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DETERMINATION OF CHEMICAL COMPOSITION OF PLUMS DURING PRE-TREATMENT AND DRYING

OZNACZANIE SKŁADU CHEMICZNEGO ŚLIWEK PODCZAS OBRÓBKI WSTĘPNEJ I PROCESU SUSZENIA

Abstract: Thanks to drying, fruits are available on the market throughout the year. Parameters of drying conditions affect eg the content of bioactive compounds in the product. The aim of the study was to investigate the effect of pretreatment conditions and the applied drying method on changes in the chemical composition of plums. Analyses were conducted on plums cv. 'Valor', which were subjected to pre-treatment including blanching, drilling and osmotic dehydration. Next they were dried by the convection method at air temperature of 60°C and flow rate of 1.5 m/s. Dehydration was run in a 61.5% sucrose solution at a temperature of 50°C for 1 or 2 h. Convection-dried plums, with no osmotic dehydration applied, constituted the reference sample. In fresh, dehydrated and dried fruits determinations included dry matter, polyphenols by colorimetry with the Folin reagent and contents of sugars by colorimetry using 3,5-DNS acid. As a result of blanching and dehydration the content of dry matter increased. Water loss after dehydration amounted to as much as 1.45 g H_2O/g d.m.$_0$ after 2 h in comparison with blanched plums. As a result of dehydration total contents of sugars and polyphenols in plums decreased (mg/100 g d.m.). In convection-dried prunes the content of polyphenols was by 30÷50% higher than in the raw material, but lower than in the reference sample.

Keywords: plums, drying, osmotic dehydration, polyphenols

Plums (*P. domestica* L.) are raw materials relatively rich in polyphenolic compounds, in which respect they exceed eg grapes, strawberries, raspberries and apples [1]. Literature data present plums as fruit of medium or high antioxidant capacity amounting to 10 µmol Trolox/g f.m. or 310 mg AA/100 g f.m., thus making plums rank second or third, after strawberry, in the group of 30 fruit analysed in cited studies [2, 3]. Moreover, plums are a valuable source of dietary fiber, minerals, particularly potassium, and beta-carotene [4-6]. These characteristics result in the advantageous action, confirmed by numerous studies, of fresh and dried plums on the functioning of the organism, eg an improvement of the blood lipid profile and a reduction of bone mass losses in women [7], improvement of lipid and glucose metabolism [8], and prevention of osteoporosis [9, 10].

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Plums are valuable dessert and processing raw materials, with prunes being one of the most popular products. They may be an additive for many foodstuffs and dishes, but also with increasing frequency they constitute a high-fiber snack, which may replace sweet, high-energy chocolate bars. Consumers searching for natural food rich in bioactive compounds select prunes, which are associated with being components of cereals or a high-value healthy snack [11]. Drying of fruit makes it possible to ensure their availability on the market throughout the year. Parameters of drying conditions affect eg the content of polyphenols and antioxidant capacity in the product [12]. Osmotic dehydration may be applied as pretreatment before convection drying, facilitating the removal of water from the raw material with the elimination of the phase transition, at a relatively low temperature. This method makes it possible to obtain a product with an advantageous taste, aroma as well as a desirable porous structure and unchanged shape [13-15]. During osmotic dehydration water from a tissue with a cellular structure (eg fruit) is removed through a semi-permeable cell membrane to the dehydrating solution, most frequently containing dissolved sugars or salts [16]. As a result of this process the activity of water in the dehydrated raw material decreases (a_w after dehydration within the range of 0.93÷0.97) [17]. Osmotic dehydration makes it possible to remove as much as 40÷70% water from the raw material at a relatively low uptake of the dehydrating substance. The ratio of the amount of removed water to an increase in the dry matter contents depends on the type of the dehydrating substance and the conditions of the process [18].

Plums of cv. 'Valor', used in this study, are characterised by large fruits, with considerable contents of solids, and they are an important raw material, both for dessert and processing purposes. This cultivar originates from Canada, and as such it is frost-resistant, but susceptible to a common fungal disease of plums, ie plum brown rot [19, 20].

The aim of this study was to assess changes in the chemical composition of plums during drying depending on the conditions of the process.

Materials and methods

Plums (*Prunus domestica* L.) of cv. 'Valor', coming from experimental orchards of the Poznan University of Life Sciences from the harvest season of 2009, were used as experimental material. Plums were washed, subjected to hot water blanching (90°C, 10 s), cooling in cold water and drilling. Pretreatment before convection drying consisted of osmotic dehydration in a 61.5% sucrose solution (water activity a_w 0.90) at a temperature of 50°C for 1 or 2 h. The weight ratio of the dehydrated raw material to the sucrose solution was 1 : 4. Following dehydration fruits were drained on a sieve, rinsed in water and dried on filter paper. Next convection drying was run at air temperature of 60°C at flow rate of 1.5 m/s. Convection dried fruits with no osmotic dehydration applied were used as the control.

Chemical analyses were performed on fresh, blanched, dehydrated and dried fruits. Dry matter content was determined by the gravimetric method [21]. Content of polyphenols was determined by colorimetry with the Folin reagent [22], by measuring absorbance at a wavelength of 760 nm in relation to the indicator blank, with results expressed in chlorogenic acid equivalents. Sugar content was determined by colorimetry with the use of the reagent containing 3,5-dinitrosalicylic acid, measuring absorbance at a wavelength of 550 nm in relation to the blank sample, with the recorded results expressed in terms of glucose [23]. Each determination was performed in three replications and mean values were calculated with standard deviations. Statistical analysis of the results was performed based on the Statistica 8.0 computer programme.

Results and discussion

The proper plum drying process was preceded by pretreatment of fruits including washing, blanching, cooling, cutting in halves and drilling as well as osmotic dehydration in a sucrose solution as the preliminary stage of drying. The latter process was omitted in case of the reference sample. Due to the limited selectivity of natural membranes in foodstuffs the diffusion process occurs not only in case of water, but also soluble low-molecular compounds, both from the raw material to the dehydrating solution and *vice versa*, which radically changes the chemical composition of the dehydrated product [24]. Thus the chemical composition of plums was analysed after each stage of pre-treatment.

The procedures of blanching and dehydration resulted in changes in the contents of dry matter, polyphenols and sugars. Fresh plums of cv. 'Valor' after harvest contained 17.9% dry matter, after blanching it was 18.2%, while after dehydration it was 24.8 and 28.7%, respectively, after 1 and 2 h (Table 1). Changes in dry matter contents were reflected in changes of water contents. This index was found to be similar, at 4.5 g/g d.m., to that in the fresh raw material and after the blanching process, while it was significantly reduced after the stage of osmotic dehydration, amounting to 3.0 g/g d.m. after the first hour and 2.5 g/g d.m. after the second hour of dehydration (Table 1). When comparing water content in the raw material and in the dehydrated product it was found that after osmotic dehydration in the sucrose solution the content of water decreased by 33% and 45%, respectively, after 1 and 2 h of the process. When analysing changes in water contents caused by osmotic dehydration it may be stated that during the first hour of the dehydration process the decrease in water contents was greater than in the following hour. Literature data also show that the rate of water content reduction decreases with the time of the osmotic dehydration process and it is greatest during the first hour or so [25, 26]. As a result of a reduction of water content in dehydrated plums a weight loss of 13% and 22% was observed after the first and after the second hour of the process, respectively. On the basis of the analysis of variance ANOVA it was found that changes in the contents of dry matter [%] and water [g/g d.m.] in plums during pretreatment in relation to fresh fruits were statistically significant ($p \leq 0.05$), while the LSD test confirmed the significance of differences for all the means.

Table 1

Changes in contents of dry matter and water during osmotic dehydration

Plums cv. 'Valor'	Contents of dry matter [%]	Contents of water [g/g d.m.]	Water loss WL [g/g $d.m._0$]	Solids growth SG [g d.m./g $d.m._0$]	WL/SG ratio
Fresh	17.9±0.55a	4.56±0.08a	-	-	-
Blanched	18.2±0.15a	4.50±0.04a	0a	0a	-
After 1 h dehydration	24.8±0.93b	3.03±0.16b	0.93±0.10b	0.18±0.03b	5.17
After 2 h dehydration	28.7±0.07c	2.48±0.01c	1.45±0.06b	0.23±0.02c	6.30

Mean values ± standard deviation
Mean values followed by the same letter vertically do not differ at p = 0.05 of significance

With *water loss* (WL) during the osmotic dehydration process *solids growth* (SG) was recorded in relation to contents of dry matter in the raw material before dehydration and the differences in values of these parameters were statistically significant ($p \leq 0.05$). Water loss after the first hour was 0.93 g/g d.m.$_0$, while after the second hour it was 1.45 g/g d.m.$_0$ (Table 1). At the same time solids growth of 0.18 and 0.23 g d.m./g d.m.$_0$ was recorded after the first and second hour of dehydration. These values of the parameter were lower than during the dehydration of strawberries in a 61.5% sucrose solution (180 min, temperature of osmotic solution 30°C), in which water loss of 3.5 g/g d.m.$_0$ and solids growth of 2.0 g/g d.m.$_0$ were found [27]. When comparing the WL/SG ratio it was stated that in case of dehydration of plums it was much higher than in the cited study, amounting to 5-1 to 6.3, while in the dehydration of strawberries it was approx. 1.8. In turn, during the dehydration of apple cubes of 10 x10 mm in a sucrose solution at a temperature of 50°C during 3 h solids growth (SG) of 1 g d.m./g d.m.$_0$ was observed, while weight loss of fruits amounted to 30% [28]. Dehydration of apple cubes of 10 x 10 mm was also investigated by Kowalska and Lenart [29], who recorded a 44% weight loss of the raw material after 3 h dehydration in a 61.5% sucrose solution at 50°C. Differences in the values of the discussed parameters result among other things from the varying tissue structure of tested fruits, their porosity and surface layer structure, but also from the different process conditions, duration and temperature as well as the dimensions of the raw material [24].

Pre-treatment procedures in plums resulted in changes in *total sugar* contents (T.S.), including *directly reducing sugars* (D.R.S.) and sucrose. After the blanching process the content of sugars in fruit *fresh matter* (f.m.) increased slightly (Table 2). Mass exchange during osmotic dehydration had a significant effect ($p \leq 0.05$) on changes in contents of sugars in analysed plums. The total sugar content increased by 43%, the content of directly reducing sugars by 32% and that of sucrose by 66% in fruit f.m. after two hours of dehydration in relation to fresh fruits (Table 2). In case of D.R.S. and T.S. contents significant differences were recorded between fresh and blanched plums and plums dehydrated for 1 h and 2 h, while in case of sucrose contents only the sample dehydrated for 2 h differed significantly from the others. When presenting the content of the above-mentioned sugars in dry matter of plums their contents were found to decrease during pretreatment processes, except for sucrose, in case of which a slight increase in its concentration was observed after blanching and dehydration (Fig. 1). On the basis of the analysis of variance it was found that osmotic dehydration had a significant effect ($p \leq 0.05$) on changes in contents of D.R.S. and T.S. in d.m. of plums. In their study Kowalska and Jadczak [28] also reported an increase in the contents of total sugars in dehydrated apples from 14 g/100 g f.m. to 17 g/100 g f.m. (20% sucrose, 50°C, 180 min), 23 g/100 g f.m. (20% sucrose, 70°C, 180 min) and 34 g/100 g f.m. (61.5% sucrose, 50÷70°C, 180 min). For comparison in this study the total sugar content increased from 13.5 g/100 f.m. to 17.5 g/100 g f.m. after the first hour and to 19.3 g/100 g f.m. after the second hour, respectively (Table 2). Kowalska and Jadczak [28] recorded a slight increase in D.R.S. (from 10 to 11÷13 g/100 g f.m.), similarly as in this study, in which the content of glucose from 9.2 g/100 g f.m. increased to 12.2 g/100 g f.m. (Table 2). Klewicki and Uczciwek [30] during dehydration of plums in 50% sucrose solutions (22, 40 and 60°C, 24 h) stated an increase in the contents of glucose and fructose, but a decrease in the concentration of sucrose (in f.m.). Variation in the presented data is connected eg with the differences in texture and size of the raw material, different process parameters, such as duration and temperature of dehydration, as well as the concentration of applied solutions. In most studies in the course of osmotic dehydration an increase was observed in the contents of sugars, dependent on the temperature and duration of the process.

Table 2

Changes in contents of sugars and polyphenols during osmotic dehydration

Plums cv. 'Valor'	Contents of D.R.S. [g/100 g f.m.]	Contents of T.S. [g/100 g f.m.]	Contents of sucrose [g/100 g f.m.]	Contents of polyphenols [mg/100 g f.m.]
Fresh	9.2±0.043a	13.5±0.08a	4.1±0.38a	276±10.8a
Blanched	9.2±0.32a	13.9±0.40a	4.5±0.15a	253±4.1a
After 1 h dehydration	12.4±0.25b	17.5±0.34b	4.9±0.45a	283±4.9a
After 2 h dehydration	12.2±0.10b	19.3±0.21c	6.7±0.23b	284±13.6a

Mean values ± standard deviation
Mean values followed by the same letter vertically do not differ at p = 0.05 of significance

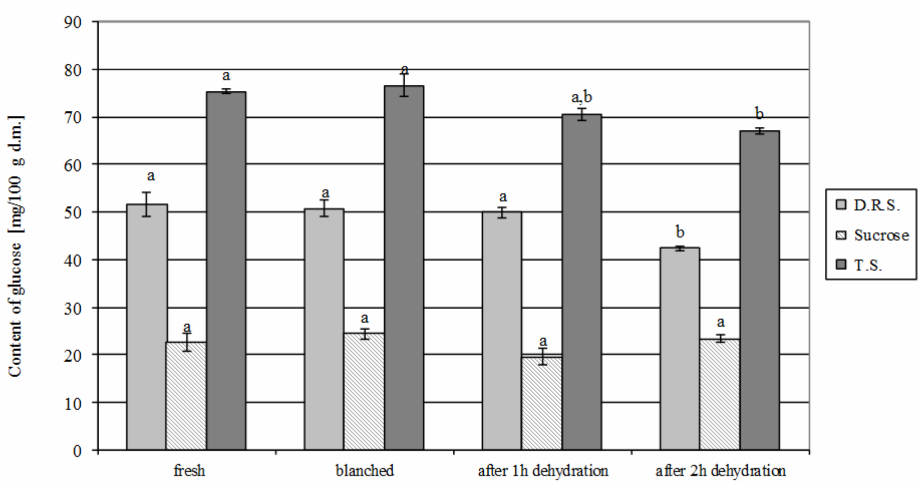

Fig. 1. The effect of osmotic dehydration on sugar contents in plums. Mean values followed by the same letter in series do not differ at p = 0.05 of significance

Procedures of pretreatment and drying also influenced the total content of polyphenols. The conducted one-way analysis of variance ANOVA showed a statistically significant effect ($p \leq 0.05$) of these procedures on the content of polyphenols (in mg/100 g f.m. and mg/100 g d.m.). As a result of the pretreatment procedures the content of polyphenols (mg/100 g d.m.) decreased, while after convection drying it increased (Fig. 2). A significant (LSD $p \leq 0.05$) reduction of polyphenol contents was recorded after 1 and 2 h of osmotic dehydration in comparison with the initial material, while the effect of blanching was statistically non-significant. The reduction of polyphenol contents after hydrothermal processes is connected mainly with the release of low-molecular compounds from the raw material to water or the dehydrating solution. After each variant of convection drying, preceded by osmotic dehydration, as well as in case when dehydration was not applied, a significant increase was observed in the contents of phenolic compounds, both in f.m. (results not included in the Table) and in d.m. of the product (Fig. 2). After osmotic-convection drying an increase was recorded in the contents of polyphenols, amounting to approx. 50% and 30%, respectively, for the samples dehydrated for 1 and 2 h. However, the greatest content of phenolic compounds was found in the reference sample, ie convection-dried without osmotic dehydration, amounting to 2665 mg/100 g d.m. (2335 mg/100 g f.m.). Many literature sources confirm an increase in the contents of polyphenols during convection drying of fruits. Ioannou et al [31] reported an increase in the polyphenol contents as a result of drying in case of mirabelle plums, by 10% at drying temperature of 50°C and by 16% at 75°C. An increase in the contents of polyphenols, particularly phenolic acids, during convection drying of plums *P. domestica* 'President', depending on the temperature of the process, was stated in a study by Del Caro et al [32]. In case of plums dried at a temperature of 85°C the content of neochlorogenic acid was higher by 46%, while that of chlorogenic acid by 63% than in fruits dried at 60°C. An increase in the contents of polyphenols was also recorded during the drying process of tomatoes [33]. This increase in the concentration of polyphenolic compounds in dried products may be connected with structural changes between polyphenols, and proteins and saccharides of cell walls, which modifies their availability [31], or with the regeneration of phenolic acids accompanying oxidative degradation of anthocyanins [32]. We also need to take into consideration the fact that the applied method of determination of polyphenols using the Folin-Ciocalteu reagent, which due to its low specificity is called the semi-quantitative method, may also concern the determination of the presence of alkaloids, proteins, vitamins or other compounds. On the other hand, the F-C reagent, by reacting with different reducing compounds, determines the antioxidant potential of the tested sample [34]. This makes it possible to draw the conclusion that in the course of drying of plums using the convection method their antioxidant activity increases, which probably results not only from the presence of polyphenols, but also high-molecular compounds formed during the drying process.

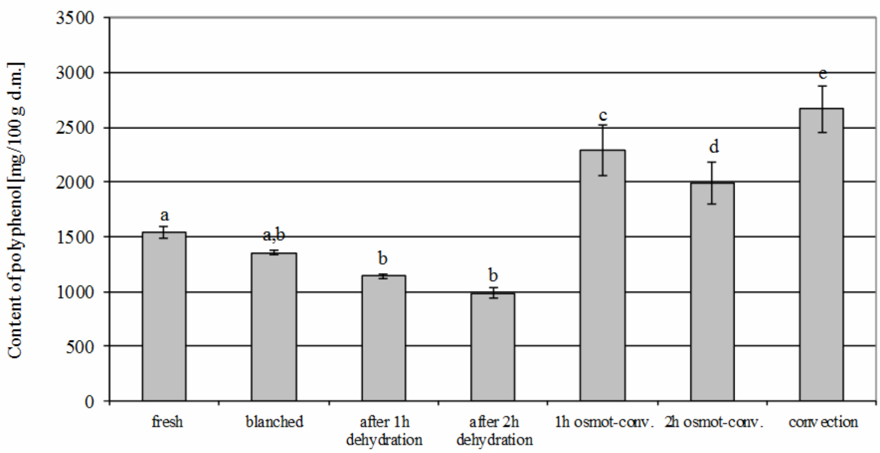

Fig. 2. The effect of osmotic dehydration on polyphenol contents in plums. Mean values followed by the same letter in series do not differ at p = 0.05 of significance

Conclusions

1. Osmotic dehydration of plums resulted in a reduction of water contents in fruits by 30÷40% in comparison with the raw material and a 13÷22% weight loss.
2. As a result of pretreatment in plums the content of polyphenols decreased by 12 to 36% (mg/100 g s/s) in comparison with the raw material. In the product dried by the convection method this content increased within the range of 30÷70% depending on the drying variant.
3. During osmotic dehydration in plums the content of directly reducing sugars and total sugar content decreased, while the content of sucrose, expressed as the content of glucose in 100 g d.m., increased slightly.
4. One-way analysis of variance ANOVA showed a statistically significant effect of dehydration on the content of sugars and the effect of drying on the content of polyphenols ($p \leq 0.05$).

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OZNACZANIE SKŁADU CHEMICZNEGO ŚLIWEK PODCZAS OBRÓBKI WSTĘPNEJ I PROCESU SUSZENIA

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Abstrakt: Suszenie owoców pozwala na utrzymanie ich dostępności na rynku przez cały rok. Parametry warunków suszenia wpływają m.in. na zawartość związków bioaktywnych w produkcie. Celem pracy było badanie wpływu procesów obróbki wstępnej i metody suszenia na zmiany składu chemicznego śliwek. W badaniach wykorzystano śliwki odmiany ‘Valor’, które poddano obróbce wstępnej, obejmującej blanszowanie, drylowanie i odwadnianie osmotyczne. Następnie poddano je suszeniu metodą konwekcyjną przy temperaturze powietrza 60°C i przepływie 1,5 m/s. Odwadnianie prowadzono w 61,5% roztworze sacharozy, w temperaturze 50°C, w czasie 1 lub 2 godzin. Jako próbkę odniesienia przyjęto śliwki suszone konwekcyjnie z pominięciem odwadniania osmotycznego. W owocach świeżych, odwadnianych i suszonych oznaczano zawartość suchej substancji, polifenoli metodą kolorymetryczną z odczynnikiem Folina oraz zawartość cukrów metodą kolorymetryczną przy użyciu kwasu 3,5-DNS. W wyniku blanszowania i odwadniania zwiększyła się zawartość suchej substancji. Ubytek wody po odwadnianiu, w porównaniu do śliwek blanszowanych, wyniósł do 1,45 g H_2O/g s.s.$_0$ po 2 h. W wyniku odwadniania w śliwkach obniżyła się ogólna zawartość cukrów oraz polifenoli (mg/100 g s.s.). W śliwkach dosuszonych konwekcyjnie zawartość polifenoli była wyższa o 30÷50% niż w surowcu, ale niższa niż w próbce odniesienia.

Słowa kluczowe: śliwki, suszenie, odwadnianie osmotyczne, polifenole