Acta Agrophysica, 2002, 77, 137-146

INFLUENCE OF WATER ACTIVITY ON MECHANICAL PROPERTIES OF OSMOTICALLY PRETREATED DRIED FRUITS

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Summary. The influence of a_w on mechanical properties of strawberries, black currants, cherries and plums that were osmotically dehydrated and subsequently convective-, microwave-convective-, freeze- and vacuum-dried was investigated. Compression-relaxation test was used to measure mechanical properties of dried fruits. It was shown that type of fruit osmotically dehydrated and dried using various methods generally has no explicitly influence on mechanical properties of the dried fruits. Higher a_w of dried fruits causes the higher plasticity of tissue, which manifests itself by a higher deformation compliance, and faster relaxation of the stress, i.e. a lower compression work and a higher relaxation index.

Keywords: work of compression, relaxation index, convective drying, microwave-convective drying, freeze drying, and vacuum drying.

INTRODUCTION

Over the past few years an increased demand has been noted among consumers for easy-to-prepare or ready-to-use dewatered foodstuffs. Convective drying is the principal method of preparation of dewatered products. Application of such operations as: initial vaporization of water, osmotic dehydration or mechanical separation of liquid from the solid body, before the drying process may largely shorten drying time as well as positively influence the organoleptic features and texture of the finished product.

Removal of water from foods results in changes of their texture. Products that have undergone drying usually have a hard or crisp texture. Convective drying results in larger damage to the structure of the fruit tissue than does osmotic dehydration to the same water content. Sitkiewicz *et al.* [7] found that apples dewatered by convective drying are softer and less crisp than osmotically dried apples. Krokida *et al.* [3] reported that osmotic dehydration reduces elastic features of the tissue of apples, bananas, carrots and potatoes, which was not observed when freeze drying and vacuum drying were applied. Convective drying results in significant changes in the size of tissue cells of apples and carrots [4]. A larger degree of dehydration prior to convective drying results in larger destruction of the apples' structure.

Jakubczyk *et al.* [2] analysed the influence of water activity on mechanical properties of dried apples. An increase of water activity in dried fruit results in a decreased resistance to deformation. Freeze-dried apples at the fruit a_w of 0.11 were characterized by the presence of glassy state, which was responsible for the additional hardening of their structure. Beveridge and Weintraub [1] found that with the increase of water activity in the range between 0.29 and 0.70, cutting force for apples falls down. Rowicka *et al.* [6] found that a_w significantly influences the rheological parameters of freeze-dried apples. The presence of water plastifies the structure of apples dried by this method, and the stress and compression work of the tissue fall with increasing water activity.

The aim of this study was to determine the influence of water activity on mechanical properties of strawberries, black currants, cherries and plums that were osmotically dehydrated and subsequently dried using various methods.

MATERIALS AND METHODOLOGY

The study material included the following frozen fruits: strawberries of the Senga Sengana variety, blackcurrants of the Ojebyn variety, stoned cherries of the Łutówka variety and halves of plums of the Węgierka Zwykła Szczepka variety. These materials, in frozen state, were purchased at a local market and placed in 61% solution of sucrose (solution a_w 0.9), in room temperature and osmosed for 24 hours. The ratio of the osmotic solution mass to the fruit mass was 4:1. Following dehydration, the fruits were rinsed on a sieve with water and subsequently dried using the following four methods:

- convective drying in laboratory dryer, at the airflow speed of 2 m/s, osmotically dehydrated strawberries were dried at the temperature of 50°C, while the rest of the fruits were dried at the temperature of 70°C,

- microwave-convective drying in laboratory dryer Plazmatronik, at the same temperatures as in the case of convective drying, with the microwave power of 120 W for the first hour of drying,
- freeze drying in freeze dryer Christ Alpha 1-4, at a pressure 70 Pa for 20 hrs, of fruits previously frozen at the temperature of -20°C for 6 hours,
- vacuum drying in laboratory dryer Conbest SPT 200, at the same temperatures as in the case of convective drying, at the pressure of 20 kPa.

In the case of each of the above drying methods, the fruits were dried until water content that correspond to a_w levels of 0.3, 0.5 and 0.7. Drying time was fixed on the earlier investigated kinetics of drying.

Mechanical properties were determined in the stress compression and relaxation test conducted with the use of the Universal Testing Machine ZWICK 1445. The dried fruits under investigation were compressed at the head speed of 20 mm/min until relative strain of 25% was reached, and subsequently the stress was relaxed for 60 seconds, simultaneously recording the change. All the measurements were taken in five repetitions. Based on the compression curves compression work was determined as the area under the compression curve in the force-time coordinate system, which was then expressed per 1 cm^3 of the investigated sample [W/cm^3]. Based on the relaxation curve, its index was calculated as the percentage of the initial force that underwent relaxation after1 minute.

RESULTS AND DISCUSSION

The compression work of strawberries that were osmotically dehydrated and dried using various methods ranged from 31.08 ± 5.60 mJ/cm^3 in the case of vacuum-dried fruits a_w of 0.3 to 0.66 ± 0.23 mJ/cm^3 in the case of convective-dried fruits of a_w 0.7 (Fig 1A). Convective dried and microwave-convective-dried fruits of a_w 0.3 were not investigated due to the difficulty in obtaining such samples. The compression work at a_w 0.7 ranged from 0.66 ± 0.23 mJ/cm^3 to2.06 ± 0.30 mJ/cm^3 regardless of the drying method employed. Reduction of a_w from 0.7 to 0.5 resulted in almost a twofold increase of compression work, which ranged from 1.08 ± 0.25 mJ/cm^3 in the case of microwave-convective dried fruits to 3.74 ± 0.85 mJ/cm^3 in the case of convective dried fruits. No significant differences of compression work were noted for microwave-convective-, freeze- and vacuum-dried fruits. Further reduction of a_w to 0.3 resulted in a 10-fold increase of compression work in the case of vacuum-dried fruits and almost a 50-fold increase in the case of freeze-dried fruits. The value of the relaxation index (Fig. 1B) at a_w 0.7 ranged from $28.30 \pm 1.19\%$ in the case of vacuum-dried fruits to $36.63 \pm 1.78\%$ in the case of convective-dried fruits, while no influence of the drying method was noted.

In the case of blackcurrants of a_w 0.7, compression work (Fig. 2A) was unrelated to the drying method following osmotic dehydration, and was equal to 1.08 ± 0.25 mJ/cm^3 and 3.74 ± 0.84 mJ/cm^3 in the case of convective-dried fruits and microwave-convective-dried fruits, respectively. The freeze- and vacuum-dried fruits were destroyed before they reached the target strain. Elevation of a_w to 0.5 resulted in over a 3-fold increase of compression work in the case of convective- and microwave-convective-dried fruits. At a_w 0.3 the resistance to deformation increased over 2- to 4-fold in the case of convective- and vacuum-dried fruits. The relaxation index (Fig. 2B) at a_w 0.7 ranged from 32.97 ± 2.98% in the case of convective-dried fruits to 35.55 ± 4.61% in the case of microwave-convective-dried fruits. The relaxation index at a_w 0.5 ranged from 23.70 ± 2.47% to 28.42 ± 3.85%, respectively, and was independent of the drying method employed following osmotic dehydration. A further a_w reduction to 0.3 resulted in no change of this index.

As was the case with strawberries and blackcurrants, the parameters that characterize mechanical properties of cherries depended on the level of a_w. No significant differences in the values of compression work were noted for dried fruits of a_w 0.7 and of a_w 0.5 (Fig. 3A). Also, no influence of the drying method at the assumed a_w levels of osmotically dehydrated cherries was noted. For both a_w values, compression work of dried cherries ranged from 2 to 3 mJ/cm^3. A reduction of a_w to 0.3 resulted in approximately a 4-times increase of compression work in the case of convective- and microwave-convective-dried fruits, almost a 10-times increase (up to 22.85 ± 1.92 mJ/cm^3) in the case of freeze-dried fruits and almost a 50-times increase in the case of vacuum-dried fruits. Having analyzed the relaxation index (Fig 3B) no difference was noted with regard to a_w between 0.7 and 0.5 and with regard to the drying method employed following osmotic dehydration. A reduction of a_w to 0.3 resulted in a reduction of the relaxation index approximately by a half.

In the case of plums that were osmotically dehydrated and dried using various methods, no significant influence of the drying method was noted on deformation compliance, which was measured by compression work, between a_w of 0.7 and 0.5. A reduction of a_w to 0.3 resulted in a 4.5-fold increase of compression work (Fig. 4A). At a_w of 0.7 and 0.5 no significant difference was noted with regard to the drying method employed following osmotic dehydration (Fig 4B). The differences in the values of the index at the above-mentioned water activities are very small. The percentage of relaxation at a_w 0.3 was lower by a half when compared to values at higher a_w's.

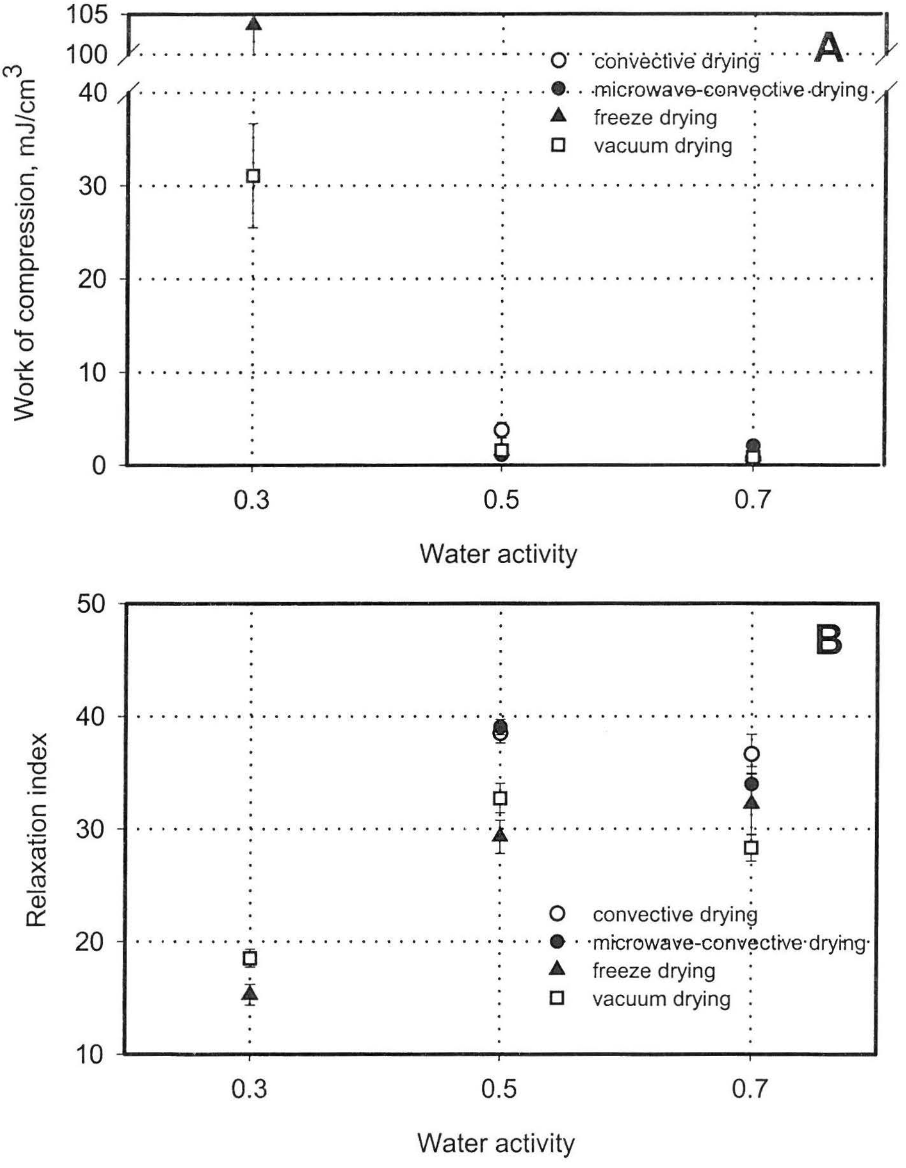

Fig.1. Effect of drying mode on mechanical properties of strawberries.

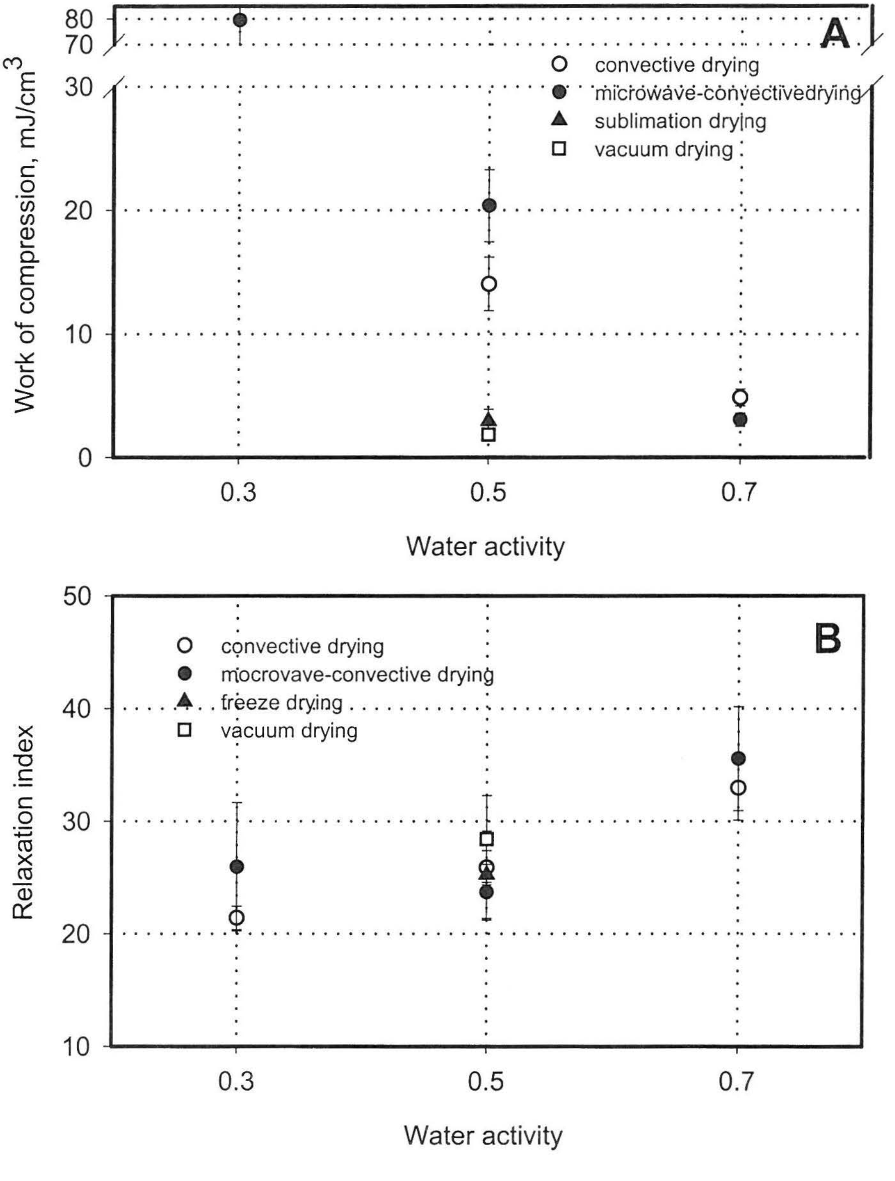

Fig. 2. Effect of drying mode on mechanical properties of black currant.

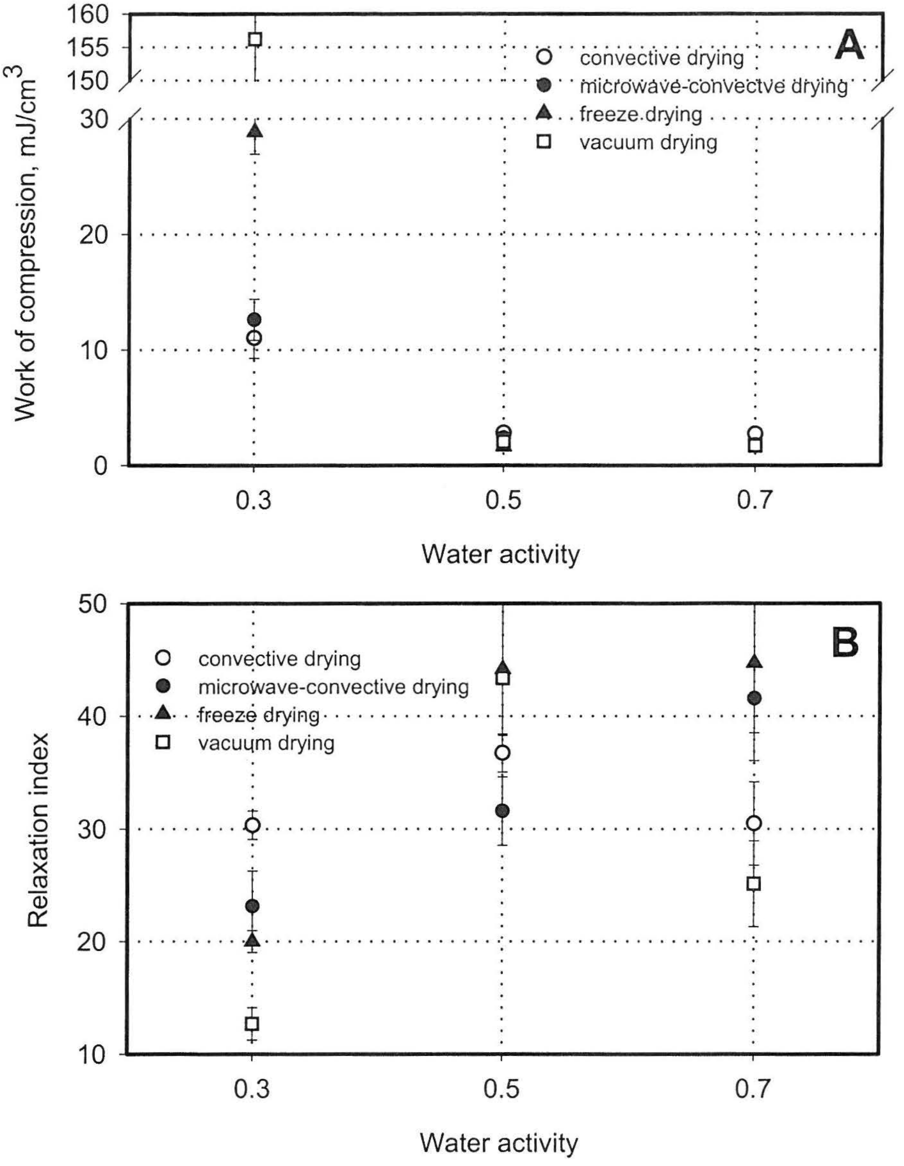

Fig.3. Effect of drying mode on mechanical properties of cherries.

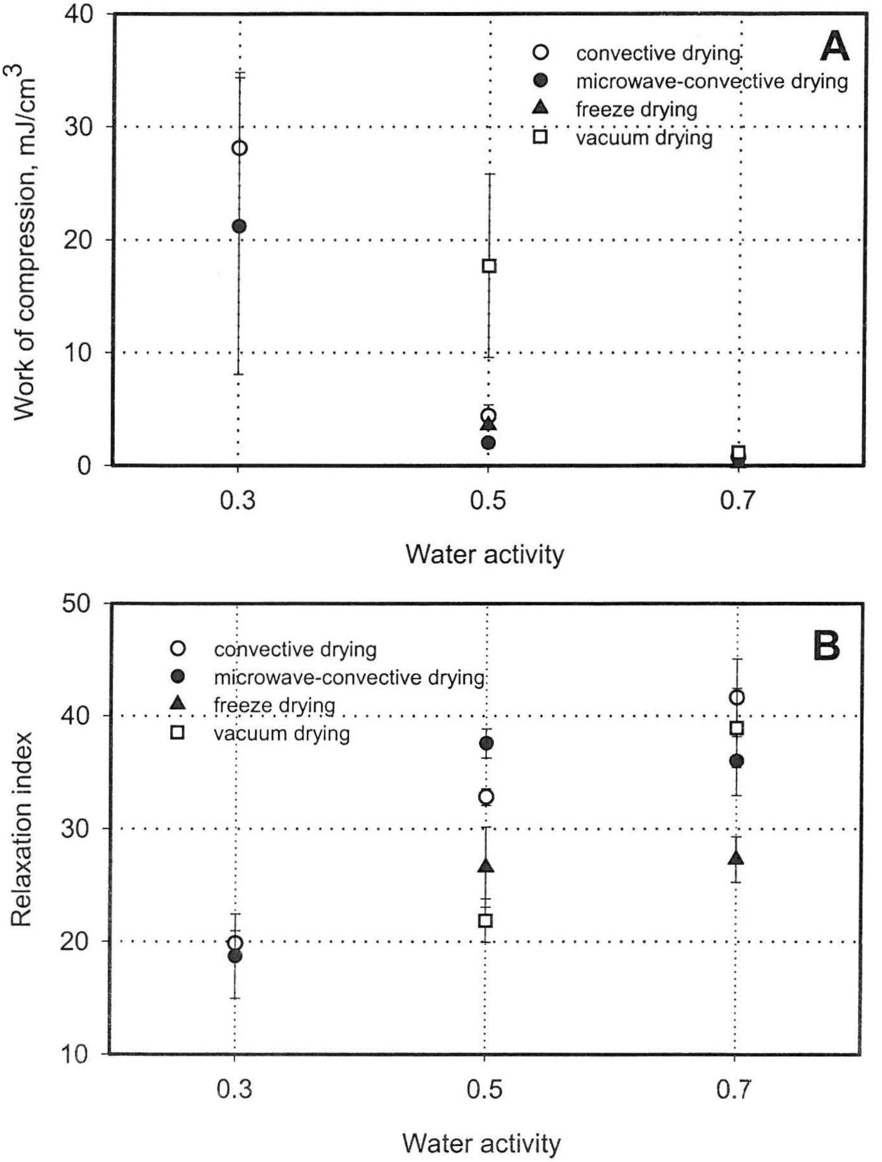

Fig.4. Effect of drying mode on mechanical properties of plums.

The results presented above prove that the type of fruit osmotically dehydrated and dried using various methods generally has no influence on the mechanical properties of the dried product. The influence of a_w of the dried fruits is important and straightforward. If the fruit's tissue is treated, according to Lewicki and Lukaszuk [4], as a liquid enclosed in a solid body matrix made up of the cell membrane, then dehydration will result in the removal of part of the water, breaking up of the matrix and the disappearance of its elastic properties and replacement of the missing water by air. The tissue of the dried fruits is a plastic body: the higher its a_w, the higher the plasticity of the tissue, which manifests itself by a higher deformation compliance and faster relaxation of the stress created on compression, i.e. a lower compression work and a higher relaxation index.

Freeze and vacuum drying facilitates the creation of a porous and highly moisture-absorbing structure. Fruits dried using these methods at a low water activity display a dominance of elastic over plastic properties when compared with convective- and microwave-convective-dried fruits. An increase in a_w results in dried fruits' plastification and increased deformation compliance, as in the presence of water the structure of the material can be easilycompacted. For this reason freeze- and vacuum-dried fruits were characterized by higher elasticity than convective- and microwave-convective-dried ones.

CONCLUSIONS

Water activity significantly influences mechanical properties of osmotically dehydrated fruits, which were subsequently dried using various methods. With increasing a_w, the resistance of dried fruits to the applied stress decreases and plastic features start to dominate over elastic features. At low a_w's the largest proportion of elastic features is to be found in freeze- and vacuum-dried fruits. The type of fruit osmotically dehydrated and subsequently dried has no explicitly influence on the mechanical properties of the product.

REFERENCES

1. **Beveridge T., Weintraub S.E.:** Effect of blanching pretreatment on color and texture of apple slices at various water activities. Food Research International, 28, 1, 83-86,1995.
2. **Jakubczyk E., Witrowa-Rajchert D., Lewicki P.P.:** Mechanical properties of dried apples during rehydration (in Polish). Zeszyty Naukowe Politechniki Łódzkiej, Inżynieria Chemiczna i Procesowa, 25, 27-36, 1999.

3. **Krokida M.K., Kiranoudis C.T., Maroulis Z.B.:** Viscoelastic behaviour of dehydrated products during rehydration, Journal of Food Engineering, 40, 269-277,1999.
4. **Lewicki P.P., Drzewucka-Bujak J.:** Effect of drying on tissue structure of selected fruits and vegetables. In: Drying'98- Proceedings of the 11th International Drying Symposium (eds. C.B. Akritidis, D. Marinos-Kouris, G. D. Saravacos, A.S. Mujumadar), ZITI Edition Halkidiki, Greece, August 19-22, vol. B, 1093-1099,1998.
5. **Lewicki P.P., Lukaszuk A.:** Effect of osmotic dewatering on rheological properties of apple subjected to convective drying. Journal of Food Engineering, 45, 119-126, 2000.
6. **Rowicka R., Nowak D., Lewicki P.P.:** Influence of water activity on rheological properties of freeze-dried apples (in Polish). In: Technologia żywności a oczekiwania konsumentów, CD, Warszawa, 1-6, 2001.
7. **Sitkiewicz I., Lenart A., Lewicki P.P.:** Mechanical properties of osmotic-convective dried apples. Polish Journal of Food and Nutrition Sciences, 5/46, 4, 105-112, 1996.

WPŁYW AKTYWNOŚCI WODY NA WŁAŚCIWOŚCI MECHANICZNE SUSZONYCH OWOCÓW WSTĘPNIE ODWADNIANYCH OSMOTYCZNIE

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Streszczenie. Zbadano wpływ aktywności wody na właściwości mechaniczne truskawek, czarnych porzeczek, wiśni i śliwek odwodnionych osmotycznie i następnie suszonych konwekcyjnie, mikrofalowo-konwekcyjnie, sublimacyjnie i próżniowo. Zastosowano testy ściskania i relaksacji naprężeń do zbadania właściwości mechanicznych suszów. Otrzymane wyniki pozwalają stwierdzić, że aktywność wody w istotny sposób warunkuje właściwości mechaniczne owoców odwadnianych osmotycznie i suszonych różnymi metodami. Ze wzrostem a_w maleje odporność suszów na przyłożone naprężenia, wzrasta przewaga cech plastycznych nad sprężystymi. Przy niskich a_w najwyższym udziałem cech sprężystych charakteryzują się susze otrzymane metodą sublimacyjną i próżniowa. Rodzaj owoców odwodnionych osmotycznie i suszonych nie wpływa jednoznacznie na właściwości mechaniczne otrzymanych suszów.

Słowa kluczowe: praca ściskania, wskaźnik relaksacji, suszenie konwekcyjne, suszenie mikrofalowo-konwekcyjne, suszenie sublimacyjne, suszenie próżniowe.