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Stone Fruit Drying Parameters

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Abstract: The paper presents the study results on technical and technological parameters in the process of low-temperature drying of stone fruit (plum and apricot) under both laboratory conditions and in a multi-purpose prototype dryer intended for plant material drying. The experimental investigations comprised flow and thermal measurements, technological and kinetic drying parameters. Major emphasis was on temperature and relative humidity of the drying agent and moisture and temperature of the dried material, as well as the drying rate.

According to the results obtained, the preheating period was 2-3 hours depending on the type of the material and the drying regime, i.e. on the condition of the drying agent. Maximum plum drying rate was recorded 2 h after the beginning of the process and amounted to about 1.15 kg w/kg d.b.h. In the case of apricot drying, maximum drying rate was approx. 0.45 kgw/kg d.b.h. and was registered only 4 hours after the beginning of the drying process, which differed from the plum drying rate, under approximately equal drying regime. In addition, the apricot drying kinetics curve differed in shape from the plum drying kinetics curve.

The obtained quality of both dried fruits under low-temperature drying conditions was found to meet standard requirements to a great extent primarily respecting sugar and acid loss and the fact that there was no odour or contamination of the fruit.

The results obtained showed that, in addition to the technical designs of the drying system, the fruit drying process was found to be significantly affected by how the process itself, the duration of which could be reduced, was being managed.

Key words: process of low-temperature drying of stone fruit, quaity of dried fruit.

Introduction

A great number of authors by their numerous theoretical and experimental studies have contributed to the rapid development of modern drying science. The mechanism of moisture flow within a material during the drying process with a conductive heat feed has been defined in researches (Antonijevic et al., 1992). However, despite intensive thorough investigations, today's knowledge of the processes taking place in moist materials does not satisfy the requirements being made by the development of new drying technologies. Investigation of these processes in their most complex forms and testing of basic theoretical dependences are still made difficult due to different ways of bonding moisture to the material and different transport mechanisms. Experimental determination of plant material drying parameters and development of technical and technological drying systems for plant materials have been presented by authors (Ginzburg et al., 1982). The problem is particularly in the lack of the possibility of identifying moisture transport coefficients in real materials even for simplified process models (Todorovic et al., 1997).

Previous experimental study results on stone fruit drying have shown that within common moisture limits, the constant drying-rate period is not recorded (Zivković, 1998). Internal moisture transport resistances are more important than the external ones, but this does not mean, yet, that the effect of the convective moisture transport on the drying rate is fully negligible, at least in the initial period of the process.

Considering the very complex bonding mechanisms between moisture and material in colloidal capillary-porous bodies, fruit equilibrium under specific temperature and moisture air conditions can be only experimentally determined.

Material and Methods

Experimental plum drying investigations were designed to comprise a certain number of repeated measurements with three regimes. The regime I comprised three phases: a preheating phase of 1 hour duration with an air temperature of 45°C, a transition phase of 11 hours' duration with the temperature of 73°C (until a subcooling phase lasting 30 minutes with the temperature of 53°C), a drying phase with the temperature of 73°C until the moisture required was reached. The regime II comprised only one phase with a constant temperature of 73°C. The duration of the drying process in each of the experiments was dependent on adequate fruit moisture reached (28.3-29.5%). The regime III comprised four phases: the preheating phase of about an hour duration with the drying air temperature of 45°C, the transition phase of about 8 hours' duration with the air temperature of 65°C, the subcooling phase of 30 minutes' duration (13 hours after the completion of the previous phase) with the air temperature of 54°C, the drying phase with the temperature of 73°C (maximum air temperature) until the ultimate moisture of the material was reached.

The apricot fruit experiments were conducted under a constant regime so that during the drying process the agent temperature and mass agent flow were maintained at constant level as permitted by existing conditions. The differences between individual experiments were therefore determined by the way the fruits were prepared for drying.

Within the framework of the research aim, the investigations comprised:

- Ambient air parameters
- Dried material temperature range
- Moisture change dynamics in the material during drying

Experimental plum and apricot drying researches were conducted using a multi-purpose laboratory dryer, and under exploitation conditions, using a Multipurpose Trailed Dryer MTD-4 prototype.

Results and Discussion

Plum fruit drying kinetics

Using the detailed measurement procedure and measurement result processing methods, characteristics of plum and apricot fruit drying kinetics were determined. Figure 1. presents plum fruit moisture change during the experiments.

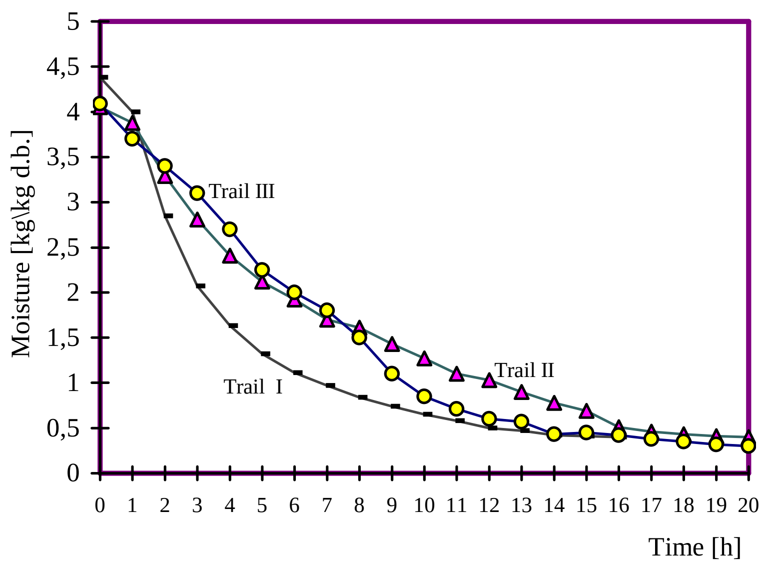

Fig. 1. Comparative review of plum fruit moisture change
for all drying regimes

The diagram analysis shows that in the experiment for the I drying regime, moisture loss was slower at the beginning of the process (the preheating phase), and hence the gentle slope of the moisture change curves. Following the preheating phase, when the agent temperature was maximum (the “intensive” drying period), the moisture transport intensity was significant. The duration of the period comprised three characteristic intervals. The first one, lasting from 3 to 5 hours, was the period of the highest-intensity moisture transport dynamics. It was then followed by the period with a lower moisture transport rate lasting from the 10^{th} to the 13^{th} hour from the beginning of the drying. The last segment of the process was characterised by a decrease in the moisture transport intensity tending toward zero (the period of equalisation of the drying rate with the interior moisture diffusion rate).

In the trials with constant maximum temperature during the entire drying process (without the preheating phase with lower temperature), as seen from the diagram, moisture transport was intensive from the very beginning. In the period from the 10^{th} to the 14^{th} hour, the intensity of the process was reduced, and after the period, it approached zero. The trials with this drying regime were conducted with a 20-hour duration, with average ultimate fruit moisture of about 0.31 kg w/kg solids.

The diagram shows dried material moisture change for the trials where, following the preheating phase, there was a transition phase where temperature was somewhat lower than maximum temperature (about 65^0C). The duration of this phase in conducted experiments was limited to a period of 8 hours.

By comparisons of the results with the data obtained in the experiments for the first drying regime, it can be seen that moisture transport after the preheating phase was slower. In addition, as it was made evident, in order to reach the same ultimate moisture of the dried material (about 0.4 kg w/kg solids) the process was prolonged to 20 h.

During the moisture change in the trials where, in addition to the preheating phase there was a subcooling phase of 30-min duration with a temperature decrease by 20^0C on the average, at the moment of the air temperature decrease, no significant alterations in the moisture change curve were recorded compared to the trials without the subcooling phase.

Temperature of the material during the drying process was another significant drying kinetics parameter. Figures 2, 3 and 4 present temperature changes in dried plum fruits. An analysis of the diagrams showed that for all experiments the temperature of the dried material increased during the process except for the experiments with subcooling with a certain drop recorded which "coincided" with the agent temperature decrease period. The most intensive temperature increase was recorded, as had been completely expected, after the termination of the preheating and subcooling phases. During the moisture transport intensity decrease phase, the fruit temperature asymptotically approached the drying agent temperature over the drying duration time.

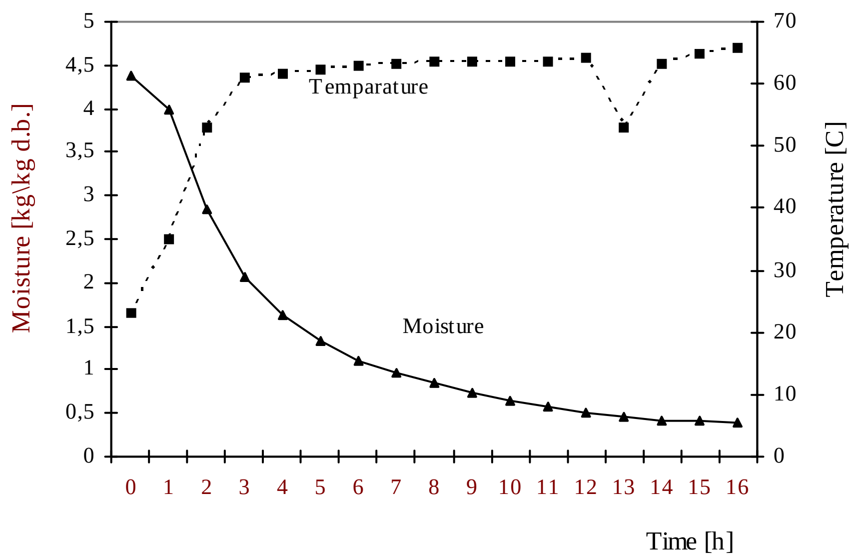

Fig. 2. Moisture and temperature change in plum fruits in the I drying regime

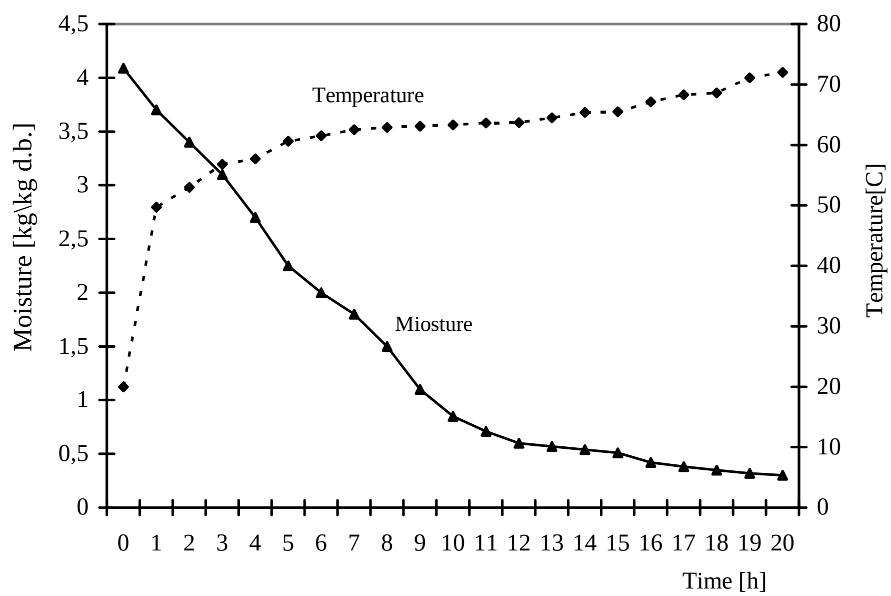

Fig. 3. Moisture and temperature change in plum fruits in the II drying regime

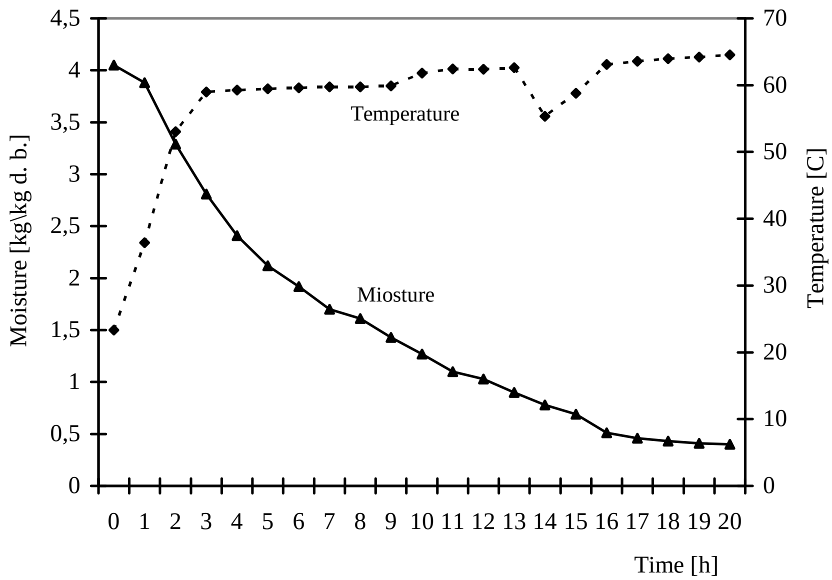

Fig. 4. Moisture and temperature change in plum fruits in the III drying regime

As seen from the presented dried material temperature diagrams, at certain places in the drying chamber, for both dryers, there were temperature variations in the same period for the same experiment. The variations in the laboratory dryer were negligible and were most likely measurement errors than actual results, which was logical considering the small dimensions and therefore the volume of the chamber. The temperature difference for the dried material in the dryer prototype, at certain places in the drying chamber, ranged from 5-10^{0}C. This was likely due to an uneven distribution of drying air as well as due to the effect of heat loss into the ambience due to the poor isolation of the dryer floor.

Apart from the moisture and temperature curves, the drying kinetics included determination of the drying rate representing the amount of evaporated moisture compared to the dried material dry basis per time unit. Drying rates for some of the experiments for plum fruits are presented in Fig. 5.

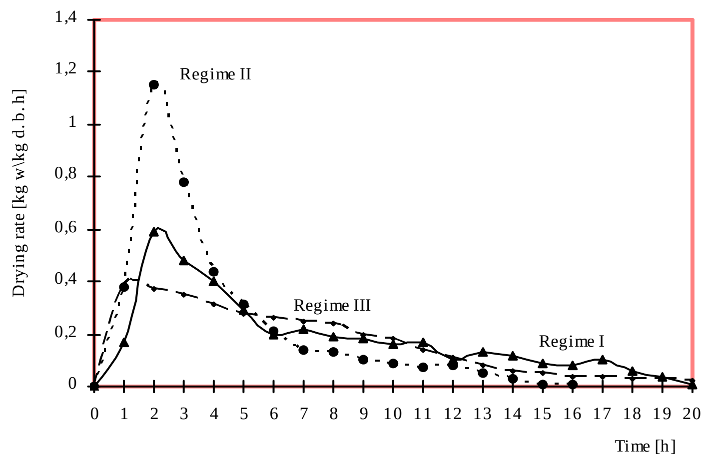

Fig. 5. Plum fruit drying rates for different regimes

As seen from the diagram analysis, the greatest drying rate for given trial conditions, was about 1.15 kgw/kg d.b.h 2.5 h after the beginning of the process, in experiments with the II drying regime. In experiments with the I drying regime, the maximum rate was recorded 2.5 h after the beginning of the process and it amounted to 0.59 kgw/kg d.b.h. The third drying regime was characterised by the greatest drying rate of 0.41 kgw/kg d.b.h reached after 1 hour.

A significant plum drying rate decrease was registered 10-12 h after the beginning of the process, meaning that the period of unsaturated surface was of short duration, which had to be taken into account when designing the duration of the technological process from the energy balance viewpoint.

Apricot fruit drying kinetics

By their thermophysical properties, apricot fruits are very similar to plum fruits, so their behaviour in the drying process is relatively similar. Basic and essential difference between the technological process of drying apricot fruits compared to that for plum fruits is in both the preparation process and the fruit shape. The preparation of apricot fruits for drying requires chemical treatment. In terms of quality, apricot drying is only acceptable when apricots are pitted and halved, peeled or non-peeled.

Bearing in mind that apricot fruits are dried without pits, significantly different characteristics of the dried material should be expected compared to plum fruits (and therefore in terms of drying kinetics parameter values).

Fig. 6. presents apricot moisture change during the drying process. As seen from the diagram, the shape of the moisture change curve for apricot is different from the plum drying curve shape; apricot moisture change shows a “rectilinear” moisture transport flow, and therefore certain segments of the drying curve cannot be easily distinguished, as with plum fruit.

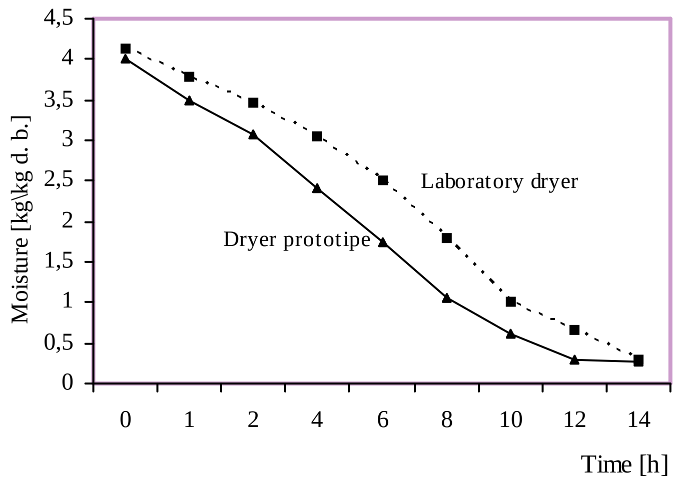

Fig. 6. Apricot fruit moisture change during drying in both dryer types

The period at which moisture transport intensity asymptotically approached zero, or at which moisture transport from the surface of the fruit into the drying agent was equalised with the interior moisture diffusion within the fruits, was recorded, similarly as with plums, 10-14 h after the beginning of the drying process.

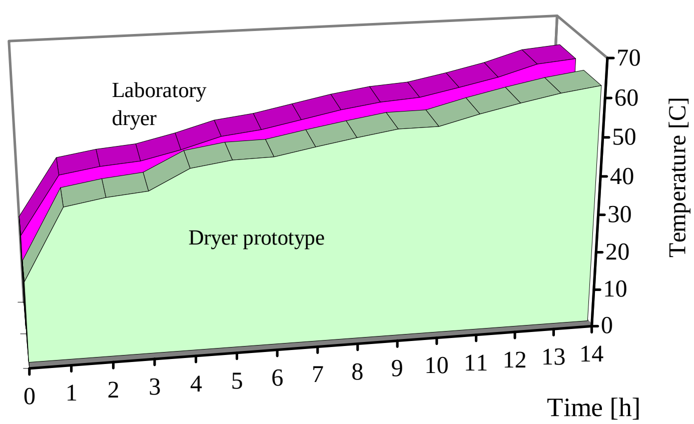

Fig. 7. –Apricot fruit temperature change in the drying process

Mean apricot fruit temperature for the given experimental conditions relatively slowly and monotonously increased with the drying period reaching the maximum value of 60^0C, (Figs. 8 and 9), compared to the mean plum temperature which rapidly reached the value of 62 – 65^0C.

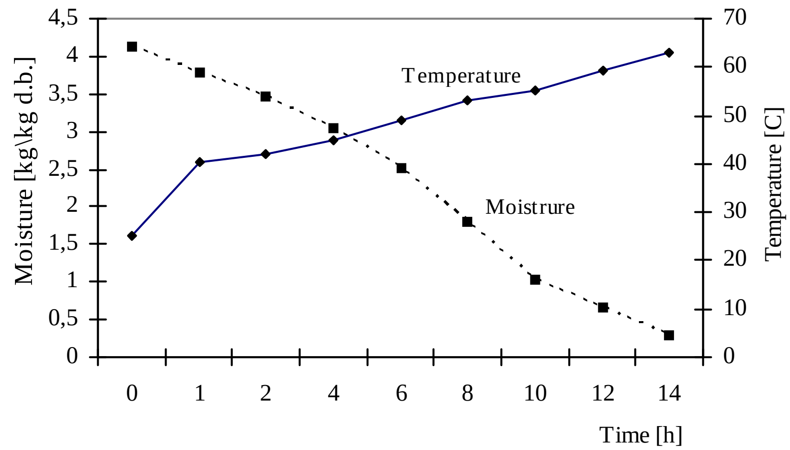

Fig. 8. Apricot moisture and temperature change during drying in a laboratory dryer

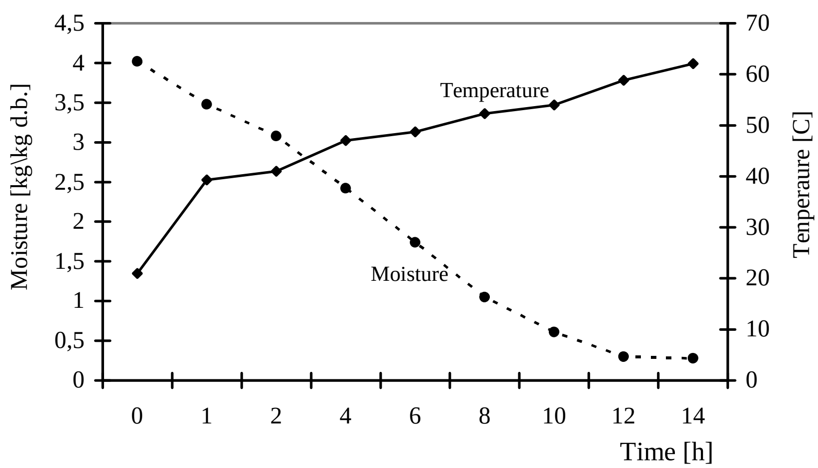

Fig. 9. Apricot moisture and temperature change during drying in a dryer prototype

For all conducted experiments, the maximum drying rate value (Fig. 10) was approximately 0.45 kgw/kg d.b.h. Maximum drying rate in apricot fruits was recorded not earlier than 4 hours after the beginning of the drying process, which was different from the plum drying rate.

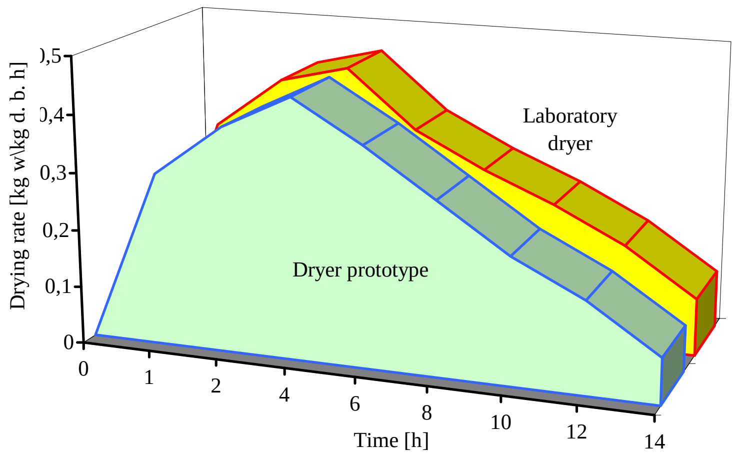

Fig. 10. Apricot fruit drying rate during drying in both dryer types

Conclusion

Drying is an extremely complex process where moisture and temperature transport mechanisms in the dried material have been insufficiently analysed and defined, which results from the existing level of knowledge and development of theoretical-experimental methods. Plant materials including stone fruit are colloidal-capillary-porous material, and so due to the complex structure of relevant transport phenomena the drying analysis is made extremely complex. In addition, drying of plant material in the static layer gives rise to additional problems due to additional complex phenomena regarding drying agent flows and convective heat and moisture transport from the surface of the moist material.

Discontinual drying process (in plums) includes the first preheating phase with maximum agent temperature (up to 75^0 C) with 2 hours' duration, following which the material is cooled by unheated air with intensive moisture transport (»fruit perspiration«). Then, in the second drying phase, the agent temperature should be as in the preheating process, and towards the end of the process (about 10 hours from the beginning of the drying), when the drying temperature considerably decreases, the drying agent temperature should be decreased (to 10^0C).

Drying should be carried out until the drying rate approaches zero (in stone fruit the period is about 30% of fruit moisture). As shown by the experimental research results, the moisture in plum fruit drying can be reached with 13 h (which is a considerably shorter period than in current technologies, and up to 30% of energy is saved).

Stone fruit drying quality is highly dependent upon the initial quality of the dried material (fresh fruits) and method of preparation of fruits for drying. As regards apricot fruit, special importance is given to the preparation process.

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PARAMETRI SUŠENJA KOŠTIČAVOG VOĆA

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Rzime

U radu su prikazani rezultati istraživanja tehničko tehnoloških parametara procesa niskotemperatuskog sušenja plodova koštičavog voća (šljiva i kajsija). Eksperimentalna istraživanja sprovedena na laboratorijskoj instalaciji i na prototipskoj univerzalnoj sušari namenjenoj za sušenje biljnih materijala, obuhvatila su strujnotermička merenja, parametre kinetike procesa i tehnološke parametre sušenja. Posebno su analizirani temperatura i relativna vlažnost agensa sušenja, vlažnost i temperatura materijala za sušenje kao i brzina sušenja.

Rezultati pokazuju da period predgrevanja materijala iznosi od 2-3 h, što je uslovljeno vrstom materijala i režimom sušenja tj. stanjem agensa sušenja. Maksimalna brzina sušenja plodova šljive nastaje nakon 2 h i iznosi oko 1,15 kg w/kg s.m.h. Kod sušenja plodova kajsija maksimalna brzina sušenja iznosi približno 0,45 kgw/kg s.m.h. i pojavljuje se tek nakon 4 časa od početka procesa u čemu se razlikuje od brzine sušenje plodova šljive za približno isti režim sušenja. Pored toga, kriva kinetike sušenja kajsija ima drugačiji oblik u odnosu na krivu sušenja šljiva.

Ostvaren kvalitet obe vrste osušenih plodova sa navedenim niskotemperaturskim režimima u velikoj meri odgovara standardima, pre svega u pogledu gubitka šećera i kiselina, kao i odsustva bilo kakvih mirisa i zagađenosti plodova.

Dobijeni rezultati ukazuju da, pored tehničkih rešenja sistema za sušenje, na uspeh procesa značajan uticaj ima i samo vođenje procesa čije se trajanje može redukovati.