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EFFECT OF DRYING ON THE CHANGE OF SUGAR CONTENT IN PLUM FRUITS

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Abstract

Drying is one of the oldest methods of preserving fruit. In the course of drying process, there is a change in some components of chemical composition to a degree depending on food type, its composition, and drying process itself. The testing was performed in three replications using plum fruits of the 'Čačanska Lepotica', 'Mildora', 'Čačanska Rodna' and 'Stanley' cultivars, at the optimum ripening stage required for drying, based on soluble solid contents. Drying was performed at the experimental dryer using the convective (streaming) drying process, at two constant air temperatures, 90 °C and 70 °C, until attaining 75% of total dry matter in the prunes. In addition to the control, the fruits were subjected to a pretreatment consisting of dipping in boiling water. This paper reviews the values of total sugars, invert sugars and sucrose in fruits of fresh and dried plums (calculated in grams per 100 grams of total dry matter), as well as the change of these parameters in prunes in relation to the fresh fruits (expressed in percentages). Drying temperature affected the change of total sugars, invert sugars and sucrose content in fruit of the tested plum cultivars. On the other side, dipping as an applied pretreatment had no effect on the change of these parameters except in the cultivar 'Čačanska Rodna', which dipped fruits are found to have higher decrease of sucrose compared with non-treated fruits. During drying, hydrolysis of sucrose occurred, manifesting in a dramatic decrease of its content in dried fruits, in relation to the starting raw material in all of the tested cultivars. Intensity of changes was conditioned by varietal characteristics.

Key words: *prune, drying temperature, dipping, invert sugar, sucrose.*

Introduction

Plum (*Prunus domestica* L.) is considered a national fruit species ranking first in the fruit growing of Serbia by both number of trees and by its annual production. Although a major part of plum yield in Serbia is processed into brandy (Popović et al., 2006), the most significant product coming from plum, in terms of nutritional value, is prune. Prune represents significant energy source for human body though is more commonly classified in high nutritional food with special dietetic and physiological importance, primarily due to its protective and therapeutic effect on digestive tract of consumers (Zlatković, 2000; Piga et al., 2003).

Drying is defined as a process of moisture loss resulting from simultaneous existence of the heat and mass transfer phenomena. Plum drying is a slow and long-term process because whole fruits are dried, hence, there are real conditions for various chemical transformations, primarily carbons, since they make up over 90% of the total dry matter of fruit (Friedman, 1996). In plum fruit, the most predominant are sugars, i.e. fermentable sugars (fructose, glucose and sucrose). During plum drying, in addition to oxidation reaction and acid hydrolysis (Dikerman et al., 2004), non-enzymatic browning reactions with sugars participating, such as caramelization and Maillard reaction (Manzocco et al., 2001; Kim end Lee, 2008), can be conducted too. Depending on the intensity of these reactions, characteristic colour and flavour of prune appears but on the other hand, they may lead to degradation of

product aroma and appearance (Dikerman et al., 2004; Sanz et al., 2001). Appropriate drying technology and raw material can affect the flow of these reactions in order to minimize the change of product quality, which is an ultimate goal of each processing.
The aim of the work was to examine the effect of drying temperature and dipping on the change of sugar content, both total and invert sugars as well as sucrose content in fruits of the plum cultivars 'Čačanska Lepotica', 'Mildora', 'Čačanska Rodna' and 'Stanley'.

Material and Methods

For the purpose of testing, plum fruits of the cultivars 'Čačanska Lepotica', 'Mildora', 'Čačanska Rodna' and 'Stanley' were obtained from the plantations of the Fruit Research Institute Čačak, in which standard agro- and pomotechnical practices were performed. Fruits for drying were selectively picked at full maturity stage for the appropriate cultivar, with the total dry mass content 15.77%, 25.50%, 22.67% and 19.59%, with average mass of about 41 g, 23 g, 36 g and 42g, respectively.
Drying of fruits was carried out in an experimental dryer for testing convective drying process (Kandić et al., 2006). An air streaming drying procedure was used at two constant air temperatures, 90 °C and 70 °C. Control fruits (without pretreatment) and dipped fruits (plum fruits which are, in laboratory conditions, immersed into boiling water for 20 seconds) were dried. Fresh plum fruits were placed in a single layer on an inox tray and 6 trays were placed in a drying chamber. Dipped and control fruits were dried simultaneously in the same experiment on the trays symmetrically placed in the drying chamber (3 trays with the control and 3 trays with dipped fruits). Through the trays with plum fruits, vertical heated air stream with predefined characteristics (temperature, flow) was introduced. Direction of vertical streaming during the process of drying was changed alternately and periodically for 60 minutes, thus achieving the same drying conditions on all of the trays. Fruit drying was completed once the fruits achieve 75% of total dry mater.
Fresh fruits have been kept in plastic bags until chemical analyses at –18 °C, while the dried fruits have been kept in plastic bags at room/ambient temperature (20 °C) until chemical analyses, for conditioning. By testing of fruit chemical composition of the investigated cultivars, the following was determined: content of dry matter (DM), obtained by drying at the laboratory dryer "Sutjeska" (Srbija) at 105 °C until constant mass, and the content of total and invert sugars and sucrose (by Luff-Schoorl's method). Results were expressed in grams per 100 gram of total dry matter (g/100 g DM).
Results were shown as arithmetical mean of three replications ± standard deviation and were processed statistically using analysis of variance (ANOVA). For testing of the difference significance of mean values of the tested parameters, Dunkan's multiple grading test for significance threshold was used $P \leq 0,05$.

Results and Discussion

Table 1 shows the content of total sugars, sucrose, invert sugars in the fresh and dried fruits of the plum cultivars, expressed in g/100 g DM for more accurate and clearer comparison. Percentage of the total sugars, invert sugars and sucrose in dried fruits compared to fresh fruit is shown in Graphs 1, 2 and 3, respectively, with the content of these parameters in fresh fruit shown by a line representing 100% of its content. Percentage of contents of the tested parameters depending on the drying temperature (a) and pretreatment influence (b) are shown separately on Graphs.
Analyzing the contents of total sugars in fresh fruit of the tested cultivars (Table 1), leads to an interesting information that the cultivar 'Čačanska Lepotica' had the highest value of this parameter (68.44 g/100 g DM). This could be explained with the fact that this cultivar, due to the lowest contents of total dry matter (15.77%), compared to the other tested plum cultivars,

has a greatest share of total sugars. In 'Mildora', the content of total sugars was 67.48 g/100 g DM, which was higher in comparison with the cultivars 'Čačanska Rodna' and Stanley, as expected, having in mind that this cultivar is known for the high content of total dry matter (Ogašanović and Ranković, 1996) and the total sugars (Mitrović et al., 2006).

Tab.1. Content of total sugars, invert sugars and sucrose (g/100 g DM) in fresh and dried fruit of cultivars

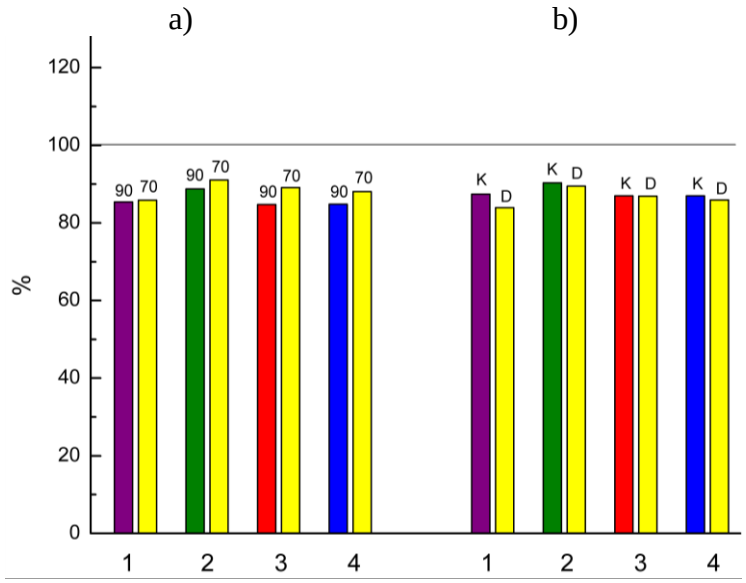
Cultivar	Sample		Total sugars	Invert sugars	Sucrose
Čačanska Lepotica	Fresh plum		68.44 ± 3.17 a	47.11 ± 2.84	20.26 ± 1.55 a
	Prune				
	90 °C	control	59.68 ± 1.56 b	51.61 ± 0.88	7.67 ± 1.56 b
		dipping	57.28 ± 3.84 b	49.66 ± 5.04	7.24 ± 2.35 b
	70 °C	control	59.98 ± 3.25 b	54.12 ± 0.10	5.57 ± 3.06 b
		dipping	57.60 ± 4.90 b	52.40 ± 6.26	4.93 ± 1.29 b
Mildora	Fresh plum		67.48 ± 5.08	41.36 ± 3.92 b	24.82 ± 1.58 a
	Prune				
	90 °C	control	59.58 ± 2.88	52.07 ± 2.70 a	7.13 ± 0.95 b
		dipping	60.25 ± 4.45	51.21 ± 3.01 a	8.59 ± 1.61 b
	70 °C	control	62.31 ± 3.26	55.31 ± 1.54 a	6.62 ± 1.74 b
		dipping	60.56 ± 3.05	54.67 ± 2.34 a	5.60 ± 0.88 b
Čačanska Rodna	Fresh plum		65.57 ± 1.66 a	39.27 ± 2.76 b	24.97 ± 3.71 a
	Prune				
	90 °C	control	55.84 ± 2.59 b	47.52 ± 4.41 a	7.90 ± 1.92 b
		dipping	55.33 ± 2.95 b	48.07 ± 2.88 a	6.89 ± 1.63 b
	70 °C	control	58.23 ± 2.47 b	47.54 ± 2.81 a	10.15 ± 2.87 b
		dipping	58.67 ± 3.51 b	50.19 ± 2.47 a	8.06 ± 2.78 b
Stanley	Fresh plum		64.80 ± 0.99 a	39.67 ± 1.77 b	23.86 ± 2.20 a
	Prune				
	90 °C	control	55.71 ± 3.29 b	48.53 ± 1.74 a	6.83 ± 1.67 b
		dipping	54.18 ± 2.43 b	48.78 ± 1.94 a	5.13 ± 0.48 b
	70 °C	control	57.00 ± 1.26 b	48.35 ± 1.55 a	8.22 ± 0.49 b
		dipping	57.20 ± 1.33 b	48.50 ± 1.71 a	8.26 ± 1.56 b

Data followed by different letters within each column and cultivar are significantly diferent according to Duncan's multiple range test at P ≤ 0.05

In dried fruits of all tested cultivars, except in 'Mildora', a lower content of total sugars was found, compared to initial fresh fruit regardless of the applied drying temperature and dipping procedure (Table 1, Graph 1). That loss is about 10-15%, although there was no juice leakage during the drying process. This was probably because of the participation of sugars in non-enzymatic browning reactions. Wilford et al. (1997), investigating the kinetics of sugar change during the drying of the plum cultivar d'Agen at three drying temperatures using convective drying, concluded that the Maillard reaction starts at about 45-50% of moisture loss, and the proof for that is profile change in the presence of some sugars.

During the drying process, there comes to the hydrolysis of sucrose in plum fruit and the increase in the contents of invert sugars. Analyzing Graph 2, dried fruit of all tested cultivars were found to act similarly regardless of the drying temperatures and dipping procedure applied, i.e. the increase is about 25-30%. Exception is the plum cultivar 'Čačanska Lepotica', in which a minimum increase in the content of invert sugars was observed, of no statistical

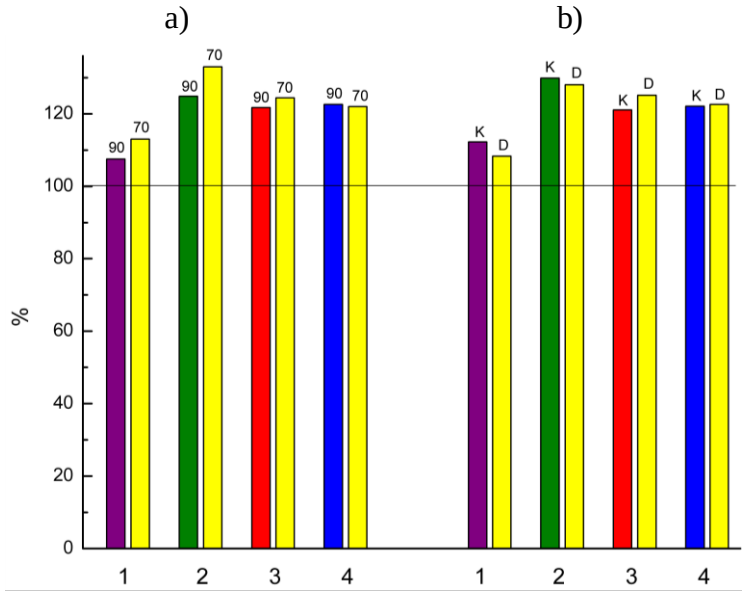
importance, and which was lower in fruits dried at higher temperatures (7.5% in total) than in dipped fruits where the increase is only 8.3%.



Graph. 1. Total sugars content in prunes compared to the frush plums, expressed as percentages

Legend:

- Cultivar: 1- Čačanska Lepotica; 2- Mildora; 3- Čačanska Rodna; 4- Stanley
- Influence of the drying temperature: 90 °C; 70 °C
- Influence of the dipping pretreatment: K- control; D - dipping



Graph. 2. Invert sugars content in prunes compared to the fresh plums, expressed as percentages

Legend:

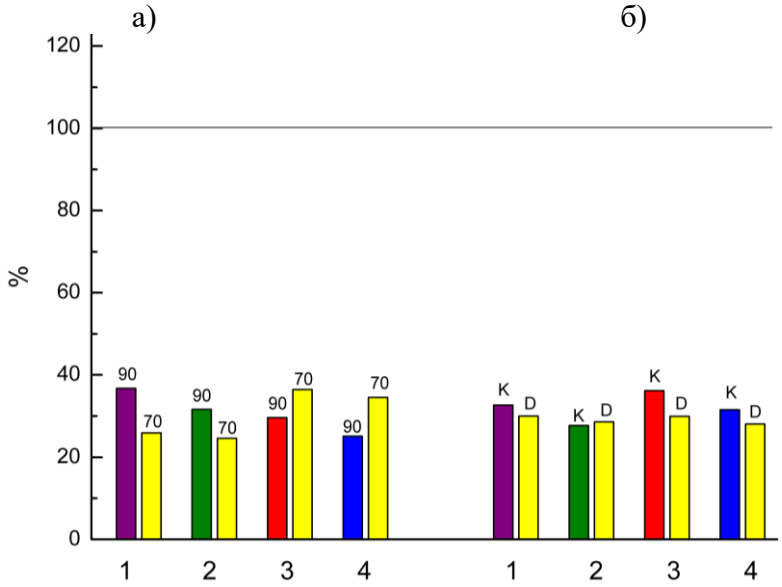
- Cultivar: 1- Čačanska Lepotica; 2- Mildora; 3- Čačanska Rodna; 4- Stanley
- Influence of the drying temperature: 90 °C; 70 °C
- Influence of the dipping pretreatment: K- control; D - dipping

Examining the carbohydrate content of prunes and their products, Dikeman et al. (2004) reported a significant increase in the content of glucose and fructose, the two most important monosaccharides in plums, in relation to fresh fruit as a starting material. Cinquanta et al.

(2002) found the increased content of glucose and fructose in dried fruits of all the plum cultivars, whereas in the cultivar 'Stanley' differences in the increased content of these simple sugars among fruits dipped in different manners were noted to be of no statistical significance, compared with non-treated fruits.

As formerly stated, results of the sucrose content in fresh and dried fruit of the investigated plum cultivars are shown in Table 1. In all tested cultivars, dramatically lower sucrose content in dried plum was found compared to fresh fruit.

Analyzing Graph 3, drying temperature is found to have greater impact on the reduced sucrose content in dried fruit of all tested cultivars in comparison with the applied pretreatments. Dried fruits of the cultivars 'Čačanska Lepotica' and 'Mildora' acted in similar way, sucrose content in fruits dried at 90 °C was about 3 times lower than in fresh fruits, while in fruits dried at 70 °C, the content was 4 times lower. In cultivars, 'Čačanska Rodna' and 'Stanley' the opposite was found, and a lower sucrose loss was observed by a lower drying temperature.



Graph. 3. Sucrose content in prunes compared to the frush plums, expressed as percentages

Legend:

- Cultivar: 1- Čačanska Lepotica; 2- Mildora; 3- Čačanska Rodna; 4- Stanley
- Influence of the drying temperature: 90 °C; 70 °C
- Influence of the dipping pretreatment: K- control; D - dipping

Dipping as an applied pretreatment, had much less effect on the reduced sucrose content in dried fruit compared with non-treated fruits, i.e. control. A slight difference was observed between dipped and control fruits in decreased sucrose content in the cultivars 'Čačanska Lepotica' and 'Stanley', whereas in 'Mildora', which dried fruits contain about 3.5 times less sucrose compared to the starting raw material, sucrose loss is the same regardless of whether the fruits are dipped or not. Only in the plum cultivar 'Čačanska Rodna', effect of dipping on reduced sucrose content was recorded so that the dipped fruits contain 3.3 times less sucrose than the fresh fruits and in non-treated fruits, representing control, sucrose amount was reduced 2.7 times.

During the process of plum drying, the hydrolysis of sucrose occurs, thereby generating glucose and fructose. Analyzing the kinetics of carbon hydrate change during drying of the plum cultivar d'Agen, Wilford et al. (1997) found that, during the drying process, sucrose is completely hydrolysed. According to them, low pH value and high moisture of fruit in early stages of drying favour the hydrolysis of sucrose generating glucose and fructose. In their

investigations, at the drying temperature of 70 °C, sucrose was completely vanished in 6-7 hours, while at 90 °C, sucrose loss was noted after 2 hours of drying. Authors Di Matteo et al. (2003) also noted a complete loss of sucrose in dried fruit of the plum cultivar Angeleno. Cinquanta et al. (2002) recorded the complete sucrose loss in dried fruit of the cultivars Angeleno and Empress too, while on the other side in the cultivar 'Stanley' only reduced content of sucrose in dried fruit compared with fresh fruit was noted, thus emphasizing that 'Stanley' is an excellent cultivar for drying. Decrease in sucrose content in the course of drying is not a plum characteristic only as a fruit species. Moreover, in the course of banana drying, the hydrolysis of sucrose occurs, i.e. there is a decrease in content of sucrose in comparison with the starting raw material. (Leite et al., 2007).

Conclusion

Based on the investigation results of the drying temperature and dipping effect on the change of total sugars, invert sugars and sucrose content in fruit of the plum cultivars 'Čačanska Lepotica', 'Mildora', 'Čačanska Rodna' and 'Stanley', the following conclusions can be drawn:

- Drying temperature affected the change of total sugars, invert sugars and sucrose content in fruit of the investigated plum cultivars. Change intensity was conditioned by varietal characteristics.
- Dipping, as a pretreatment applied, had no effect on the change of these parameters content, except in the cultivar 'Čačanska Rodna' in which greater decrease of sucrose compared to non-treated fruits was noted.
- In dried plum fruits of the cultivars 'Čačanska Lepotica', 'Čačanska Rodna' and 'Stanley', a lower content of total sugars was noted, based on the calculation of the total dry matter in relation to initial fresh fruit, regardless of the drying temperatures and dipping procedure applied. The only exception was the cultivar 'Mildora' in which there were no statistical differences in the total sugar content in dried fruit compared to fresh fruit.
- During the drying process, an increase of invert sugars content occurred in all tested cultivars, except in 'Čačanska Lepotica', in which there was no statistically significant increase in the content.
- In the course of plum drying, the hydrolysis of sucrose occurred, which was manifested in a dramatic decrease of its content in dried fruits compared to starting raw material in all tested cultivars.

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