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Changes in Quality Characteristics of Yeast Dried by Various Methods

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Abstract

This study was to compare the quality characteristics of yeast (*Saccharomyces cerevisiae*) dried using different methods. The yeast sample was dried at 50°C for hot-air drying (HD), freeze drying (FD), and vacuum drying (VD) while it was dried at 40-80°C in case of microwave vacuum drying (MVD). The drying characteristics, moisture diffusivity, survival kinetics, and morphological damages were evaluated. MVD showed the shortest drying time (1.5 hrs), followed by HD, VD, and FD. The initial drying rate of MVD was four times faster than that of HD. The MVD sample showed 10 times higher moisture diffusivity than the HD sample. The MVD sample showed similar survival to the FD sample. Both pseudo-z value (108.7°C) and z value (107.5°C) were similar each other. The morphological structure of MVD sample was similar to that of FD one. MVD seemed very advantageous due to its short drying time, low temperature, excellent viability, and less damaged morphology.

Key words: yeast, drying, moisture diffusivity, survival, morphology

Introduction

Yeast has been used as a fermentation agent for bread and wine and as a main constituent of a cultivating media. It has also been used as a health supplement or ingredients for various foods. It is usually dehydrated into an active dry form for the preservation and application purpose.

Drying of yeast causes damage to the cellular structure including rupture of cell membrane and changes in cell composition (Alpas *et al.*, 1996). The damage may further cause the destruction of heat-sensitive components as well as the cell death. Therefore, viable cell number is a good index for evaluating the degree of either heat damage experienced during conventional drying or freezing damage in case of freeze drying. In short, the cell viability of yeast is one of the most important quality characteristics of the dried yeast.

Such dehydration methods as hot-air drying, fluidized-bed drying, spray drying (Labuza *et al.*, 1970, 1972; Elizondo and Labuza, 1974), drum drying, and tunnel drying (Alpas *et al.*, 1996) are generally used for yeast. The methods are economical but may result in inferior quality especially during the later stage of drying. In case of vacuum drying and freeze drying (Kodato, *et al.*, 1999; Cerrutti *et al.*, 2000), product quality may be better but the cost may be more expensive. A promising alternative would be vacuum drying using microwave energy (Kim *et al.*, 1997). The death of microorganisms under microwave field is considered thermal and can be described by the conventional death kinetics. The microwave vacuum drying is very attractive process with respect to the cost as well as the product quality; however, there has been little attempt to produce active dry yeast by this technique.

In this research yeast sample was dried using hot-air drying (HA), freeze drying (FD), vacuum drying (VD), and microwave vacuum drying (MVD). The drying characteristics, moisture diffusivity, survival kinetics, and morphological damage of yeast were evaluated to compare the quality characteristics of dried yeast products.

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Materials and Methods

Materials

Fresh commercial pressed yeast was obtained from

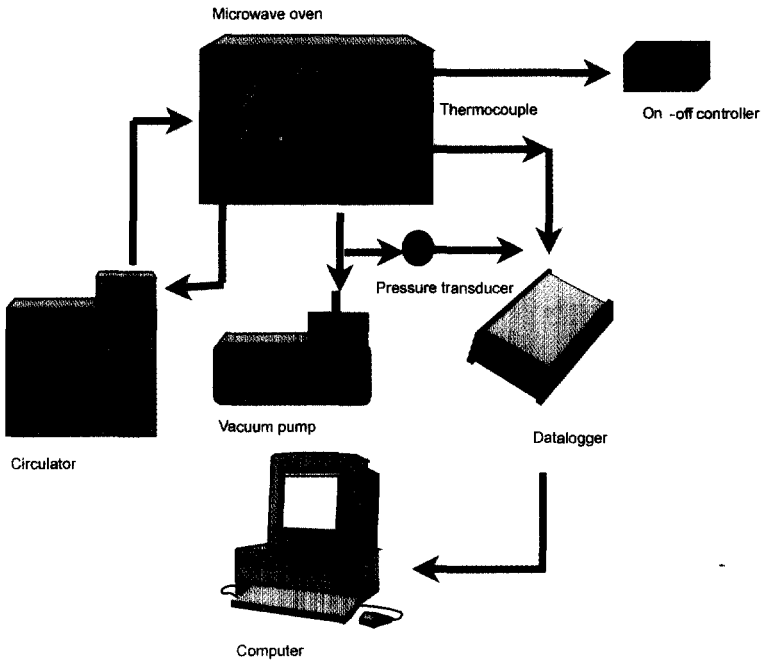

Fig. 1. Schematic presentation of a laboratory microwave vacuum drier.

Jenico Foods Co, Ltd. (Seoul, Korea). The sample was in the form of paste and kept at −75°C in a deep freezer (GS Laboratory Equipment, ULT 2586-5-D30, USA) until used. The dried samples were then sealed in foil-laminated pouches.

Dehydration of yeast

Yeast samples (5 mm thickness) were dried using HD, VD, FD, and MVD. The drying experiments for triplicate samples were run at least three times.

In case of HD and VD, sample temperature was maintained at 50°C with K-type thermocouple probe and on-off controller. Samples were dried for three hours in a forced-convection hot air drier (Yamato Constant Temperature Oven, model DN-61, Japan) and for six to nine hours in a vacuum drier (Fisher Isotemp Vacuum Oven, model 281, USA), respectively.

The samples were frozen for 24 hours in a deep freezer (GS Laboratory Equipment, ULT 2586-5-D30, USA) before FD. The frozen samples were then dried in a laboratory freeze drier (Labconco Freeze Drier 5, USA) at ambient temperature with a condenser temperature of -50°C and a vacuum of 100 mmHg for 14 hours.

MVD was done in a laboratory microwave vacuum drier (model MVD-1, 2,450 MHz and 800 W, The Catholic University of Korea, Korea) shown in Fig. 1. Samples were placed on a circular teflon dish (100 mm diameter and 5 mm depth) and dried at 1 kPa (10 mmHg) and 40, 50, 60, 70, and 80°C for two hours. Pressure was monitored with a pressure transducer and a desired product temperature was monitored and maintained with a K-type thermocouple probe and a on-off controller. Samples were taken and weighed at 5 to 10 min intervals during drying.

Determination of moisture content and drying characteristics

Triplicate samples were dried at 105°C for 3 hours to determine the moisture content. Drying characteristics were analyzed with respect to time vs. temperature, time vs. moisture content, and moisture content vs. drying rate.

Determination of moisture diffusivity and its temperature dependence

The transient state diffusion is expressed by Fick's second law (Barbosa-Canovas and Vega-Mercado, 1996):

$$\frac{\partial m}{\partial t} = \frac{\partial^2 m}{\partial x^2} \quad (1)$$

where m=moisture content (kg water/kg solid), t=time (s), D=moisture diffusivity (m^2/s), and x=diffusion path (m).

The above equation can be solved in terms of infinite series for a infinite slab:

$$\frac{m - m_e}{m_0 - m_e} = \frac{8}{\pi^2} \sum_{n=1}^{\infty} \frac{1}{(2n-1)^2} \exp \frac{-(2n-1)^2 \pi^2 Dt}{4L^2} \quad (2)$$

where m_e=equilibrium moisture content (kg water/kg solid), m_0=initial moisture content (kg water/kg solid), L=slab thickness (m).

All terms in the above series may drop out for $n \geq 2$ because they are much smaller than the term for n=1.

$$\frac{m}{m_0} = \frac{8}{\pi^2} \exp \frac{-\pi^2 Dt}{4L^2} \quad (3)$$

The moisture diffusivity can be obtained from the above equation and its temperature dependence can be calculated from the following Arrhenius-type equation:

$$D = D_o \exp \frac{-E_D}{RT} \quad (4)$$

where D_o=pre-exponential factor (m^2/s), E_D=activation energy for diffusion (J/mol), R=gas constant (8.314 J/molK), and T=absolute temperature (K)

Survival kinetics

D-value and z-value in Eqn. (5) and Eqn. (6) were used to analyze survival kinetics of yeast during drying.

$$\frac{dN}{dt} = -\frac{2.303}{D} N \quad (5)$$

$$\frac{dN}{dT} = -\frac{2.303}{z} D \quad (6)$$

where N=number of viable cells (cfu/g), t=time (min), D=decimal reduction time (min), T=temperature (℃), and Z z-value (℃).

Enumeration of yeast

YPD agar medium (yeast extract 1%, polypeptone 2%, and dextrose 2%) was used to count viable cells of yeast (Adegoke, *et al.*, 1997). Colonies were counted after incubating duplicate plates at 30℃ for 24 hours. Results were expressed as colony forming units (cfu) per gram of solids.

Observation of surface structure of yeast cell

The surface structure of yeast cells after each dehydration treatment was observed with scanning electron microscope (JEOL Scanning Microscope, model JSM-5410LV, USA) at a 3,500 magnification level.

Statistical analysis

Statistical software (SigmaPlot 5.00, SPSS Inc., USA) was used to analyze data and to obtain the least square fit of the lines.

Results and Discussion

Changes in sample temperature during drying

Fig. 2 shows the changes in sample temperature during HD, VD, and MVD of yeast at the set temperature of 50℃. The sample reached 50℃ after 10 min of HD; while, it reached 50℃ after 30 min of VD. The slower temperature rise of VD seemed due to the slow heat conduction from the heating plate to the sample in a vacuum drier. In case of MVD, 80 min was required for the sample to reach 50℃. This slowest temperature rise was

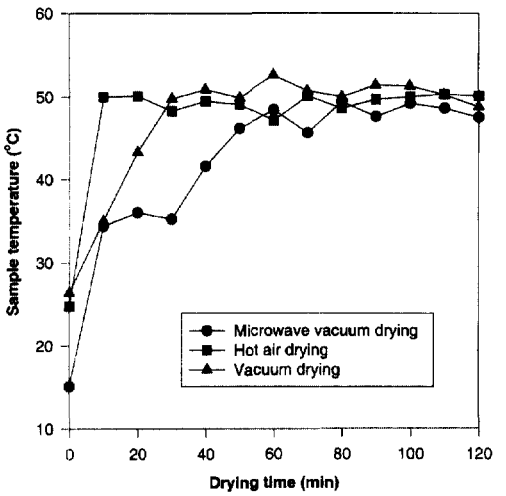

Fig. 2. Changes in temperature of yeast (*Saccharomyces cerevisiae*) during microwave vacuum drying, hot air drying and vacuum drying at 50℃.

mainly due to the fast drying and the enough loss of heat by evaporation in the initial stage of MVD.

Changes in sample moisture content and drying rate

Fig. 3 shows the changes in sample moisture content during HD and MVD at 50°C. The changes during VD and FD were omitted owing to the relatively slow changes as compared to the former drying methods. The sample moisture content decreased to 0.10 kg water/kg solid for the initial period of 20 min of MVD. It took 1 hr and 30 min for the sample to reach the final moisture content of 0.05 kg water/kg solid. In HD, it took 1 hr and 10 min to dry to 0.09 kg water/kg solid, 2 hrs to 0.06 kg water/kg solid and 3 hrs to 0.05 kg water/kg solid. In VD, 6 hrs were needed to dry to 0.09 kg water/kg solid and 9 hrs to 0.05 kg water/kg solid. In case of FD, at least 14 hrs were required to get the moisture content of 0.05 kg water/kg solid.

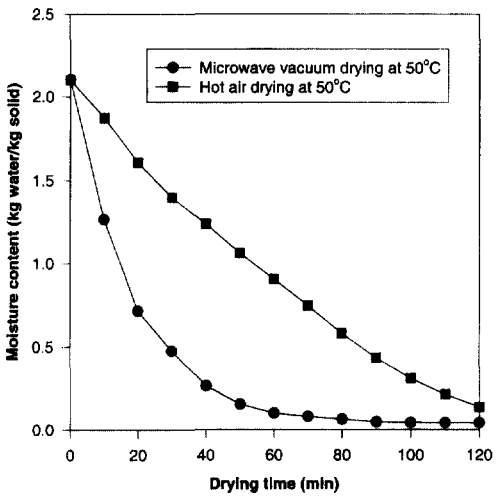

Fig. 3. Changes in moisture content of yeast (*Saccharomyces cerevisiae*) during microwave vacuum drying and hot air drying at 50°C.

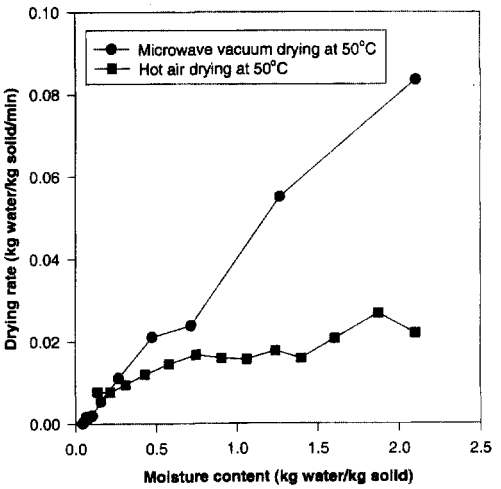

Fig. 4. Changes in drying rate of yeast (*Saccharomyces cerevisiae*) with respect to its moisture content during microwave vacuum drying and hot air drying at 50°C.

Fig. 4 shows the drying rates of HD and MVD at 50°C. In HD, constant rate period was observed down to the critical moisture content of 0.09 kg water/kg solid and then the falling rate period began. In contrast, MVD began with falling rate period. The initial drying rate (0.084 kg water/kg solid/min) of MVD was four times faster than that (0.022 kg water/kg solid/min) of HD.

Moisture diffusivity of sample dried by different methods

The moisture diffusivity at 50°C of HD sample and MVD sample were 7.42×10^{-10} m^2/s and 6.73×10^{-9} m^2/s, respectively. The MVD sample had 10 times higher moisture diffusivity than the HD sample. This seemed due to the difference in porosity of the two samples. The MVD sample had a lot of pores due to the high internal pressure and the rapid moisture escape. The diffusivity values of microwave vacuum dried samples also increased with drying temperature. The temperature

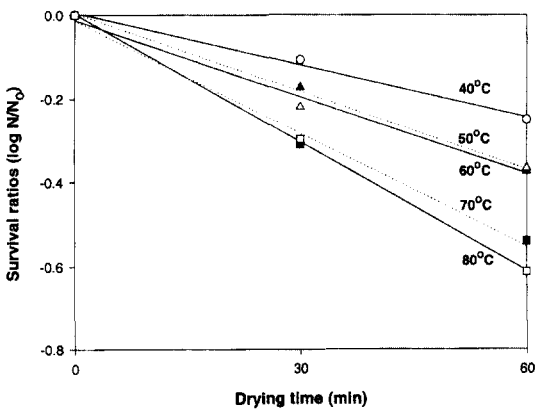

Fig. 5. Changes in logarithmic survival ratios of yeast (*Saccharomyces cerevisiae*) during microwave vacuum drying for 60 min at various temperatures.

dependence could be expressed as an activation energy of diffusion of 6538.8 J/mol.

Survival of yeast dried by different methods

The survival of yeast in the sample dried at 50°C was compared based on the logarithmic reduction. The smaller value the logarithmic reduction, the higher the survival. The logarithmic reduction values were 0.48 for FD, 0.60 for MVD, 1.02 for HD, and 1.23 for VD. The survival was in the order of FD, MVD, HD, and VD. However, the MVD sample showed similar survival to the FD sample. And the lowest survival of VD sample seemed due to the long drying time of 9 hrs.

Fig. 5 shows the logarithmic survival ratios during MVD for 1 hr at different temperatures. The logarithmic survival ratios decreased linearly with drying time and also decreased as drying temperature increased. From the curves in Fig. 5, D values at different temperatures

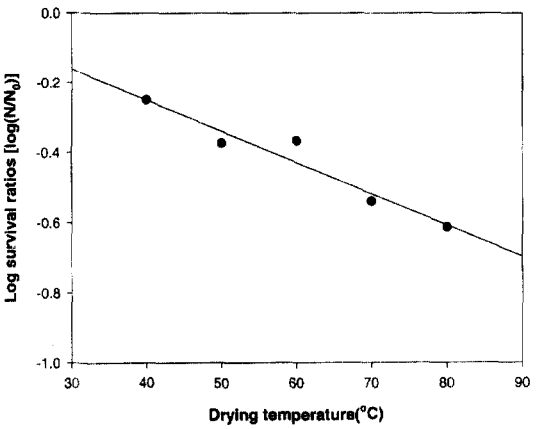

Fig. 6. Relationship between drying temperature and logarithmic survival ratios of yeast (*Saccharomyces cerevisiae*) microwave vacuum dried for 60 min.

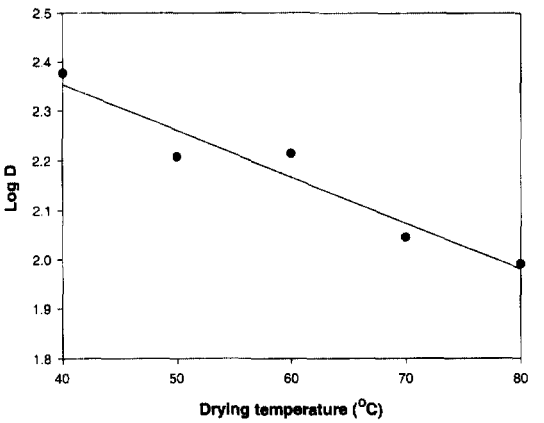

Fig. 7. Relationship between drying temperature and logarithmic D-values of yeast (*Saccharomyces cerevisiae*) microwave vacuum dried for 60 min.

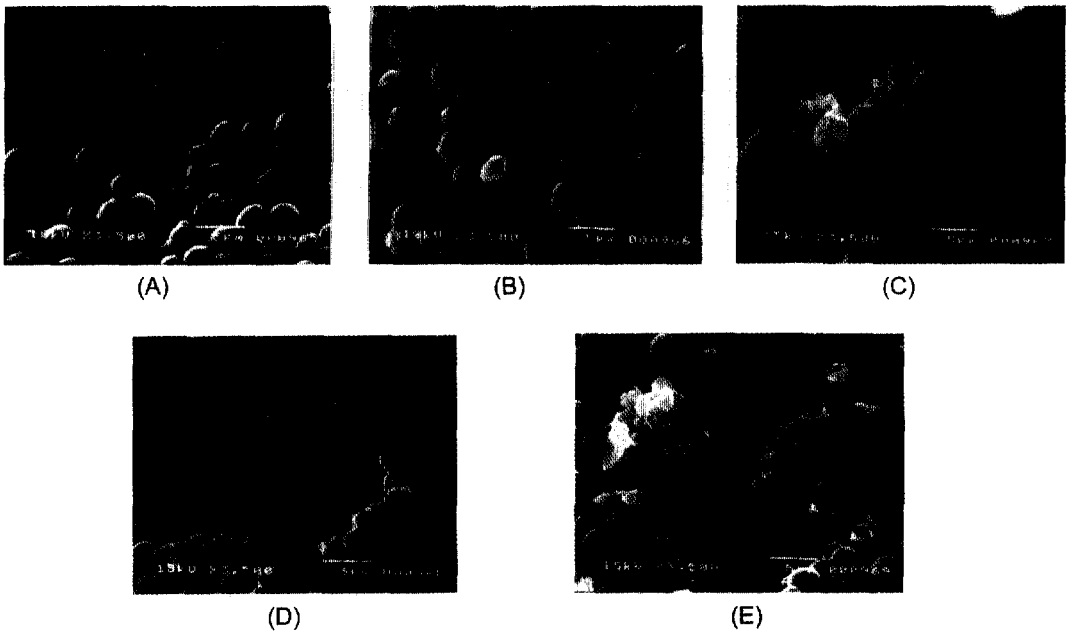

Fig. 8. Scanning electron micrographs (3,500X) of micro-wave vacuum dried yeast (*Saccharomyces cerevisiae*) at 40°C (9A), 50°C (9B), 60°C (9C), 70°C (9D), and 80°C (9E).

were calculated. As shown in Fig. 6, the logarithmic survival ratios decreased linearly with temperature increase. From Fig. 6, pseudo-z value was calculated to be 108.7°C. In Fig. 7 the logarithmic D values were plotted with temperatures to calculate z-values of 107.5°C. Both pseudo-z value and z value were similar each other.

Morphological changes of yeast dried by different methods

As shown in Fig. 8, the yeast cell was more damaged as the drying temperature of MVD increased from 40°C to 80°. As shown in Figs. 8-11, the morphological structure of MVD sample was similar to that of FD one. However, the HD and VD samples had much severer damages on the cell surface.

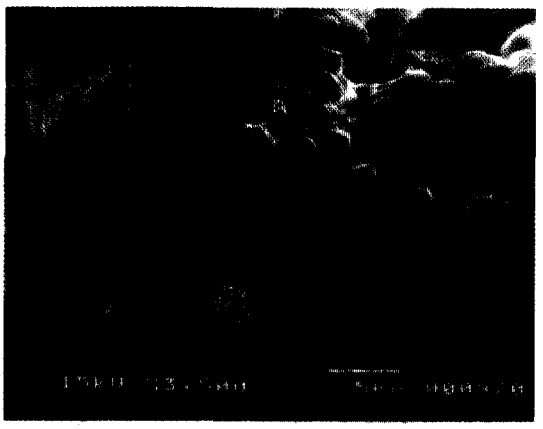

Fig. 9. Scanning electron micrographs (3,500X) of hot air dried yeast (*Saccharomyces cerevisiae*) at 50°C.

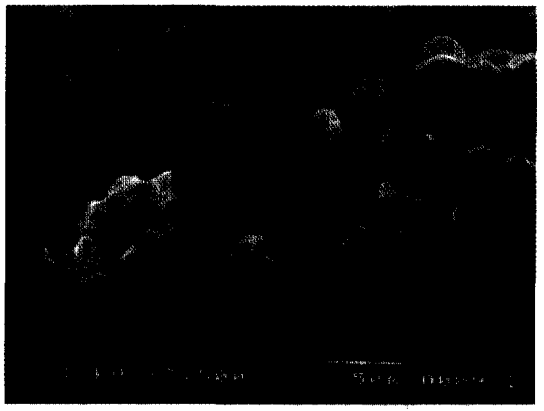

Fig. 10. Scanning electron micrographs (3,500X) of vacuum dried yeast (*Saccharomyces cerevisiae*) at 50°C.

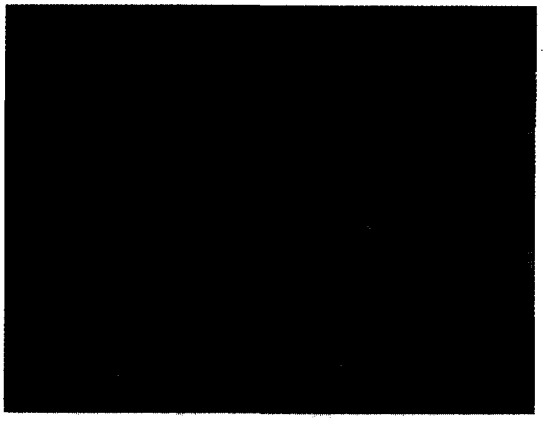

Fig. 11. Scanning electron micrographs (3,500X) of freeze dried yeast (*Saccharomyces cerevisiae*).

Conclusion

MVD was very advantageous for the yeast dehydration since its drying time was short and its drying temperature was relatively low. In addition, the cell viability and morphology of MVD sample was similar to that of FD sample.

Acknowledgements

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