THE DRYING LEUROTUS MUSHROOMS BY DIFFERENT TYPES OF ENERGY

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Summary: Drying is the most effective method of food preservation today. This method is also the most expensive too. It is the main objective drying process which helps to achieve the highest quality by the minimum energy consumption. The most appropriate way in dehydrating cultivated mushrooms is the drying by infrared radiation, but this method has not acquired a significant spread through the phenomenon of thermal diffusion.

Key words: mushrooms, energy consumption, infrared drying, the combined method of exposure

As is known by convective air drying the air is the carrier of heat from heating apparatus the product, which is more energy intensive than in the infrared where the air carrier does not perform the function of heat and moisture removal only feature. We suggest combining the two methods of supplying heat drying, which will reduce the relative humidity, and thus increase the driving force of the process compared with infrared drying.

We have carried out a combined process of drying leurotus mushrooms by temperature from 40–70 C. Irradiation was carried out at the top and bottom tubular product “dark” infrared generators with a wavelength 2.0 ... 4.0 mm. The irradiated level by infrared heaters was E = 8 W/m2. Distance from infrared heaters to product was 15 cm simultaneously performed exposure convective heat from the outside heater with capacity 1 kW, with a velocity of coolant 6 m/s. Mushrooms were placed 8 mm thick on the mesh tray, which is inserted into the drying chamber.

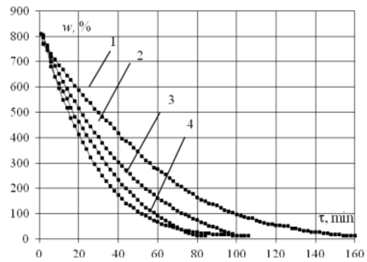


Fig. 1. The convective drying curves of mushrooms (the cultivated leurotus mushroom) by the temperatures °C: 1 – 40, 2 – 50, 3 – 60, 4 – g 70

As we can see the warming–up mushroom growth of the coolant temperature from 40 to 70 C under reduced time from 160 to 85 minutes (Pic. 1). The drying rate period was observed before the first critical point.

Approximating the data of the first period of drying, derived equations obey a linear law.

By coolant temperature:

40 °C: $W = -11.541\tau + 805.95$ by $R^2 = 0,9946$;
50 °C: $W = -13.943\ \tau + 820.99$ by $R^2 = 0,9962$;
60 °C: $W = -18.06\ \tau + 837.09$ by $R^2 = 0,9861$;
70 °C: $W = -15.654\ \tau + 826.61$ by $R^2 = 0,9945$.

Where W – moisture,%;
τ – Time, minutes;
R^2 – tail probability.

By the data approximating of the second drying period, we have derived an equation that subordinate the exponential law:

40 °C: $W = 1250.5e^{-0.027\tau}$ by $R^2 = 0,9815$;
50 °C: $W = 1354.8e^{-0.035\tau}$ by $R^2 = 0,9672$;
60 °C: $W = 1532.1e^{-0.045\tau}$ by $R^2 = 0,9521$;
70 °C: $W = 1515.3e^{-0.053\tau}$ by $R^2 = 0,9734$.

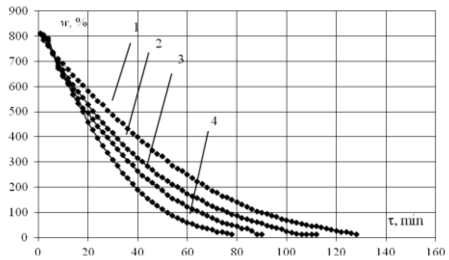


Fig. 2. The infrared drying mushrooms curves (the cultivated leurotus mushroom) by the temperatures °C: 1 – 40, 2 – 50, 3 – 60, 4 – 70

As we can see the warming up mushroom growth is in the coolant temperature from 40 to 70 C under reduced time from 128 to 78 minutes (Fig. 2). The drying rate period was observed before the first critical point.

Approximating the data of the first period of drying, we have derived equations which are subordinated to the linear law.

By the coolant temperature:

40 °C: $W = -9.96\tau + 793.51$ by $R^2 = 0,99$;
50 °C: $W = -15.702\tau + 821.62$ by $R^2 = 0,99$;
60 °C: $W = -20.76\tau + 838.32$ by $R^2 = 0,97$;
70 °C: $W = -17.77\tau + 836.68$ by $R^2 = 0,97$.

Approximating the data of the second period of drying, we have derived equations that subordinate the exponential law:

40 °C: $W = 2213.7e^{-0.036\tau}$ by $R^2 = 0{,}975$;
50 °C: $W = 1453.5e^{-0.039\tau}$ by $R^2 = 0{,}954$;
60 °C: $W = 1335.5e^{-0.045\tau}$ by $R^2 = 0{,}96$;
70 °C: $W = 1404.6e^{-0.054\tau}$ by $R^2 = 0{,}98$.

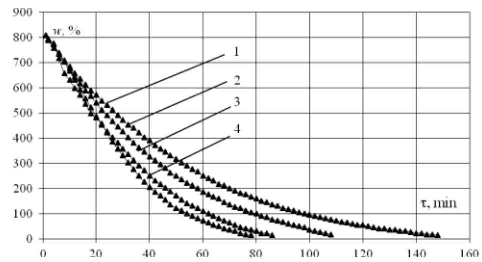


Fig. 3. The combined drying mushrooms curves (the cultivated leurotus mushroom) by the temperatures °C: 1 – 40, 2 – 50, 3 – 60, 4 – 70

The drying curves are characterized by the changing in moisture content W with integral time function. That shows the increasing coolant temperature, by the drying process duration which is reduced to a small value in achieving the final amount of moisture WC = 13.63 % (for each drying method).

As we can see the warming–up mushroom growth is the coolant temperature from 40 to 70 C under reduced time from 150 to 78 minutes (Pic. 3). The drying rate period was observed before the first critical point.

Approximating the data of the first drying period, are derived equations subordinate the linear law.

By the coolant temperature:
40 °C: $W = -10.2\tau + 798.57$ by $R^2 = 0{,}9938$;
50 °C: $W = -13.806\tau + 797.72$ by $R^2 = 0{,}9938$;
60 °C: $W = -18.485\tau + 813.2$ by $R^2 = 0{,}9978$;
70 °C: $W = -24.433\tau + 840$ by $R^2 = 0{,}9958$.

Approximating the data of the second drying period, are derived equations that subordinate the exponential law:

40 °C: $W = 1464.9e^{-0.028\tau}$ by $R^2 = 0{,}988$;
50 °C: $W = 2075e^{-0.045\tau}$ by $R^2 = 0{,}9555$;
60 °C: $W = 2025.1e^{-0.056\tau}$ by $R^2 = 0{,}954$;
70 °C: $W = 996.42e^{-0.045\tau}$ by $R^2 = 0{,}9954$.

The speed drying Curves

Basing on the drying cultivated leurotus mushroom curves the curves for each of the drying methods were constructed.

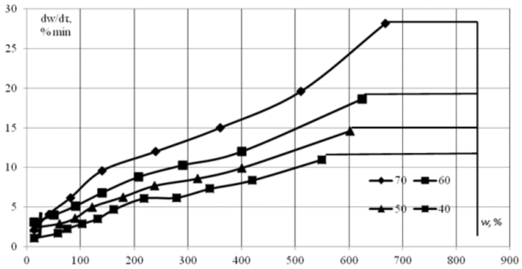


Fig. 4. The leurotus mushroom speed drying curves which was cultivated in convection method by the temperatures °C: 40, 50, 60, 70

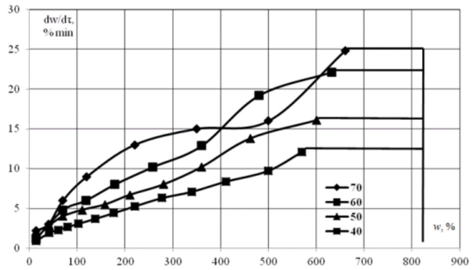


Fig. 5. The leurotus mushroom speed drying curves which was cultivated in infrared method by the temperatures °C: 40, 50, 60, 70

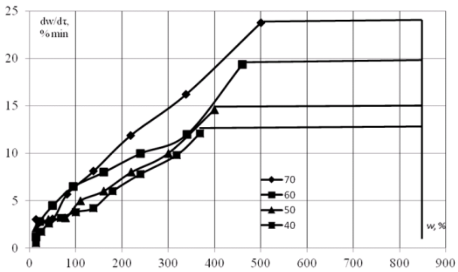


Fig. 6. The leurotus mushroom speed drying curves which was cultivated in combined method by the temperatures °C: 40, 50, 60, 70

By the deriving the kinetics drying equation in experimental dependences d*w*/dt we have been found that the first stage of drying rate can be considered approximately constant. As the temperature of the coolant is increased from 4.86 kg / (kg · min) (to 60 °C) to 9.6 kg / (kg · min) (for 80°C).

Have been analysing the second period of drying derived approximation equation at temperatures:

40 °C

The combined method (a power)$dW/d\tau = 0{,}088W^{0{,}823}$ by $R^2 = 0{,}946$
Convective (linear) $dW/d\tau = 0{,}018W + 1{,}116$ by $R^2 = 0{,}98$
The infrared method (a power) $dW/d\tau = 0{,}145x^{0{,}671}$ by $R^2 = 0{,}991$

50 °C

The combined method (linear) $dW/d\tau = 0{,}031x + 1{,}304$ by $R^2 = 0{,}984$
Convective (linear) $dW/d\tau = 0{,}020W + 2{,}118$ by $R^2 = 0{,}989$
The infrared method (a power) $dW/d\tau = 0{,}411W^{0{,}543}$ by $R^2 = 0{,}954$

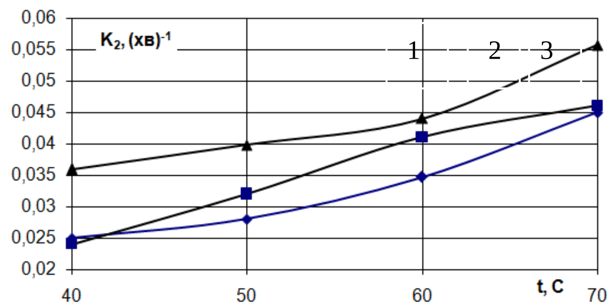
60 °C

The combined method (linear) $dW/d\tau = 0{,}035W + 1{,}976$ by $R^2 = 0{,}961$
Convective (linear) $dW/d\tau = 0{,}024W + 2{,}976$ by $R^2 = 0{,}991$
The infrared method (a power) $dW/d\tau = 0{,}177W^{0{,}743}$ by $R^2 = 0{,}992$

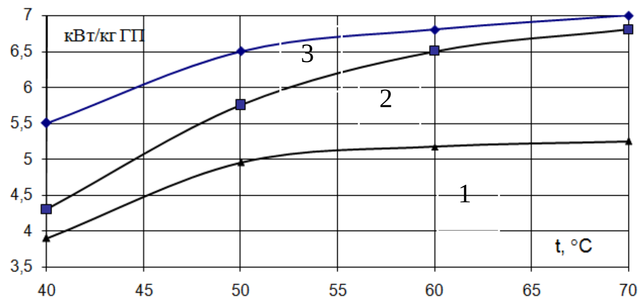
70 °C

The combined method (linear) $dW/d\tau = 0{,}043W + 1{,}932$ by $R^2 = 0{,}995$
Convective (a power) $dW/d\tau = 0{,}385W^{0{,}637}$ by $R^2 = 0{,}992$
The infrared method (a power) $dW/d\tau = 0{,}392W^{0{,}626}$ by $R^2 = 0{,}968$

We have reconstructed the dependence energy consumption curve by the temperature of the coolant with different energy ways methods (Pic. 7)



Pic. 7. The rate coefficient in the second drying period by the coolant temperature
1 – convection; 2 – Infrared; 3 – combined.



Pic.8. The energy consumption dependence by the coolant temperature with different energy ways methods kWh / kg in finished product: 1 – convection; 2 – Infrared; 3 – combined.

We can see from these graphs with increasing temperature, the carrier increased energy consumption and at the same time a combination of convection and infrared heat supply there is the least cost.

Conclusions

On the basis of the analysis we can conclude about the great prospects directly. During the researching, the quality of the dried product is the most protein and total nitrogen found in mushrooms in the combined method of drying. Since this is the need to research and to improve this method of drying which will reduce the cost of drying process by 35%, increase shelf life and improve product quality.

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