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DETERMINATION OF THE CRITICAL FLUIDIZING VELOCITY FOR COARSE-GRAINED MATERIALS USING CELERY CUTS

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Key words: fluid drying, celery, fluidizing velocity

This work shows results of a celery root cut to pieces of a cube (10x10x10 mm) drying in a fluidizing bed. The course of water content changes in the celery root cut, depending on the bed height (from 4 cm to 20 cm) and drying air temperatures in range from 40°C to 80°C was tested. The temperature of the drying air has a significant influence upon the velocity of water content change in the bed. The analysis of airflow resistance changes depending on the resting layer height was carried out. The critical airflow velocity during testing for all height's of the layer was 4.5 ÷ 4.8 m/s.

INTRODUCTION

Drying consistently plays an important role in all processes of food conservation and storage. Heat exchange between the drying gas (most often the air) and the fixed bed subjected to drying can be carried out in a convective and a contact manner. Due to a very small velocity of the drying air flowing thorough the bed, small values of penetration coefficients are obtained for the heat exchange between air and bed particles [Pabis, 2002]. Drying by the stream of hot air in a fluid state provides more advantageous conditions for heat and mass exchange than in the case of fixed packing [Lewicki & Lenart, 1990]. Fluid drying, requiring greater speed of the drying factor in comparison to the convective-streamline drying, can be carried out in the bed of even porosity. This condition is fulfilled by the layer consisting of particles possessing the same shape, size and field of surface in any section such as: powders, sands [Sreenivasan & Raghavan, 2002], millet [Sivashanmuhan & Sundaram, 1999], and among agriculture products, seeds and grains [Jaros, 2002]. The minimal air velocity for particles 1 mm in diameter is from approximately 0.5 m/s to approx. 1.2 m/s, and for particles of 10 mm from approx. 1 m/s to approx. 6 m/s [Grace, 1982].

Fluid drying of the products such as vegetables and fruits, which require preliminary preparation (obtaining of the suitable shape, for example), has not been studied so far, therefore the hydrodynamics and kinetics of such products drying have not been known.

The aim of this work was to study the airflow resistance in cut celery and calculate the critical bed fluidization velocity. The scope of the work covered preparation of cut celery in a form of cubicles and measurements of airflow resistance in a layer of the material subjected to fluid drying.

MATERIALS AND METHODS

Selected roots of celery (*Apium graveolens* L. var. *rapaceum*) were used for all experiments. Celery was peeled from the outer layer in order to get rid of side roots and dirt using a vegetable peeler type T5-S/Electrolux. Peeled roots were cut in the TRS/Dito mill-cut. Material in a form of cubicles (10x10x10 mm) was used throughout the study. Sliced and weighed (electronic scale type WPE-300) material was placed in a drying chamber. The drying process was carried out in a laboratory non-fluid dryer. The measurements were carried out at five drying temperatures within the range from 40°C to 80°C for five bed heights in the range from 4 to 20 cm, each measurement point every 4 cm. The drying air was sucked in from the laboratory room through the tube with the calibrated flange installed. The velocity of the drying factor was identified based on the charts showing a relationship between pressure on the ruff and the velocity of the air. The value of pressures' difference was read on the scale of Recknagl's micromanometer, then based on the chart of the ruff properties, the velocity of air flow for the given pressures' difference was read. The value of air resistance was a direct measurement of the difference between meniscuses in both tubes, on the scale of an U-tube. The results consisted of the difference measured under and over the fluidizing bed.

RESULTS AND DISCUSSION

The measured values were characterised for absolute errors, calculated on the base of the size measurement. In the case of direct measurement absolute errors were defined based on the class of the equipment accuracy or on the base of the value of the smallest scale of the equipment. Table 1 shows absolute errors of the measured values.

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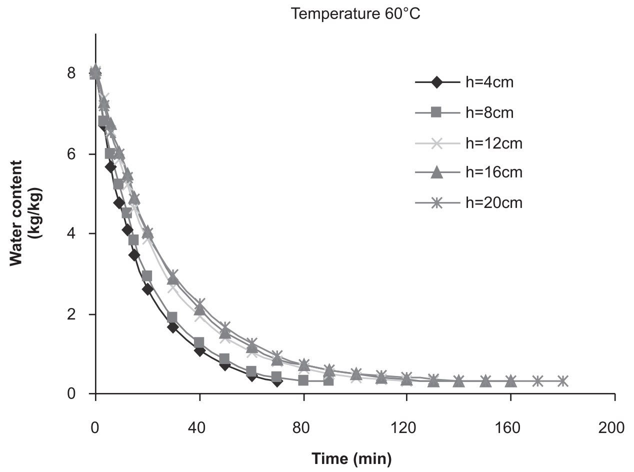

FIGURE 1. Water content changes of celery slices in beds with the resting height from h=4 cm to h=20 cm at the temperature of drying air t_p= 60°C.

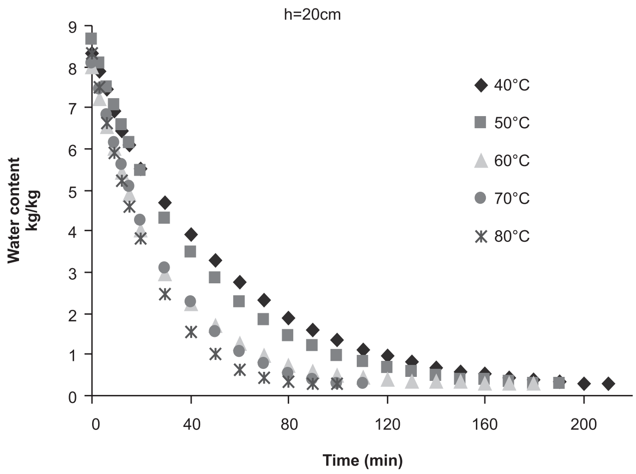

FIGURE 2. Water content changes in sliced celery of resting height h=20 cm at the drying air temperature from t_p= 40°C to t_p= 80°C.

The process of fluid drying is a result of heat and mass exchange between two mediums (sliced celery and air), therefore its analysis was carried out based on sliced celery mass changes depending on temperature of the drying air and depending on the resting bed height. An examplary chart of water content changes depending on the bed height during drying with the air at the temperature of 60°C is shown in Figure 1.

Analysis of charts shows that drying times for celery slices in the beds of resting heights 12, 16, and 20 cm are slightly different – the curves of water content are almost covering themselves. The greater drying velocity for layers 4 cm and 8 cm high resulted from the difficulty in stabilization of the fluid drying manner since particles movements in these beds were on the border of fluidization and pneumatic transport.

An example of water content changes depending on the temperature of drying air, in the bed of resting height of 20 cm was shown in Figure 2.

Analysis of the results for drying times depending on the drying air temperature showed, that by increasing the drying air temperature twice, for example from 40°C to 80°C, it is possible to shorten the drying time from 2.5 to 3 times, independently from the bed height.

The air velocity for which the layer (bed of the dried product) resistance is maximal is called the critical velocity. Since at the beginning of the studies, the value of critical velocity for the coarse-grained materials, such as tested celery slices, was unknown, it was calculated on the basis of airflow resistance measurements during drying of the material layer. The measurements were carried out for five different resting bed heights.

TABLE 1. Setting-up of absolute (systematical) errors of the measured values.

Measured value	Absolute error
Sample mass	0.1 g
Dry sample mass	0.01 g
Sample volume	0.1 cm^3
Sample temperature	0.1°C
Bed height	5 mm
Pressures' difference	1.0 mm H_2O
Air flow velocity	0.1 m/s

An example setting of the obtained results of the tested parameters during the drying process of celery cubicles of 10 cm in length, depending of the bed height is shown in Figure 3. The resting heights of the tested bed were as follows: 4, 8, 12, 16 and 20 cm.

During measurements, a change was noticed in the bed height in relation to the height at the beginning. The change in the bed height caused by drying shrinkage and mass decrease resulted in the necessary correction of the drying air velocity. It was concluded that the critical airflow velocity through the beds of celery cubicles 10 mm long, was in the range of 4.5 ÷ 4.8 m/s. It was also noticed that the air flowing through the bed of higher height was characterised by slightly greater critical velocity, although those differences were insignificant for the tested bed heights.

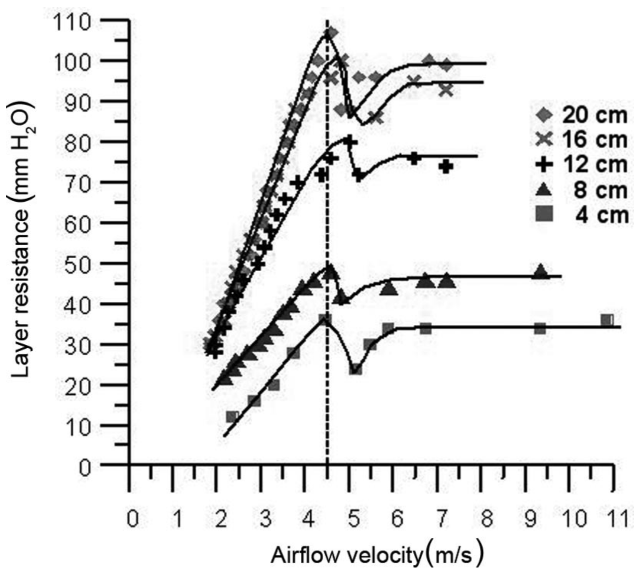

FIGURE 3. The measurement results of air flow resistance in layers of celery slices at the resting bed height from h=4 cm to h=20 cm.

CONCLUSIONS

1. The temperature of the drying air has a significant influence upon the velocity of water content change in the bed of sliced celery. The influence of the bed height is minimal.

2. The critical airflow velocity during testing of the bed of celery cubicles of 10 mm at length was 4.5 ÷ 4.8 m/s. It was observed that the air flowing through the higher bed was characterised by greater critical velocity, although for the tested bed heights (from h=4 cm to h=20 cm) these differences were insignificant.

3. The changes in the bed mass and height, by drying shrinkage and mass decrease, resulted in the necessary correction of the drying air velocity. It is therefore necessary to continue the work on the testing and preparation of the mathematical model for dependency between changes in the dried bed and in the drying factor parameters.

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WYZNACZENIE KRYTYCZNEJ PRĘDKOŚCI FLUIDYZACJI MATERIAŁÓW GRUBOZIARNISTYCH NA PRZYKŁADZIE KRAJANKI SELERA

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W pracy przedstawiono wyniki badań procesu suszenia krajanki korzenia selera w postaci kostek sześciennych o wymiarach 10x10x10 mm, w złożu fluidyzacyjnym. Badano przebieg zmian zawartości wody w suszonym materiale w zależności od wysokości złoża (od 4 cm do 20 cm) oraz temperatury powietrza suszącego w zakresie od 40°C do 80°C. Temperatura miała znaczący wpływ na szybkość zmian zawartości wody, natomiast wysokość złoża minimalny. Przeprowadzono analizę zmian oporów przepływu powietrza przez warstwę w zależności od jej wysokości spoczynkowej. Prędkość krytyczna przepływu powietrza dla wszystkich wysokości złoża wynosiła 4.5 ÷ 4.8 m/s.