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# Effects of potassium metabisulfite pre-treatment and different drying temperatures on some chemical properties and color retention of Russian olive (*Elaeagnus angustifolia*) fruit

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## ABSTRACT

Silverberry is an important medicinal fruit that used for reducing pain. The present work was carried out to study the effect of potassium metabisulfite (KMS) and air drying temperature on quality of Russian olive fruit. Different KMS levels (0, 1, 2 and 4%) and drying temperatures (45, 60 and 75 °C) were used and some traits such as weight loss (WL), rehydration ratio (RH-R), TSS (total soluble solids), TA (total acidity), TSS/TA ratio, ascorbic acid, color parameters ($L^*$, $a^*$, $b^*$, chroma and Hue, TEPL, TEPa and TEPb, ΔE and BI), total phenol (TP), and potassium were measured. WL, RH-R and total color change (ΔE) increased with increment of pre-treatment concentration. All traits except TSS, were significantly affected by drying temperature. The TA, ascorbic acid and TP raised by increasing air temperature from 45 to 60 °C. Temperatures higher than 60 °C led to increase ΔE. Increment of temperature from 45 to 75 °C led to an increasing trend of browning index, $a^*$, $b^*$ and chroma, however, $L^*$ (lightness) and hue angle decreased. In general, using higher KMS concentrations as pre-treatment improved weight loss during drying, however, significant color change observed and color retention significantly reduced. Drying temperature higher than 60 °C also increased browning index of Russian olive fruit, however, total phenols increased in parallel. Thus, it is suggested that drying temperatures lower than 60 °C may be good treatment for drying silverberry fruits.

## INTRODUCTION

Russian olive or silverberry (*Elaeagnus angustifolia* L.), belongs to Elaeagnaceae family and is a Eurasian tree (Asadiar et al., 2012). Its flowers are fragrant, insect-pollinated, and silvery on the underside, covered with minute scales and fruits are reddish-brown, elliptic, 9-12 mm long and 6-10 mm wide with whitish pulp (Cansev et al., 2011; Ersoy et al., 2013). Leaves are alternate, simple, grayish-green, and are covered with minute scales. Because of richness in antioxidants, phenols (benzoic acid, cinnamic acid) and flavonoids (myricetin, epigallocatechin gallate), its fruit is considered as a functional food recently (Patel, 2014). In Iranian traditional remedies, dried fruit or pulp's powder and seed of this fruit have been used as an analgesic agent for reducing of pain in rheumatoid arthritis. In addition, pharmacological studies have shown muscle relaxant activity, antibacterial, anti-inflammatory and antinociceptive effects (Karimi et al., 2010).

One of the most commonly used preservation methods for fruits and vegetables is drying, by which longer shelf life is accomplished by reducing water activity (Prabhanjan et al., 1995) that can be achievable by different drying techniques including sun drying, hot-air drying, spray-drying, microwave drying, osmotic dehydration and freeze-drying (Chong & Law, 2011). Barbosa-Canovas and Vega-Mercado (1996) suggested that mechanical air dehydration leads to some advantages over sun drying, including (a) reduction in contamination, (b) uniformity in the product, (c) shortening drying time and, (e) lower labor cost.

Several studies have been conducted on the effect of air temperature on physical properties and nutritional quality of air-dried fruits and vegetables (Ashebir et al., 2009; Esmaeili Adabi, 2013; Garau et al., 2007; Madrau et al., 2009; Vega-Gálvez et al., 2009; Vega-Gálvez et al., 2012). In Chinese jujube fruits, the increment of drying temperature (from 50 to 70 °C) increased browning (Fang et al., 2009). Drying temperature significantly increased colorimetric parameters of pear fruit, including $a^*$ and $b^*$ due to the non-enzymatic browning reaction, which turned the samples more reddish and yellow when the temperature is rose (Mrad et al., 2012). Ben Haj Said et al. (2013) stated that color characteristics of *Allium roseum* significantly change by drying temperatures. Vega-Galvez et al. (2012) and López et al. (2013) reported that color difference significantly increased with temperature increment.

Chemical pretreatments are also used to reduce drying time. Vásquez-Parra et al. (2013) indicated that chemical pre-treatment decreased moisture content of gooseberry fruits. Eleyinmi et al. (2002) showed that potassium metabisulfite increased dehydration index of pepper under drying condition. Prajapati et al. (2009) stated that blanching with potassium metabisulfite (KMS) before drying checks the enzymatic spoilage and also improves the color and texture of the shreds.

The silverberry fruit pulp is whitish in maturity stage that affects its commercial value. However, drying may influence its color. Drying temperature and potassium metabisulfite dipping as a chemical pre-treatment may affect the colorimetric properties of Russian olive fruits powder, but to the authors' knowledge, there is no report in this regard.

Therefore, the objectives of this study were to determine a) the effect of drying temperature on color degradation; b) influence of potassium metabisulfite as a chemical agent to increase dehydration rate of fruit and c) interactive effects of these treatments on some quality attributes of Russian olive fruit.

## MATERIALS AND METHODS

### Sample preparation, chemical pre-treatment, and drying process

Fruit harvested at the mature stage from a commercial orchard, in Kashmar, Khorasan-e-Razavi province, Iran, in September 2014. Harvested fruit then transported to the Horticultural Laboratory of the University of Birjand, to detect defected fruits for future study. The initial moisture content of fruit was 27±0.6% wet basis (wb) determined using the oven at 105 °C until constant weight (AOAC, 2000). Fruits dipped in potassium metabisulfite (KMS) solution (0 as control, 1, 2 and 4%) for 1 min 25 °C, then surface dried with absorbent paper. Pretreated samples dried in a convective oven dryer (Binder FED-720, Germany) using three inlet temperatures including 45 °C (as control), 60 °C and 75 °C with an air velocity of 0.75 m $s^{-1}$ to a final moisture content of about 10% wb. Air velocity measured by an anemometer (Adolf Thies GmbH & Co. KG. Hauptstraße 76-37083 Göttingen, Germany). The pulp was removed from seed, then packed and sealed in polyethylene bags and kept under 5±1 °C until used for future studies.

### Weight loss

Weight loss percentage of dried fruits during drying was calculated as followed (1):

$$\text{Weight loss (\%)} = \frac{\text{Wi}-\text{Ws}}{\text{Wi}} \times 100 \qquad (1)$$

Where wi is the initial (i) weight of fruit samples, and ws is the weight of fruit samples at $s^{th}$ weighing time during the drying process (Fang et al., 2009).

### Rehydration ratio (RH-R)

To determine the rehydration ratio, three dehydrated Russian olives without fissures were selected and soaked in distilled water at a 1:10 ratio of fruit to distilled water (w/w). Rehydration was carried out at 25 °C for 14 h. Then, the fruits were taken out from the water and put onto an absorbent paper as long as there is no water on the fruit surface, at which time, the weight of fruits was determined.

Rehydration ratio was calculated as follows (2):

$$RH - R = \frac{m_e - m_0}{m_0} \times 100 \qquad (2)$$

Where $m_0$ and $m_e$ were the weight of fruits at initial time and after 14 h of rehydration, respectively, and RH-R is the rehydration ratio as percentage (Fang et al., 2009).

### Color measurement

The color of pulp powder was evaluated using a colorimeter (TES 135, Shenzhen Youfu Tools Co., Ltd. - Taiwan). Hunter color values including L*, a*, b*, chroma, and Hue were calculated (McGuire, 1992), and used for all color differences. The total effect of pretreatment (TEP) on color values of dehydrated fruits were calculated using the following equations (3, 4 and 5):

$$TEP_L = L_T - L_C \qquad (3)$$

$$TEP_a = a_T - a_C \qquad (4)$$

$$TEP_b = b_T - b_C \qquad (5)$$

Where TEPL, TEPa, and TEPb are total effects of any treatments on L (brightness or lightness), a (redness), and b (yellowness), respectively. Subscript T stands for treatment concentrations (potassium metabisulfite at 1, 2 or 4%) while subscript C stands for control (0%).

There are also three other derived color calculations including total color change parameter (ΔE) (Maskan, 2001), the ratio of yellowness over redness (Y=b/a) (Batu, 2004) and browning index (BI). Browning index represents the purity of brown color and is considered as an important parameter associated with browning (Palou et al., 1999). The equations of derived color measurements were as follows (6, 7 and 8) to calculate total color change affected by pretreatments:

$$\Delta E = [(TEP_L)^2 + (TEP_a)^2 + (TEP_b)^2]^{0.5} \quad (6)$$

The ratio of yellowness over redness (Y) was evaluated as followed:

$$Y = \frac{b}{a} \quad (7)$$

Browning index (BI) was calculated as followed:

$$BI = \frac{[100(x - 0.31)]}{0.17} \quad (8)$$

Where $x = \frac{(a + 1.75L)}{(5.645L + a) - 3.012b}$

**Total soluble solids (TSS), titratable acidity (TA) and ascorbic acid**

The TSS were measured using a hand-held refractometer (0-32 % Brix, Guang Zhou, China). Two grams of fruit powder were added to 10 ml distilled water. The samples were then placed into a water bath at 77.5 °C for 30 min, and finally transferred for 1 h to room temperature in order to cool down. The solution was then filtered (using Whatman Filter Paper, Grade 2) and one drop of the filtrated solution was used for refractometer reading as Brix (Fang et al., 2009).

The TA was measured by acid-alkali neutralization titration method. For this, 5 g of pulp powder was dispersed in 20 ml distilled water and then heated by immersing in a water bath at 77.5 °C for 30 min. The solution was diluted with distilled water to a final volume of 50 ml in a volumetric flask and then filtered (using Whatman Filter Paper, Grade 2). Five drops of phenolphthalein were added to 10 ml of filtrate and titration was performed by 0.1 M NaOH until the solution turned to pink for at least 30 s. TA was calculated using the following equation (9):

$$\text{Titratable acidity (\%)} = \frac{VNAk}{M} \times 100 \quad (9)$$

Where V is the volume of consumption of NaOH, N is the concentration of NaOH, A is the dilution factor, *k* is the conversion factor (0.067 for malic acid) and M is the sample weight in g (Bi et al., 2014). These data were used to show TSS/TA ratio.

Vitamin C content was determined by the 2, 6-dichloroindophenol titration method as described by Fang et al. (2009) with some modifications. The dried powder of pulp (5 g powder) was dispersed in 10 ml of 3% meta phosphoric acid solution and then homogenate. The sample solution was transferred into a 50 ml volumetric flask, diluted with an extraction solvent to the volume of 50 ml and filtered (using Whatman Filter Paper, Grade 2). Then, 10 ml of filtrate was transferred into a 50-ml conical flask, and finally, titration was done with 2, 6-dichloroindophenol until the solution turned to pink and kept for at least 30 s. A calibration curve was also prepared using ascorbic acid (Merck KGaA, Darmstadt, Germany) and results were expressed mg ascorbic acid in 100 g of powder.

**Total phenols**

One g of pulp powder was extracted by the addition of 10 ml of 70% (v/v) aqueous methanol (Merck KGaA, Darmstadt, Germany), after being shaken for 2 h at room temperature, and centrifuged at 4000 × *g* for 10 min. Consequently, the supernatant was separated from the solid particles and was analyzed for total phenolic content (TPC). Total phenolic content (TPC) was estimated by Folin-Ciocalteau's (FC) assay with some modifications (Makkar et al., 1993); 450 µl of distilled water was added to 50 µl of prepared extract. Then 250 µl of FC reagent (FC, Merck KGaA, Darmstadt, Germany) (1 N) was added, vortex-mixed and left to stand for 5 min. Next, 1.25 ml of $Na_2CO_3.10H_2O$ (20%, Merck KGaA, Darmstadt, Germany) was added to the mixture and incubated for 40 min under dark conditions at room temperature. Finally, the absorbance was measured at 725 nm using a spectrophotometer (Biospec 1601, Shimadzu, Tokyo, Japan). A calibration curve was also prepared using gallic acid (Merck KGaA, Darmstadt, Germany) and results were expressed as mg gallic acid per 100 g dry matter.

### Potassium analysis

Oven-dried materials of fruit pulp of each replication were used. Dried samples of each replicate were ground separately and ashed in a porcelain crucible at 550 °C for 6 h. Each of the yielded white ash was added to 2 M hot hydrochloric acid (HCl), filtered into a 50-ml volumetric flask, and finally topped to 50 ml with distilled water. Potassium (K) was measured on these solutions. K was analyzed using a flame photometer (Corning 405, Corning, Halstead, Essex, UK).

### Statistical analysis

The experiment was arranged in a completely randomized design as 4×3 factorial. Data were analyzed with ANOVA using GenStat program (version 12.1, Copyright 2009, VSN International Ltd., UK). Means were separated with Tukey test at 95% level of confidence. Each treatment consisted of four replications and each replicate consisted of 250 g of pulp powder.

## RESULTS AND DISCUSSION

### Weight loss (WL)

The WL increased with the increment of KMS concentration (Fig. 1) and also drying temperature (Fig. 2) increment. The simple effect of KMS showed the highest WL with 4% concentration and 60 and 75°C drying temperatures led to the highest values of this parameter (Table 1). The increment of weight loss under KMS concentration increment was in agreement with the finding of Ahmadzadeh Ghavidel and Ghiafeh Davoodi (2009) on tomato. Pangavhane et al. (1999) found that the chemical dipping before drying reduced the drying time of the final product. It is suggested that modification of skin structure by the highest KMS (4%) may result in lowest internal resistance to water diffusion and thus, highest weight loss.

More WL observed in higher drying temperature that may be related to changes occurred in the crystalline to amorphous in the waxy cuticle of fruits under high temperature and then resulted in increased skin water permeability (Price et al., 2000).

Interactive effects of pre-treatment and drying temperature indicated the highest WL in fruit pre-treated with potassium metabisulfite (2%) and drying temperature of 60 °C, however, there were no significant differences with other treatments, with the exception of 0 and 4% under 45 °C (data not shown).

### Rehydration ratio (RH-R)

Rehydration ratio is affected by both KMS concentration and drying temperature ($P < 0.05$), although the interaction between those factors unaffected this variable. Regarding to simple effects, the highest RH-R value obtained with 4% KMS or at 60 °C drying temperatures, although there is no significant difference between 40 and 75 °C (Table 1). Fang et al. (2009) on jujube showed that increment of drying temperature led to higher RH-R. Rehydration is a complex process aimed at the restoration of previously dried materials in contact with water. Any reduction in RH-R value may be due to cellular damage which led to modification of osmotic properties of the cells, as well as lower diffusion of water through the surface during rehydration (Kaymak-Ertekin, 2002). Fang et al. (2009) reported that the degree of rehydration is dependent on the degree of cellular and structural disruption.

**Color**

All color characteristics ($L^*$, $a^*$, $b^*$, $C$ and H°) were influenced by drying temperature (Table 2) and interaction of KMS concentration × drying temperature (Table 4), although KMS alone unaffected those values. The $L^*$ (representing lightness) value statistically decreased with increasing temperature from 45 to 75 °C ($P < 0.0001$) that may be due to a larger extension of Maillard reaction leading to a darker fruit pulp color (Vega-Gálvez et al., 2009). The interaction between KMS and temperature indicated the highest values for this variable with 45 °C in all concentrations of KMS and 60 °C in 0% of KMS (Table 4). The highest $a^*$ (representing redness and greenness) value was observed at 75 °C that was significant compared with other temperatures ($P < 0.0001$), which corresponded to the pulp powder becoming more reddish. About of $b^*$ (representing yellowness) value, it was found that drying at higher temperatures (75 °C) tended to give higher yellowness compared with other temperatures. This increase of yellowness may be justified by the generation of brown products due to non-enzymatic reactions (Oliveira et al., 2015). Generally, the color change in food materials during thermal processing is caused by the reactions taking place, such as pigment degradation (especially carotenoids and chlorophyll), and browning reactions such as Maillard condensation of hexoses and amino components and the oxidation of ascorbic acid (Barreiro et al., 1997; Lee & Coates, 1999; Lozano & Ibarz, 1997).

The saturation index or chroma (C) and the hue angle (H°), as shown in Table 2, provide more information about the spatial distribution of colors than direct values of tri-stimulus measurements (Sigge et al., 2001). The increase in $a^*$ value denotes a redder chroma which is indicative of the enzymatic or/and non-enzymatic reactions (Mrad et al., 2012). Data from interactive effects of KMS and temperature showed the lowest hue angle value with all KMS concentrations at 75 °C drying temperature (Table 4). The browning reactions occurring during drying and enzymatic reactions due to polyphenol oxidase and Maillard are the contributing factors to the color change of products (Mrad et al., 2012). Similar results were obtained during hot-air drying of apple at 70 °C (Kutyła-Olesiuk et al., 2013).

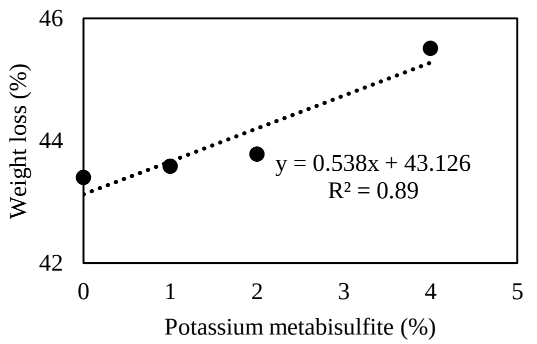


**Fig. 1.** Correlation between potassium metabisulfite and weight loss of fruit

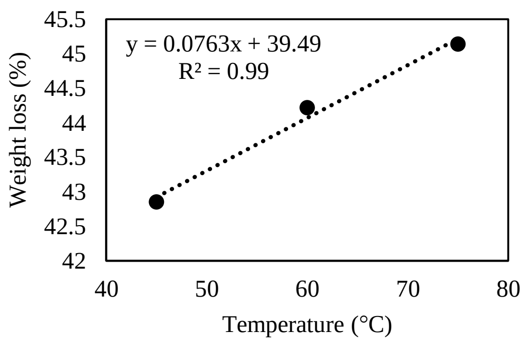


**Fig. 2.** Correlation between drying temperature and weight loss of fruit

**Table 1**. Effects of KMS pre-treatment and drying temperatures on weight loss and rehydration ratio of silverberry pulp

| KMS (%) | Weight loss (%) | RH-R (%) |
|---|---|---|
| 0 | 43.40$^{b}$† | 40.31$^{b}$ |
| 1 | 43.58$^{b}$ | 36.82$^{b}$ |
| 2 | 43.78$^{b}$ | 40.03$^{b}$ |
| 4 | 45.51$^{a}$ | 47.45$^{a}$ |
| Drying temperature (°C) | | |
| 45 | 42.85$^{b}$ | 37.48$^{b}$ |
| 60 | 44.22$^{a}$ | 46.89$^{a}$ |
| 75 | 45.14$^{a}$ | 39.08$^{b}$ |

†Values with the same letter in the same column were not significantly different (*P* > 0.05) by Tukey test.

**Table 2**. Effects of drying temperatures on color characteristics of silverberry pulp

| Drying temperature (°C) | *l* | *a* | *b* | chroma | Hue |
|---|---|---|---|---|---|
| 45 | 96.06$^{a}$† | 7.79$^{b}$ | 22.03$^{c}$ | 28.65$^{a}$ | 72.10$^{a}$ |
| 60 | 94.55$^{b}$ | 8.13$^{b}$ | 24.95$^{b}$ | 26.23$^{b}$ | 71.95$^{a}$ |
| 75 | 89.92$^{c}$ | 9.91$^{a}$ | 26.87$^{a}$ | 23.12$^{c}$ | 69.77$^{b}$ |

†Values with the same letter in the same column were not significantly different (*P* > 0.05) by Tukey test.

**Table 3**. Effects of drying temperatures on TEPL, TEP a, b/a and browning index of silverberry pulp

| Drying temperature (°C) | TEPL | TEPa | b/a | BI |
|---|---|---|---|---|
| 45 | -0.058$^{b}$† | 0.9921$^{a}$ | 2.937$^{ab}$ | 31.58$^{c}$ |
| 60 | -1.744$^{c}$ | 0.2452$^{ab}$ | 3.085$^{a}$ | 36.53$^{b}$ |
| 75 | 2.259$^{a}$ | -0.4879$^{b}$ | 2.718$^{b}$ | 43.13$^{a}$ |

†Values with the same letter in the same column were not significantly different (*P* > 0.05) by Tukey test.

The highest and lowest values of TEPL were observed in 75 °C and 60 °C, respectively (Table 3). The interaction between drying temperature and chemical pre-treatment indicated the highest TEPL in 75 °C and 2% of pre-treatment, although had no difference with other levels (0, 1 and 4%) under 75 °C. Moreover, under 60 °C drying temperature, a reducing trend was observed about this variable with an increment of KMS concentration. The lowest change in brightness was observed at 60°C with different levels of KMS (Table 4), thus drying temperature should not be increased higher than 60 °C (Table 4). TEPa showed changes with drying temperature and reduced linearly (Fig. 3; $R^2$=1) as temperature increased, although there was no significant difference between 60 and 75 °C (Table 3). Yellowness index (b/a) significantly decreased as temperature increased from 60 to 75 °C (Table 3). In ureaddition, browning index also significantly increased with temperature increment (Table 5, Fig. 4) and a linear correlation ($R^2$=0.99) was observed that was in agreement with Fang et al. (2009) on Chinese jujube. The interaction between drying temperature and chemical pre-treatment showed the highest value of this trait at 75 °C and all levels of KMS (Table 4).

The BI is a common indicator in sugar-containing products submitted to processes where enzymatic and nonenzymatic browning take place (Pathare et al. 2013). Total color change (ΔE) significantly affected by pre-treatment (Fig. 5) and increased with KMS concentrations compared with control (0%), although there was no significant difference among 1, 2 or 4% concentrations, which was in contrast with Ergünş and Tarhan (2006) report. Jokić et al. (2009) who found that chemical pre-treatments decrease total color change. ΔE may result from Maillard reaction leading to a darker pulp color (Vega-Gálvez et al., 2009), non-enzymatic reactions (Oliveira et al., 2015) or pigment degradation (Barreiro et al., 1997; Lee & Coates, 1999; Lozano & Ibarz, 1997).

**Table 4**. Interactive effects of KMS pre-treatment × drying temperature on l, hue, TEPL, and BI of silverberry pulp

| Temperature (°C) | KMS (%) | *l* | Hue | TEPL | BI |
|---|---|---|---|---|---|
| 45 | 0 | 96.11$^{abc}$† | 72.78$^{a}$ | 0.000$^{abcd}$ | 30.78$^{e}$ |
| | 1 | 96.98$^{a}$ | 72.88$^{a}$ | 0.863$^{abcd}$ | 32.19$^{cde}$ |
| | 2 | 95.92$^{abc}$ | 70.57$^{cde}$ | -0.198$^{abcd}$ | 31.25$^{e}$ |
| | 4 | 95.22$^{abcd}$ | 72.18$^{ab}$ | -0.898$^{bcd}$ | 32.08$^{de}$ |
| 60 | 0 | 96.30$^{ab}$ | 71.63$^{abc}$ | 0.000$^{abcd}$ | 34.06$^{cde}$ |
| | 1 | 94.32$^{bcd}$ | 72.62$^{ab}$ | -1.979$^{cd}$ | 36.23$^{cde}$ |
| | 2 | 93.54$^{de}$ | 72.17$^{ab}$ | -2.755$^{d}$ | 39.18$^{abc}$ |
| | 4 | 94.06$^{cd}$ | 71.38$^{bcd}$ | -2.240$^{d}$ | 36.63$^{bcde}$ |
| 75 | 0 | 87.66$^{g}$ | 69.11$^{f}$ | 0.000$^{abcd}$ | 45.48$^{a}$ |
| | 1 | 90.43$^{f}$ | 69.99$^{ef}$ | 2.771$^{ab}$ | 43.41$^{ab}$ |
| | 2 | 91.69$^{ef}$ | 70.20$^{def}$ | 4.028$^{a}$ | 39.13$^{abcd}$ |
| | 4 | 89.90$^{f}$ | 69.77$^{ef}$ | 2.238$^{abc}$ | 44.49$^{a}$ |

†Values with the same letter in the same column were not significantly different ($P > 0.05$) by Tukey test.

**Table 5**. Effects of KMS pre-treatment and drying temperatures on TA, TSS/TA ration and ascorbic acid of silverberry pulp

| KMS (%) | TA (%) | TSS/TA | Ascorbic acid (mg 100$^{-1}$ g D.W.) |
|---|---|---|---|
| 0 | 1.15$^{b}$† | 12.42$^{a}$ | 1.98$^{c}$ |
| 1 | 1.18$^{b}$ | 12.39$^{a}$ | 2.13$^{b}$ |
| 2 | 1.18$^{b}$ | 12.45$^{a}$ | 2.15$^{b}$ |
| 4 | 1.30$^{a}$ | 11.51$^{b}$ | 2.27$^{a}$ |
| Drying temperature (°C) | | | |
| 45 | 1.03$^{c}$ | 13.97$^{a}$ | 1.90$^{c}$ |
| 60 | 1.32$^{a}$ | 10.99$^{c}$ | 2.30$^{a}$ |
| 75 | 1.26$^{b}$ | 11.62$^{b}$ | 2.19$^{b}$ |

†Values with the same letter in the same column were not significantly different ($P > 0.05$) by Tukey test.

**Table 6**. Interactive effects of KMS pre-treatment × drying temperature on TA, TSS/TA and ascorbic acid of silverberry pulp

| Temperature (°C) | KMS (%) | TA (%) | TSS/TA | Ascorbic acid (mg 100$^{-1}$ g D.W.) |
|---|---|---|---|---|
| 45 | 0† | 1.14$^{fg}$ | 12.38$^{bc}$ | 1.68$^{c}$ |
| | 1 | 1.02$^{hi}$ | 14.10$^{a}$ | 1.73$^{c}$ |
| | 2 | 0.98$^{i}$ | 14.79$^{a}$ | 2.10$^{b}$ |
| | 4 | 0.99$^{i}$ | 14.63$^{a}$ | 2.10$^{b}$ |
| 60 | 0 | 1.21$^{def}$ | 11.86$^{cd}$ | 2.10$^{b}$ |
| | 1 | 1.34$^{bc}$ | 10.73$^{ef}$ | 2.45$^{a}$ |
| | 2 | 1.27$^{cde}$ | 11.31$^{cde}$ | 2.13$^{b}$ |
| | 4 | 1.44$^{ab}$ | 10.06$^{f}$ | 2.53$^{a}$ |
| 75 | 0 | 1.11$^{gh}$ | 13.02$^{b}$ | 2.15$^{b}$ |
| | 1 | 1.18$^{efg}$ | 12.34$^{bc}$ | 2.20$^{b}$ |
| | 2 | 1.31$^{cd}$ | 11.26$^{de}$ | 2.23$^{b}$ |
| | 4 | 1.46$^{a}$ | 9.87$^{f}$ | 2.18$^{b}$ |

†Values with the same letter in the same column were not significantly different ($P > 0.05$) by Tukey test.

**Table 7**. Effects of drying temperatures on total phenols of silverberry pulp

| Temperature (°C) | 45† | 60 | 75 |
|---|---|---|---|
| Total phenol (mg g$^{-1}$ D.W.) | 260.81$^{c}$ | 323.01$^{b}$ | 350.21$^{a}$ |

†Values with the same letter in a row were not significantly different ($P > 0.05$) by Tukey test.

## TSS, TA and ascorbic acid

The TSS was not statistically different for KMS concentrations, air temperature and their interaction (data not shown) that was in disagreement with Vega-Gálvez et al. (2009) report on red pepper. The highest TA value observed in 4% KMS that was significant compared with others. The TA significantly affected by drying temperature and highest amounts of TA obtained with 60 °C (Table 5) that was in agreement with Vega-Gálvez et al. (2009) on red pepper. Interaction of KMS and drying temperature showed the highest TA in 4% KMS under 60 and 75 °C.

Application of KMS at 4% concentration was led to the lowest TSS/TA ratio (Table 5). The increment of drying temperature from 45 to 75 °C reduced TSS/TA ratio (Table 5). The interaction between pre-KMS and drying temperature (Table 6) showed the highest amount of this ratio with 45°C, and 1, 2 or 4% of chemical treatment. It is suggested that increasing trend of this ratio may be resulted from decreasing of TA and/ or increment of TSS that may result from higher water loss and more concentrated soluble solids.

Application of KMS led to the increment of ascorbic acid and the highest value observed in 4% KMS (Table 5). The increment of drying temperature resulted in increasing trend of this variable, compared with 45 °C (Table 5). Interaction of KMS and temperature showed the lowest rate of ascorbic acid in 0 and 1% KMS and 45 °C (Table 6). The mechanism of vitamin C degradation is specific for each food system and is dependent on many factors, including pH, other components contained in the food, and reducing or oxidizing conditions (Serpen & Gökmen, 2007). In addition, Mrad et al. (2012) showed that drying of pear pieces at a temperature of 60 °C (in comparison to drying at 30, 40 and 50 °C) can be considered as an optimum for pear in order to achieve acceptable ascorbic acid content and shortening drying time. However, some authors reported conflicting results about tomato (Demiray et al., 2013) and Acerola residues (Nóbrega et al., 2014). Madrau et al. (2009) showed that there were no significant differences between all drying temperatures (55 and 75 °C) on the vitamin C content of apricot.

## Total phenols

This variable unaffected with KMS or interaction of KMS and temperature, however, air temperature has an important effect on it. A significant increment is observed at 60 and 75 °C, compared with 45 °C (Table 7) that might be due to the availability of precursors of phenolic molecules used by non-enzymatic interconversion (Que et al., 2008). Similarly, an increasing trend observed in apricot and plum after drying with hot air (Madrau et al., 2009; Piga et al., 2003). They stated that polyphenol oxidase activity strongly higher at low temperatures (approximately 55 °C) and reduced at 75 °C. It is highly likely the reason for higher phenolic content observed at higher drying temperatures in our study.

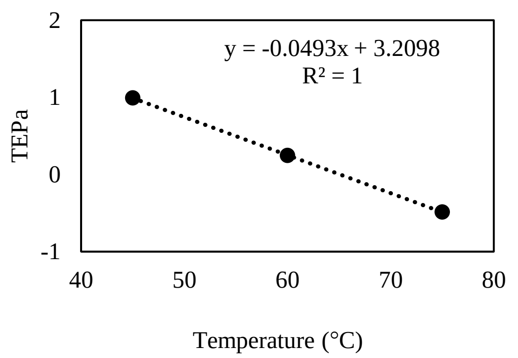


**Fig. 3.** Correlation between drying temperature and TEPa

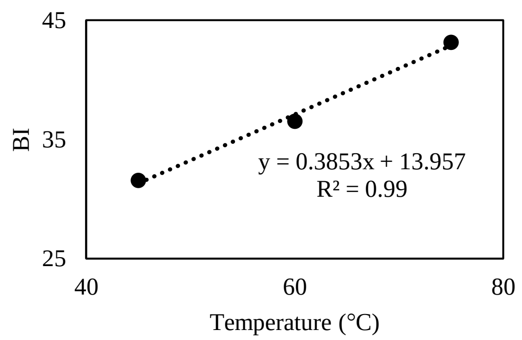


**Fig. 4.** Correlation between drying temperature and browning index

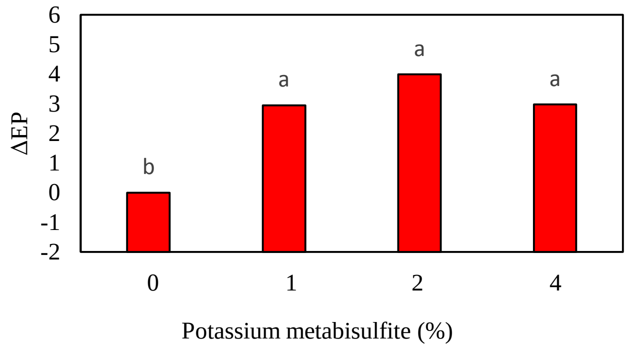


**Fig. 5.** Effect of different potassium metabisulfite concentrations on ΔEP

**Potassium content**

Potassium concentration of pulp powder increased as KMS concentration increased (data not shown), which was in agreement with findings of Eleyinmi et al. (2002) on pepper. Changes in salt content over time depend on the original concentration of the dipping solution.

## CONCLUSION

Some qualitative parameters of Russian olive fruit were studied after treatment with different levels of KMS (0, 1, 2 or 4%) and hot-air oven drying (45, 60 or 75 °C). Color and phenolic contents may be very important for this fruit after drying process.

Results indicated that increment of KMS concentration induced weight loss under drying condition, but did not positive effect on color retention and increased ΔE. So, KMS pretreatment just was effective to reduce drying time and not positive for color retention and/ or improvement.

Drying temperature also significantly influenced total phenols and ΔE, and temperature higher than 60 °C led to the increment of these traits and also browning index, which is not a good trait. So, it is suggested that drying temperature used for this fruit should not be higher than 60 °C to achieve a better quality and more bright color.

## CONFLICT OF INTEREST

All authors stated that there is no conflict in their research.

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# تاثیر پیش تیمار متابی‌سولفیت پتاسیم و دماهای مختلف خشک کردن بر برخی خصوصیات شیمیایی و حفظ رنگ میوه سنجد

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**چکیده**

**سنجد یکی از میوه‌های مهم مورد استفاده برای کاهش درد است. این تحقیق در جهت بررسی تاثیر پیش تیمار متابی سولفیت پتاسیم و دمای هوای خشک کردن بر کیفیت میوه سنجد انجام شد. سطوح مختلفی از متابی سولفیت پتاسیم (۰ به عنوان شاهد، ۱، ۲ و ٤ درصد) و دمای هوای خشک کردن (٤٥، ٦٠ و ۷۰ درجه سلسیوس) استفاده و صفاتی از قبیل درصد کاهش وزن، نسبت آب‌گیری مجدد، میزان مواد جامد محلول، اسیدیته قابل تیتراسیون، نسبت مواد جامد محلول به اسیدیته قابل تیتراسیون، اسید آسکوربیک، خصوصیات مرتبط با رنگ (روشنایی، قرمزی، زردی، کروما، زاویه هیو، تغییرات هرکدام از پارامترهای ذکر شده، تغییرات کلی رنگ، شاخص قهوه‌ای شدن)، میزان فنول کل و پتاسیم میوه بررسی گردید. با افزایش غلظت پیش تیمار متابی سولفیت پتاسیم، درصد کاهش وزن و نسبت آب‌گیری مجدد و تغییرات کلی رنگ میوه سنجد افزایش معنی‌داری نشان داد. علاوه بر آن تمامی صفات به استثنای مواد جامد محلول میوه بطور معنی‌داری تحت تاثیر دمای هوای خشک کردن قرار گرفتند. افزایش دمای هوای خشک کردن از ٤٥ به ٦٠ درجه سلسیوس منتج به افزایش اسیدیته قابل تیتراسیون، اسید آسکوربیک و فنول کل شد. تغییرات کلی رنگ در دمای بیش از ٦٠ درجه سلسیوس افزایش یافت. شاخص قهوه‌ای شدن، قرمزی، زردی و کروما با افزایش دمای هوای خشک کردن از ٤٥ به ۷٥ درجه سلسیوس افزایش معنی‌داری نشان داد اما میزان روشنایی و زاویه هیو دچار کاهش گردید. بطورکلی، افزایش غلظت پیش تیمار شیمیایی متابی سولفیت پتاسیم کاهش وزن را بطور معنی‌داری افزایش داد، با این حال سبب تغییر رنگ معنی‌دار نیز گردید و حفظ رنگ را کاهش داد. در دمای هوای خشک کردن بیش از ٦٠ درجه سلسیوس بطور موازی سبب افزایش معنی‌دار شاخص قهوه‌ای شدن و میزان فنول کل گردید. بنابراین، استفاده از هوای گرم با دمای کمتر از ٦٠ درجه سلسیوس به عنوان یک تیمار خوب برای خشک کردن میوه سنجد پیشنهاد می‌گردد.**

**کلمات کلیدی:** دمای هوای خشک کردن، شاخص قهوه ای شدن، متابی سولفیت پتاسیم، کاهش وزن