the resulting product will be more hygienic. In addition, by using an oven dryer, the temperature and drying operating conditions can be adjusted, so that the weather conditions do not affect the drying process using an oven dryer. By using an oven dryer, the quality of the dried material will be maintained because in the process the oven dryer using a batch dryer, which means that the dried materials are put in one by one to dry so that the possibility of damage caused by collisions can be avoided [7]. Recently, many researchers have studied the use of microwave drying process for various product. Different from conventional drying that the external heat source is used to heat the material and the heat transfers from outside part inward, microwave heating occurs by the rapid polarization and depolarization of charged molecules inside the subjected material. Microwaves work by passing microwave radiation to water, fat, and sugar molecules that are often found in food ingredients. These molecules will absorb the electromagnetic energy. This energy absorption process is known as dielectric heating. The molecules in food are electrically dipole (electric polished), meaning that the molecule has a negative charge on one side and a positive charge on the other side. As a result, the presence of changing electric fields induced by microwaves on each side will rotate to align themselves with one another. The movement of these molecules will create heat as friction occurs between one molecule and another. The heat energy produced by this event serves as a heating agent in the process of drying food ingredients in the microwave [8]. Microwave is electromagnetic radiation with a frequency of 2.45 GHz with a wavelength of 12.24 cm [9]. The principle behind microwave oven drying is liberating moisture by agitating water molecules in the organic substances with the help of electronically produced microwaves. Drying is exceptionally fast and gets completed within a few minutes and generates little heat [10].

The advantages of using the microwave as a drying tool have advantages including the heating time for many foodstuffs using the microwave which is about a quarter of the time used in conventional heating [11]. The fast-drying time is offset by the high microwave frequency. The high frequencies used in microwaves allow fast energy transfer and high heating rates thus preserving the nutrient and vitamin content as well as the taste, sensory characteristics, and colour of food [12]. Microwave heating is considered to be more energy efficient than conventional heating because heat is generated in food [11]. Microwave equipment is suitable for on-site cleaning systems, low-cost system maintenance, and environmentally friendly processing because microwave generation does not produce exhaust gases or toxic waste [12]. The heating system of microwave can be turned on or off instantly [13]. Microwave technology is now equipped with the use of an automatic heating system so that control of use is easier and prevents overheating.

The use of microwaves also has some downsides. The main disadvantage in the microwave heating process is the non-uniform temperature distribution. This results in hot and cold spots on products that are heated by microwaves [14]. The non-uniform temperature distribution in microwave heating occurs mostly in solid foods and batch method in cavity ovens such as grains [15]. Some of the other disadvantages of the microwave are high initial costs, limited penetration of microwaves, and decreased quality of heated food [16]. The most important disadvantage of this technology is the high investment costs and inefficiencies in the use of energy and inappropriate methods can result in poor quality results such as discoloration, taste, and reduced nutrition [17].

Application of microwave drying

Microwave drying can be used for drying food ingredients that are used to making a powder. The use of microwaves for drying food is more efficient and produces more even heat [18]. This is following the working principle of microwave, where microwave radiation penetrates foodstuffs, triggering friction against water, fat, and sugar molecules to produce heat.

Color is an important visual indicator to characterize the appearance of food [19]. During thermal processing, the color of RGB exposed to a microwave field with rich oxygen was prone to be brown, which resulted in the changes in the visual color of RGB [21]. Based on drying study of giant turmeric and turmeric using ovens and microwaves, it showed that the color is getting darken as

Table 1. Comparison of the use microwave drying and oven drying foodstuff properties

No	Tools	Sample	Time	Power (Watt)	Temperature	Final Moisture Content	Color	Resource
1	Microwave	Giant Turmeric	75	-	65	8.78	Orange	[19]
			65	-	80	8.76	Dark orange	
			45	-	120	9	Brown	
2		Turmeric	75	-	65	9.22	Dark yellow	
			65	-	80	8.78	Orange	
			45	-	120	9.19	Dark orange	
3		Black sticky rice		180	-	6.35	-	[20]
4		Pomegranate	20	210	-	2.2	-	[2]
			20	350	-	1.25	-	
			20	490	-	0.35	-	
5	Oven	Giant Turmeric	75	-	65	6.19	Dark yellow	[19]
			65	-	80	7.03	Orange	
			45	-	120	8.4	Dark orange	
6		Turmeric	75	-	65	6.52	Yellow	
			65	-	80	5.73	Yelow	
			45	-	120	8.32	Dark yellow	
7		Black sticky rice		-	50	7.57	-	[20]
8		Pomegranate	100	-	50	2.8	-	[2]
			100	-	60	2.1	-	
			100	-	70	0.7	-	

of the temperature increases [19]. The browning phenomenon was induced by the Maillard reaction of amino acids and reducing sugar due to rising temperature [22]. Microwave drying is preferable to oven drying as it retains curcumin levels. This also affects the final color of drying, where microwave-dried turmeric tends to have a darker color than oven-dried turmeric.

Water content is the amount of water contained in food ingredients. The amount of moisture contained in the material after drying indicates the quality of the drying method used. Microwave drying shows better results than the oven. Based on research from on drying black sticky rice using a microwave and an oven in the same condition, it showed the moisture content of 6.35% for the microwave and 7.57% for the oven [20]. The result showed the microwave is more effective to dry black sticky rice.

The main nutritional content of fresh peanuts is 65% carbohydrates, 16% protein, and 6% fat for every 100 grams of ingredients. The total energy produced from the three substances is 370 kcal/100 grams. Bogor nut seeds also contain 6-12% oil, about half of the peanut oil content. Meanwhile, potatoes contain 66-90% carbohydrates, protein, antioxidants, potassium, vitamin B6, and vitamin C. Drying peanuts and potatoes is one way to extend shelf life. In the process it is necessary to consider the efficiency of the drying rate

The drying rate is the amount of water evaporated per unit time. The drying rate depends on a range of conditions such as the difference in vapor pressure

Table 2. Microwave drying in peanuts and potato

No	Sample	Power (Watt)	Drying rate	Moisture content (%)	Efficiency (%)	Source
1	Peanuts	450	113.93 g/h	12.075	98.585	[24]
		675	168.12 g/h	15.225	97.541	
		900	225.18 g/h	13.935	98.870	
2	Potato	100	0.18 kg/s	5	-	[25]
		160	0.28 kg/s	4.9	-	
		240	0.36 kg/s	4.8	-	

between the wet surface and the drying surface, the drying air velocity, the surface area, and the mass transfer coefficient [23]. Temperature and drying rate are proportional, if the drying temperature increases, the drying rate will also increase. Based on research from on drying peanuts using the microwave showed that the drying rate increases in line with the increase in power used [24]. This condition is also in line with research regarding potato drying using a microwave which also increased the dry rate along with the increase in power used [25].

Pumpkin is a vine that contains carbohydrates, protein, calcium, phosphorus, iron, and vitamins B and C. The nutritional content of pumpkin is a potential source of nutrition at an affordable price. Another agricultural product that is rich in nutrients is edamame. Edamame is an agricultural product that has a short shelf life. Processing edamame into flour can extend its shelf life. Edamame contains protein, amino acids, and nutritional value equivalent to cow's milk. It is necessary to use a drying method that can maintain the content in edamame. While ginger is a spice that can be harvested once a year so it is usually stored in dry form. Red ginger and elephant ginger will experience a decrease in quality if they are not processed immediately because they have a fairly high water content, around 90%.

Water activity is a measure of the condition of the presence of water in food products. The presence of water in food is a combination of the amount and availability of water in the product. Based on Tabel.3 shows that the highest water activity value is obtained in microwave drying with the highest power in each experiment[26, 28-29].

Water absorption is the ability of flour to absorb water. Moisture content, particle size, and differences in chemical content affect the water absorption [30](Rufaizah, 2011). The drier the flour could result in the higher its water absorption ability. This is supported by study of Pumpkin, Giant, & Red which shows that the highest water absorption value is found in the highest microwave power level due to the higher microwave power used at the same heating time will produce drier flour compared to lower power level.

The bulk density of powders is defined as the mass of particles that occupy a unit volume of the container. Bulk density is an important psychological property of preprocessed flour because it plays an important role in storage, marketing, and transportation [31]. Based on research from using pumpkin, edamame, and giant ginger samples [26-28] shows that the bulk density with the highest value is found in the highest power treatment, each consisting of 720 Watt, 722 Watt, and 723 Watt.

Table 3. Use of microwave drying in the process of making flour for some food ingredients

No	Sample	Power (Watt)	Drying rate	Moisture content (%)	Efficiency (%)	Source
1	Peanuts	450	113.93 g/h	12.075	98.585	[24]
		675	168.12 g/h	15.225	97.541	
		900	225.18 g/h	13.935	98.870	
2	Potato	100	0.18 kg/s	5	-	[25]
		160	0.28 kg/s	4.9	-	
		240	0.36 kg/s	4.8	-	

However, based on research bulk density red ginger at 630 Watt is 0.01 Watt lower than the bulk density at power 340 Watt and 525 Watt, both of which have a bulk density value of 0.43 [29].

Oil Absorption shows the amount of oil that can be absorbed by food ingredients. Oil absorption is related to air absorption and protein structure which is a minor component composed of lipids and polysaccharides [32]. Protein in powder form with small particle size and low density absorbs more oil than high-density protein, this is in accordance with the results of research on giant edamame and ginger [27-28], where the highest bulk density of 0.43 has the lowest oil absorption value, which is 2.03, and bulk density of 0.355 on giant ginger has an oil value absorption of 1,095.

2. CONCLUSION

Microwave heating is considered to be more energy efficient than conventional heating because heat is generated in food. Drying efficiency using microwave drying reaches 98.87%. The high frequencies used in microwaves allow fast energy transfer and high heating rates thus preserving the nutrient and vitamin content as well as the taste, sensory characteristics, and colour of food Setting the drying speed can be controlled by varying the power used. The higher the power used, the faster the drying process will cause electricity costs to be more expensive. The results obtained are proportional to the costs incurred. Drying using microwave drying is relatively more expensive than drying using an oven.

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