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MODELING THE THIN-LAYER DRYING OF BEE POLLEN

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Abstract: *Bee pollen provides proteins, lipids, vitamins and minerals in bee nutrition. Bee pollen also has a significant nutritive value as a supplement to human nutrition. Fresh bee pollen must be dried in order to reduce water activity for the development of various microorganisms. Convective drying is common method for bee pollen dehydration. In this paper, several drying temperatures (40, 50 and 60◦C) were investigated during the 3 hours convective hot air drying. Several drying models used in literature were fitted to experimentally obtained drying curves in order to find most suitable one. The best fit was achieved with Two-term (for 60◦C) and Hii et al. (for 40◦C and 50◦C) drying models. The coefficient of determination was the primary criterion for selecting the best model to describe the drying curves.*

Key words: *Bee pollen, convective drying, drying models.*

1. INTRODUCTION

Bees voluntarily collect pollen and nectar from different varieties of plants. A part of oilseed rape pollen is later placed on the market for human consumption while the rest is used for making the brood food. Pollen is the main source of protein, fat, vitamins and minerals in bee nutrition (Nedić et al. 2003). The number of broods in the hive and the life expectancy of worker bees largely depend on the amount of pollen available in the food (Jevtić et al., 2009; Di Pasquale et al., 2016). The chemical composition of pollen varies depending on the plant from which it was collected and the method of storage and storage (Campos, 1997; Campos et al., 2010). In addition to its exceptional benefits for bees, pollen is also used in human nutrition and in apitherapy. Due to its valuable nutrients and biological ingredients, pollen is used as a natural dietary supplement. Pollen brought by bees is collected in the raw state by placing pollen traps at the entrance to the apiary. Water content has a crucial impact on maintaining pollen quality, varying in the range of 20 to 30 g per 100 g (Bogdanov 2004). Good beekeeping practice instructs beekeepers to collect pollen daily and then dry it at a temperature of 40oC. This avoids the occurrence of pollen fermentation, mold growth and the development of mycotoxins and a decrease in vitamin C content due to the potential decomposition of ascorbic acid in the aquatic environment (Petrović et al., 2014; Kostić, 2015). In dry pollen, the water content should be in the range of 4 to 8% (Mustaers, 2005; Official Gazette of the Republic of Serbia, 101/2015). This research is about examinating drying kinetics of bee pollen for several common drying regimes during hot air drying. Appropriate drying moddels were compared in order to find most suitable one for drying kinetics description.

2. MATERIAL AND METHOD

2.1 Drying material preparation

For the purpose of pollen drying a fresh sample of pollen (Fig. 1) was used in the experiments collected with pollen traps placed at the entrance of beehive on oilseed rape melliferous pasture (*Brassica napus L.*). Up to the moment of drying a fresh oilseed rape pollen has been vacuum packed and stored in a deep-freezer.

Figure 1. Fresh pollen sample.

The oven-dry method was used as one of the commonest methods of determining sample moisture content. It consists of taking a pollen sample, determining its exact weight, and dry the sample in an oven at a temperature of 105◦C for 24 hours, then weighing the sample and determining the moisture loss by subtracting the oven-dry weight from the moist weight. (Shreve et al., 2006) The obtained resultes showed 23.48% of water content at dry basis in fresh pollen sample.

2.2 Drying experiment and apparatus

Moisture analyzers (MA) type BTS110D was used for fast and precise moisture determination of a sample based on mass loss during heating process. Moisture analyzer has 2x100W halogen radiators for the material heating. Weigth measurement precision was 0.1%. Material drying temperatures were 40, 50 and 60◦C within drying time of aproxx. 3 hours.

2.3 Drying models

The change of moisture ratio (MR) was monitoring in time in order to describe drying process. The experimental data were fitted to the four suitable thin layer drying models given in Table 1.

Table 1. Mathematical models applied to the drying curves

Model no	Model name	Model eqation
1	Newton	$MR=exp(-a\cdot\tau)$
2	Page	$MR=a\ exp(-b\cdot\ \tau^{c})$
3	Two-term	$MR=\ a\cdot exp(-b\cdot\ \tau)+\ c\cdot exp(-d\ \cdot\ \tau)$
4	Hii et al.	$MR=\ a\ exp(-b\cdot\ \tau^{c})\ +\ d\ exp(-e\cdot\ \tau^{f})$

The moisture ratio was calculated from equation (Eq.1)

$$MR = \frac{M - M_e}{M_o - M_e} \tag{1}$$

where MR is the dimensionless moisture ratio, M, M_e and M_o are the moisture ratios at any time, the equilibrium moisture content and the initial moisture content in % wet basis respectively (Crank, 1975; Akpinar, 2003; Aghbashlo, 2009).

Non-linear regression analysis was performed for the drying data by using Table Curve 2D (Systat Software Inc. 2002) software. The coefficient of determination (R^2), refer to (Eq.2), was the primary criterion for selecting the best model to describe the drying curves. The higher the values of R^2, the better the goodness of the fit.

$$R^2 = 1 - \left[\frac{\sum_{i=1}^{N} \left(MR_{pre.i} - MR_{exp.i} \right)^2}{\sum_{i=1}^{N} \left(\overline{MR}_{pre.i} - MR_{exp.i} \right)^2} \right] \tag{2}$$

where $MR_{exp,i}$ is the *i*-th experimentally observed moisture ratio, $MR_{pre,i}$ is the *i*-th predicted moisture ratio and N the number of observations.

3. DISCUSSION ON THE RESULTS

Bee pollen samples were dried in thin layer without significant overlapping of the pollen layers (Fig. 1). All experimental measurements were performed with the initial mass of the pollen between 10 and 30 grams for one experiment. The results were obtained as average from several measurements per experimental setup. Moisture content of the material during time (Fig. 2) is shown by various temperatures. Moisture analyzer was used for moisture determination of a sample at 40, 50 and 60°C temperatures within approx. 3 hours period. Similar drying parameters were used by other authors (Ayla et al. 2018; Kanar and Mazi, 2019).

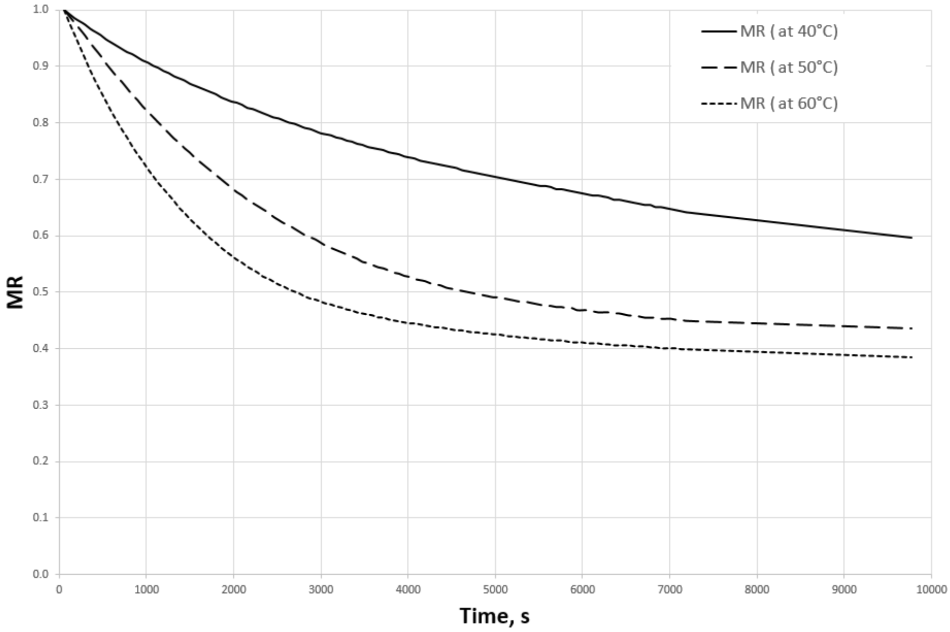

Figure 2. Experimental moisture ratio (MR) vs. drying time

Results showed that moisture content decreased significantly during the first hour and decreased slowly afterwards. The increase in drying air temperature speeded up the drying process. Drying temperature of 40°C, that is usually used in commercial bee pollen dryers, caused the lowest moisture losses of the material, i.e. longest drying process. Consequently, the temperatures of 50°C and 60°C provided significantly higher moisture losses and faster drying, especially during the first hour. However, these temperatures cannot be applied commercially because of the negative effect on bee pollen chemistry.

Table 2. Models statistical analyses results of drying of bee pollen

Modeli		Temperatura sušenja, ◦C		
		40	50	60
Newton	*a*	7.00E-05	0.000144923	0.000188471
	R^2	0.939450177	0.880916352	0.652645816
Page	*a*	1.041089474	1.17398675	1.547991912
	b	0.001938031	0.01263654	0.102953381
	c	0.62229691	0.494719869	0.296557935
	R^2	0.998690294	0.985763468	0.975768703
Two-term	*a*	0.7729104	0.347861731	0.425651713
	b	2.84E-05	-2.11E-05	9.38E-06
	c	0.231420855	0.67658605	0.605087952
	d	0.000387506	0.000375882	0.000706727
	R^2	0.999891682	0.999760904	**0.999832886**
Hii et al.	*a*	0.294024002	0.511453175	0.674503839
	b	0.000564436	0.000122151	0.001172592
	c	0.921854898	1.164404222	0.928837485
	d	0.715087533	0.513393603	0.397758832
	e	4.76E-05	0.007832316	1.578265722
	f	0.918535311	0.336645546	-0.64823896
	R^2	**0.999923003**	**0.999967006**	0.999700354

The influence of drying air properties on drying process was compared to the four commonly used literature models. The regression analysis, refer to Table 2, showed that the solutions of Hii et al. model provided satisfying match with the results obtained for the drying temperatures of 40°C and 50°C. The values of R2 in Hii et al. model were in range 0.999923003 and 0.999967006 respectively. For the temperatures of 60°C, best fit was achieved with Two-term model. The value of R2 in Two-term model models was 0.999832886.

4. CONCLUSION

The influence of drying air properties on drying kinetics were analyzed in this paper. Conventional sample heating was performed at drying temperatures of 40, 50 and 60°C. The higher moisture loss was achieved with drying temperature of 60°C, especially at the beginning of the drying process, i.e. first hour period. For this drying temperature regime, Two-term model provided best fit with experimental results, with highest R^2 value of 0.999832886. However, the drying model provided by Hii et al. can be widely used for the description of drying process at lower drying temperatures.

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