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THE INFLUENCE OF TEMPERATURE AND DOLOMITE ADDITION ON THE DRYING KINETICS OF SUGAR BEET PULP (BETA VULGARIS L.)

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Abstract. The aim of this study is to investigate the hot air drying kinetics of sugar beet pulp, without and with dolomite addition, in order to establish the drying mechanism. The influence of temperature and dolomite addition on the drying rates is observed. The drying constant rates and the activation energies for different working conditions are determined. The obtained results show that the drying took place in falling rate period. The obtained activation energy values correspond to the mechanism mass transfer at low amount of dolomite addition and combined mechanism, mass transformation (evaporation process) – mass transfer, at higher amount.

Keywords: *sugar beet pulp, hot air drying, dolomite, constant rate, activation energy*

INTRODUCTION

Sugar beet processing operations comprise several steps, including extraction of sucrose by diffusion, juice purification, evaporation, crystallization, dried-pulp manufacture, and sugar recovery from molasses [1, 2]. The extraction of sucrose by hot water diffusion from the plant "beta vulgaris L." is an important production operation in the sugar industry. The extraction products are: a) the liquid phase containing all water-soluble components called raw juice and b) the solid phase, the wet pulp, containing the insoluble components of the sugar beet.

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The raw juice proceeds to the juice purification operations in order to obtain sugar. Byproducts of sugar beet processing include the pulp and the molasses. These products may be used separately or combined. They may be dried or otherwise processed in a variety of ways to produce a range of high-quality animal feeds whose nutritional value is close to that of the hay [2, 3].

The sugar-enriched water from the diffusion contains 10 -15 % sugar. The insoluble compounds of the beet, which remain after complete aqueous extraction of the soluble constituents under industrial processing conditions, called "marc", is sent to the dried-pulp manufacture operations. The sugar beet pulp is made of: hemicelluloses (26%), pectin (24%), cellulose (23%), coagulated protein substances (9%), sucrose (6%), lignin (4.5%), soluble mineral matter (4.0%), insoluble mineral matter (3.0%) and fat (0.5%) [4].

Considering the nature of the compounds entering this byproduct, as well as the large amount resulting from diffusion extraction, 350-400 kg/tone of sugar product, sugar beet pulp is also an important source of raw material for the production of animal food, adhesives based on of pectin glue with properties similar to the Arabic gum or dextrin solutions [2].

The use of sugar beet pulp as animal feed shows two disadvantages: the high volume and high moisture content 80-90% [4]. These lacks lead to high transport costs and limited storage period due to deterioration by fermentation and molding. For conserving sugar beet pulp are used silage and drying [5]. The reduction of moisture content by drying will decrease or inhibit the microbial growth in the storage period.

In addition, the nutritional value of sugar beet pulp can be enhanced by the addition of micro- and macro-minerals and other nutrients, supplements which maintain a good health and increase milk production. Animal feeding practice uses numerous mineral supplements to provide calcium. Limestone (calcium carbonate) is the most widely used [6]. The effects of calcium magnesium carbonate (dolomite) supplementation on performance of cows dairy production and on the diet and metabolism, was already studied [7, 8]. With the addition of dolomite ($CaCO_3$, $MgCO_3$), calcium and magnesium pectinates are formed, and thus Ca^{2+} and Mg^{2+} ions are easily assimilated [2].

The drying kinetics of the sugar beet pulp, without and with dolomite ($CaCO_3$–$MgCO_3$) addition, is carried out in the present study. Different authors investigated hot air drying of sugar beet pulp, but not in the presence of dolomite. The most of them tried to find the proper model to describe or simulate the drying process of sugar beet pulp [9, 10]. In the present research, the influence of temperature and the addition of dolomite on the drying rate was observed and analyzed. Constant rates and activation energies for different working conditions were calculated in order to establish the drying mechanism.

RESULTS AND DISSCUSION

The drying rates (kg/kg.h) obtained as a function of moisture content, are calculated by the relation (1) [11]:

$$D_R = \frac{M_i - M_{i-1}}{\Delta t} \quad (1)$$

where M_i is the moisture content dry basis (kg water/kg dried matter) at the moment t_i.

Figure 1 shows the influence of temperature on the drying rate for two cases: a. without dolomite and b. with 5.0 grams dolomite.

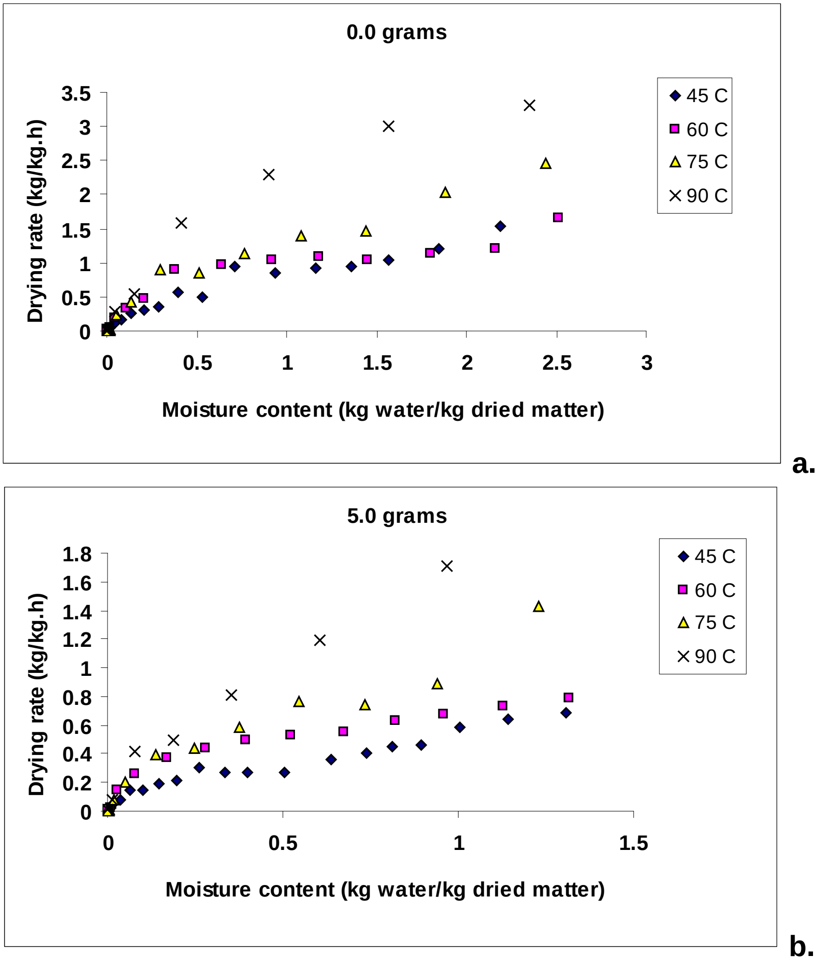


Figure 1. Influence of temperature on drying rates

It can be observed that in both cases dolomite-free sample (Figure 1.a) and dolomite sample (Figure 1.b), the drying rates decrease over the whole range of material moisture content. The continuously decreasing of the drying rate with the moisture content indicates the specific curve of falling rate period [12]. This behavior could indicate that the moisture of the material is bound by different binding energy and/or the moisture transfer within the solid porous material is made by different mechanism [13].

Falling rate period can be observed also when the influence of dolomite addition for the same temperature (e.g., at 75 ^{0}C) is followed (Figure 2).

The analysis of the drying curves shows that the temperature has a positive strongly influence on drying rates (Figure 1.a, 1.b) comparative to the dolomite addition which has a negligible influence on drying rates (Figure 2).

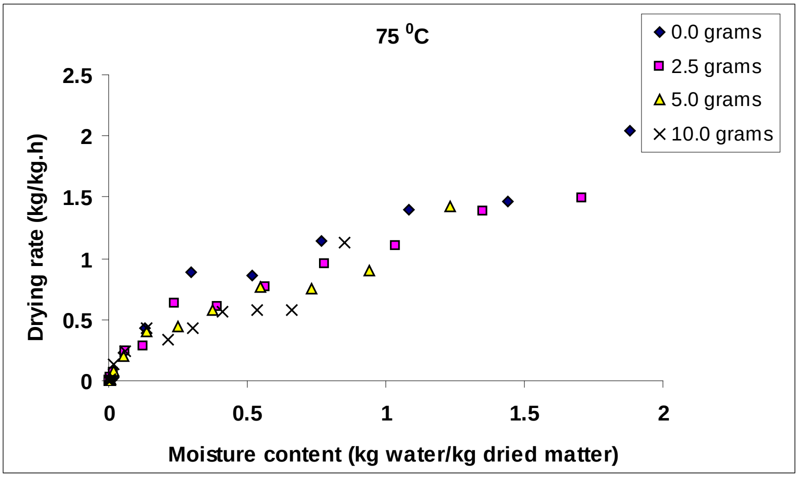


Figure 2. Influence of dolomite addition on drying rates

This behavior is confirmed for all analyzed cases at temperatures lower than 75 ^{0}C, by the variation of drying degree, η (Figure 3). Determinations have been made for all working temperatures and for all dolomite additions specified in the experimental section.

It can be observed that at a drying time of 50 minutes, the drying degree value is two times higher at 90 ^{0}C than at 45 ^{0}C. At 100 minutes drying degree reaches unit value, η=1, in both cases, with and without dolomite addition.

Experimental data on the drying degree versus time were further used to determine the constant drying rates, k, calculated by next equations [14]:

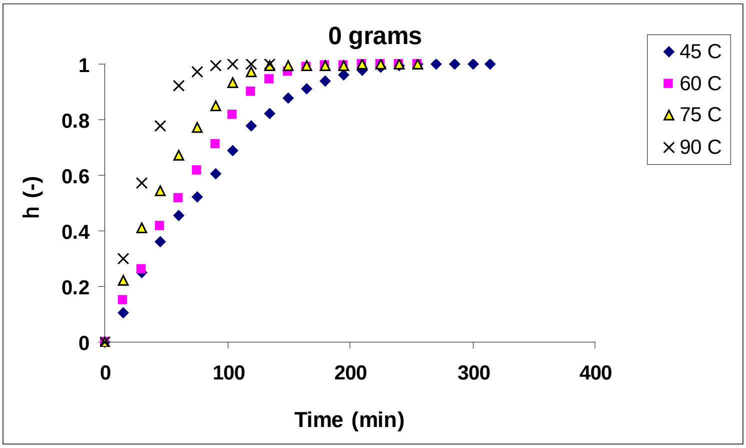
$$-\frac{dM}{dt} = k \cdot M \tag{2}$$

$$M = M_0(1-\eta) \tag{3}$$

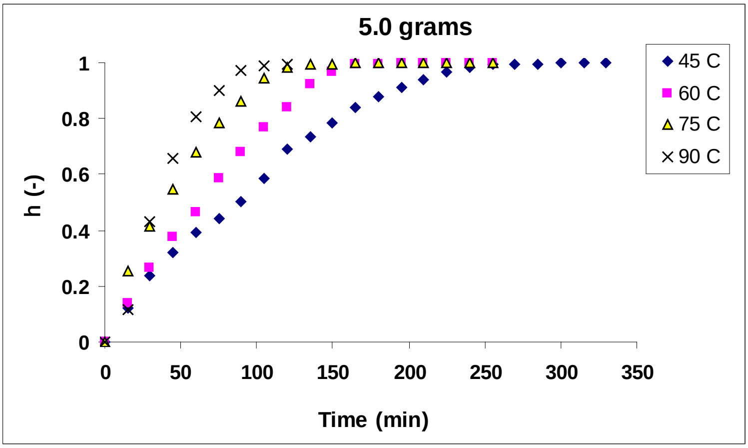
$$-\frac{dM}{M} = kdt \tag{4}$$

The integration of equation (4) at the limitation conditions, leads to the equation:

$$-\ln(1-\eta) = k \cdot t \tag{5}$$



a.



b.

Figure 3. Influence of temperature and the dolomite addition on drying degree

For two of the analyzed cases, the results are presented in the diagrams in Figure 4.

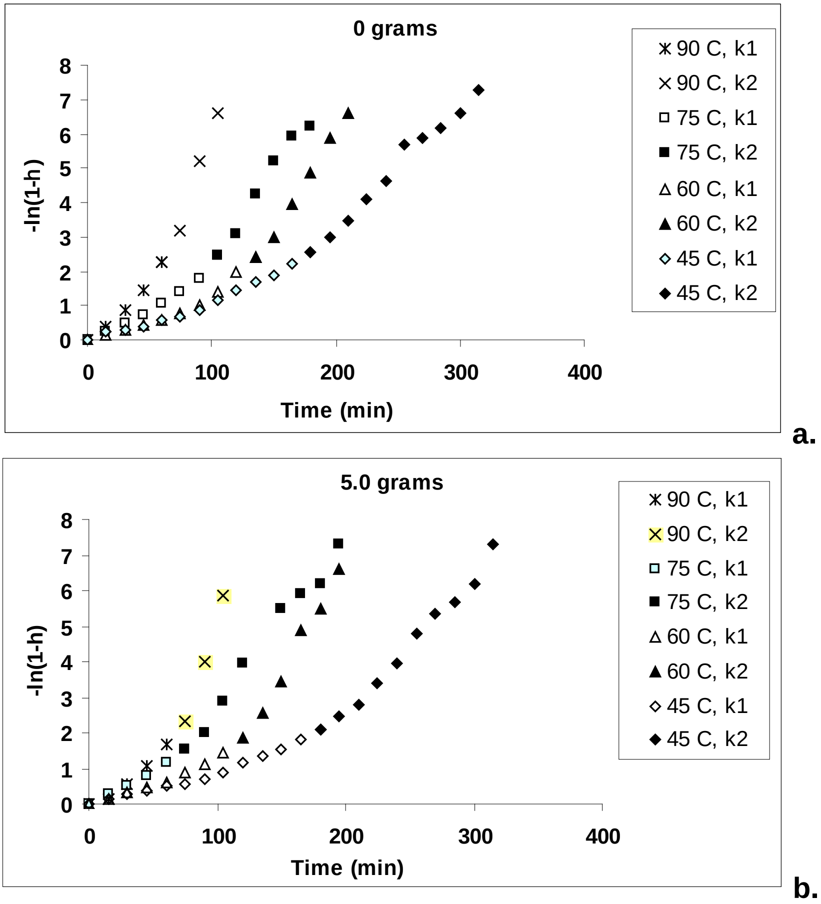


Figure 4. Diagrams –ln(1-η) vs. Time

Diagram analysis (Figure 4) for all working conditions shows that the points are not collinear. Changing the slope suggests the change of drying mechanism. The values of the constant rates determined from the slope of each linear representation –ln(1-η) vs. time, are shown in Table 1.

It can be noted that the values of constant rates decrease with the increase of added dolomite. It is also observed that the values of constant rates for the beginning of drying are smaller than those obtained for the second drying period at each temperature.

The numerical values of the constant drying rates were mathematically processed and plotted in the coordinates of the lnk vs. 1/T (Figure 5).

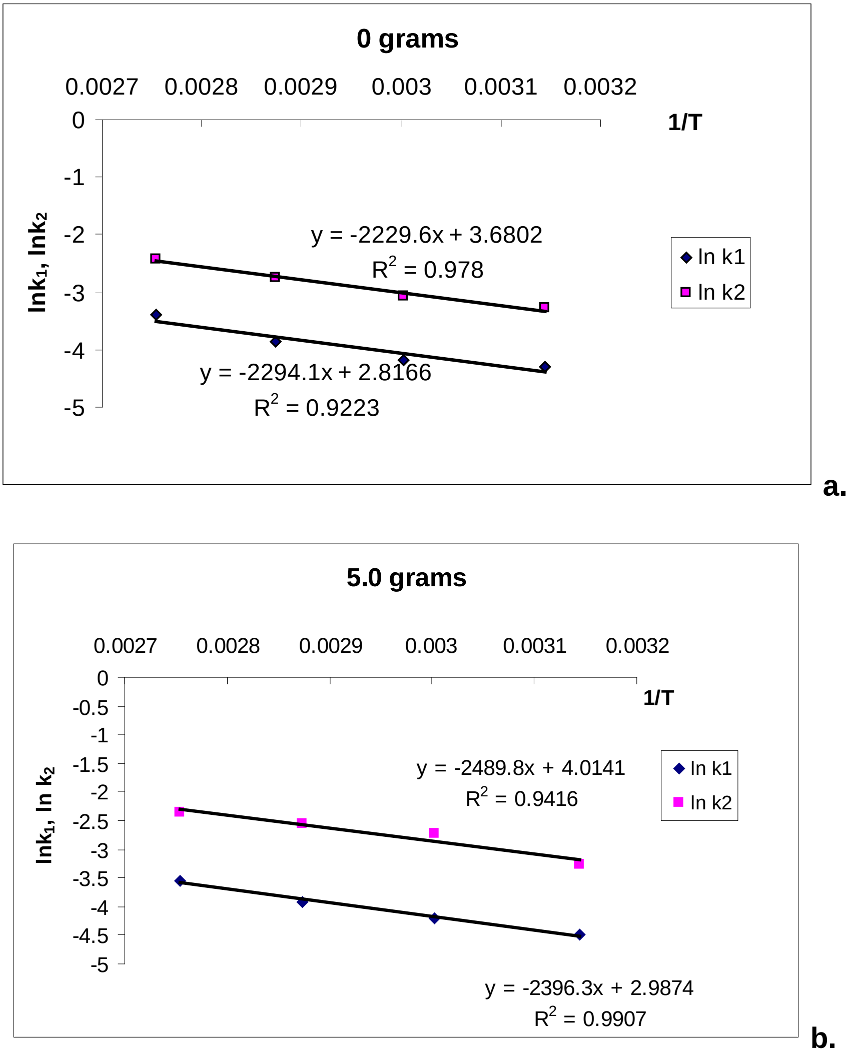


Figure 5. lnk vs. 1/T (a. 0 grams, b. 5.0 grams)

From the slopes of the obtained lines, the activation energies of the drying process were calculated. Values are shown in Table 1.

Table 1. Constant rates and activation energies

Addeed dolomite (grams)		**Constant rates** (min^{-1})		**Activation energy** (kJ/mol)	
0.0					
T	1/T	k_1	k_2	Ea_1	Ea_2
318	0.003145	0.0135	0.0376	19.00	18.48
333	0.003003	0.0154	0.0459		
348	0.002874	0.0209	0.0637		
363	0.002755	0.0333	0.0890		
2.5					
318	0.003145	0.0138	0.0354	19.78	18.60
333	0.003003	0.0171	0.0581		
348	0.002874	0.0224	0.0536		
363	0.002755	0.0367	0.0908		
5.0					
318	0.003145	0.0112	0.0379	20.25	19.42
333	0.003003	0.0124	0.065		
348	0.002874	0.020	0.078		
363	0.002755	0.0286	0.1178		
7.5					
318	0.003145	0.0085	0.0209	22.81	22.17
333	0.003003	0.0110	0.0343		
348	0.002874	0.0153	0.059		
363	0.002755	0.0253	0.0979		
12.5					
318	0.003145	0.0086	0.0213	26.18	23.81
333	0.003003	0.0098	0.0469		
348	0.002874	0.0153	0.069		
363	0.002755	0.0253	0.0711		

All obtained activation energy values are lower than 42.0 kJ/mol, which show that the drying process takes place following the mass transfer mechanism [14]. Analyzing the results, it can be observed the increase of activation energy values with the amount of dolomite addition.

This increase confirms the trend of drying mechanism modification from mass transfer to the combined mechanism, mass transformation (evaporation) – mass transfer.

CONCLUSIONS

The drying kinetics of the sugar beet pulp, without and with dolomite addition, was studied in this research work.

The experimental results have shown that the drying rates decrease with the moisture content decrease, being characterized by the specific falling rate period. The analysis of the drying curves shows that the temperature strongly influences the drying rates comparative to the dolomite addition which only slightly influences the drying rates.

The obtained values of activation energy (19.00 -26.18 kJ/mol) indicate that internal mass transfer mechanism for low amount of dolomite addition and the combined mass transformation (evaporation) - mass transfer mechanism control of the drying process.

EXPERIMENTAL SECTION

Sugar beet pulp was obtained from “TEREOS” sugar factory, Luduş, Romania. In order to determine the drying rates, several sets of experiments were carried out. During the experiments, the moisture removed from sugar beet pulp at four temperatures: 45^0, 60^0, 75^0 and 90^0 Celsius, and for various dolomite additions: 0.0, 2.5, 5.0, 7.5 and 12.5 grams were measured. Drying was carried out in a dryer under constant conditions [11]. Each sample was obtained by intimately mixing of the dolomite with marc in the proportions shown above. The material so prepared was placed in a thin-layer of 8 mm, in 100 mm diameter Petri dishes and then in dryer. Gravimetric measurements were made at each 15 minute, as described in literature [15].

The used dolomite has a content of 21.5% MgO, 32.6% CaO, 1.85% R_2O_3 (R = Fe, Al, Si) and particles size of less than 0.125 mm.

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