Energy consumption in convectional drying of apples

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Abstract: Energy consumption in convectional drying of apples. The work aimed at determination of thermal energy consumption in heating up the drying medium during convectional drying of apple particles in the tunnel and fluidization dryers, as well as determination of the effect of temperature and shape of the cut apple particles on energy consumption. Dynamics of energy consumption changes as the function of temperature was higher during drying of bigger apple particles, particularly when the fluidization drying method was used. The effect of particles’ shape and dimensions on the thermal energy consumption was lower during drying in the tunnel dryer, but drying time in the tunnel dryer was considerably longer, and the thermal energy consumption was twice as much. The differences in energy consumption needed for apple drying in both dryers were the bigger, the bigger were the apple particles.

Key words: energy, drying, apples, dryers.

INTRODUCTION

Drying of food products as well as fruits and vegetables has been one of the oldest methods for food conservation and storage. The agricultural products are usually dried by convectional method, where the heated up air is most often used as drying medium. This process aims at removing the substantial amount of water included in the product being dried. It directly influences the quality and nutritional value of the product, since it can be stored longer under appropriate conditions. Besides, the product mass and volume decrease considerably during drying; these properties influence the costs of product transport and storing. Maintaining of product quality is important; to fulfill certain quality requirements of the dried material it is essential to use the raw material of highest grade.

The drying process not only removes substantial amount of water from the organic material, it also prevents the growth of microorganisms, like mould fungi, bacteria or yeast. These factors are very important especially during storing of apples, which are the most significant species among the orchard fruits grown in the country. They have a high nutritional value and are highly appreciated because they are tasty, healthy and dietetic. These fruits are suitable not only for storing and eating in their original form throughout the year, but also for processing. They are good components of babies’ breath and other food products. One of the methods for processing of this valuable raw material is drying of the whole or cut apples, applied both on a commercial scale and in the households. The cut fruits can be subjected to technological operations to obtain the appropriate external and internal properties.
of the product: colour, smell, taste, consistency and moisture content [Koźbial 2002].

Drying of agricultural products is a very energy consuming conservation operation and very often the energy inputs decide on profitability of this operation. However, many research results point out at possible energy and fuel savings, as well as environmental protection [Pabis S., Pabis J. 1984]. The reduced energy inputs in the process of organic material drying can be achieved by application of various actions.

Energy savings of 10–20% can be achieved by reutilization of the part of heat using the recirculation and drying of the product in parallel flow or in counter flow, depending on product specification [Pabis 1994].

Application of initial fruit and vegetable pre-drying after completion of water blanching prior to drying enables to reduce energy consumption by 30% with simultaneous increases in a 24-hour throughput of the dryers.

Combination of the tunnel-carriage method followed by fluidization drying enables to reduce the thermal energy consumption by 30% when compared with a reverse method. A decrease in energy consumption during drying is influenced by the drying methods for a given product, as well as its shape and the outspread surface of particles, through which the water is carried away from the material being dried [Kaleta and Górnicki 2001].

AIM AND SCOPE OF WORK

The work aimed at determination of thermal energy consumption needed for heating up the drying medium during drying of cut apples in the tunnel and fluidization dryers as well as at determination of the effect of drying medium temperature and the shape of apples on this energy consumption.

During drying in the tunnel dryer there were used the apples in the form of cube particles of side 1 cm, the plasters and the quavers, while fluidization drying was performed with the apple cubes of sides 0.5 and 1 cm and cuboids of dimensions 1 × 2 × 2 cm. In both cases the same temperature of drying medium was used: 50, 60 and 70°C.

METHODIC

The results of Koźbial (2002) and Kity (2003) investigations were used in determination of thermal energy needed for heating up the drying medium. The investigation methodic is given in these works. The energy consumption was calculated according to investigation methodic for dryers [Pabis and Kulik 1998].

RESULTS OF INVESTIGATIONS AND THEIR ANALYSIS

Exemplary results of calculations are presented in the form of diagrams (Fig. 1), which illustrate graphically the relative changes in Q/Qmin as a function of temperature (where Q is energy consumption at a given drying medium temperature, while Qmin is the minimal energy consumption calculated for given drying process parameters).

Basing on the course of curves (Fig. 1) one can determine the thermal energy consumption for a given drying medium temperature and evaluate the drying process characteristic from the viewpoint
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of its energy consumption. In the range of investigated temperatures (50–70°C) the energy consumption during drying of apples in the form of cubes of side 0.5 cm decreased by 6%, while for the cubes of side 1 cm the reverse course of energy consumption was found, where it increased by 6% under the same thermal conditions; the characteristic course was degressive. The highest energy consumption (of progressive characteristic and a 15% dynamic of increase) was found during drying of apple cuboids of dimensions $1 \times 1 \times 2$ cm.

Figure 2 presents the changes in energy consumption as a function of temperature for apple particles dried in the tunnel dryer.

Analyzing the course of curves one can find that the least energy consumption occurred during drying of cut apples in the form of cubes of side 1 cm, while slightly higher energy consumption (by 20%) was found for apple plasters, and the highest values were recorded for quavers (increase of almost 100%). The thermal energy consumption increased with temperature for all the shapes of apples dried in the tunnel dryer, but dynamics of changes was different. The least energy consumption dynamics was recorded for the apple plasters, where in

FIGURE 1. Dependence between energy consumption $Q/Q_{\text{min}}$ and temperature for various apple particle dimensions dried by fluidization ($Q$ – energy consumption at a given temperature, $Q_{\text{min}}$ – minimal energy consumption)
the range of drying medium temperature from 50 to 70°C it increased only by 2%. The slightly higher dynamics of energy consumption changes was found for apple cubes of side 1 cm, and the highest value occurred for quavers (increase of 40%).

Figure 3 presents comparison between energy consumption courses during drying of apple particles of various shape in the tunnel and fluidization dryers.

Considering these courses one can find that only in the case of fluidization drying of apple particles of smallest dimensions there was recorded a decrease in energy consumption along with an increase in drying temperature. In the remaining cases the energy consumption increased when the temperature was increased. The difference between energy consumption values during drying of apple cubes of side 0.5 cm in the tunnel and fluidization dryers varied and was equal to ±15% for the extreme temperatures of 50 and 70°C; only at 60°C the energy consumption values for both drying methods were the same. An increase in particle dimensions and cutting of apples into different forms caused considerable increase in energy consumption in both the drying methods used.
CONCLUSIONS AND PROPOSALS

1. The highest effect of drying medium temperature and the shape and dimensions of the cut apples on thermal energy consumption was found in both the fluidization and tunnel drying.

2. The energy consumption dynamics as a function of temperature was higher during drying of bigger apple particles, particularly in application of fluidization drying.

3. The effect of particle shape and dimensions on thermal energy consumption was lower during drying in the tunnel dryer than in the fluidization dryer, however, the drying time in the tunnel dryer was considerably longer and thermal energy consumption was twice as much.

4. The higher were apple particles, the bigger were differences in energy consumption needed for apple drying in the tunnel and fluidization dryers.

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Streszczenie: Energochłonność konwekcyjnego suszenia jabłek. W pracy przedstawiono wyniki zużycia energii cieplnej potrzebnej do nagrzania materiału podczas suszenia krajanki jabłek metodą konwekcji wymuszonej w suszarce z poziomym przepływem powietrza (suszarka tunelowa) oraz w suszarce fluidyzacyjnej.

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