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DRYING KINETICS OF DIFFERENT FRUIT POMACES IN A HEAT PUMP DRYER

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Abstract

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Apple, blueberry (wild and cultivated), raspberry, chokeberry, and morello pomaces are dried at temperature 45°C to equilibrium moisture content in a laboratory pilot heat pump dryer. The kinetics of drying process of the fruit pomaces is investigated. The studied pomaces except that of raspberry showed two drying periods: a constant-rate drying period and falling rate-drying period. The drying time is the longest in the cultivated blueberry pomace. Dried pomaces are raw material for use in functional foods with a defined content of bioactive substances and antioxidant activity.

Key words: drying, kinetics, pomaces, fruit, heat pump

Abbreviationss: U – moisture content, U_p – equilibrium moisture content, τ – drying time, N – drying rate at a first process period, K – drying coefficient, R^2 – coefficient of determination

Introduction

Drying of foods is a major operation in the food industry, consuming large quantities of energy. Dried foods are stable under ambient conditions, easy to handle, possess extended storage life and can be easily incorporated during food formulation and preparation. Drying is a complex process and involves simultaneous mass and heat transfer accompanied by physical and structural changes (Jayaraman and Gupta, 2006). These changes influence drying characteristics of the materials. The quality of dried product depends on the quality of raw material, and changes occurring during drying.

Heat pump drying is finding increasing applications in food industry for drying nuts, fruit, vegetables, herbs and fish products in many countries (Rahman et al., 1997; Guochen et al., 2009; Castell-Palou and Simal, 2011). Heat pumps have been known to be energy efficient and when using in drying operations. Unlike conventional air dryers, a heat-pump dryer is more cost-effective as it can extract and re-utilize the heat of the circulating air in a closed cycle and the latent energy of the water vapor obtained from the drying of a product. Meanwhile, a heat-pump dryer is capable of lower drying temperature therefore, it is benefit for high quality products drying at relatively low cost (Guochen et al., 2009).

Knowledge of drying kinetics is important in the design, simulation and optimization of drying processes. Drying curves are usually expressed by empirical models defining drying rate constants based on first order kinetics built by regression using the experimental data and depend on the product shapes (Wang et al., 2007; Vega-Gálvez et al., 2009; Kumar et al., 2011). Empirical models are commonly used for various food materials due to their simpler approach. However problems in accuracy, limits the applications of empirical models. Some limitations of empirical models could be reduced by using semi-empirical models based on heat and mass transfer of the drying operation (Jayaraman & Gupta, 2006; Seiiedlou et al., 2010).

In recent years there is a growing interest in the evaluation and use of the waste generated by the food industry. The pomaces generated by the juice producing industry consist of pressed skins, disrupted cells from the fruit pulp, seeds and stems. Pressed apple skin is characterized by a high content of polyphenols. The apple pomace has higher antioxidant activity in comparison with the processed apple juice (Wolfe et al., 2002; D`Abrosca et al., 2007). A similar trend has been

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established for pomace and juice from chokeberries (Oszmiacski & Wojdylo, 2005).

The objective of this study is to investigate the drying kinetics of different fruit pomaces in a heat pump dryer.

Materials and Methods

Apple, blueberry (wild and cultivated), raspberry, chokeberry, and morello pomaces are subject of study. The pomace is a by-product obtained during juice processing. Apples (Granny Smith variety) are refrigerated and stored until the juice processing. The fruit pomaces are frozen.

The studied samples have weight 0.800 kg and dried at temperature 45°C (to equilibrium moisture content) and air velocity of 1.5 $m.s^{-1}$ in a laboratory pilot heat pump dryer. The initial and final moisture contents of the fruit pomaces are shown in Table 1.

Investigation of drying process kinetics

The drying process curves are obtained based on experimental data:

$$U = f(\tau) \quad (1)$$

where, U is the moisture content (kgH_2O/kg dry matter) and τ is the drying time (min).

The equations for drying rate are derived from the drying process curves applying graphic differentiation:

$$dU / d\tau = f(U) \quad (2)$$

The drying rate at the first process period is described by the equation:

$$- dU / d\tau = N = const \quad (3)$$

where, N is the drying rate at the first process period (min^{-1}).

Approximating the drying curve at the second process period to a straight line the drying rate is described by the equation:

$$- dU / d\tau = K (U - U_e) \quad (4)$$

where, K is a drying coefficient (min^{-1}).

Table 1
Moisture content (U, $g.kg^{-1}$) of fruit pomaces

Fruit pomaces	Raw	Dried
Sample 1: Apple pomace	818.3	50.3
Sample 2: Morello pomace	799.3	69.4
Sample 3: Wild blueberry pomace	647.9	61.5
Sample 4: Cultivated blueberry pomace	734.8	45.9
Sample 5: Raspberry pomace	779.2	97.5
Sample 6: Chokeberry pomace	731.9	46.2

The coefficient of determination (R^2) is used as criteria for verifying the goodness of fit (Ertekin and Yaldiz, 2004).

Results and Discussion

The experimental drying curves of pomaces from select fruit raw materials are shown in Figure 1. It shows the changes in the moisture content of the products as a function of the time at constant drying air temperature and velocity. It is apparent that the changes in the moisture content of apple and raspberry pomaces in time are the largest and least, respectively.

The drying rate decreases continuously with increasing drying time or decreasing moisture content. At the beginning of the drying process, the drying rate is very high, and the drying rate is continued to decrease as the moisture content approaches the equilibrium moisture content. Similar results are presented for red pepper (Akpinar et al., 2003), onion slices (Sarsavadia et al., 1999), etc.

Apple, wild blueberry, and chokeberry pomaces exhibits two drying periods: a constant-rate drying period and falling rate-drying period. These periods are less apparent on drying of cultivated blueberries and morello pomaces. A constant minimum drying rate is observed when drying raspberry pomace in view of the fact that initial moisture content of the material is much lower than that of other fruit pomaces (200 $g.kg^{-1}$).

The drying of apple and morello pomaces is proceeding at high speed. These pomaces have approximately twice as high initial moisture content as that of blueberries, raspberry, and chokeberry but the drying process ends in approximately the same time of all.

The drying coefficient is an important parameter characterizing the intensity of moisture exchange. It is necessary measure in the design of dryers.

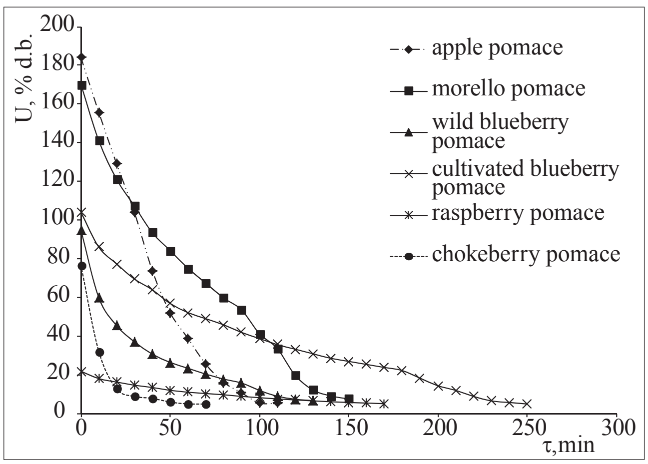

Fig. 1. Experimental drying curves of fruit pomaces

Table 2
Drying rate (N, min^{-1}) and drying coefficient (K, min^{-1}) of fruit pomaces

Sample №	N, min^{-1}	R^2	K, min^{-1}	R^2
Sample 1	2.6599	0.9988	0.0238	0.9834
Sample 2	1.1611	0.9472	0.0344	0.9580
Sample 3	1.8799	0.9039	0.0166	0.8587
Sample 4	0.7411	0.9429	0.0082	0.7894
Sample 5	0.8781	0.9796	0.0157	0.9580
Sample 6	3.2036	0.9508	0.0283	0.9487

The values of drying rate at the first process period and drying coefficients at the second process period for the fruit pomaces are shown in Table 2. Data is demonstrated that the obtained kinetic constants correlate very well with the experimental data, as the coefficients of determination for all samples are high ($R^2 > 0.75$). The values of drying rate at the first process period are ranged from 0.74 (cultivated blueberry pomace) to 3.20 min^{-1} (chokeberry pomace). The drying coefficient at the second process period is the highest in the morello pomace (0.0344 min^{-1}). It is the lowest in the cultivated blueberry pomace (0.0082 min^{-1}) and in which the drying time is respectively the longest.

Differences in drying time respectively the drying rate, most probably due to different structure and composition as well as considerable differences in initial moisture content of the fruit pomaces.

Conclusions

The kinetics of drying process of fruit pomaces in heat pump dryer is investigated. The studied pomaces except that of raspberry showed two drying periods: a constant-rate drying period and falling rate-drying period.

Differences in drying time respectively the drying rate, most probably due to different structure and composition as well as considerable differences in initial moisture content of the fruit pomaces.

Dried pomaces are raw material for use in functional foods with a defined content of bioactive substances and antioxidant activity.

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