Chemical Bulletin of "Politehnica" University of Timisoara, ROMANIA
Series of Chemistry and Environmental Engineering
Chem. Bull. "POLITEHNICA" Univ. (Timisoara) *Volume 62(76), 1, 2017*

Intensification of the Drying of Some Vegetable Granules By Using the Fluidization Process

A. Tamas and S. Alexander

Politehnica University Timisoara, Faculty of Industrial Chemistry and Environmental Engineering, Blv. Vasile Pârvan 6, 300223 Timisoara, Romania, e-mail: andra.tamas@upt.ro

Abstract: The paper presents the study of drying kinetics for fluidized bed drying of some cereal (wheat, rice, corn for popcorn), green lentils and goji fruits. For each case, the characteristics of the fixed bed (density, porosity), the density and particle diameter, as well as the hydrodynamic properties of the fluidized bed (minimum and full fluidization velocities, height and porosity) were determined.

Keywords: drying velocity, fluidized bed drying, moisture content

1. Introduction

Due to a better heat and mass transfer, shorter drying time, better quality of the products obtained, and shorter reconstitution time, fluidized bed drying (FBD) is commonly used for drying particulate materials like grain and fruits. Due to the rapid drying FBD has been considered as an economical drying method in comparison with other drying techniques. FBD has been also recognize as a gentle, uniform drying procedure, resulting in a very low residual moisture content with a high degree of efficiency [1-4].

The process of drying in fluidized bed has been used to dry a wide range of food products - sorghum [5], rapeseed [6], grass seeds [7], wheat, rice, corn [8], soybean [9], potatoes, apples [10], freezing carrots [11], mint leaves [12]; pharmaceutical powder products [13], wheat flour [14]; industrial products – lignite [15], aluminium oxide spheres - porous (γ- Al_2O_3) and non-porous (Al_2O_3) [16,17]. Improving the drying process of biomass particles can be done by using a vibrating fluidized bed with pulsed gas flow [18] or an agitated fluidized bed [19].

In the performed experimental studies, the efficiency of the drying process was highlighted by establishing the evolution of the mass and moisture content of the grains in time, as well as by calculating the drying velocity. The efficiency of heat transfer from the drying agent to the grains was quantified by calculating the value of the heat transfer coefficients.

2. Experimental

The experimental fluidized bed drying plant is shown in Figure 1. The main geometric dimensions of the plant components are:

- tube 4: diameter - d_4 = 70 x 7 mm; height - H_4 = 610 mm;
- tube 5: diameter - d_5 = 42 mm; height - H_5 = 150 mm;
- orifice plate aperture: d_0 = 20 mm;
- hole size of the perforated bed plate: d_1 = 3 mm.

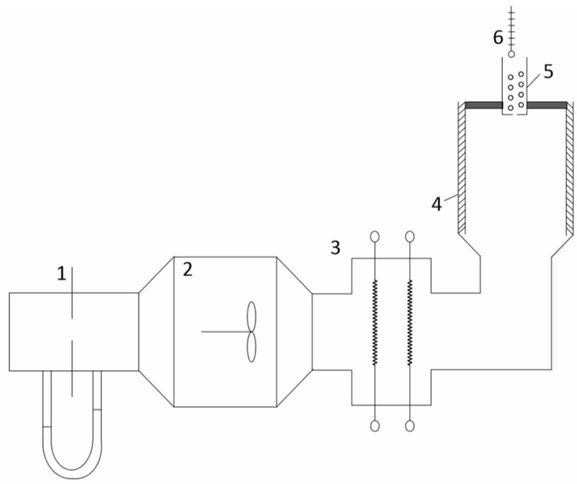

Figure 1. The scheme of the fluidized bed dryer
1 – diaphragm, 2- blower, 3- electrical resistances, 4 – tube, 5- fluidization column, 6- thermometer

The electric resistances used for heating the air have adjustable heating power that can be varied between 17.5 and 41.5 mW. The experiments started from the same initial amount of wet material (50 g), at two air temperature values and three fluidization velocities, respectively. At constant intervals (5 minutes) the amount of moisture removed from the material was determined by weighing (analytical balance SCALTEC SAC 64). The relative humidity and air temperature were measured using an Huger electronic thermohygrometer.

The properties of the grains subjected to fluidization as well as those of the fixed bed (experimentally determined), are shown in Table 1.

3. Results and Discussion

The minimum fluidization velocity and the full fluidization velocity were calculated from the values of Re_m and Re_f criteria, analytically determined from the value of Arhimedes number (Ar)[3]:

TABLE 1. The properties of the grains and of the fixed bed

Sample	Particle diameter d_p, mm	Bed density ρ, kg m^{-3}	Particle density ρ_p, kg m^{-3}	Porosity of the fixed bed $\varepsilon 0$
Wheat	3.87	664	1230	0.460
Rice	3.09	780	1248	0.375
Lentil	5.8	700	1120	0.375
Corn for popcorn	6.29	735	1225	0.400
Goji berries	6.1	435	870	0.500

TABLE 2. Minimum and full fluidization velocities

Sample	t_{med1} = 24.5°C				
	Ar · 10^{-6}	Re_m	w_m, m s^{-1}	Re_f	w_f, m s^{-1}
Wheat	2.55	261.9	1.03	2570.3	10.1
Rice	1.32	178.4	0.878	1836.3	9.03
Lentil	7.83	489.2	1.28	4539.4	11.9
Corn for popcorn	10.9	584.9	1.41	5364.4	12.96
Goji berries	7.08	463	1.154	4314.2	10.75

$$Ar = \frac{d_p^3 \cdot (\rho_p - \rho_{air}) \cdot \rho_{air} \cdot g}{\eta_{air}^2} \quad (1)$$

where: d_p - particle diameter (m); ρ_p, ρ_{air} - particle and air densities (kg m^{-3}); g- gravitational acceleration (m s^{-2}); η_{air}- dynamic viscosity of air (Pa.s).

$$\mathrm{Re}_m = \frac{Ar}{1400 + 5.22 \cdot \sqrt{Ar}} \quad (2)$$

$$\mathrm{Re}_f = \frac{Ar}{18 + 0.61 \cdot \sqrt{Ar}} \quad (3)$$

$$\mathrm{Re} = \frac{w \cdot d_p \cdot \rho_{air}}{\eta_{air}} \quad (4)$$

The minimum and full fluidization velocities corresponding to the average air temperature (24.5°C) are shown in Table 2. The fluidization index (K_w) was calculated as the ratio between the air velocity in the tube 4 and the minimum fluidization velocity.

Variations in porosity and height of the fluidized bed, depending on the type of the grain and the values of the fluidization index, are shown in Figures 2a and 2b.

The heat transfer coefficient from air to the grains (α) was calculated from the Nusselt (Nu) number determined as a function of the Ar, Re and Prandtl (Pr) criteria [3]:

$$Nu = 0.943 \cdot \mathrm{Re}^{-1} \cdot \mathrm{Pr}^{0.33} \cdot Ar^{0.69} \quad (5)$$

The variation of the heat transfer coefficient according to the air velocity through the fluidization column, at the average air temperature of 24.5°C, is shown in Figure 3.

For lentils, at two average values of the drying agent temperature and fluidization index respectively, the amount of moisture removed in time is shown in Figure 4.

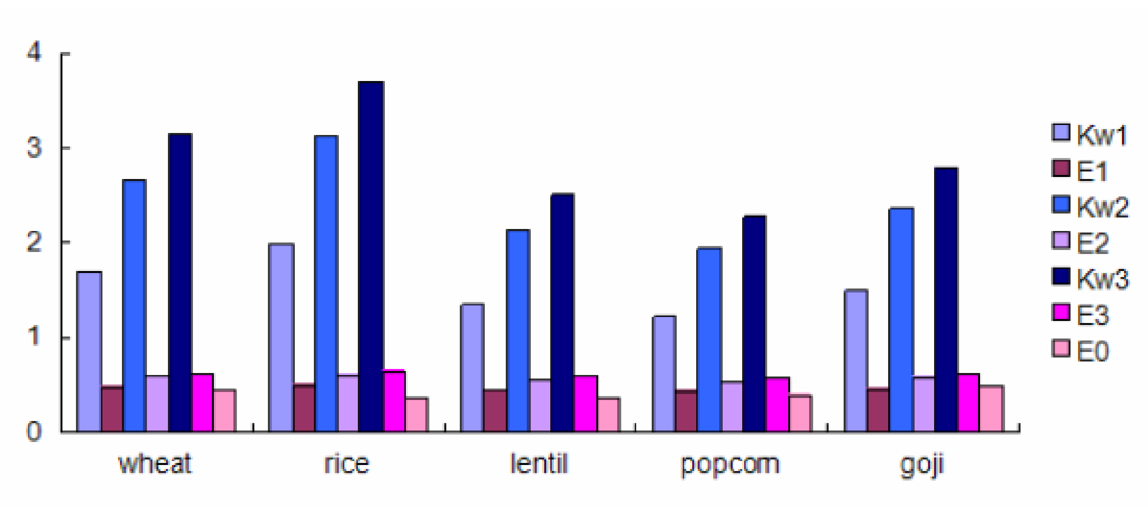

Figure 2a. The variation of the fluidized bed porosity

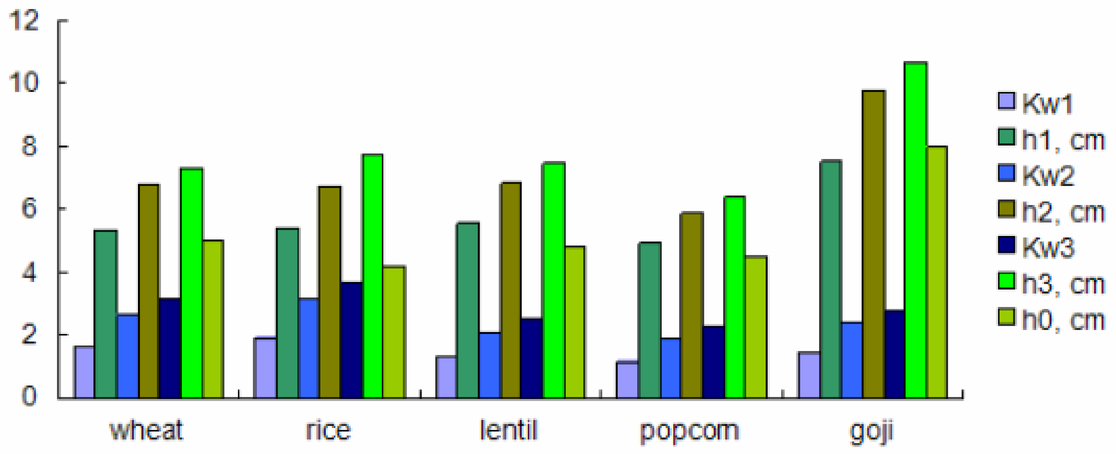

Figure 2b. The variation of the fluidized bed height

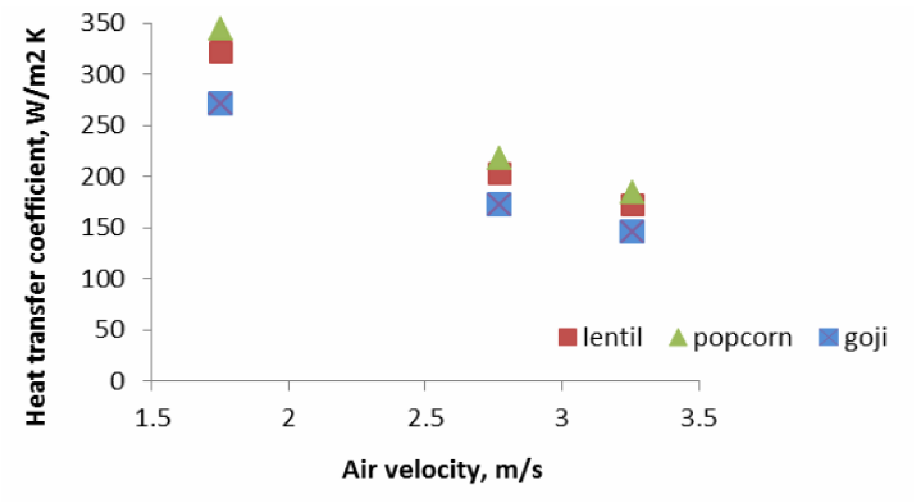

Figure 3. The variation of the heat transfer coefficient

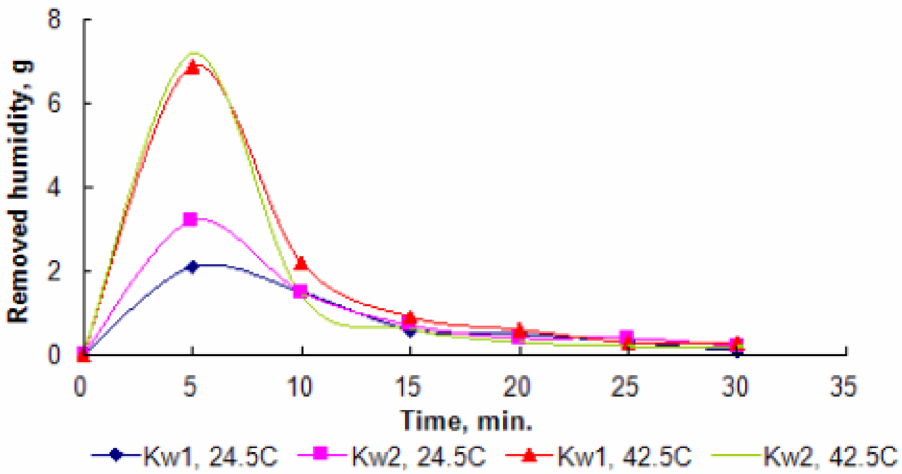

Figure 4. The removed humidity vs. time (lentils)

Both for lentils and for the other grains, it was found that most of the moisture was removed from the grains during the first five minutes of drying. The process is more favored by the higher temperature of the drying agent and influenced to a lesser extent by the increase in the fluidization index. The moisture removed in the first moments of drying corresponds to free humidity, mechanically retained, mainly by adhesion to direct contact with the surface of the grains due to superficial tension.

The variation of the humidity of lentils and wheat grains in time is shown in Figure 5.

In comparison with the drying of wheat, for lentil it is found that the increase in the fluidization index leads to a more pronounced decrease of the grain humidity, at the same value of the drying time. Thus, after 25 minutes, the differences between the values of the final moisture are 2.61% for lentils and 0.52% for wheat. The nature of the grain and its dimensions also influence how humidity decreases over time. At 24.5°C and the lowest value of the fluidization velocity (index), the percentage of decrease in moisture, after 25 minutes of drying, is 24.4% for wheat and 66.1% for lentils.

The evolution in time of the drying velocity at different air temperatures and the lowest values of the fluidization index, is shown in Figure 6. The drying velocity decreases exponentially in time depending of the nature and size of the granules. Also, its value is higher if the drying is done with warmer air.

4. Conclusions

In the paper was studied the fluidized bed drying of some vegetable grains with different size and structure. Also, for each case, the properties of the fixed and fluidized bed were determined.

It has been noticed that the value of the air to grain heat transfer coefficient decreases with the increase of air velocity and depends on the nature and size of the grains.

The drying efficiency depends on the values of the fluidization index, the temperature of the drying agent and the nature of the grain. In short times, it was possible to reduce the grains humidity by reaching high drying velocities when operating with drying agent (air) at relatively low temperatures (max. 45°C), which makes the process suitable for the drying of thermosensitive materials.

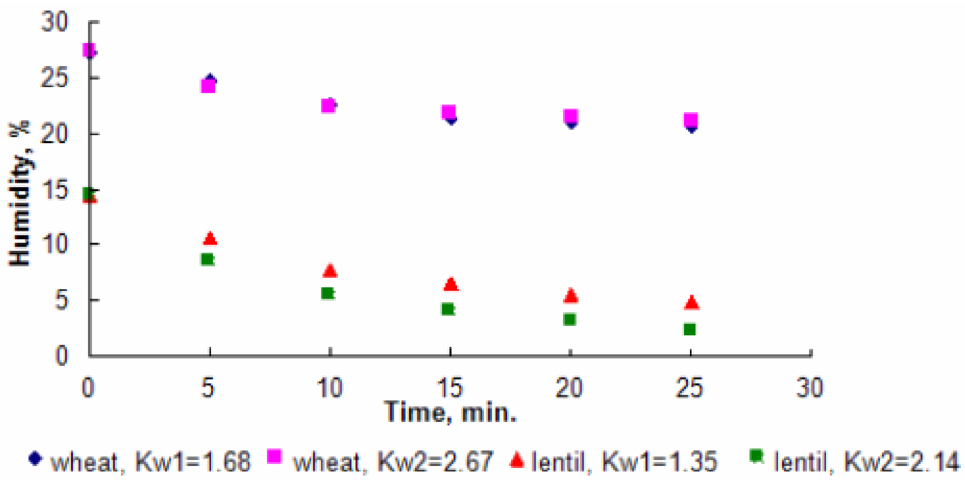

Figure 5. The grains humidity vs. time

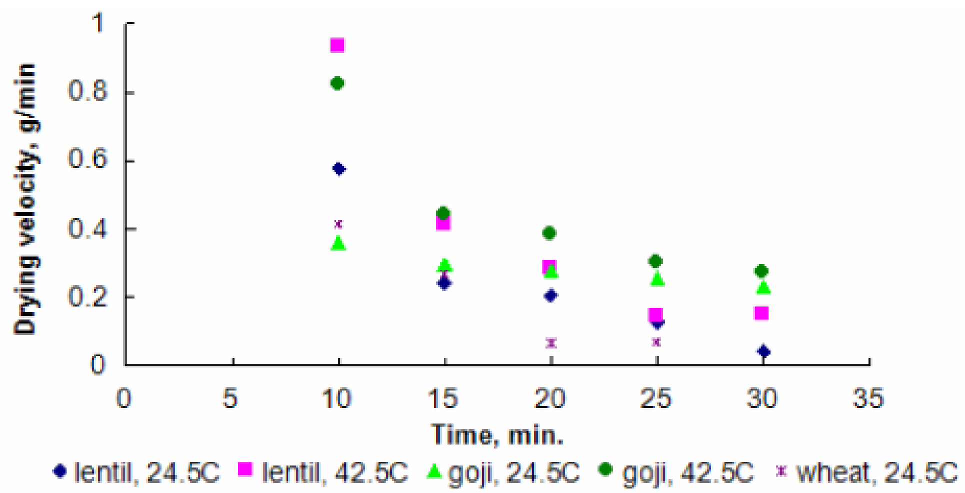

Figure 6. Drying velocity vs. time

REFERENCES

1. Jinescu G., Vasilescu P. and Jinescu C., Dinamica fluidelor reale in instalatiile de proces, Ed. SemnE, Bucuresti, **2001**.
2. Welty J.R., Wicks C.E., Wilson R.E. and Rorrer G.L., Fundamentals of Momentum, Heat, and Mass Transfer, 4th ed., John Wiley&Sons Inc., NY, **2001**.
3. Tamas A.and Minea R., Uscarea – Aspecte teoretice și aplicative, Ed. Politehnica, Timisoara, **2006**.
4. Gazor H.R. and Mohsenimanesh A., *Czech.J. Food Sci.,* 28(6), **2010**, 531-537.
5. Sandeepa K., Basava Rao V.V. and Mohan Rao S.R., Proceedings of the 14th International Conference on Fluidization –From Fundamentals to Products, May 26-31, Noordwijkerhout – Netherlands, **2013**.
6. Khorshidi J. and Davari H., *Adv. Chem. Eng. Sci.*, 2, **2012**, 129-135.
7. Rizzi Jr. A.C., Passos M.L. and Freire J.T., *Braz. J. Chem. Eng.*, 26(3), **2009**, 545-554.
8. Jittanit W., Srzednicki G. and Driscoll R., *Drying Technol.,* 28(10), **2010**, 1213-1219.
9. Prachayawarakorn S., Prachayawa P. and Soponronnarit S., *LWT* 39, **2006**, 770-778.
10. Kaleta A., Gornicki K., Winiczenko R. and Chojnacka A., *Energy Convers. Manage.*, 67, **2013**, 179-185.
11. Tatemoto Y., Mibu T., Yokoi Y. and Hagimoto A., *J. Food Eng.*, 173, **2016**, 150-157.
12. Ceylan I. and Gurel A.E., *Appl. Therm. Eng.,* 106, **2016**, 899-905.
13. Bareschino P., Marzocchella A. and Salatino P., *Powder Technol.*, 308, **2017**, 158-164.
14. Vengateson U. and Mohan R., *Resour.-Effic. Technol.,* 2, **2016**, S124-S135.
15. Si C., Wu J., Wang Y., Zhang Y. and Liu G., *Fuel Process. Technol.*,135, **2015**, 112-118.
16. Idakiev V.V., Lazarova P.V., Buck A., Tsotsas E. and Morl L., *Powder Technol.*, 306, **2017**, 26-33.
17. Perazzini H., Freire F.B. and Freire J.T., *Chem. Eng. Process.*, 118, **2017**, 124-130.
18. Jia D., Cathary O., Peng J., Bi X., Lim C.J., Sokhansanj S., Liu Y., Wang R. and Tsutsumi A., *Fuel Process. Technol.,* 138, **2015**, 471-482.
19. Moreno R.M, Antolin G. and Reyes A.E., *Biosyst. Eng.*,151, **2016**, 65-71.

Received: 16 February 2017
Accepted: 20 March 2017