

Research Article

Efficacy of Zeolite Adsorption on the Green Tea Production by Fluidized Bed Dryer

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Abstract: Green tea (classified as unfermented tea) gained more attention due to their health benefit. Since green tea included to the heat sensitive product, it required the application of low drying temperature during moisture content removal. In order to avoid the unwanted of metabolic process due to longer drying period, the application of zeolite adsorption for air dehumidification in the fluidized bed drier was investigated. This study focuses on the effect of air flow rate, temperature and zeolite-tea leave ratio on the moisture content and drying time. The longer the drying time, the moisture content of green tea leaves decreases significantly. The fastest decreasing time obtained when applying 0,46 m/sec of air flow rate with 70°C of drying temperature and 25:75 of zeolite-tea leave ratio. Decreasing the drying temperature at 50°C, longer the drying time than drying at 70°C while slower air flow rate (0, 44 m/sec) applied. Modifying the zeolite-tea leave ratio from 25:75 into 75:25, fasten the drying time.

Keywords: Air dehumidification, fluidized bed drier, green tea, moisture content, zeolite adsorption

INTRODUCTION

Tea is the second favorite beverages consumed in the world which produced from the leaves of the plant *Camellia* sp. The differences in the processing of tea leaves, resulted in different types of tea, mainly black tea (78%) and green tea (20%). Recently, green tea (classified as unfermented tea) gained more attention due to their health benefit (Yan *et al.*, 2012; Tang *et al.*, 2009; Nagao *et al.*, 2005). However, there is less investigation on the drying of inactivated tea leaves. Drying of a post harvested leaves is considered as a critical step in the manufacturing to keep the natural of flavor and aroma with minimum deterioration of their natural compounds (Orphanides *et al.*, 2013; Dou *et al.*, 2007).

Fresh leave tea usually contain 75-80% of moisture content and less than 6% of moisture content permitted contain in the dried tea leave in order for preservation. Decreasing the moisture content inhibits the microbial growth and prevent biochemical change during storage, however, loss of its moisture content significantly also may provide volatiles or bioactive compounds loss and/or form new compounds due to oxidation or esterification. These changes may desirable and may be avoided. After the free moisture content has been removed, the continuing exposure of heat to the leaves possibly produced a burnt taste (Temple *et al.*, 2001).

For heat-sensitive products (e.g., food and pharmaceuticals), an additional requirement for quality

retention is low drying temperatures. The drying at low temperature is preferred for drying the volatile compounds to protects against the degradation of the active constituents. Yet, the longer drying period may continue the unwanted metabolic process and affect the final product (Díaz-Maroto *et al.*, 2002; Hossain *et al.*, 2010; Orphanides *et al.*, 2013). Many studies about drying mainly focused on the optimisation of the drying methods (Orphanides *et al.*, 2013; Gazor and Mohsenimanesh, 2010; Atuonwu *et al.*, 2011). Therefore, increasing the efficiency of low temperature drying by zeolite adsorption is an interesting area to explore because it can provide shorter drying time and reduce the degradation of active compounds. Atuonwu *et al.* (2011) stated that energy consumption possibly decrease about 45-55% by applying low temperature drying (50°C) by zeolite adsorption compared to a conventional convective dryer at the same drying temperature. In this case, the capacity of the air to evaporate water from the product at low temperature increased by applying the dehumidicated drying air. As the drier air applied after dehumidification, the higher sensible heat and the latent heat carrying capacity are increased, although it implies more energy need to apply for regeneration. This present study focuses on the aspects of low temperature of fluidized bed drying regarding on the application of zeolite adsorption. The effect of air flow rate, temperature and zeolite-tea leave ratio were evaluated on their drying time.

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MATERIALS AND METHODS

Materials: Green tea was obtained from local tea factory of Rumpun Sari Medini. Zeolite and sodium hydroxide was bought from Bratachem (Semarang, Indonesia).

Drying of green tea leave: The tea leaves were dried in the fluidized bed drier equipped with a zeolite adsorber. The fluidized bed drier was composed of a cylindrical chamber with an 300 mm ID and 1200 mm height (Fig. 1). the humidity of air was adsorbed by zeolite before drying and the zeolite was placed on a adsorber box, sized 30×30×15 cm. In addition, the zeolite also placed on the drying chamber with ratio of zeolite and green tea at 75:25 and 25:75. The air flow rates were 0.44; 0.46 and 0.50 m/sec, inlet drying temperatures were 50 and 70°C and the outlet air temperatures were decreased with the decreasing of air flow rates, in the range of 31-39°C.

Zeolite activation: Before drying, the zeolite need to be activated to optimized the adsorption of the humidity in the air and the vaporized moisture content of solid. Initially, the diameter of zeolite was reduced up to 2 mm. Then, the zeolite was heated on a furnace at 400°C for 4 h in order to evaporate any water trapped in the pores of the zeolite. The following stage was removing the impurities stack on the surface of the pores by using sodium hydroxide. Twenty five grams of zeolite was treated on 150 mL of 1N NaOH at 70°C for 2 h and then dried in the oven at 110°C for 4 h. The zeolite was cooled in a desiccator before using.

Water content analysis: The water content of green tea leaves was determined by the gravimetric method. Green tea leaves (120 g) was placed in a fluidized bed dryer and heated at 50 and 70°C. The samples were taken every 15 min and weighed in an analytical balance (OHAUS Pioneer TM PA2102C, Ohaus

Instruments Co., Ltd., Shanghai, China) until constant weight can be obtained. The value of water content was determined using Eq. (1), as follows:

$$WC = \frac{w_t - w_n}{w_t} \quad (1)$$

where,

WC = The weight of water in the tea leave

w_t = The weight of tea leave at t minutes

w_n = The weight of tea leave at constant weight

RESULTS AND DISCUSSION

Effect of air flow rate on the drying rate: Drying of green tea leave starts from the initial moisture content solid entering the dryer equipment and finishes when there is no longer change of the solid weight. This condition shows that the final moisture content have approached the equilibrium of moisture content. During drying, the heat transferred from the internal of tea leave by conduction and following the molecular convection to the surface of tea leave. This heat is used to evaporate the water inside the tea leave. Therefore, the water can be migrate from leave into the air and brought to the outside of the drying chamber. Figure 2 presents the effect of air flow rates on the drying rates. It shows that higher air flow rate provide higher drying rate at the same time in the earlier time of drying. However, at the end of drying, the drying rate shows in the constant range of 35±15 g/h.

In the early stage of drying, the evaporation of moisture content of solid takes place easily and smooth because there is large differences between the tea and air temperatures. The temperature of tea leave slowly increased and get faster, until it reached the air temperature. The longer the drying time, the removal of

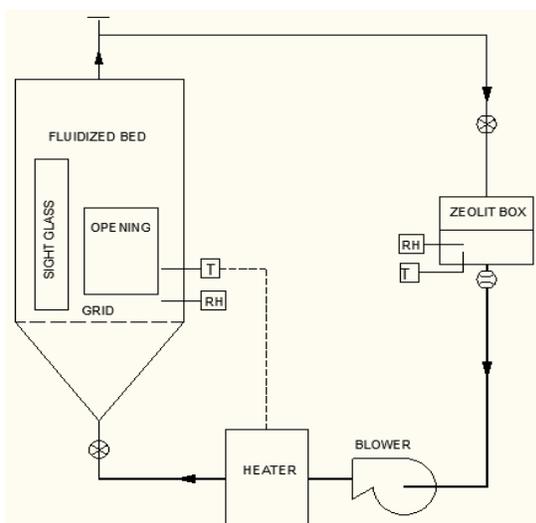


Fig. 1: Drying equipment schematic

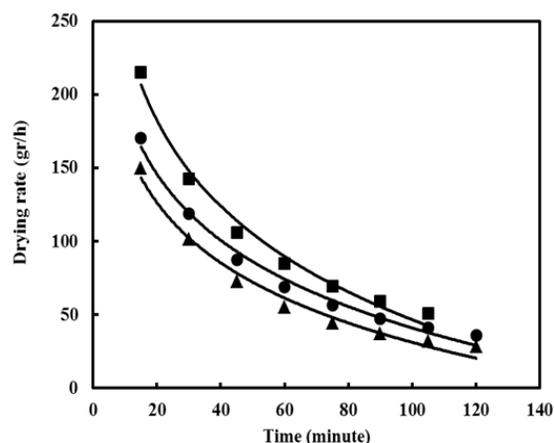


Fig. 2: Effect of air flow rate on the drying rate at 70°C of drying temperature with zeolite-tea leave ratio of 25:75. Air flow rate: ●: 0.44 m/sec; ▲: 0.46 m/sec; ■: 0.5 m/sec

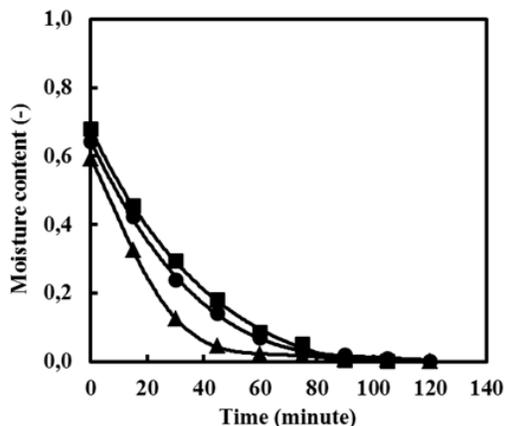


Fig. 3: Effect of air flow rate on the moisture content with zeolite-tea leave ratio of 25:75 and 70°C of drying temperature. Air flow rate: ●: 0.44 m/sec; ▲: 0.46 m/sec; ■: 0.5 m/sec

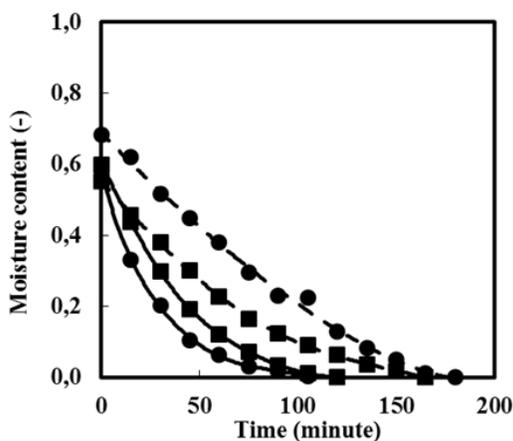


Fig. 4: Effect of air flow rate and temperature on the moisture content with zeolite-tea leave ratio of 25:75. Air flow rate: ●: 0.44 m/sec; ■: 0.5 m/sec; Temperature: 50°C (dash line); 70°C: (solid line)

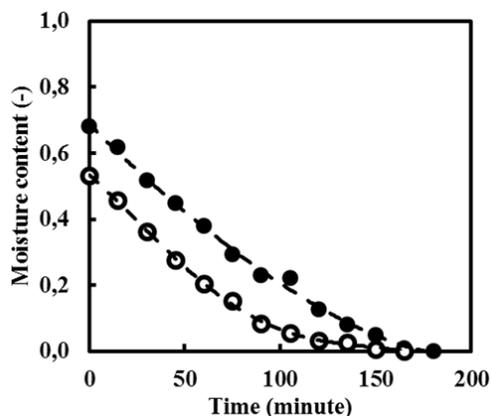


Fig. 5: Effect of zeolite-tea leave ratio on the moisture content at 50°C of drying temperature and 0.44 m/sec of air flow rate. Zeolite-tea leave ratio: ●: 25:75; ○: 75:25

water from the tea leave decrease due to the decreasing of drying rate. The drying rate decrease because the temperature difference between tea and air were very narrow and even approximately constant. Therefore, the driving force of water to evaporate also decrease significantly.

When the drying rate decrease, the calor energy contained in the air dryer was used to evaporate the bound water in the cell cavity. This bound water are going to flow through the capillary to reach the surface of the leave due to the difference of water vapor pressure.

Effect of air flow rate and temperature on the moisture rate: Figure 3 and 4 shows the effect of air flow rates and temperatures on the moisture content regarding to the drying time. The longer the drying time, the moisture content of tea leaves decreases significantly. Because there will be more calor transferred into the material, then there will be more moisture content moved from the inside of tea leave into the drying chamber. The fastest decreasing time obtained when applying 0.46 m/sec of air flow rate with 70°C of drying temperature and 25:75 of zeolite-tea leave ratio. While, applying air flow rate of 0.44 m/sec fasten the drying time than applying air flow rate of 0.5 m/sec, inconsiderable. Decreasing the drying temperature at 50°C, longer the drying time than drying at 70°C. However, applying the air flow rate of 0.44 m/sec longer the drying time comparing to apply 0.5 m/sec of air flow rate at 50°C of drying temperature. This result is in agreement with the previous result obtained by Gazor and Mohsenimanesh (2010) that the increasing of drying temperature decreased the drying time of canola in the fluidised bed dryer.

Effect of zeolite-tea leave ratio on the moisture rate: Figure 5 shows the effect of zeolite-tea leave ratio on the drying time and moisture content. Modifying the zeolite-tea leave ratio from 25:75 into 75:25, fasten the drying time. This condition possibly occur due to the higher adsorption of water vapor release from the tea leave into the zeolite. The faster the adsorption of water vapor, the moisture content in the air will be reduced faster, therefore the water will be separated from the tea leave easily. This result is in agreement with the previous result that adsorption dryers are more energy efficient than conventional dryers at low drying temperatures. Although extra investment costs would be incurred, the increasing energy costs should make for low payback periods while satisfying stringent environmental regulations and of course, product quality demands (Atuonwu *et al.*, 2011).

CONCLUSION

The longer the drying time, the moisture content of green tea leaves decreases significantly. The fastest

decreasing time obtained when applying 0.46 m/sec of air flow rate with 70°C of drying temperature and 25:75 of zeolite-tea leave ratio. While, applying air flow rate of 0.44 m/sec fasten the drying time than applying air flow rate of 0.5 m/sec, inconsiderable. Decreasing the drying temperature at 50°C, longer the drying time than drying at 70°C. However, applying the air flow rate of 0.44 m/sec longer the drying time comparing to apply 0.5 m/sec of air flow rate at 50°C of drying temperature. Modifying the zeolite-tea leave ratio from 25:75 into 75:25, fasten the drying time.

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REFERENCES

- Atuonwu, J.C., G.V. Straten, H.C.V. Deventer and A.J.B.V. Boxtel, 2011. Optimizing energy efficiency in low temperature drying by zeolite adsorption and process integration. *Chem. Eng. Trans.*, 25: 111-116.
- Díaz-Maroto, M.C., M.S. Pérez-Coello and M.D. Cabezudo, 2002. Effect of different drying methods on the volatile components of parsley (*Petroselinum crispum* L.). *Eur. Food Res. Technol.*, 215: 227-230.
- Dou, J., V.S.Y. Lee, J.T.S. Tzen and M.R. Lee, 2007. Identification and comparison of phenolic compounds in the preparation of oolong tea manufactured by semifermentation and drying processes. *J. Agr. Food Chem.*, 55: 7462-7468.
- Gazor, H.R. and A. Mohsenimanesh, 2010. Modelling the drying kinetics of canola in fluidised bed dryer. *Czech J. Food Sci.*, 28(6): 531-537.
- Hossain, M.B., C. Barry-Ryan, A.B. Martin-Diana and N.P. Brunton, 2010. Effect of drying method on the antioxidant capacity of six Lamiaceae herbs. *Food Chem.*, 123: 85-91.
- Nagao, T., Y. Komine, S. Soga, S. Meguro, T. Hase, Y. Tanaka and I. Tokimitsu, 2005. Ingestion of a tea rich in catechins leads to a reduction in body fat and malondialdehyde-modified LDL in men. *Am. J. Clin. Nutr.*, 81: 122-129.
- Orphanides, A., V. Goulas and V. Gekas, 2013. Effect of drying method on the phenolic content and antioxidant capacity of spearmint. *Czech J. Food Sci.*, 31(5): 509-513.
- Tang, N., Y. Wu, B. Zhou, B. Wang and R. Yu, 2009. Green tea, black tea consumption and risk of lung cancer: A meta-analysis. *Lung Cancer*, 65: 274-283.
- Temple, S.J., C.M. Temple, A.J.B.V. Boxtel and M.N. Clifford, 2001. The effect of drying on black tea quality. *J. Sci. Food Agr.*, 81: 764-772.
- Yan, J., Y. Zhao, S. Suo and B. Zhao, 2012. Green tea catechins ameliorate adipose insulin resistance by improving oxidative stress. *Free Radical Bio. Med.*, 52: 1648-1657.