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Osmotic dehydration of apple and pear slices: color and chemical characteristics

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Abstract. Osmotic dehydration is the pre-treatment method of preservation the fruits and vegetables to increase their shelf life. This method consists of immersing fruits and vegetables in concentrated solutions of salt or sugar. The effect of osmotic dehydration was investigated on the color and chemical characteristics of dehydrated fruits (apple and pear) in fructose osmotic solutions. Difference in CIE-LAB, chroma - C* and hue angle H* were performed with a Chroma Meter CR-400/410. Apple (*Malus domestica 'Jonathan'*) and sweet autumn pear variety (*Pyrus comunis*) were osmotically dehydrated in three aqueous solution of fructose (40, 60 and 80%), during 3 h of process at temperatures of 20 ºC, with fruit/osmotic agent ratio of 2:1. Water loss and solids gain showed significant differences depending on the concentration of the osmotic agent and process time. The use of highly concentrated osmotic solutions induced losses of phenolic content (TPC) and ascorbic acid in the sliced apples and pears. Fructose concentration and osmosis time induce significant increase of a* and b* colorimetric parameters but did not affect the lightness (L*) of pear slices.

Keywords: osmotic dehydration; apple; pear; color; polyphenols.

1. Introduction

Fruits are important and natural sources of dietary fiber, minerals, vitamins (A, B), and especially vitamin C (ascorbic acid) in high concentrations, and they are also an essential source of carbohydrates. Fruit consumption, which plays an essential role in promoting health, is associated with lowering the incidence of chronic diseases and should be an integrated part of our daily diet.

Osmotic dehydration, used in food processing and preservation, is an alternative method of preserving fruits and vegetables, such as: pineapple [1], mango [2], bananas and apples [3], carrots [4], apple, strawberry, pear, kiwi, plum, nectarine, and melon [5], and slices of coconut [6], which retain their characteristics color, aroma and nutritional composition. Osmotic dehydration leads to an extended shelf life, because it reduces the water content of a material by approximately 50%, so that growth and development of microorganisms is inhibited, enzymes are inactivated, and also physical and chemical modifications of the material are minimal [7]. This process can be carried out at low temperatures or at room temperature, and therefore consumes less energy than the process of air drying or vacuum drying.

Osmotic dehydration is a non-thermal pretreatment process that involves the immersion of foods in osmotic agents such as glucose, fructose, sucrose, sodium chloride, alcohols, starch solutions and corn syrup, and is well know that the characteristics of the osmotic agent used, such as its molecular weight, strongly affect dehydration [8-10] The osmotic dehydration is defined as a slow process of mass counter - current transfer [1, 8]. Osmotic dehydration reduces water activity, so it is a widely used pretreatment technique, but it is very valuable to reduce time and energy consumption in other complementary techniques. During this process, the moisture is eluted from the inside of the food to the hypertonic solution and depends mostly on cell membrane permeability [8]. Water transport in the liquid solution occurs only by molecular diffusion, liquid diffusion, hydrodynamic flow, capillary transport, surface diffusion, and most commonly a combination of these mechanisms. This mass transfer depends on the geometry of the foods, temperature, and the concentration of the osmotic solution [1]. During osmotic treatment, increasing concentrations of the solution leads to an increase in the rate of water loss and solids gain. The osmotic agent is chosen depending on the product used (fruits or vegetables, meat, fish, etc.). The fruits that are osmotically dehydrated, in the form of slices, have sensory characteristics similar to the fresh fruits, therefore the method is preferred because it has economic advantages through energy savings. These partially dehydrated vegetables and fruits are used in various products: ice-cream, jellies, candied fruits, sauces, some desserts, bakery products, for direct consumption or components of cereals for breakfast foods [11].

Apples are fruits produced by the tree *Pyrus malus L.* or *Malus communis Lam*. They have a special role in nutrition, and through the wide variety of summer, autumn and winter varieties, fresh fruits are provided throughout the year. The dietary value of apples can be evidenced by a high water content 84-87%, total dry matter 12-14%, including carbohydrates up to 15%, proteins 0.3%, pectic substances 0.8-1.2%, mineral

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substances 0.3%, tannins 0.12%, organic acids - up to 0.8%, a reason to be recommended in the daily consumption. Apples are major sources of phenolic compounds and present a strong antioxidant capacity compared to other fruits [12]. In 2017, the main producers of apples in the EU were Poland (160 800 ha - 28.9 % of the EU's apple), Italy and Romania (55 800 ha and 55 100 ha respectively) [13]. Suceava County, in particular Falticeni area, has favorable climate and soil conditions; it is known as a major apple producing nationwide and has many small farms utilizing family and local labor. Along with apples, pears ensure the consumption needs of fruits, especially during the autumn-winter period. There are varieties of pears that maintain their superior quality traits until spring. Pears are the fruit of *Pyrus communis L.*, as with apples, size, individual weight, specific weight and color are highly variable. Pears contain: water 83 %; sugars 10 %; other carbohydrates, acids, vitamins (A, B1, B2, PP, C). Another important aspect is their richness in basic elements, the analyzes carried out showing that at 100 g fresh fruit the content of mineral elements is: 4.42 mg eq. K, 0.43 mg eq. Na, 0.45 mg eq. Ca, 0.73 mg eq. Mg, and 0.07 mg eq. Fe. Apples and pears have the following medicinal properties: diuretic, laxative, remineralizing, anti-inflammatory, and antioxidant.

The quality of apple and pear fruits (flavor, color, taste, appearance) can be significantly improved by osmotic dehydration, the fruits can be kept in a stable form for consumption after the production period. According to [14], the osmotic pretreatment improved the color of mango chips, immersed into 65 ºBx sucrose solution at 30 ºC.

Osmosis time is the most important factor affecting the total phenolic content in the osmotic dehydration with aqueous solution of sucrose of pear slices (*Pyrus communis* cv Conference) [15].

In this work, fructose solution is used for dehydration of the apple (*Malus domestica 'Jonathan'*) and sweet autumn pear variety (*Pyrus communis*). This study was conducted to evaluate how the concentration of osmo-active solute affects the color, mass transfer (water loss and solid gain), total phenolic and acid ascorbic content of dehydrated apple and pear slices.

2. Experimental

2.1. Sample preparation

The apples of the Jonathan variety (*Malus domestica 'Jonathan'*) and the pears from the variety of autumn sweets (*Pyrus communis*) were purchased from a local producer from Falticeni (Romania) and stored at 4 ºC until use. Then, the fruits were equilibrated to room temperature, washed, peeled and cut into 10 mm and 20 mm cubes, from the fruits tissue with a ceramic knife and oriented parallel to the natural apple/pear axis.

2.2. Osmotic treatments

The osmotic dehydration of samples was carried out at 20 ºC, using fructose solutions with different concentrations: 40, 60 and 80 %, prepared by adding fructose to distilled water. In all experiments, a weight ratio of solution / fruit samples of 2:1 (w/w) was used. The cubes of apples and pears (1 cm^3 and 2 cm^3) were divided into three groups, depending on the treatments applied and placed in fructose solutions (Table 1). The fruits were introduced into beakers, the osmosis agent was added, and the samples were shaken by using an orbital shaker (200 rpm).

Table 1. Operating conditions used for osmo-dehydration apple and pear slices.

Variables	Values					
Fruit slices size, mm	10			20		
Fructose concentration, % w	40	60	80	40	60	80
Osmosis time (t, min)	30	30	30	30	30	30
	60	60	60	60	60	60
	90	90	90	90	90	90
	120	120	120	120	120	120
	150	150	150	150	150	150
	180	180	180	180	180	180

Weight of apple and pear slices was measured individually. For each set of experiments, before and after the process, samples of the fruits were removed from the beaker, washed with water to remove the remnants of osmotic solution, then dried with a filter paper towel and weighed.

Weight reduction (WR) is used to characterize osmotic dehydration, and was calculated according to the following equation [16]:

$$WR\ \% = \frac{W_i - W_t}{W_t} \times 100 \qquad (1)$$

where W_i is the initial weight of sample cubes (g), W_t the weight of sample cubes after osmotic dehydration for any time *t* (g).

2.3. Physicochemical parameters

The color parameters: Lightness (L*), Redness (a*) and Yellowness (b*) were measured by using a Minolta Chroma Meter (Model CR 400/410).

Total phenolic content (TPC) of the methanolic extract of fruits was expressed as equivalent gallic acid (GA), mg GA/100 g fresh weight (FW), using a standard curve prepared at different concentrations of GA, and were assayed using the Folin-Ciocalteau reagent [17].

The ascorbic acid (AA - expressed in mg/100 g FW of fruits) was separated, identified and dosed in a HPLC SHMADZU system coupled with UV–VIS detector (DAD), A ZORBAX - C18 column (5 μm, 250x4.6) [13].

Titratable acidity (expressed as malic acid equivalents) was determined by titrating 5 mL of juice diluted in 50 mL dilution with 0.1 N NaOH, with phenolphthalein as indicator, until the pH reached the value of 8.2.

The dry matter content in fruit samples, before and after osmotic treatment, was determined gravimetrically at 102 º C in an oven, for 24 h until a constant weight was attained.

2.4. Statistical analysis

Each treatment was performed in triplicates, and each time with other fruits, and these results were reported as means ± standard deviation. Statistical significance of differences between the individual treatments was evaluated by using one-way ANOVA (Minitab 17 software). The null hypothesis was "*All means are equal*", while the alternative hypothesis was "*At least one mean is different*". The significance level considered was $\alpha = 0.05$.

3. Results and discussion

The physico-chemical parameters of the fruits samples are illustrated in Table 2. The total phenolic content (mg GAE/100 g fresh matter) observed in the apple was 434.07 and 380.80 mg in pear sample.

The content of ascorbic acid fresh matter of apple was 25.9 mg per 100 g, while in pear the content of ascorbic acid was found to be 23.6 mg per 100 g of fresh matter, in the same range as reported by [18]. Ascorbic acid and the total phenol content of the treated pear/apple slices remained almost constant during osmotic drying, the results indicated that the effects of osmotic dehydration and fructose concentrations not remarkably impact on antioxidant properties.

Table 2. Physico-chemical parameters of fresh and osmotic dehydrated fruit samples.

Common name	M (%)	Dry matter (%)	AA[a] (mg/100 g)	TA (mg/100 mL)	TP[a] (mg GAE/ 100 g)
Fresh pears	78.57±1.18	21.43±1.18	23.63±0.272	0.14±0.006	380.8±2.433
OD_{40}	63.60±0.828	36.40±0.828	29.17±0.237	0.14±0.003	390.4±1.109
OD_{60}	62.66± 0.439	37.337±0.439	28.96±0.260	0.14±0.003	391.1±0.851
OD_{80}	52.09±0.510	47.91±0.510	30.9±0.264	0.14±0.005	394.83±0.504
Fresh apples	79.90±0.92	20.10±0.92	25.9±0.435	0.24±0.003	434.07±2.423
OD_{40}	61.99±0.786	38.07±0.594	31.06±0.317	0.235±0.007	447.13±0.881
OD_{60}	54.20±0.487	45.80±0.487	31.43±0.272	0.24±0.006	449.06±0.895
OD_{80}	46.26±0.363	53.74±0.363	32.46±0.433	0.24±0.005	451.4±0.702

[a] Values are referred to mg/100 g fresh weight vegetable.
M = Moisture (g water/100 g of sample); AA = Ascorbic acid; TA = Titratable acidity; TP = Content of total phenols; OD_{40} = Osmotic dehydration with fructose solution 40%; OD_{60} = Osmotic dehydration with fructose solution 60%; OD_{80} = Osmotic dehydration with fructose solution 80%.

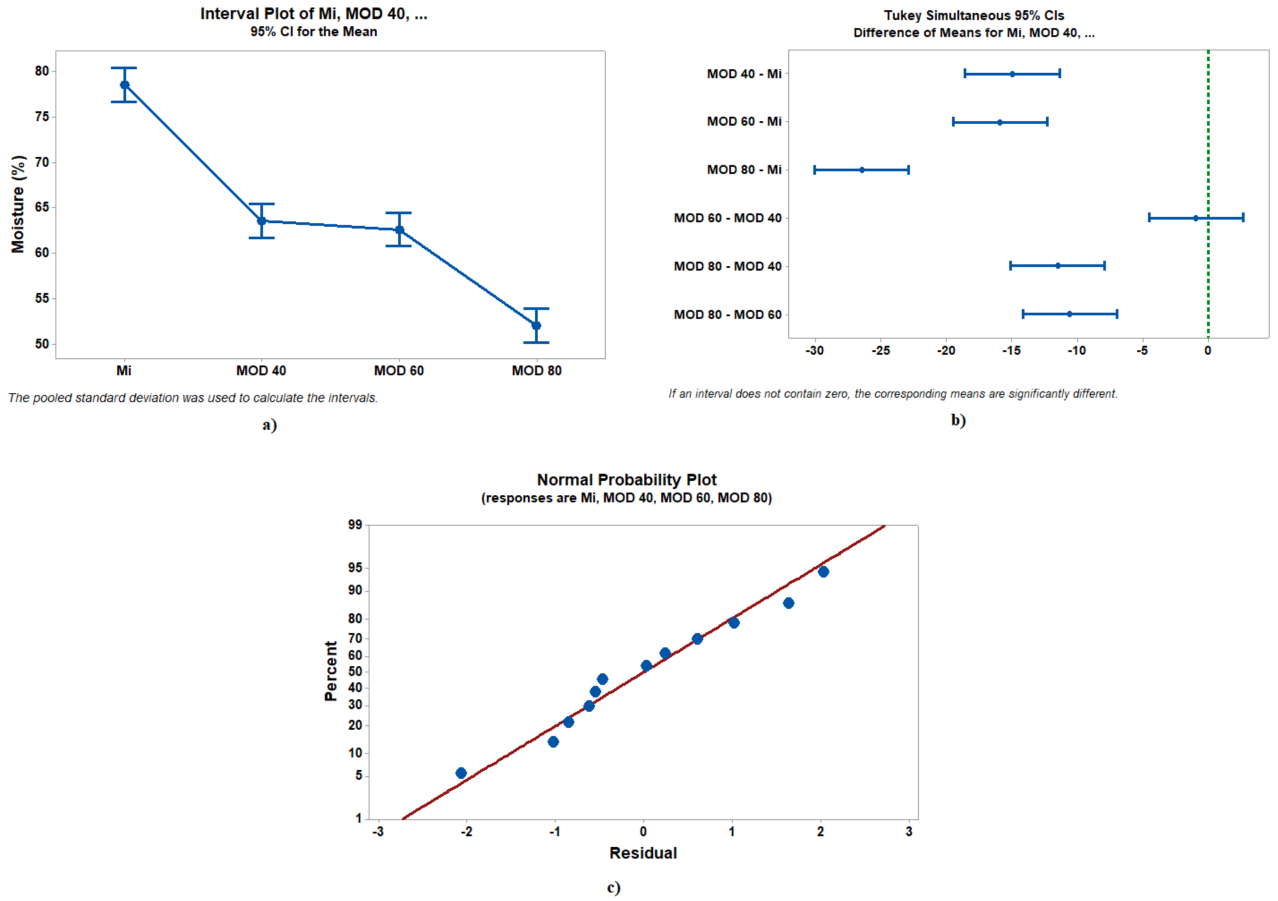

Figure 1. a) Interval plot for pear moisture (Mi – moisture of fresh pear samples, MOD - moisture after osmotic dehydration with fructose solution (40%, 60% and 80%)); b) Comparison of data by using Tukey method; c) Normal probability plot.

Osmotic dehydration was performed in osmotic fructose solution with different concentrations: 40%, 60% and 80%, and solution to samples weight ratio was 2:1. The osmotic process was studied in terms of weight reduction. After the 180 minutes of dehydration of pear in 80 % fructose solution, the dry matter content was increased from the initial 21.43 % to 47.91 %. The dry matter content in apple, during 180 min of osmotic dehydration in 80 % fructose solution, was changed from 20.10% to 53.74% (Table 2). Results showed that osmotic dehydrated apples have the greatest weight loss compared to pears at all concentrations of the osmotic agent.

In the case of pear samples moisture, it was observed that $p = 0.000$, which mean that the differences between some of the means are statistically significant. From Figure 1a it can be seen that the moisture of pear samples after osmotic dehydration with fructose solution 80% has the lowest mean, while fresh pear samples have the highest mean regarding moisture. The moisture of pear samples after osmotic dehydration with fructose solution 40% and 60% can be grouped in the same category which means that their means are not significantly different according to the results illustrated in Figure 1b. R^2 value is 98.59%, which means that the model fits our data well and the factor explains 98.59% of the variation in the response. The residuals are normally distributed, and they appear to generally follow a straight line according to Figure 1c.

In the case of apple samples moisture, it was also obtained $p = 0.000$ which means that the differences between some of the means are statistically significant. The highest mean regarding moisture in the case of apple samples was registered as was expected for fresh samples, while the lowest mean was obtained for apple samples after osmotic dehydration with fructose solution 80% (Figure 2a). Moisture loss through dehydration is higher in the case of apple samples compared to pear samples. From Figure 2b it can be observed that the intervals do not contain zero, which means that the means are significantly different. The factor explains 99.41% of the variation in the response ($R^2 = 99.41\%$).

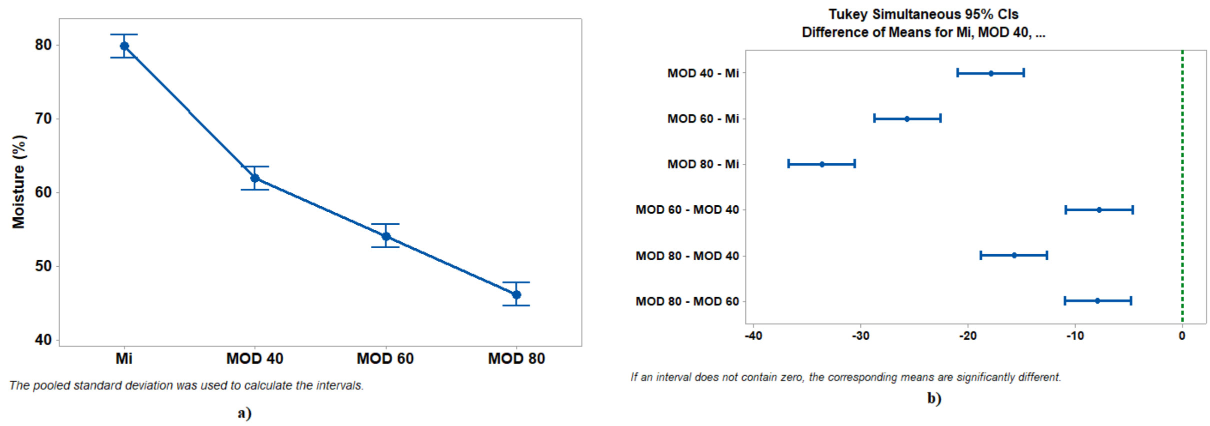

Figure 2. a) Interval plot for pear moisture (Mi – moisture of fresh apple samples, MOD - moisture of apple samples after osmotic dehydration with fructose solution (40%, 60% and 80%)); b) Comparison of data by using Tukey method.

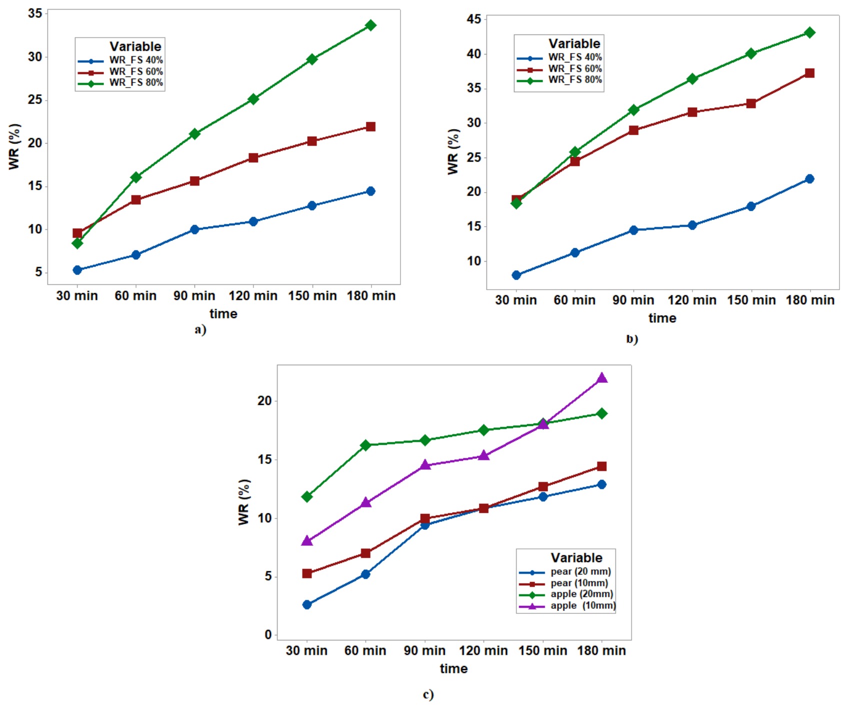

Figure 3. Variation of weight reduction (WR, %) in time of: a) pear samples (10 mm) and b) apple samples (10 mm) during osmotic dehydration with different concentration of fructose solution; c) variation of WR in time of pear and apple samples (10 and 20 mm) during osmotic dehydration with fructose solution 40%.

From Figures 3 a and b it can be observed that WR increased in time for both types of samples (pear and apple) during osmotic dehydration with all three concentration of fructose solutions used in this study. The higher increase was obtained for apple and pear samples during osmotic dehydration with fructose solution 80%, and higher values of WR were obtained for apple samples comparative with pear samples. Fruit slices size influences the WR values and it was observed that: thinner slices (10 mm) have a higher WR value compared to thicker slices (20 mm) during osmotic dehydration of pear samples (Figure 3c), while during osmotic dehydration of apple samples, this was observed only after 180 min, otherwise WR had higher values for 20 mm slices. In a study of mass transfer during osmotic dehydration of apples, the authors observed that in all osmotic solutions tested (sucrose; dextrose and dextrose + sucrose mixtures), WR - weight reduction (g/100 g) increases with increasing concentration of solutions [19]. The differences between some of the means are statistically significant since for both types of samples were obtained lower *p*-values than α – value (p = 0.014 in the case of pear samples and p = 0.01 - apple samples). From Figures 4a and 4c it can be seen that the WR of pear and apple samples after osmotic dehydration with fructose solution 80% have the highest mean as was expected.

The WR of pear samples after osmotic dehydration with fructose solution (FS) 40% and 60% can be grouped in the same category, as well as WR FS 60% and 80%, which means that their means are not significantly different according to the results illustrated in Figure 4b.

In the case of apple samples, WR FS 60% and 80% are grouped in the same category which means that their means are not significantly different according to the results presented in Figure 4d. The factor explains 43.35% of the variation in the response (R^2 = 43.35%) in the case of pear samples and 58.23% (R^2 = 58.23%) for apple samples, respectively.

Color CIELAB parameters for samples during the osmotic dehydration with fructose solution 80%, after 180 min, are presented in Table 3.

Osmotically treated samples did not significantly change lightness (L^*), 35.4 for L^* value representing less darkening compared to fresh samples, while a* (redness), b* (yellowness) increased slightly for pear samples. The increase in times of apple treatment leads to a decrease in L*. A decrease in L* indicates enzymatic browning of the apple sample. These results are in accordance with those obtained by [20] on apricot cubes and [21] for apples, Red Delicious variety. Browning of fruit tissues is associated with the activity of polyphenol oxidase and the concentration phenolic compounds, hence the immersion of fresh fruit cut into liquids greatly reduces the concentration of oxygen in the tissues and thus helps prevent browning [22].

The use of different concentrations of the osmotic agent during the osmosis process does not significantly affect the color parameters of the finished product.

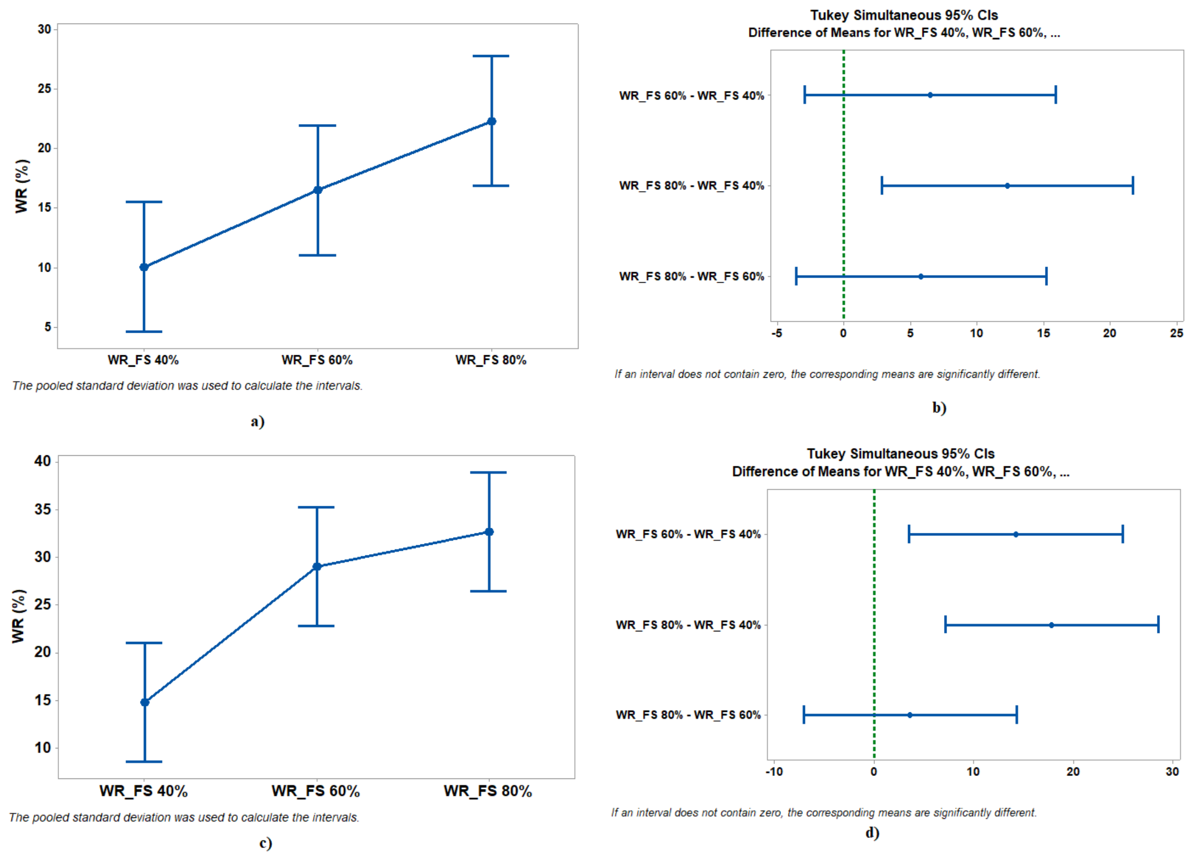

Figure 4. Interval plot for WR of a) pear and c) apple samples (10 mm) (WR (%) after osmotic dehydration with fructose solution (FS, 40%, 60% and 80%)); WR comparison of data by using Tukey method b) pear and d) apple samples.

Table 3. Color CIELAB parameters for samples during the osmotic dehydration.

Samples	L^*	a*	b*	Hue angle	Chroma
Pear initial	33.666	-0.5	8.833	93.3	8.866
Pear after treatment	35.4	3.3	-4.5	-52.5	5.6
Apple initial	43.466	-1.366	9.166	97.666	9.3
Apple after treatment	28.766	2.5	-3.266	-52.466	4.1

4. Conclusions

The effect of osmodehydration treatments with osmotic fructose solution with different concentrations: 40%, 60% and 80%, on the color parameters (luminosity and chroma) and chemical characteristics of the apple and sweet autumn pear variety were investigated. Luminosity (L^*) showed a slight increase for pear samples treated with osmotic solutions. Whereas, apple samples treated with fructose solution showed a 33% decrease in L^* values, L^* and Chrome were the color attributes that underwent further changes. On the other hand, the treated pear and apple samples were in the redness (+*a*) area after osmotic dehydration.

The results indicated that the effects of osmotic dehydration and fructose concentrations not remarkably impact on antioxidant properties, polyphenols and ascorbic acid contents remained almost constant.

The osmodehydration treatments produced a little increase in total phenolic concentration of pear and apple (from 380.8 to 394.83 mg GAE/100 g), respectively (from 434.07 to 451.4 mg GAE/100 g). This effect can be mainly attributed to the reduction of the amount of water in the samples. Osmotic dehydration caused a significant loss of moisture from the tissue of apples and pears.

Conflict of interest

Authors declare no conflict of interest.

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