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SCIENTIFIC PAPER

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DRYING OF BIOLOGICAL MATERIALS IN A SPOUT–FLUID BED WITH A DRAFT TUBE

The possibility of applying a spout–fluid bed with a draft tube and conical bottom was investigated for drying fluid media with a certain content of suspended material was investigated. The major goal who to study the drying of biological materials and products of food the industry. Experimental results concerning the fluidmechanical characteristics of a spout–fluid bed with a centrally situated draft tube and the drying characteristics were obtained on a pilot scale unit, 0.250 m in diameter, with a bed consisting of polyethylene particles 3.6 mm mean diameter and 940 kg/m^3 density. Within the regime of the fluid mechanical stability, the system could be used for drying biological suspensions with satisfactory results.

The preservation of the functional and nutritional characteristics of natural, thermally sensitive suspensions as a product in dried powder form requires a more sophisticated process. One of them is the convective drying process. The most common process used so far for drying suspensions to powders has been spray drying. Research and development in the field of spouted and modified spouted bed enabled the prospective use of these systems in drying processes.

On the basis of fluid mechanical investigations and heat transfer studies in spouted beds and modified spouted bed, systems for the drying of granulated materials, and different inorganic, organic and biological suspensions, were most frequently developed [1–12].

The drying process in a spout–fluid bed with a draft tube is performed in such a manner that a bed of inert particles is established with hot air, to attain the corresponding temperature regime. The suspension is introduced into the bed through the spout at the bottom of the column. Due to the intensive circulation of the bed particles, the suspension is dispersed and a thin film coat of the liquid forms on the surface of the particles. During the residence in the bed, the film dries and is carried into the spout, where the contact with hot air is intensified. During the residence in the draft tube the film is completely dried and a scum of dry material is formed on the particle surface. In the zone above the spout, due to fluid–particle, particle–particle drag forces and inertion forces from the impact with the deflector positioned in the spout, the scum is detached from the particles and carried away in the air stream to the collector. The particles are retained in the bed for repetitive wetting.

EXPERIMENTAL SYSTEM

Experiments were performed in a stainless steel column of 0.250 m internal diameter, the height of the unit with the supporting unit was 2.2 m. From a two fan, air was introduced into the column through a 0.05 m diameter nozzle, situated centrally at the bottom of the column (nozzle flow) and through a conical perforated distributor at the bottom of the column (annular flow). The nozzle was manually shifted along the axis of the column, so that its top could be situated as required at 0 to 100 mm above the bottom. A draft tube of 0.06 m diameter and 0.6 m long, who axially mounted above the nozzle, with the possibility of changing the distance of the lower end from the bottom of the column in the interval 0 to 100 mm. The mobile nozzle could enter the draft tube, which enabled it to operate without a net at the top of the nozzle and avoid the occurrence of a maximal pressure during the gradual establishment of a spouted bed, when the nozzle is moved downwards and out of the draft tube. The deflector is positioned at 0.2 m above the top of the draft tube. Air who heated by a electrical exchangers of 11 kW, for each stream. During drying the suspension was pumped to the nozzle where it was dispersed by compressed air. The dried powder was separated in a cyclone. The scheme of the experimental system is given in Figure 1.

Polyethylene balls of density 940 kg/m^3, diameter 3.6 mm and sphericity 0.889 were the bed particles.

Air flow in the annular and nozzle region was measured by calibrated orifices it was determined indirectly. In the annulus using the functional dependence of the pressure gradient in its cylindrical part on the air flow in the packed static bed.

The pressure drop in the nozzle and annular flow was measured relative to the top of the column.

The particle flow was determined from the particle velocity in the annulus, which was visually observed through a glass window in the cylindrical part of the column and measured by a stop–watch.

The temperatures were measured at the inlet of the nozzle and annular flow, in the bed of particles, at the column outlet, after leaving the cyclone and the bag filter.

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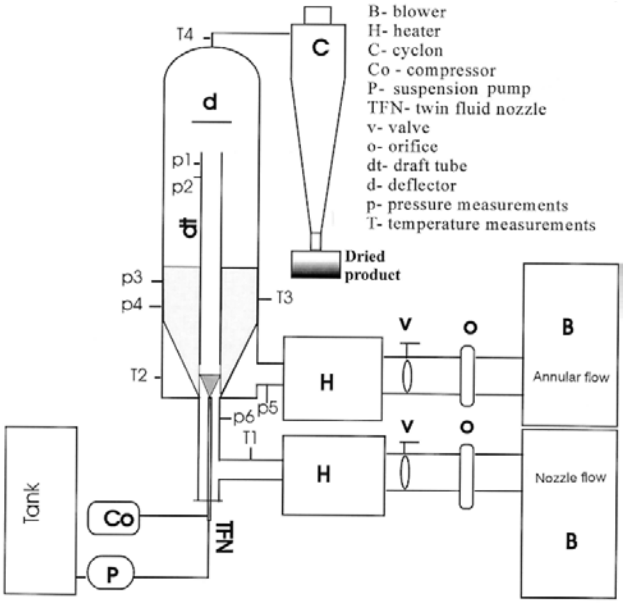

Figure 1. Scheme of a spout–fluid bed with a draft tube

Granulometric analysis of the powdered product was performed using an Alcatel HR 850 instrument and the moisture content by standard oven drying at 105°C.

RESULTS AND DISCUSSION

The drying process in a spout–fluid bed with a draft tube occurs in the draft tube itself and its intensity depends on the temperature and air mass flow, temperature of the inlet particles and thickness of the coating film.

The maintaining of material and energy balances in the column depends on the value of the air flow rate in the bed annulus M_A. During the observation of the air flow value in the annulus M_A as a function of the change in the annular flow at the bottom of the annulus, it was noticed that an increase of the annular flow at the bottom brings about a general increase of the air flow rate in the annulus, Figure 2.

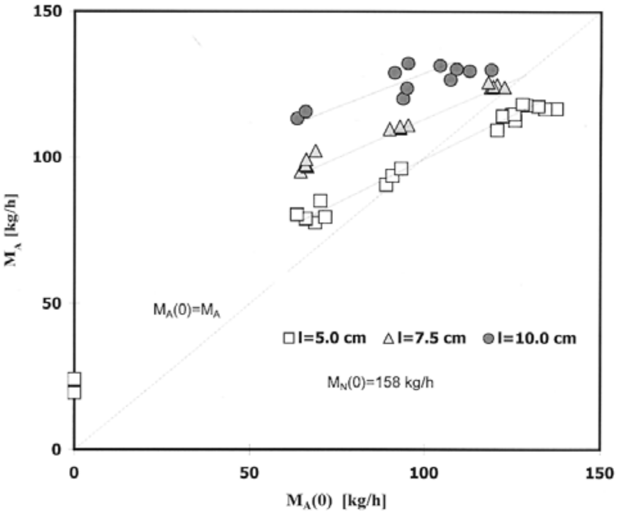

Figure 2. The effect of $M_A(0)$ on M_A

It has been noticed that intensive by–passing of the air from the annulus toward the draft tube tavres place in a spout fluid bed with a draft tube which lowers the annular flow rate, relative to the air supply at the bottom of the column. There is also a increase in the flowrate through the draft tube. Previously published results [12] have shown that the air "by–pass" through the draft tube, canses an increase in the particle circulation in the bed and also contributes to the instability of column operation after exceeding certain fluid–mechanical parameters, Figure 3.

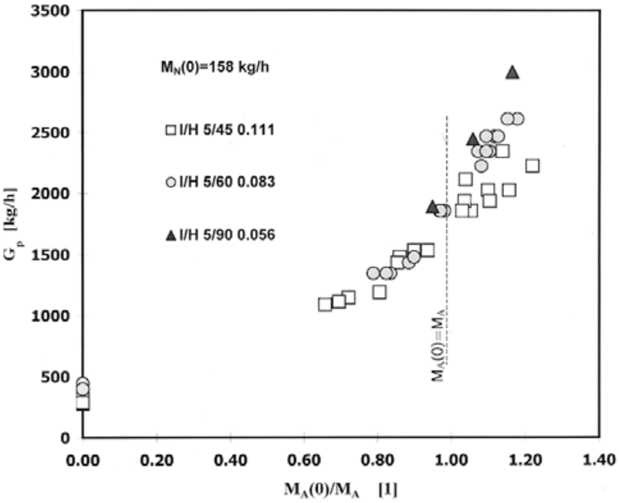

Figure 3. The effect of air by–pass on particle circulation

Knowledge of the value of particle circulation in the bed is essential for the drying process of suspensions as the thickness of the film on the surface of the inert particles is directly proportional to the value of circulation, that is to the frequency of the particle entering the jet dispersion zone at the top of the nozzle. As the drying regime is that of forced convection, it is more favorable to have as thin a film as possible, several microns in our experiments, which allows drying in the draft tube, scum formation and detachment, powdering and removal in the shortest possible time.

The drying of suspensions in a spout–fluid bed with a draft tube depends on the inert particle temperature, that is, on the bed temperature. As the coated particle gives away its heat content in the course of drying in the draft tube, after contact with the deflector and shaking off of the powder, the temperature of the inert particles is equal to that in the annulus. Measurements of the temperature profile in the axial and the radial direction are in full agreement with the results obtained in the investigation of the evaporation of pure water [12]. The introduction of hot air at the bottom of the annulus at of approximately 60°C, relative to the bed temperature, the air in a relatively short distance gives away heat to the particles, which enter the draft tube at a temperature higher than that when entering the dispersion zone. As the polyethylene particles have their own heat capacity, this amount of heat is concentrated at the surface and the liquid film is therefore in a "temperature sandwich" of the particle surface and hot air. A steady state is established when the total introduced heat is used up in the draft tube for the evaporation of moisture and the inert particles fall down to the top of the annulus at the bed temperature.

The stability of the drying process in a spout fluid bed with a draft tube depends on the shaking of the dried scum and the removal of the powder. If steady state conditions have not been established, the drying process will convert to that of coating, according to the analysis presented in [6]. The coating process can be successfully achieved in such systems, but in the present investigation it was an unwanted effect, which appeared during the examination of extreme capacities or wrongly evaluated system parameters.

To avoid unwanted effects, the drying should be commenced after heating up the inert particles and thermostating the system as a whole, so that the supplied heat night be used for water evaporation.

On the basis of the heat balance for a spout–fluid bed with a draft tube, after rearranging and integrating, the time necessary to heat the particle to a certain temperature is:

$$\frac{M_b C_{pp}}{C_{pf}(M_N(0)+M_A(0)+kA)} \cdot$$

$$\frac{C_{pf}[M_N(0)T_N(0)+M_A(0)T_A(0)]+kAT_a-[C_{pf}(M_N(0)+M_A(0))+kA]T_b(0)}{C_{pf}(M_N(0)T_N(0)+M_A(0)T_A(0))+kAT_a-[C_{pf}(M_N(0)+M_A(0))+kA]T_b} = t$$

The overall heat transfer coefficient k was experimentally determined and for the system polyethylene particles–air it is 11W/m^2°C.

Comparison of the experimental data on the heating dynamics of the bed and the values obtained from the previous equation are given in Figure 4. By applying the equation it is possible to observe the change of temperature with time by defining the steady state temperature. This is very important for practical application, as it is possible, when drying pharmaceutical and food materials, to perform sterilization in a certain period and then subsequently thermostat and dry the materials.

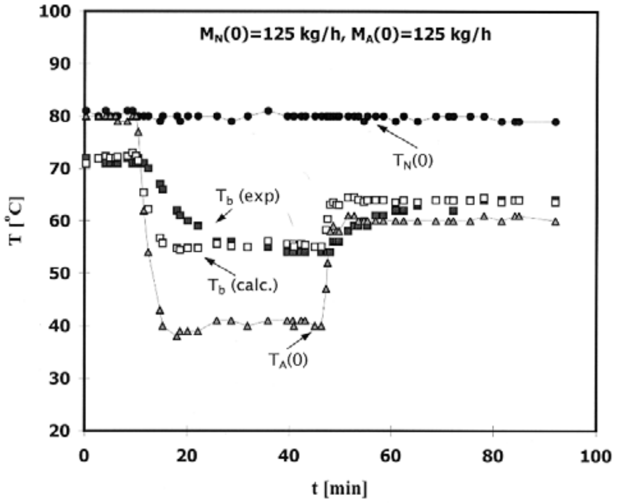

Figure 4. Bed temperature, experimental and calculated

During the our experiments the starting raw material for drying was blood plasma, obtained by separation from previously stabilized (20% trisodium citrate) hog blood. The separation was performed in a laboratory centrifugal separator. The chemical composition and selected functional properties of the powder produced as described were determined according to standard methods. The water content was determined by drying at 105°C, the total protein content by the Kjeldahl method and the stability of the emulsion dried plasma–hog fat–water was checked after 2 and 24 h at room temperature and after thermal treatment for 1h at 70°C, and the strength of the gel was first determined by a Hopler consist meter.

Investigation of the protein content of the powder obtained by drying animal blood plasma in a spout–fluid bed with a draft tube gave the results shown in Figure 5. The inlet temperature is a function of the suspension flowrate. The interval of the exit temperatures was 60–89°C, the observed minimum being between 70 and 75°C. Similar results were obtained [3] for spouted bed drying, but an explanation of this phenomenon has not been presented and it should be taken into account in further investigations.

The effect of the experimental conditions on the water content (humidity) of the produced powder and its linear decrease with increasing outlet temperature are presented in Figure 6. This relationship makes it possible to achieve the humidity required by standards and the economy of the process could be maintained.

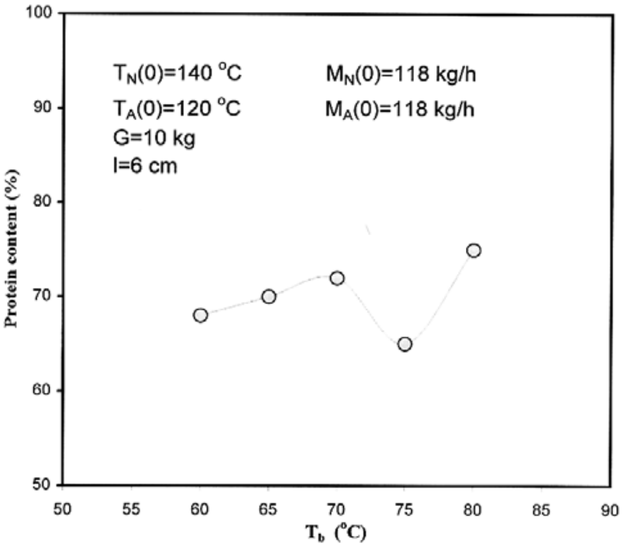

Figure 5. Protein content of the dried powde as a function of the outlet temperature

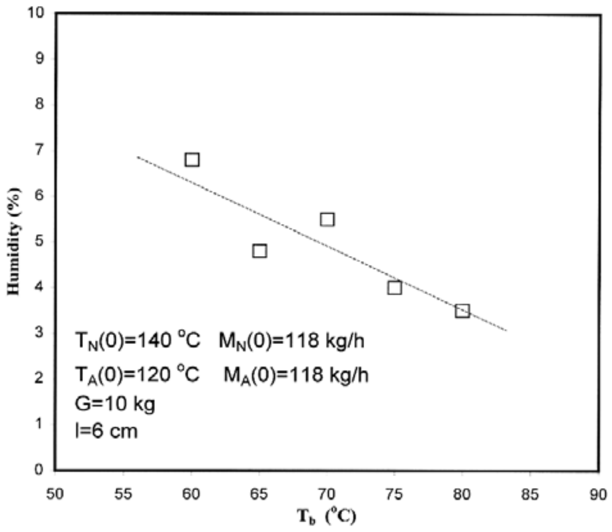

Figure 6. Humidity of the dried powder as a function of the outlet temperature

The effect of the inlet temperature of the annular air flow at the humidity of the dried powder and the protein content at various exit temperatures is given in Figure 7 and Figure 8.

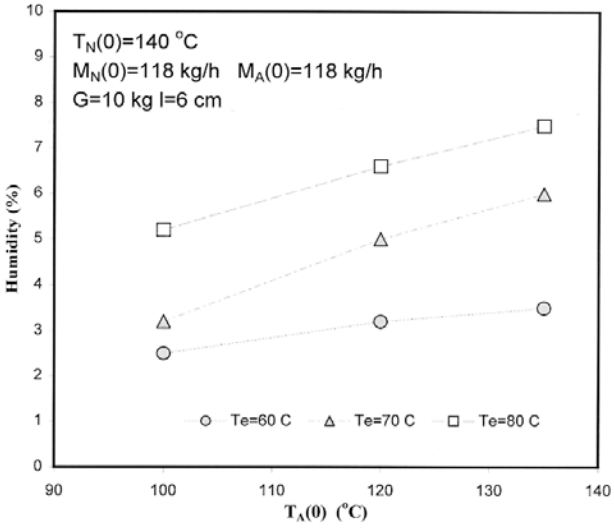

Figure 7. Influence of the inlet annular air temperature on the powder humidity

It should be noted that the temperature increase in the region 100–135°C has a comparatively small effect on the increase of the humidity of the obtained powder. Although it might seem to be contradictory, it should be noted that different values of the suspension flowrate maintain the same exit temperature at different inlet air temperatures. It may be seen from Figure 8 that for all experiments the protein content in the powder samples was about 70%, which is not markedly influenced by the inlet air temperature. This is very important from the point of view of the design of spout–fluid bed driers with

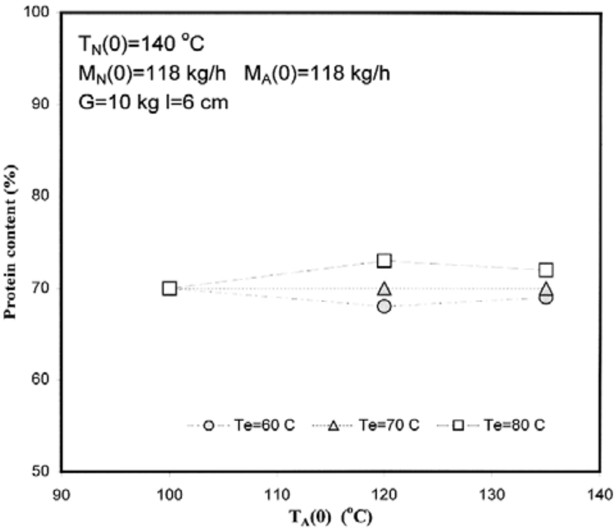

Figure 8. Influence of the inlet annular air temperature on the powder protein content

a draft tube, as it allows the combination of inlet parameters of the system, without an effect on the quality of the produced powder.

On the basis of the values shown in Table 1, it could be generally concluded that the plasma dried in a spout–fluid bed with a draft tube of our own design gives a high protein powder which is not inferior to a standard sample. Furthermore, the emulsion stability, strength of the gel and the weight loss during thermal treatment, were more favorable in almost all products than in the standard sample. On the average, thermally untreated emulsions from the powder obtained in our process were considerably more stable at the majority of the ingredient ratios. Also the weight loss during thermal treatment of the standard sample in comparison with samples from our experiments was 1.31 % higher and the strength of the gel less than 0.1 kg/cm^2, which proves the superiority of our product.

Brewery yeast is a very important material in the food industry as a source of vitamin B complex, amino acids and proteins. On the other hand, as a waste material it is a very large ecological problem, and therefore, its treatment in a drying process might be a solution for varions problems.

The drying of brewery yeast was conducted with the aim of investigating the possibilities of its drying and powder hold up in the bed as a consequence of the coating of inert particles during the drying process. The intensity of coating versus time for different bed temperatures is presented in Figure 9. It may be seen that there are two diferent curves for the same bed temperature as due to the basic chemical composition of the starting materials. Namely, the chemical analysis of brewery yeast showed that sugar was present in the suspension. Sticky materials improved the coating of inert particles.

With decreasing bed temperature the hold up of the materials in the bed increased and for a bed

Table 1. Functional characteristics of dried blood plasma

$T_N(0)$		140							100		Ref.
$T_A(0)$		100				135			120		
T_e		65	70	75	80	60	70	80	65	70	
ML		5.08	6.09	5.72	7.27	5.03	6.92	5.95	6.02	6.17	7.48
SG		0.2	0.17	0.17	0.1	0.26	0.09	0.15	0.3	0.25	0.09
Stability of the emulsion											
1:5:5	2h	+	+	+	+	+	+	+	+	+	+
	24h	+	+	+	+	+	+	+	+	+	+
	70°C	+	+	+	+	+	+	+	+	+	+
1:7:7	2h	+	+	+	+	+	+	+	+	+	+
	24h	+	+	+	+–	+	+–	+	+	+	+–
	70°C	+	+	+	+	+	+	+	+	+	+
1:9:9	2h	+	+	+	+	+	+	+	+	+	+
	24h	+–	+–	+	+–	+	+–	+	+	+–	–
	70°C	+	+	+	+	+	+	+	+	+	+

$T_N(0)$, $T_A(0)$, T_e – air temperature
ML (%) – mass loss during thermal treatment for 1 hour at 70°C
SG (kg/cm^2) – gel strength
Ref. – standard sample
1:n:n – plasma : fat : water, treatment after 2. 24 h and heat treatment at 70°C
+ stable emulsion, +– partially decomposed emulsion, – decomposed emulsion

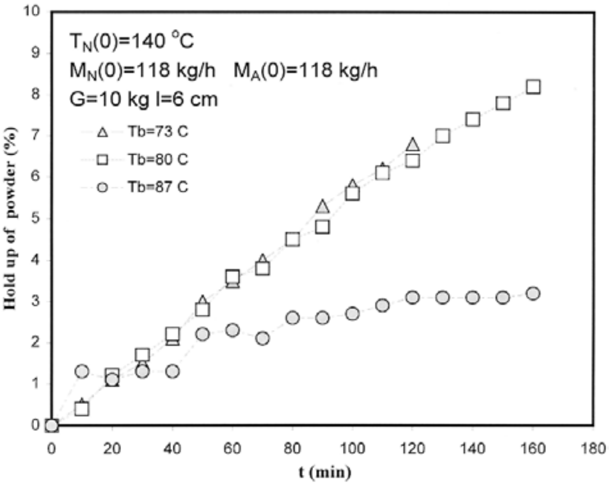

Figure 9. Hold up of the powder product in the bed versus time

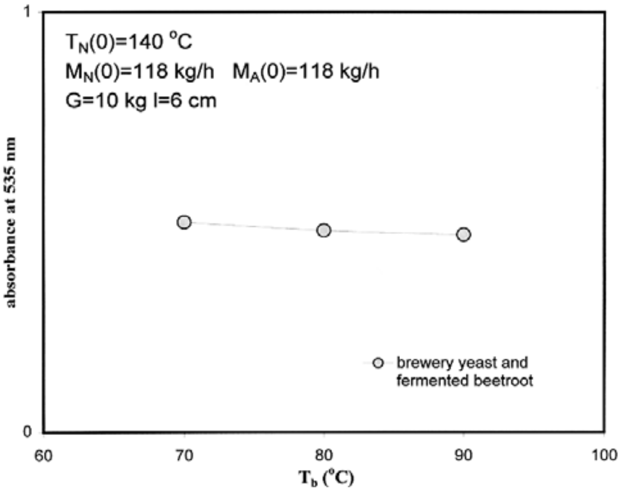

Figure 10. Influence of the outlet air temperature on the color of the powdered product

temperature of 87°C process was stable and continuous.

The subsequent dried materials were mixtures of brewery yeast (Saccharomyces uvarum) and fermented red beet juice (Beta vulgaris) in the rations 80:20, 70:30 and 50:50. The contents of humidity, sugar and a–amino nitrogen were determined during the experiments as a function of the bed temperature and the results are presented in Table 2. It may be seen from Table 2 that the drying process, for the experimental conditions, did not influence the sugar and α–amino nitrogen content.

The change in the intensity of the color of the dehydrated materials, related to different temperatures in the bed, was also investigated. The results showed that the color intensity decreased with increasing bed temperature, 8% for 80°C and 12% for 90°C in comparison to the color of powder dried at 70°C, bed temperature, Figure 10.

CONCLUSION

The results of the investigation of the drying of different biological materials in a spout fluid bed with a draft tube and inert particles show that the obtained powders are of very high quality. The protein content and humidity of the samples were closes to the higher limit proposed by standards.

The application of a spout–fluid bed system with a draft tube for drying biological and food materials was justified from the point of view of product quality, simple construction and exploitation for varions capacities.

Table 2. The content of moisture, α–aminonitrogen and sugars in brewery yeast suspension with fermented beetroot, in % d.m.

sample	before drying			after drying		
brewery yeast : fermented beetroot	humidity	α–amino–nitrogen	sugar	humidity	α–amino–nitrogen	sugar
80:20, T_e=70°C	90.2	8.9	24	4.8	8.9	23
70:30, T_e=70°C	87.5	8.2	25.5	4.3	8.2	25.5
70:30, T_e=80°C	87.5	8.2	25.5	4.0	8.1	25.5
70:30, T_e=90°C	87.5	8.2	25.5	3.8	7.9	24
50:50, T_e=70°C	86.5	6.8	22	4.5	6.6	22

SYMBOLS

A – cross–section of the column, m^2
c_p – heat capacity, kJ/kg°C
c_{pf} – heat capacity of air, kJ/kg°C
c_{pp} – heat capacity of the particles, kJ/kg°C
D_c – column diameter, m
D_{DT} – draft tube diameter, m
d_i – nozzle diameter, m
d_p – particle diameter, m
G – mass of bed, kg
H – height of bed, m
h – air humidity, kg water/kg dry air
H_e – outlet air humidity, kg water/kg dry air
H_i – inlet air humidity, kg water/kg dry air
k – overall heat transfer coefficient, $W/m^{2o}C$
L – liquid mass flowrate, kg/h
L_{DT} – length of the draft tube, m
l – distance of the draft tube from the bottom of the column, m
$M_A(0)$ – air mass flowrate at the bottom of the annulus, kg/h
$M_N(0)$ – air mass flowrate in the nozzle, kg/h
M_A – annular air mass flowrate, kg/h
Qloos – heat loss, kJ/h
T – temperature, °C
$T_A(0)$ – temperature of air at the bottom of the annulus, °C
T_a – temperature of annular air, °C
T_b – bed temperature, °C
T_e – outlet temperature, °C
$T_N(0)$ – nozzle air temperature, °C
T_p – temperature of the particles, °C
T_w – temperature of the column wall, °C
t – time, s
v – particle velocity, m/s
v_A – particle velocity of the botton of the annulus, m/s

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IZVOD

SUŠENJE BIOLOŠKIH MATERIJALA U FONTANSKO–FLUIDIZOVANOM SLOJU

(Naučni rad)

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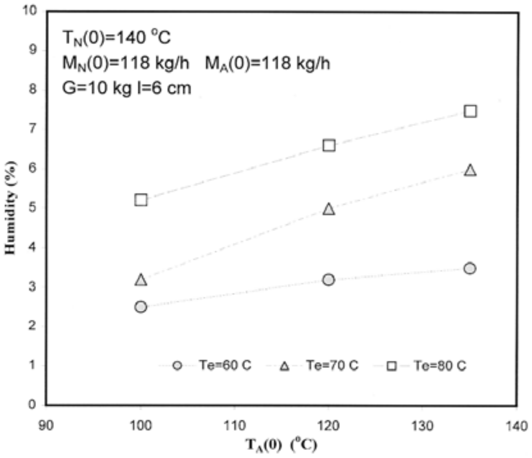
Predmet ovog rada je ispitivanje mogućnosti primene fontansko–fluidizovanog sloja sa centralnom cevi u cilju sušenja suspenzija različitog sadržaja suspendovanih materija. Osnovni cilj je bio ispitivanje mogućnosti sušenja bioloških materijala i proizvoda prehrambene industrije. Eksperimentalni rezultati su dobijeni ispitivanjem fluidno–mehaničkih karakteristika i procesa sušenja u poluindustrijskoj jedinici prečnika 250 mm, sa centralnom cevi i slojem inertnih čestica polietilena, prečnika 3.6 mm i gustine 940 kg/m^3. Uz poštovanje uslova fluidnomehaničke stabilnosti, ispitivani sistem se može sa uspehom koristiti za sušenje bioloških suspenzija.

Ključne reči: Sušenje • Biološke suspenzije • Fontansko–fluidizovani slo • Centralna cev •
Key words: Drying • Biological suspensions • Spout–fluid bed • Draft tube •


T_N(0)=140 °C
M_N(0)=118 kg/h M_A(0)=118 kg/h
G=10 kg l=6 cm
Humidity (%)
0
1
2
3
4
5
6
7
8
9
10
T_A(0) (°C)
90
100
110
120
130
140
Te=60 C
Te=70 C
Te=80 C