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Chemical Industry & Chemical Engineering Quarterly 16 (2) 133–137(2010) CI&CEQ

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SCIENTIFIC PAPER

UDC 663.12.047.7

DOI 10.2298/CICEQ100123021P

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

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. The temperature and air velocity at the bottom of the column have been varied in the range from 30 to 60 °C and from 6 to 10 m/s in a duration of 60 min. The moisture of dryied 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 the preservation of immobilized yeast as a starter and provides the biological activity of dried particles. A rehidration process of dryied particles proved that dried particles could completely restore their original shape and starting volume, while the mechanical resistance is somewhat reduced. The cells preserved in this way completely restore their catalytical activity after the rehidration.

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

For industrial application of immobilized cell systems and their use for a longer period of time, it is necessary to apply adequate preservation by using different preservation methods like freezing, salting or drying. The availability of the water is determined by measuring the 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 the pure water (p_0):

$$a_w = p/p_0$$

The 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 of $0.10 < a_w < 0.55$ [9].

In the present research, the drying of immobilized yeast cells in the spouted bed with a draft tube under different temperatures 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

The experiments were performed in a 30° conical glass column of 40 mm internal bottom diameter and the height of the unit was 450 mm. From a fan, through the the micro-filter and an electrical heater, the sterilized air was fed into the column from the bottom through 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 wet particles. The 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 through a glass wall of the column. The scheme of the experimental system is given in Figure 1.

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

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Paper received: 23 February, 2010
Paper revised: 10 March, 2010
Paper accepted: 18 March, 2010

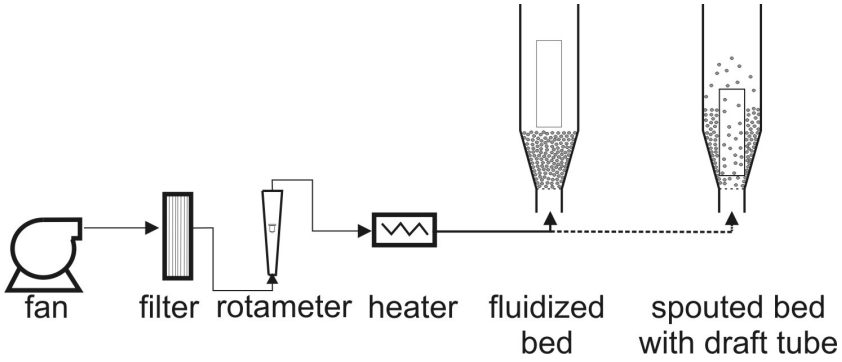

Figure 1. Scheme of experimental spouted bed drier with a draft tube.

geelation process, the imobilised 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 a pneumatic removal of wet particles from the bottom of the column and their sticking on the interior surface of the column wall which decreased the process efficency.

Therefore, the particles were dried first in a conical fluidized bed for 25 min, and after that, by moving the draft tube down 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 min).

The drying process lasted for a total of 60 min while the drying dynamic was monitored by taking samples of uniform mass in equal time intervals and determing the mass loss of the samples.

The determination of the starting dry material content as well as the final moisture after drying, was done by using a 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 a microscope with a scale). The same sample of particles was then transferred to a physiological solution. The rehydration process lasted for 90 min, while the rehydration dynamic was monitored by taking samples at equal time intervals and determining their moisture.

A 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 min.

The 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 a 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 and 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 the same temperature. With the mass loss particles were approaching conditions of minimal fluidization, while by further continuation of the process the intensive fluidization phase was achieved characterizing

the third phase of drying. In the second phase, with marked appearance of the channels, the local circulation of particles in the shape of spouted bed was observed. Very fast circulation of particles in the local spout has their intensive mass loss and non equal size particles distribution in the bed as a consequence. On the basis of visual observation of the bed, removing of the surface humidity of Ca-alginate particles coincided with the beginning of fluidization of the bed, the draft tube was pushed from the top of the column to the level at 10 mm from the bottom and spouting was started. In all experiments the drying was performed for 60 min.

Immobilized yeast cells drying curves were first determined at a constant temperature by varying air velocity in the entrance of the column from 6-10 m/s at constant temperature of 30 °C during 60 min (Figure 2). First 25 min of drying was in a fluidized bed and from 25 to 60 min of drying time it was in a 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 the increase of the particle circulation in the bed as a consequence. By increasing drying velocity, a faster decrease of material moisture was achieved. In the first 20 min of drying the moisture of particles differed most for three different air velocities, and after 60 min the 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).

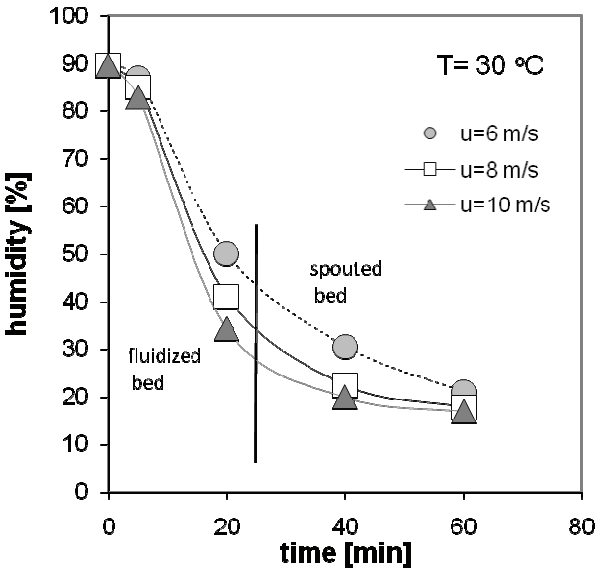

Figure 2. Drying curves of immobilized yeast as a function of air velocity.

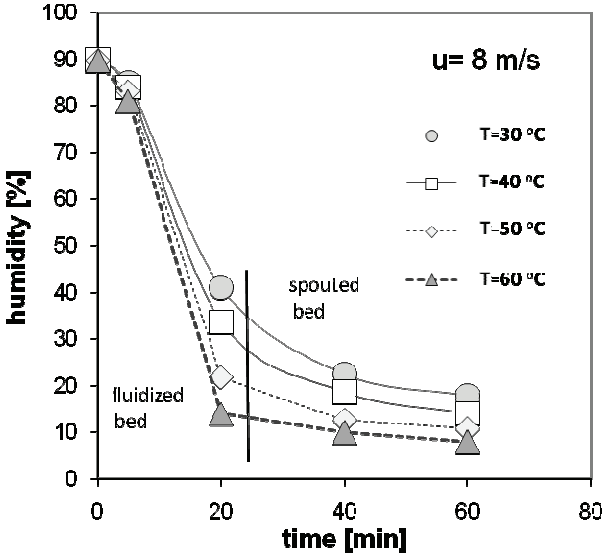

Figure 3. Drying curves of immobilized yeast as a function of temperature.

When the drying process was controlled by diffusion of humidity through the particles, a drying curve had an asymptotic shape to the equilibrium moisture for the experimental set up. By changing drying temperatures, a significant difference was achieved in the moisture content of the particles. After 60 min of drying at 30 °C, the 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 the achieved percentage moisture content was 8.04.

The rehydration ability of dried particles was also monitored and the experimental data are shown in Figure 4. As it was also the case of drying, in the first 20 min particles rehydrated very fast until 60% of the moisture content was achieved. After that the

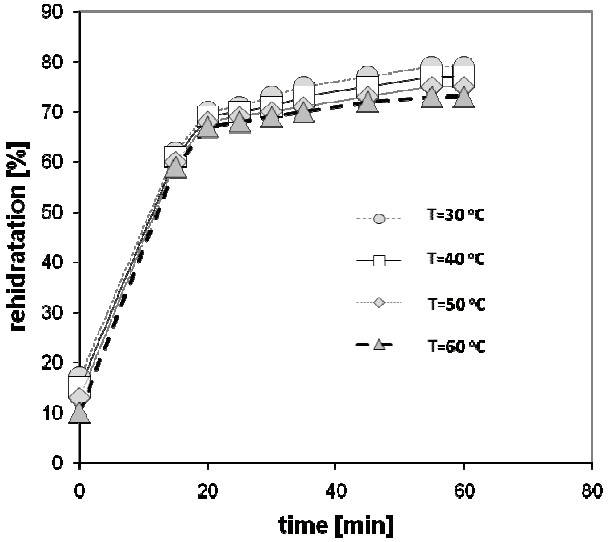

Figure 4. Rehydration ability of dried particles.

rehydration process was significantly slower. Maximally achieved percentage of the water content after 24 h was 92% of the moisture content before drying.

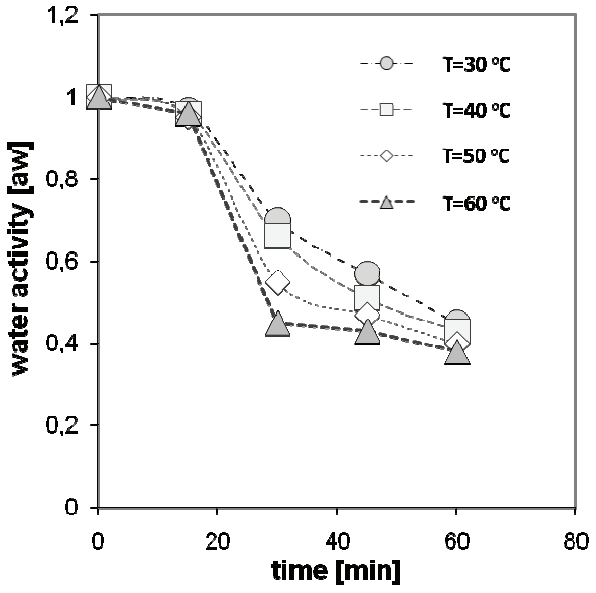

Figure 5. Water activity as a function of drying temperature.

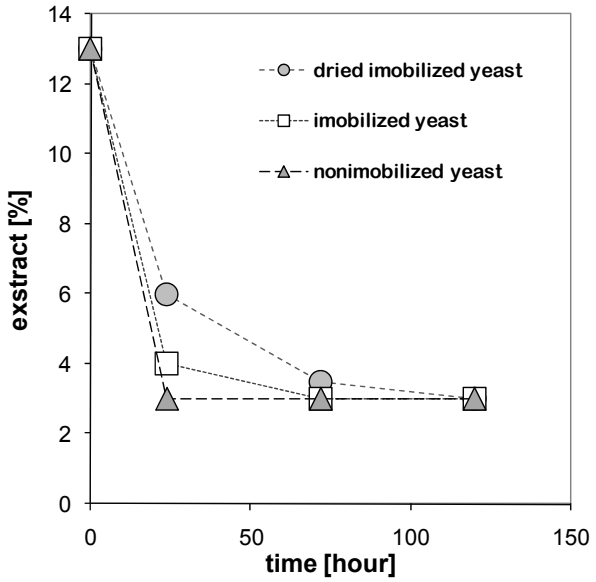

Figure 6. Catalytic activity of dried cells.

Water activity in dried samples (t = 40 °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 h the same performance as with non-dried samples was obtained.

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 the packed bed through a developed fluidized bed and a pneumatic transport through the draft tube. It was also determined that by drying immobilized yeast cells at the temperatures from 30-60 °C, the samples with the water activity in the range of 0.40-0.45 could be obtained which meant that the preservation of the 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 a pilot unit drier design.

Symbols

a_w Water activity, 1
p Pressure, Pa
p_0 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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NAUČNI RAD

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

Imobilisane ćelije pivskog kvasca u Ca-alginatu su sušene u laboratorijskoj sušnici sa konicnoim 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 rehidratacije, osušene čestice su vraćale svoju prvobitnu zapreminu i oblik, dok je njihova mehanička otpornost smanjena u odnosu na čestice pre sušenja. Ćelije, sačuvane na ovaj način su, nakon rehidratacije, zadržavale svoju katalitičku aktivnost. Dobijeni rezultati u ovom radu su polazni parametri za projektovanje pilot sušionika.

Ključne reči: sušenje; fontanski sloj; centralna cev; pivski kvasac; imobilisane ćelije.