QUALITY ASSESSMENT OF FREEZE- AND CONVECTIVE DRIED PLUM VARIETIES

TAMÁS ANTAL, LÁSZLÓ SIKOLYA

Department of Vehicle and Agricultural Engineering, College of Nyíregyháza, H-4400 Nyíregyháza, Kótaji u. 9-11, Hungary
antalt@nyf.hu; sikolya@nyf.hu

ABSTRACT

This paper deals with a comparison between two different drying processes. Hot-air and a vacuum-freeze drying processes were used for drying samples of plum (*Prunus domestica* L.) varieties (*'Cacanska lepotica'*, *'Cacanska rana'* and *'President'*). The main objective of our research was to analyse and simulate the change of the quality parameters formed during dehydration by comparing two known drying procedures convective dehydration and lyophilisation.

The study shows the drying kinetics of the two drying methods, and examines some special parameters which characterize the quality of dried products, including the microstructure, rehydration, and texture. The shape of cell structure was determined by electro-microscope. Thin layer drying model (third-degree polynomial) were applied for prediction of the freeze drying process. For model evaluation R^2 (coefficient of determination) was calculated. The model estimates showed a good agreement with experimental data. The highest values of hardness and rehydration were found freeze dried plum varieties.

Keywords: plum, drying, microstructure, rehydration, firmness

INTRODUCTION

Drying is one of the possible ways of processing vegetables and fruits. The most frequently applied method of this ancient preservation procedure is the artificial convective drying. This procedure became popular mainly as a result of its simple use and low operational costs; however, we should not forget its disadvantages, which are related to the quality of the dried product. These disadvantages include significant decreases in nutritional value, shrinkage, formation of a hard, non-permeable layer, and denaturation of proteins (BOURAOUT ET AL., 1994; LEWICKI, 1998).

Research has been conducted for a long time on preserving fruits and vegetables in such a way that they keep their original properties for the cold winter months as well. Nowadays, in the 21st century the requirements set out for dried fruits and vegetables including that they should be microbally stable, keep their physical, chemical and mechanical parameters and have excellent storage, packaging and transportation properties.

In addition, they should have high nutrient contents suitable for producing functional foods and food supplements. Only a few drying methods are suitable for satisfying the above-mentioned demands on preservation. According to our present knowledge, the most tolerant dehydrating method is vacuum freeze-drying. Better quality of lyophilized products results from the fact that the temperatures applied during lyophilization are much lower than during traditional drying and that the denaturation processes typical of the traditionally dried products does not occur. During lyophilization, no internal diffusion takes place because the sublimation starting from the surface gradually spreads to deeper layers; the ice directly passes into steam (KARATHANOS ET AL., 1996).

In this study the effect of two drying methods on drying characteristics, rehydration rate, hardness and microstructure were investigated. Moreover it was compared quality of convective dried and freeze dried plum varieties, which ones spring from Hungary. However, the study of plum drying is scarce in the literature.

MATERIAL AND METHOD

Materials

During the measurements were tested plum varieties (*Prunus domestica* L.) ('*Cacanska rana*', '*Cacanska lepotica*', '*President*') of exactly known origin purchased from local producers and traders (Nyíregyháza, Hungary).

We cleaned the material to be dried and cut it to size then placed it on the tray of the dryer in single layer. The samples were cut into 20 mm pieces, and total mass of the samples were 300 grams. We performed the drying test of the varieties both simultaneously and separately. The analyses were replicated three times.

Drying experiments

We performed the dehydration of the horticultural products (plum varieties) used in the experiments with the following dryers:

1. Convective drying - LP 302 (Labor MIM, Budapest) laboratory cylindrical drying cabinet (drying parameters: 8 h; 80 °C; 1.1-1.5 m/s).
2. Lyophilisation – Armfield FT 33 (Armfield Ltd., UK) laboratory vacuum freeze drier (drying temperature from -50 to 20°C; the pressure ranged from 80 to 100 Pa, drying time: 24-25 h).

In order to exactly analyse the processes taking place during the drying, we equipped the laboratory freeze dryer with a data recording system (platform cell – scale instrument – DATPump software).

Description of measuring instruments

The characteristics influencing the quality of the dried products were measured and evaluated with the following instruments and methods:

1. *Moisture content* measurement: PRECISA HA 60 (Precisa Gravimetrics AG, Switzerland) type quick moisture meter. The initial moisture content of the samples were found as 82.7-79.3%, (wet basis), respectively.

2. Measurement of the *drying parameters* of the convective method: TESTO 4510 type (Testo AG., Germany) measuring instrument.

3. *Structures of tissue* were examined using an electro-microscope (Bresser Biolux Al, 20x - 1280x, Bresser AG, Germany).

4. Measurement of the *rehydration activity* of the dried material in moistening agent (LIN ET AL., 1998).

The process of the experiment was as follows: we measured the weight of the samples dehydrated by various methods, then placed them in pots filled with water of 75 °C. During the experiment, we ensured the permanent temperature of the liquid by means of liquid supply. We removed the samples from the liquid after 60 min periods and eliminated the surplus moisture from their surfaces with an absorbent. At the end of the experiment we measured the weights of the rehydrated samples and calculated the rehydration rate (RR). The value of the rehydration rate (RR) shows how much the amount of the water absorbed again can increase the weight of the dried product.

The rehydration rate (RR) can be calculated in the following way (1):

$$RR = \frac{m_{rh}}{m_d}$$

where:

m_{rh} – mass of the rehydrated material [g],
m_d – mass of the dried material [g].

5. Determination of the *product hardness*: Brookfield CT3-4500 type (Brookfield Engineering Laboratories, Middleboro, USA) texture analyser. The description of the measurement process: ANTAL ET AL. (2013).

Data analysis
All data were analyzed using the analysis of variance (ANOVA). The Duncan's test was used to establish the multiple comparisons of mean values. A statistical program PASW Statistics 18 was used to perform all statistical calculations. All tests were performed in triplicate and the average values were reported.

RESULTS

Drying kinetics
During the drying process one of the most important tasks was to determine the drying curve (change of water content in function of the time).
Figure 1 demonstrates the change of moisture level in plum samples (*'President'*, *'C. Rana'* and *'C. Lepotica'*) during freeze drying and the curves fitting.

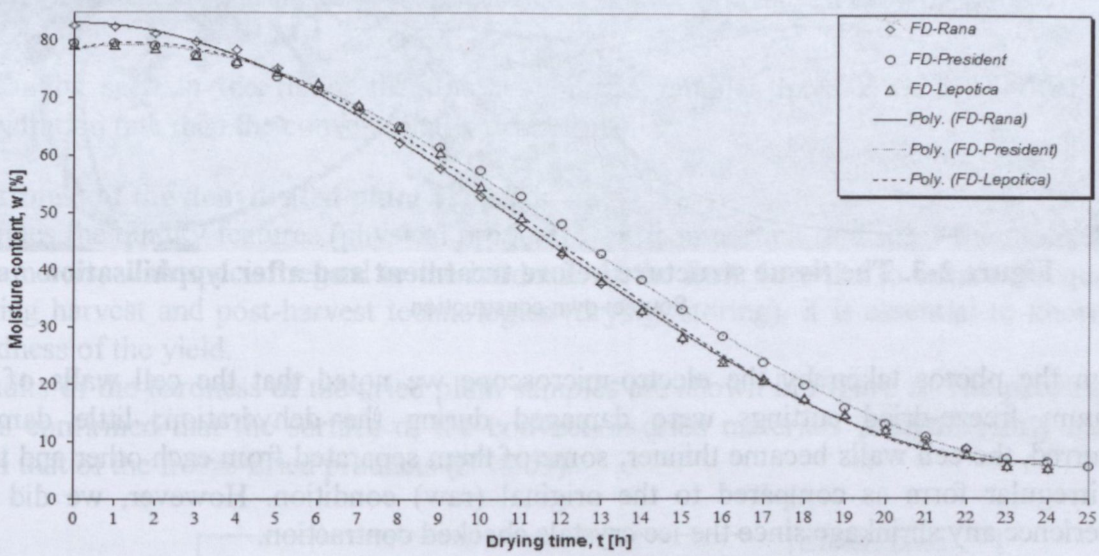

Figure 1. Drying curve of convective- and freeze dried plum slices
Source: own construction

The figure indicates that the drying period of the vacuum-freeze drying process is longer than the convective dehydration, because of the minor drying rate. The freeze drying process of plum varieties took 24-25 h, this is in agreement with YURDUGÜL AND BOZOGLU (2009). The authors reported that the wild plum duration of lyophilisation procedure 24 h.
We defined a relationship for the characterisation of the drying processes of lyophilised plums. The processes can be approximated with third-degree polynomials. The functions representing the moisture content reduction of the drying materials can be described with the following equation: $w=at^3+bt^2+ct+k$, where: *w* – moisture content of the product [%]; *t* – drying period [h], *a, b, c, k* – drying constants of the third-degree polynomial the values of which depend on the characteristics of the material: the variety, the freezing speed, the ripeness and the tendency to lose water.
The drying curve of the lyophilisation describes by a higher degree polynomials; the drying constants and statistical evaluation can be read in the *Table 1*.

Review on Agriculture and Rural Development 2014. vol. 3 (1) ISSN 2063-4803

Table 1. Drying constant of the third-degree polynomial and statistical evaluation

Plum varieties	Drying constant				Statistics
	a [-]	b [-]	c [-]	k [-]	R^2
Cacanska rana (d.t.=24 h)*	0,0121	-0,4266	0,0658	83,15	0,9990
Cacanska lepotica (d.t.=24 h)*	0,0144	-0,5306	1,4787	78,553	0,9987
President (d.t.=25 h)*	0,0117	-0,4565	1,217	78,393	0,9995

* drying time

Source: own construction

Microstructure of plum after treatments

We describe the deformations and damage of the plant tissues under the effect of the drying with microscopic tests. A range of 10 times magnification was used in the images. *Figure 2* shows the tissue of the *'Cacanska rana'* variety plum at the beginning of the dehydration, while *Figures 3* and *4* show the lyophilized and convective dried *Rana* plum samples under the microscope.

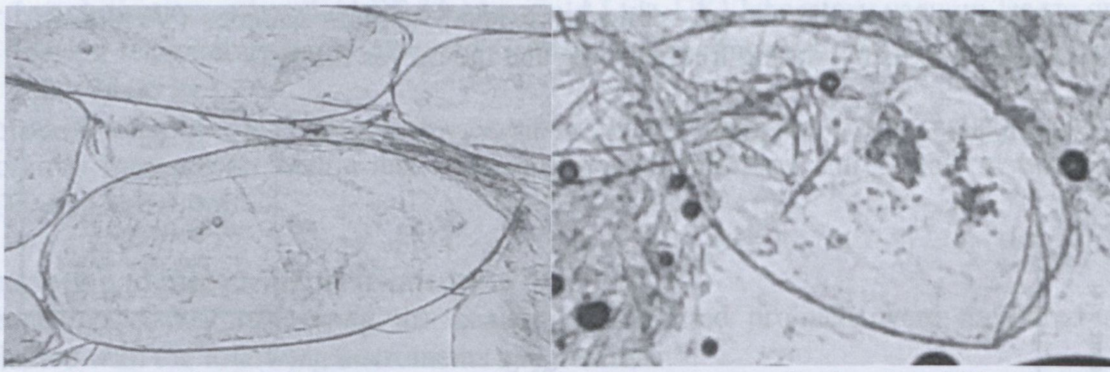

Figure 2-3. The tissue structure before treatment and after lyophilisation

Source: own construction

From the photos taken by the electro-microscope we noted that the cell walls of the vacuum freeze-dried cuttings were damaged during the dehydration; little damage occurred, the cell walls became thinner, some of them separated from each other and took an irregular form as compared to the original (raw) condition. However, we did not experience any shrinkage since the ice crystals checked contraction.

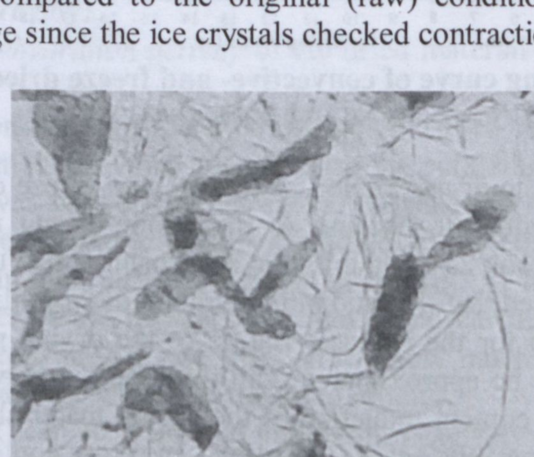

Figure 4. The tissue condition after convective heat treatment

Source: own construction

For the samples dried with the traditional method, the cellules shrunk, the cell walls became thinner, separated from each other and went through deformation which did not recover even during rehydration.

Effect of various drying methods on the rehydration

The rehydration curves of the dried plum samples are illustrated in *Figure 5*, at 75 °C water temperature. We indicated the significant differences of the treatments on the figure (*P<0.05*).

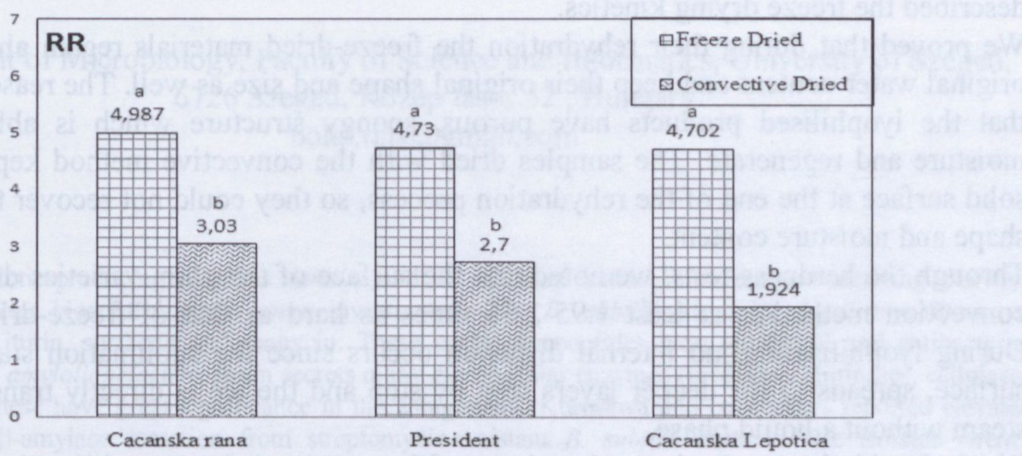

Figure 5. Rehydration capacity of the dried plum varieties

Source: own construction

Different letters in the same column indicate a significant difference (p<0.05), Duncan test

It can be seen in the figure that the lyophilized samples have a significantly higher rehydration rate than the conventionally dried fruits.

Hardness of the dehydrated plum varieties

Besides the quality features (physical properties), it is important to discuss the mechanical parameters, with special regard to the hardness of the fruit. In order to ensure the quality during harvest and post-harvest technologies (drying, storing), it is essential to know the hardness of the yield.

Results of the hardness of the dried plum samples are shown in *Figure 6.* The penetration tests confirmed that the surface of the convection-dried materials is significantly harder than that of the freeze-dried products (*P<0.05*).

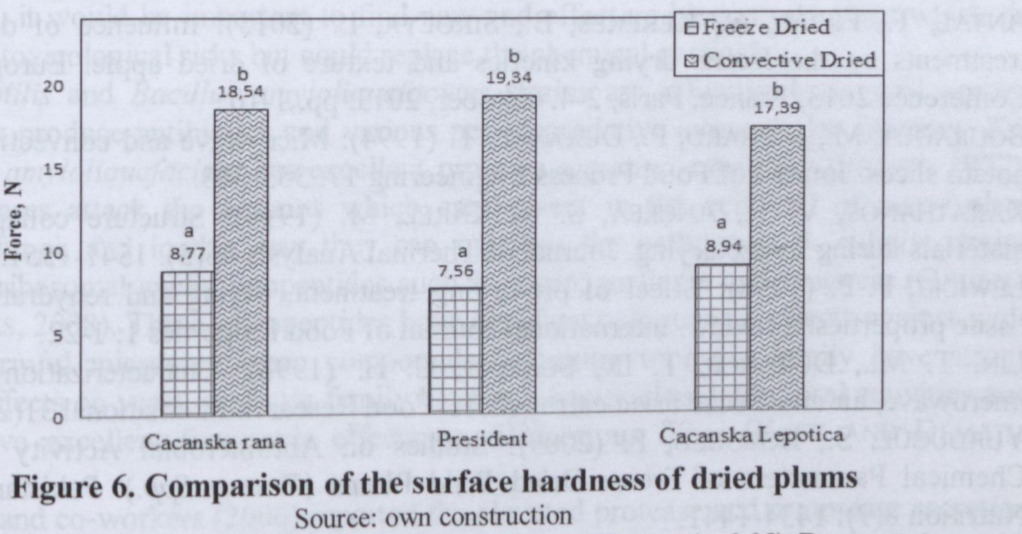

Figure 6. Comparison of the surface hardness of dried plums

Source: own construction

Different letters in the same column indicate a significant difference (p<0.05), Duncan test

CONCLUSIONS

With regard to the results of the drying kinetics, we found that the temperature and pressure applied for the freeze-drying is much less while the drying time is much longer than those for the convection drying. The third-degree polynomial model adequately described the freeze drying kinetics.

We proved that during their rehydration the freeze-dried materials regain almost at their original water content and keep their original shape and size as well. The reason for this is that the lyophilised products have porous, spongy structure which is able to absorb moisture and regenerate. The samples dried with the convective method kept their hard, solid surface at the end of the rehydration process, so they could not recover their original shape and moisture content.

Through the hardness tests, we noted that the surface of the plum varieties dried with the convection method is at least 1.95-2.56 times as hard as that of freeze-dried products. During lyophilisation, no internal diffusion occurs since the sublimation starts from the surface, spreads to the deeper layers step by step and the ice is directly transformed into steam without a liquid phase.

We dealt with the monitoring and analyses of the structural changes taking place during the drying process. The specimens were analysed and recorded by means of a transmission electro-microscope. From the photos taken we revealed that for the lyophilised products the tissue became less damaged and the cell walls were less deformed by the drying process than for the materials dried with the convection method.

ACKNOWLEDGEMENTS

This research was supported by the European Union and the State of Hungary, co-financed by the European Social Fund in the framework of TÁMOP-4.2.4.A/ 2-11/1-2012-0001 'National Excellence Program'.

REFERENCES

ANTAL, T., FIGIEL, A., KEREKES, B., SIKOLYA, L. (2013): Influence of different pre-treatments on the freeze drying kinetics and texture of dried apple. European Drying Conference 2013, France, Paris, 2-4. October, 2013. pp. 1-10.

BOURAOUT, M., RICHARD, P., DURANCE, T. (1994): Microwave and convective drying of potato slices. Journal of Food Process Engineering 17: 353-363.

KARATHANOS, V. T., ANGLEA, S. A, KAREL, M. (1996): Structure collapse of plant materials during freeze drying. Journal of Thermal Analysis 46(5): 1541-1551.

LEWICKI, P. P. (1998): Effect of pre-drying treatment, drying and rehydration on plant tissue properties: a review. International Journal of Food Properties 1: 1-22.

LIN, T. M.., DURANCE, T. D., SCAMAN, C. H. (1998): Characterization of vacuum microwave, air and freeze dried carrot slices. Food Research International 31(2): 111-117.

YURDUGÜL, S., BOZOGLU, F. (2009): Studies on Antimicrobial Activity and Certain Chemical Parameters of Freeze-Dried Wild Plums (*Prunus Spp.*). Pakistan Journal of Nutrition 8(9): 1434-1441.