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Application of microwaves for drying of durian chips

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ABSTRACT

In this study, alternative processes, i.e. microwave vacuum (MWVC) drying and combined microwave-hot air (MWHA) drying, were evaluated and compared with hot air (HA) drying with regard to producing un-oily crispy durian chips. Fresh durian chips of the Mon Thong variety with an initial moisture content of 197.7–213.9% dry basis (d.b.) were dried by MWVC to a final moisture content of 3.5% (d.b.) under microwave power of 150, 200 and 250 W and a pressure of 10 and 30 kPa. The same microwave powers as for the MWVC process were used in MWHA drying combined with a drying temperature of 65 °C, air velocity of 0.3 m/s and 80% air recycled, as used in the HA drying. The quality of the dried durian chips was considered in terms of colour, percentage of shrinkage, texture and microstructure. The energy utilization of the drying system was evaluated in terms of the specific energy consumption (SEC). The results showed that MWHA drying provided a higher drying rate than MWVC and HA drying. The drying rate increased with an increase in the microwave power and a decrease in pressure, which led to a shorter drying time. However, the microwave power level had more effect on the drying rate than the pressure level. High microwave power also produced dried products with low lightness, shrinkage and hardness values, but more crispy and with large pore sizes. Dried durian chips from the combined microwave techniques had higher lightness and crispness values and more porous structure with larger void area fraction but less shrinkage and hardness than those dried by HA. The combined microwave techniques gave lower specific energy consumption (SEC) than HA drying, and the SEC decreased with an increase in microwave power. The overall preference of dried durian chips from MWHA was higher than that from MWVC but lower than that of commercial fried durian chips.

1. Introduction

Durian, regarded as the King of fruits in South East Asia, is a tropical fruit with a characteristic thorn-covered husk, large size and strong odour. Durian flesh, the edible part of the fruit, is easily deteriorated by microorganisms. This damage leads to a remarkable loss in both the production and price of durian, especially during the harvesting season. This problem can be overcome by processing durian flesh to produce other products such as durian paste, durian ice-cream, freeze dried durian and durian chips. The latter is currently a preferred commercial product which is normally produced by a deep-frying process. However, the oily product from this process may not be preferred by health-conscious customers and becomes rancid after a long period of storage (Jamradloedluk et al., 2007; Bai-Ngew et al., 2011; Suwanchote et al., 2012) due to the effect of lipid oxidation during the preservation process (Prachayawarakorn et al., 2008). To avoid oily products, hot air drying (HA) is proposed as an alternative method (Calín-Sánchez et al., 2011; Raikham et al., 2013). However,

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this method requires a long drying time with low energy efficiency and also deteriorates the product quality (Alibas, 2007; Bondaruk et al., 2007; Nathakaranakule et al., 2010) in terms of nutrients, colour, flavour (Drouzas et al., 1999; Zhang et al., 2006; Reyes et al., 2007; Huang and Zhang, 2012), shrinkage and texture (Bai-Ngew et al., 2011). Product quality can be better maintained by freeze drying and vacuum drying. However, freeze–drying requires high investment and operating costs and thus is only suitable for high value products (Lin et al., 1998; Giri and Prasad, 2007) such as herbs. As for vacuum drying, it has a poor mass transfer rate and leads to a long drying time (Drouzas et al., 1999; Lewicki, 2006; Wang et al., 2013).

Better energy efficiency and dried product quality can be obtained by microwave drying (Dev et al., 2011) which provides a higher drying rate than hot air drying (Reyes et al., 2007). Microwave energy can be directly absorbed by moisture in drying material (Piotrowski et al., 2004; Cui et al., 2006; Bai-Ngew et al., 2011; Puente-Díaz et al., 2013) and lead to heat generation within material by two mechanisms, i.e. dipolar rotation and ionic conduction, caused by altering the electromagnetic field (Alibas, 2007; Clary et al., 2007; Orsat et al., 2007; Varith et al., 2007). The high heating rate of microwaves raises the product temperature rapidly, causing high vapour pressure to develop inside the product (Nahimana and Zhang, 2011), resulting in a very rapid transfer of water to the surface of the product. This phenomenon causes a more porous structure to develop inside the dried product and leads to lower shrinkage, increased crispiness, and lower energy consumption. The downside of microwave drying is its non-uniform electromagnetic field, which causes uneven heating of the drying sample. The penetration of microwaves into the product is also limited by electromagnetic properties of the product and the frequency of the microwave power (Drouzas et al., 1999; Cui et al., 2006; Therdthai and Zhou, 2009; Dev et al., 2011; Huang and Zhang, 2012). Moreover, a high mass transport rate in microwave drying may result in low product quality or undesirable changes in the food texture, leading to some product damage (Zhang et al., 2006). However, to overcome this limitation, microwave heating can be applied in combination with other common drying methods (Lewicki, 2006; Askari et al., 2009; Therdthai and Zhou, 2009; Dev et al., 2011; Huang and Zhang, 2012) such as hot air drying, vacuum drying and fluidized bed drying. A combined microwave-hot air drying (MWHA) technique may be a better alternative way. This method provides a higher drying rate and a better quality of product compared to microwave drying or hot air drying (Chandrasekaran et al., 2013). This is because the hot air helps evaporate the surface moisture that is diffused from the inner layer of the drying product. However, combined microwave and hot air drying is operated at an atmosphere pressure which has a high boiling point for water which may lead to dried products with poor qualities, such as dark colour and deterioration of some important nutrients for heat sensitive materials.

Hence, for better quality of heat sensitive products such as vegetables and fruits, microwave vacuum drying (MWVC) is applied. This method combines the advantages of microwave and vacuum drying (Giri and Prasad, 2007; Wang et al., 2013). Products dried by the microwave vacuum method produce a more porous and uniform structure as compared to those which have undergone hot air drying (Giri and Prasad, 2007; Therdthai and Zhou, 2009; Nahimana and Zhang, 2011). This is due to volumetric pressure developing inside the product from the microwaves (Clary et al., 2005) and the low boiling point of water under vacuum helping to dry the food at a low temperature (Cui et al., 2006).The pros of MWVC are also improving the quality of the dried product, increasing the energy efficiency of the drying processes, enhancing the drying rate (Bondaruk et al., 2007; Clary et al., 2007; Nahimana and Zhang, 2011; Huang et al., 2012; Péré and Rodier, 2002; Cui et al., 2006), and decreasing the creation of hot spots on the surface of the product (Zhang et al., 2007). Therdthai and Zhou (2009) reported a reduction in drying times of mint leaves under microwave vacuum drying by 85–90% compared to hot air drying. The application of MWVC in producing oil-free durian snacks was proposed by Lin et al. (1998). Bai-Ngew et al. (2011) reported that durian chips dried by the microwave vacuum method can reach a fat content some 90% lower than that produced by HA drying. Moreover, the texture and structure are similar to the fried durian chips produced commercially. Low oxygen levels in the MWVC help prevent oxidation (Chandrasekaran et al., 2013) and produce a dried product with more lightness and crispness, but less hardness and shrinkage compared to hot air drying (Drouzas et al., 1999; Nahimana and Zhang, 2011).

Despite the pros of the MWVC, the con of this method is a higher investment compared to MWHA and HA. The objective of this work is therefore to evaluate the drying kinetics and quality of dried durian chips undergoing MWVC and to compare these findings with MWHA and HA. The quality attributes of dried durian chips included colour, shrinkage, texture and microstructure. The energy consumption of each drying process is also compared in terms of total specific energy consumption (SEC).

2. Materials and methods

2.1. Materials

Fresh durian (*Durio zibetbinus* Murr.) of the Mon Thong variety was obtained from a local market. The samples were peeled and the seeds removed from the edible flesh. The initial moisture content of the flesh was approximately 197.7–213.9% dry basis (d.b.), as determined by the AOAC method 934.06 (AOAC, 1995), and its total soluble solid content, measured by a refractometer, was in the range of approximately 14–15 °Brix. The fresh durian flesh was sliced to a thickness of 1.5 mm by a slicing machine. Durian chips (sliced flesh) weighing 61 g were used under each experimental condition.

2.2. Microwave vacuum dryer

The microwave vacuum dryer, shown in Fig. 1, was a modified domestic microwave oven (LG, Model MS2427BM, Thailand) with a capacity of 24 l, power output of 800 W and microwave frequency of 2450 MHz. Durian samples were placed in a vacuum chamber on a two-level tray, which was on a plate connected to a load cell via a rod. Changes in the weight of the durian samples were shown by a weight indicator and recorded by a computer. A power supply to a magnetron was controlled by a microwave power control system. Pressure inside the chamber was reduced by a vacuum pump (Emmecom, Model AL50M50, Italy) connected to a 1.5-kW motor, stabilized by a buffer pressure tank and controlled by a pressure control system. The sample temperature was measured with a precision of ±0.8 °C by a fibre optic sensor (Omega FOBS-2) and recorded on a computer via a fibre optic thermometer (Omega, model FOB104, Omega Engineering, Canada).