

DRYING OF IMMOBILIZED YEAST CELLS IN SPOUTED BED DRYER WITH A MOVING DRAFT TUBE

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Abstract

Brewery yeast cells immobilized in Ca-alginate were dried in a laboratory scale spouted bed with a draft tube. The experiment was conducted under variable temperatures and air flow rates. Temperature and air velocity at the bottom of the column has been varied in the range from 30 to 60 °C and from 6 to 10 m/s in a duration of 60 minutes. The moisture of dried particles was in the interval of 10.00 to 21.00 g/g, while the water activity was in the range of 0.40 to 0.45, what ensures preservation of immobilized yeast as a starter and provides the biological activity of dried particles. Rehydration process of dried particles, proved that dried particles could restore completely their original shape and starting volume, while the mechanical resistance is somewhat reduced. The cells preserved in this way after rehydration completely restore their catalytical activity.

Key words: drying, spouted bed, draft tube, brewery yeast, immobilized cells

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Introduction

For industrial application of immobilized cell systems and their use for a longer period of time, it is necessary to apply adequate preservation, by different preservation methods, like freezing, salting or drying. The availability of water is determined by measuring water activity (a_w), which gives the relation between bound and unbound water, and by definition is the partial pressure of water in the product (p) divided by that of pure water (p_0):

$$a_w = p/p_0$$

Research conducted in this study assessed the optimum water activity needed for better survival of dried microbiological mass. Generally, the germination of mold spores or the development of yeast and bacteria is inhibited when the water activity is lower than 0.7-0.8 [1-7]. Also, it was determined that at the value of $a_w < 0.069$ the survival was better [8], and the zone of optimal survival was in the interval $0.10 < a_w < 0.55$ [9].

In the present research, the drying of immobilized yeast cells in the spouted bed with draft tube, under different temperature and air flow rate regimes, was investigated. The main goal was to define the influence of drying parameters on particle rehydration capability and viability, and consequently the catalytic activity of the yeast cells.

Materials and methods

Experiments were performed in a 30° conical glass column of 40 mm internal bottom diameter and height of the unit was 450 mm. From a fan, through the the micro filter and electrical heater, sterilized air was fed into the column from the bottom trough a stainless steel screen. The draft tube of 40 mm inlet diameter and 200 mm long, was axially mounted above the bottom, with the possibility to change the distance of the lower end from the bottom of the column in the interval 0 to 90 mm. Sterilized air at temperatures ranging from 30 to 60 °C, heated by electric heaters just before entering the dryer, was used for drying of wet particles.. Temperatures of the inlet air were measured by termocuple at the entrance of the column. Air flowrate was measured by a rotameter. The particle behavior was visually observed trough a glass wall of the column. The scheme of the experimental system is given in Figure 1.

Figure 1. Scheme of experimental spouted bed drier with draft tube

The bed particles were produced by dropwise addition of a mixture of 4 parts of 2% water solution of Na-alginate and one part brewery yeast cells, into the 2 % solution of Ca-alginate. In this manner, through a geelation process, immobilised yeast cells in Ca-alginate matrix, in the form of spherical particles of 2.5 mm diameter were obtained.

In preliminary experiments [10], working with a single particle, the following values for minimum fluidization velocity U_{mf} , and terminal velocity U_T , for wet ($U_{mf}=2.03$ m/s, $U_T=6.2$ m/s), and dried particles ($U_{mf}=1.05$ m/s, $U_T=4.5$ m/s) were determined.

Using the above data, it was established that the air flow rate trough the inlet bottom from 6 to 10 m/s, ensured the fluidization of particles under the drafte tube, and also prevented pneumatic removal of wet particles from the bottom of the column, and their sticking on the interior surface of the column wall which were decreasing the process efficiency.

Therefore the particles were dried first in a conical fluidized bed for 25 min, and after that, by moving down the draft tube from the level at 90 mm to the level at 20 mm from the bottom, in a draft tube spouted bed for the rest of the drying time, 35 minutes.

Drying process lasted for a total of 60 minutes, while the drying dynamic was monitored by taking samples of uniform mass in equal time intervals and deterring the mass loss of the samples.

Determination of starting dry material content as well as the final moisture after drying, was done by using standard procedure, drying on 105 °C, up to a constant mass.

Rehydration after drying was done in a physiologic solution. From the total amount of dried particles a sample of 5 particles was taken and the average diameter was determined microscopically.(by using microscope with a scale). The same sample of particles was then transferred to a physiological solution. Rehydration process lasted 90 min, while the rehydration dynamic was monitored by taking samples in equal time intervals and determining their moisture.

Catalytic activity of immobilized yeast cells preserved by drying was compared to that of suspended and freshly immobilized cells, and it was determined by fermentation of industrially produced worth (extract content 12.95%).

Fermentation was conducted in flasks filled with 200 ml of worth , in the shaking conditions at a speed of 115 rpm. In all three samples there was the same amount of yeast cells:

Samples:

- 1) 10 ml of yeast suspension,
- 2) 10 ml of yeast suspension which was immobilized in Ca-alginate matrix, and
- 3) 10 ml of yeast suspension which was immobilized in Ca-alginate matrix, and dried on 30 °C at air rate of 8 m/s for 60 minutes.

Extract was determined by density measurements.

Results and discussion

In the course of drying Ca-alginate particles, with or without immobilized yeast cells, the whole layer underwent three phases. In the first phase, when the particles were surrounded by surface moisture it was not possible to achieve fluidized or spouted bed in the column, independently of the air flow rate because the packed bed was formed.

In preliminary experiments it was determined that by increasing air velocity this effect could not be overcome. Due to very strong adhesion forces, agglomerates of particles were formed, that were moving by creating channels through which air was circulating therefore the particles could not be evenly treated. The same effect occurred when the velocities were much higher than the terminal velocity of immobilized particles, because the agglomerates were sticky enough to stay in a static bed. Through the same phases the bed went also at a constant air velocity, while drying at same temperature. With mass loss particles were approaching conditions of minimal fluidization, while by further continuation of process, intensive fluidization phase was achieved, characterizing the third phase of drying. In the second phase, with marked appearance of channels, the local circulation of particles in the shape of spouted bed was observed. Very fast circulation of particles in the local spout as a consequence has their intensive mass loss and non equal size particles distribution in the bed. On the basis of visual observation of the bed, removing of surface humidity of Ca-alginate particles coincided with the beginning of fluidization of the bed, and the draft tube was pushed from the top of column to the level at 10 mm from the bottom, and spouting was started. In all experiments the drying was performed for at 60 min..

Immobilized yeast cells drying curves were first determined at a constant temperature by varying air velocity in the entrance of column from 6-10 m/s at constant temperature of 30 °C during 60 min, Figure 2. First 25 min of drying was in fluidized bed and from 25 to 60 min of drying time it was in spouted bed with the draft tube, with intensive circulation in the bed. Earlier published results, [11] showed that the air "by-pass" through the draft tube, had as a consequence the increase of the particle circulation in the bed. By increasing drying velocity, faster decrease of material moisture was achieved. In the first 20 min of drying the moisture of particles differed the most for three different air velocities, and after 60 minutes, achieved moisture content was almost the same. The same results of drying dynamic at different temperatures, 30, 40, 50 and 60 °C at constant air velocity of 8 m/s, were obtained, Figure 3.

Figure 2. Drying curves of immobilized yeast as a function of air velocity

Figure 3. Drying curves of immobilized yeast as a function of temperature

When the drying process was controlled by diffusion of humidity through the particles, drying curve had asymptotic shape to the equilibrium moisture for the experimental set up. By changing drying

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temperatures, significant difference was achieved in the moisture content of the of particles. After 60 minutes of drying at 30 °C, moisture of the corresponding material was 17.85, at 40 °C it was 14.08, at 50 °C it was 10.4 while at 60 °C, achieved percentage moisture content was 8.04.

Rehydration ability of dried particles was also monitored and the experimental data are shown on Figure 4. As it was also the case of drying, in the first 20 minutes particles rehydrate very fast until 60% of moisture content was achieved. After that rehydration process was significantly slower. Maximally achieved percentage of water content after 24 hours was 92% of moisture content before drying.

Figure 4. Rehydration ability of dried particles

Figure 5. Water activity as a function of drying temperature

Water activity in dried samples ($T=40^{\circ}\text{C}$, $u=6$ m/s) was in the interval of 0.40-0.45, Figure 5., and therefore the stability of biomaterial was achieved. On the other side yeast cells retained their catalytic activity, which was confirmed by measuring their fermentation ability and comparing it to that of suspended cells and freshly immobilized ones, Figure 6. Fermentation was conducted in flasks in shaking conditions, at the temperature of 30 °C, with the same starting amount of yeast cells in all three samples, and for dried immobilized brewery yeast, (40°C , $u=6$ m/s) after 72 hours the same performance as with non dried samples was obtained.

Figure 6. Catalytic activity of dried cells

Conclusion

In the presented investigation of the drying process of Ca-alginate particles with immobilized yeast cells in the spouted bed dryer with a draft tube, it was established that the bed undergoes several fluid-mechanic phases, from packed bad, through developed fluidized bed and pneumatic transport trough the draft tube. It was also determined that by drying immobilized yeast cells at the temperatures from 30-60 °C, samples with water activity in the range 0.40-0.45 could be obtained which meant that the preservation of activity of dried yeast was ensured. Dried samples after rehydration restore their catalytic activity, so their further application in fermentation processes is possible. The experimental results obtained in this paper are the basic data for pilot unit drier design.

Symbols:

a_w water activity, 1

p	pressure, Pa
p_o	vapor pressure, Pa
T	temperature, °C
U	air velocity, m/s
U_{mF}	minimal fluidization velocity, m/s
U_T	terminal velocity, m/s

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Sažetak

SUŠENJE IMOBILISANIH ČELIJA PIVSKOG KVASCA U SUŠIONIKU SA FONTANSKIM SLOJEM I POKRETNOM CENTRALNOM CEVI

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Imobilisane ćelije pivskog kvasca u Ca'alginatu su sušene u laboratorijskoj sušnici sa konicnim fontanskim slojem. Eksperiment je izvodjen pri različitim temperaturama i protocima ulaznog vauduha. Temperatura je menjana u intervalu od 30 do 60 °C, a brzina vazduha na ulazu u kolonu je menjana od 6 do 10 m/s, pri konstantnom vremenu sušenja u svim eksperimentima u trajanju od 60 min. Početna vlažnost čestica koje su sušene, kretala se u intervalu od 10,00 do 21,00 g vlage/g suve materije, dok je aktivnost vode bila u opsegu od 0,40 do 0,45, koja obezbedjuje korišćenje osučenih čestica kao starter kultura, uz istovremeno sprečavanje bioloških procesa u osučenim imobilisanim česticama. Nakon rehidracije, osušene čestice su vraćale svoju prvobitnu zapreminu i oblik, dok je njihova mehanička otpornost smanjena u odnosu na čestice pre sušenja. Čelije, sačuvane na ovaj način su, nakon rehidracije, zadržavale svoju katalitičku aktivnost. Dobijeni rezultati u ovom radu su polazni parametri za projektovanje pilot sušionika.

Figure caption

Figure 1. Scheme of experimental spouted bed drier with a draft tube

Figure 2. Drying curves of immobilized yeast as a function of air velocity

Figure 3. Drying curves of immobilized yeast as a function of temperature

Figure 4. Rehydration ability of dried particles

Figure 5. Water activity as a function of drying temperature

Figure 6. Catalytic activity of dried cells

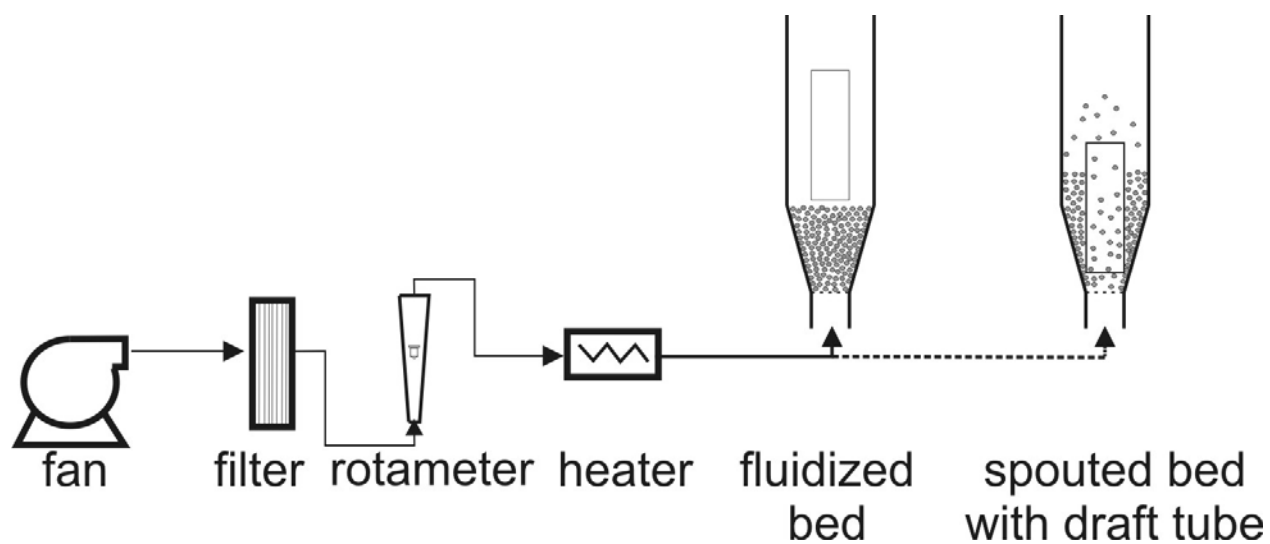


Figure 1.

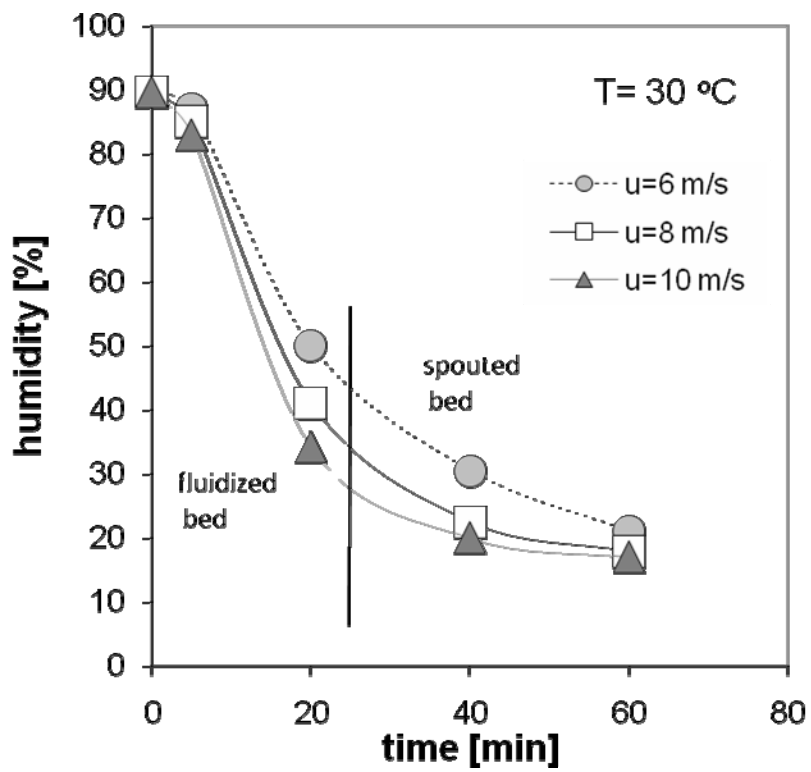


Figure 2

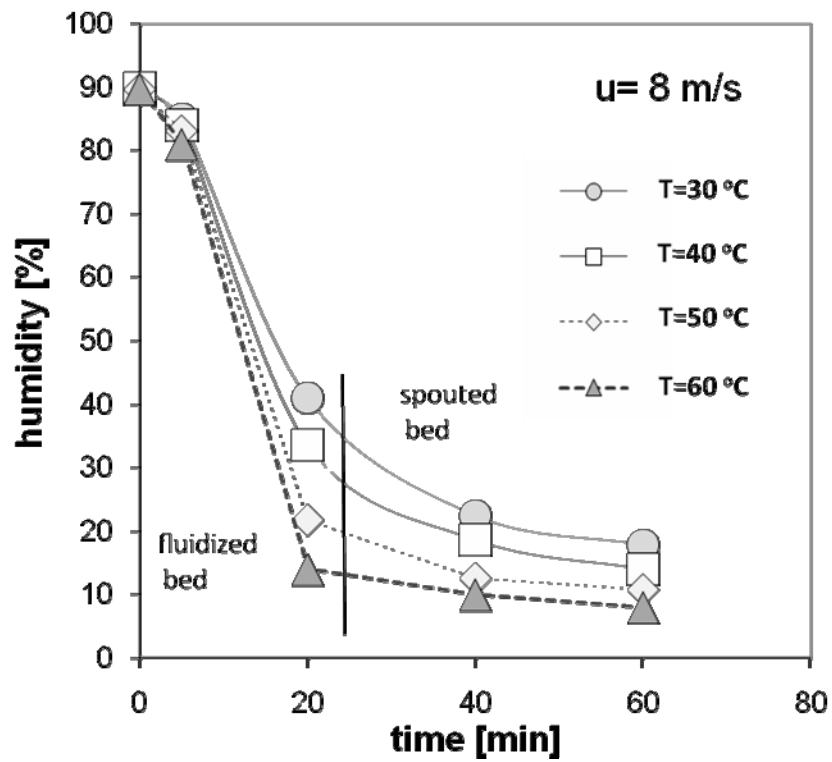


Figure 3

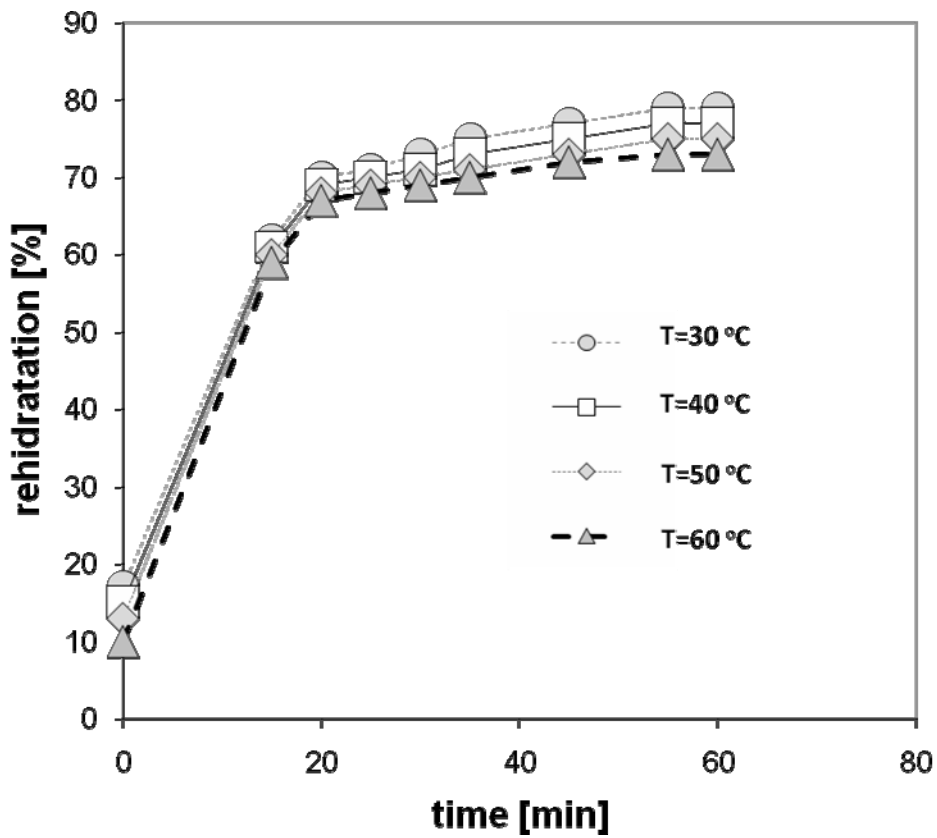


Figure 4

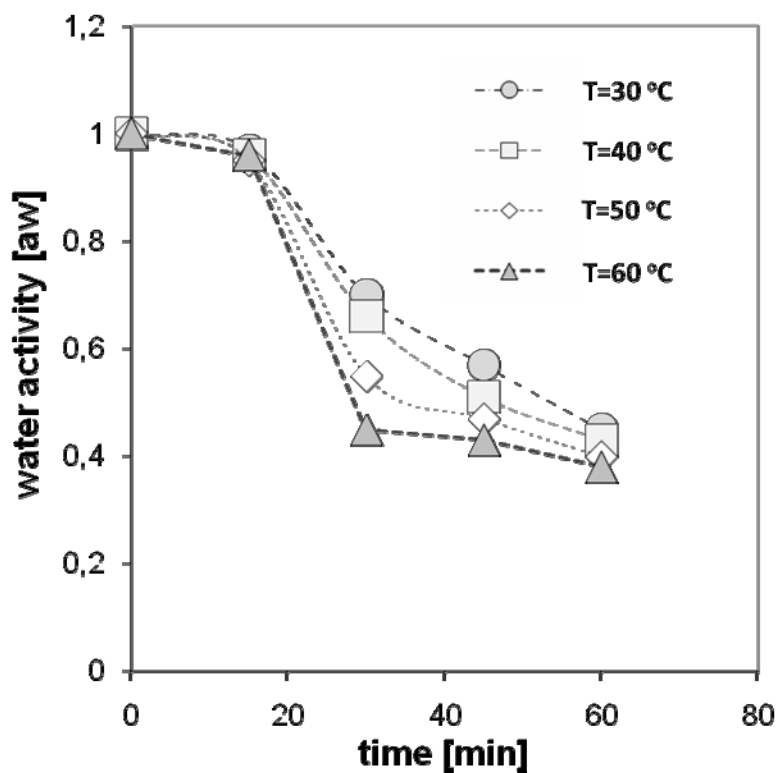


Figure 5

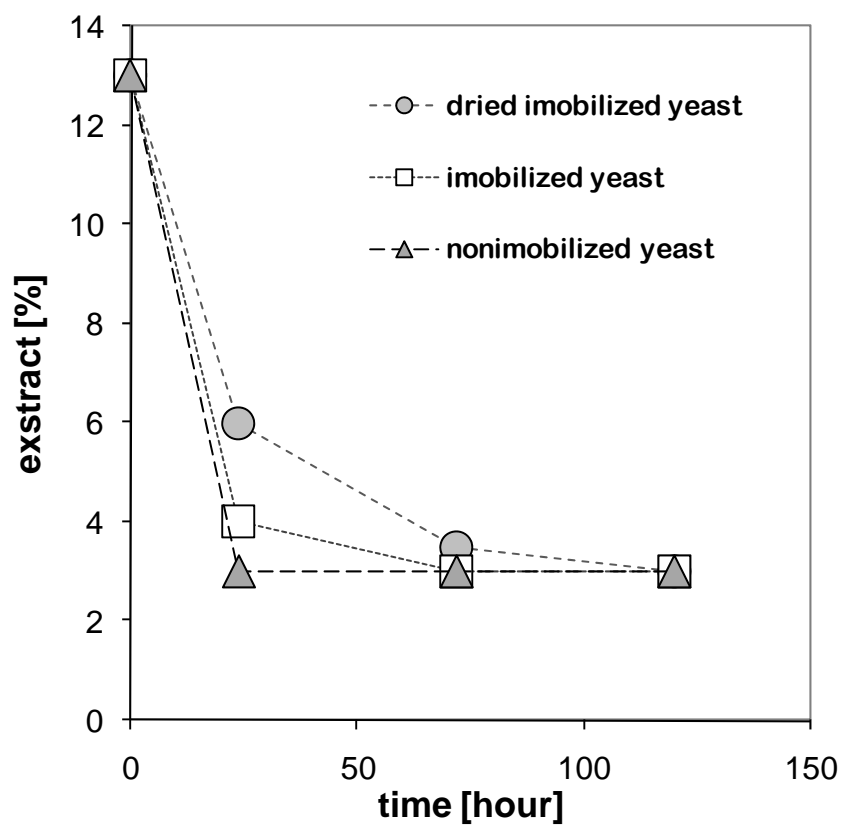


Figure 6