Response of Black (*Morus nigra*), White and White Shahtoot (*Morus alba*) Mulberry Fruits to Ascorbic Acid Treatment and Drying Methods

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Abstract

The drying process plays an important role in heat-sensitive product dehydration. This study was conducted to evaluate the response of three species of mulberry fruit (Morus nigra L. (Black mulberry), Morus alba L. (White mulberry), and Morus alba L. (White shahtoot) grown in Halabja, Kurdistan region, Iraq. Four levels of ascorbic acid treatment at 0%, 10%, 20% and 30% lthen, divided into two groups; the first dried under solar radiation the second dried by one of the very high-quality machines (oven) for drying all kinds of vegetables and fruits. The mulberry fruits were harvested at the ripening stage by hand in April 2021 from the trees 10 years old. The results appeared that black mulberry is significantly superior that has higher moisture and total sugars content while having the lowest ash content and polyphenol oxidase activity on the two other species. Additionally, the ascorbic acid treatment significantly decreased total sugars content and peroxidase activity, while significantly increasing moisture content and polyphenol oxidase activity in fruits as compared to untreated fruits. Furthermore, sun drying significantly increased the fruits content of moisture, ash, total sugars, and polyphenol oxidase activity as compared to oven drying.

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Introduction

Mulberry is a tropical, subtropical, and temperate plant also fast growing and it grows under different climatic conditions (Gungor and Sengul, 2008). Mulberries can be planted in a wide area of climate, and the composition and nutritional value of mulberry can effect by soil conditions (Imran *et al.*, 2010). Mulberry fruits were harvested several times, (four to seven times in a year, according to the field's service). The first harvested fruits are usually used for fresh consumption, while the harvested fruits in the last have higher sugar content (Eyduran *et al.*, 2015). Given mulberries are extremely perishable depending on their high moisture content (>70%) and structural weakness also, giving them a shorter shelf-life than one week at room temperature (20^{o}C) (Teng and Lee, 2014). The previous study indicated that the nutritional value of mulberry fruits different according to the species of the moisture (%) 71.5-74.6, protein (g/100g DW) 1.55-1.2, fat (%) 1.10-0.85, fiber g/100g 1.47-11.75, ash (g/100g) 0.57-2.45, total dry weight (%) 29.5-24.4, ascorbic acid mg/100g 22.4-19.4, total acidity (%) 1.40-1.37, and the minerals contained in (mg/100g) Ca 152 - 132, Mg 106-115, K 1668-834, Fe 4.2-4.5, N (%) 0.75-0.92 (Jan *et al.*, 2021).

Ascorbic acid and steam blanching treatments are used for the prevention of enzymatic browning and also, for the control of pathogenic microorganisms (Burnham et al., 2001). The fruit is in a naturally acidic environment; additional acidification may reduce the PPO activity or inactivate it below pH 3. Also, PPO is sensitive to pH variations. The main acidifying agents are citric acid and ascorbic acid.... etc, (Ioannou, 2013). Ascorbic acid pretreatment is an antioxidant that keeps the fruit from darkening and enhances the destruction of bacteria during drying (Kendall and Arno, 1990).

The oldest method of preserving food is dehydration also a widely used operation for fruit and vegetable preservation that works by removing water from the food, thus preventing the growth of microorganisms and decay. Water is removed to the final concentration ensuring microbial stability of the product and minimizing chemical and physical changes of the material during storage. In most drying processes, water is removed by convective evaporation in which heat is supplied by hot air (Singh *et al.*, 2015). Mulberry fruits are dried and used in tonics, usually consumed for their antioxidant, antimicrobial, and anti-inflammatory characteristics. As interest in fruit trees, especially mulberries, is now growing, it is important to study their composition and how to preserve the high quality of the mulberries commonly grown in each country. The human body cannot synthesize minerals thus they must be gotten through food. It is clear that fruits have the best source of minerals in human nutrition. It is possible that many fruit types may have a better effect on human metabolism because of their different nutritional composition (Koyuncu *et al.*, 2014). The drying process is playing an important role in heat-sensitive product dehydration. Solar drying is a better choice to reduce the loss and produce good quality red dacca after harvesting (Elangovan and Natarajan, 2021). The dehydrated fruits are high in a range of dietary fibers and other bioactive compounds with prebiotic effects (e.g. polyphenols). The nutrient content in traditional dehydrated fruits remains similar to the equivalent fresh fruit, though more concentrated. Traditional dried fruits are good sources of a number of micronutrients with the exception of vitamin C. Increasing intake of traditional dried fruits may also contribute to other potential mechanisms for reducing the risk of type-2 diabetes (T2DM) such as the impact of polyphenols on modulation of sugar absorption and metabolism and any potential benefit of dried fruit as a snack on appetite and weight control (Sadler *et al.*, 2019). Therefore, the main objective of the present study was to investigate the impact of ascorbic acid and drying methods on the quality and enzyme activity of three mulberry fruit species.

Materials and Methods

Mulberries: Three main species of mulberries grown in namely *Morus nigra* L. (Black mulberry), *Morus alba* L. (White mulberry), and *Morus alba* L. (King White - a non-staining cultivar) were selected. Moreover, the mulberry fruits were harvested at the ripening stage by hand on April 2021 from the trees 10 years old and were grown in a private orchard.

Experimental Procedure: Before drying the uniform berries of shape and color were selected in all mulberry species. All mulberry species were pretreated separately (500g for each experimental unit) were dipped for 30 seconds in a solution of ascorbic acid with consternations (0, 10, 20 and 30%) at room temperature. Then, divided into two groups; the first dried under solar radiation after putting it in clean trays for 72 hours at 35 - 40 ºC up to dehydration. The second group was dried by one of the very high-quality machines for drying all kinds of vegetables, and fruits called Minor (Iranian-made) for 48 hours at 60 ºC. The fruits were placed in polyethylene bags at 20 ºC until analysis. After one week the following chemical properties were evaluated in dried mulberry samples (total solids (TS %) and moisture content (%) as described by Aljabary, (2018), ash (%) as approached by (Liang *et* *al.,* 2012), total sugar content (%), polyphenol oxidase activity was determined by the approach suggested Shi *et al.*, (2002), and peroxidase were determined (Wahid, 1980).

Statistical analysis

The Complete Randomized Design (CRD) within factorial experiments with three factors was used (3 mulberry species x 4 ascorbic acid consternations x 2 drying methods) with three replicates. To carry out the variance (ANOVA) analysis using SAS 9.1 software. Duncan's multiple range tests at 5% level was used to calculate the Mean comparisons (Al-Mehmedi and Al-Mehmedi, 2012).

Result and discussion

Moisture content (%)

The data in table 1 shows that the fruits of black mulberry had significantly higher moisture content than both white shahtoot and white mulberry.

As for the ascorbic acid, the result exhibited that the highest concentration of ascorbic acid has the significantly highest moisture content compared with control and other treatments.

On the other hand, the table 1 also shows that the highest moisture content was found in the fruits that were dried by the sun, which was significantly superior to the fruits that were dried by the oven.

The interaction between mulberry species and drying methods, the result exhibited that all species dried by the sun are significantly superior on all species dried by the oven. While the black mulberry dried by the sun has the highest moisture content 28.01% compared with other samples, however, the lowest percentage was found in the white mulberry that drying by the oven 11.35%.

As for the interaction between mulberry species and ascorbic acid concentrations, the result shows that the black mulberry treated with a high concentration of ascorbic acid has a significantly higher moisture content 25.41% compared with other treatments, while the lowest 14.85% was found in the white mulberry fruits that untreated ascorbic acid.

The data in the same table shows that the fruits treated with 30% ascorbic acid and sun-dried had the highest rate 29.47% of moisture content, which was significantly superior on the other interaction treatments. Whilst, the lowest percentage 11.17% was found in the fruits treated with 10 % ascorbic acid and dried by the oven.

The highest moisture content 39.50% was obtained in the black mulberry fruits treated with 30% ascorbic acid sun-dried, while the lowest moisture content 10.13% in black mulberry fruits treated with 10% ascorbic acid and oven-dried.

Total solid content (%)

The data in table 2 exhibited that the white shahtoot species had the highest percentage of total solid and followed by white mulberry and the lowest in black mulberry.

The highest total solid was found in fruits untreated and treated with 20% ascorbic acid, which was significantly distinguished from the other treatments, and the lowest was found in the fruits treated with 30% ascorbic acid.

The same table indicated that the oven drying of fruits caused to higher significant total solid content than sun drying.

The result shows that interactions between all mulberry species dried by the oven are significantly superior on all species dried by the sun. While the white mulberry dried by the oven has the highest total solid content 88.65% compared with other samples, however, the lowest percentage was found in the black mulberry that drying by the sun 71.99%.

Table1. Effect of ascorbic acid concentrations and drying methods and their interactions on moisture content (%) of three mulberry species

Drying Methods	Species	Ascorbic Acid (%)				Species X Drying Methods
		0	10	20	30	
Sun	White Shahtoot	19.17 f	21.70 e	22.07 de	24.17 de	21.78 c
	White Mulberry	18.10 f	27.33 b	23.20 de	24.73 cd	23.34 b
	Black Mulberry	23.53 de	26.90 bc	22.10 de	39.50 a	28.01 a
Oven	White Shahtoot	11.23 gh	13.21 g	10.92 gh	12.78 gh	12.04 d
	White Mulberry	11.60 gh	10.18 h	12.23 gh	11.39 gh	11.35 d
	Black Mulberry	16.70 f	10.13 h	12.21 gh	11.31 gh	12.59 d
Species X Ascorbic Acid	Species					Species
	White Shahtoot	15.20 e	17.46 cd	16.49 de	18.47 bc	16.91 b
	White Mulberry	14.85 e	18.76 bc	17.71 cd	18.06 cd	17.35 b
	Black Mulberry	20.12 b	18.52 bc	17.16 cd	25.41 a	20.30 a
Drying Methods X Ascorbic Acid	Drying Methods					Drying Methods
	Sun	20.27 d	25.31 b	22.46 c	29.47 a	24.38 a
	Oven	13.18 e	11.17 f	11.79 ef	11.83 ef	11.99 b
Ascorbic Acid (%)		16.72 c	18.24 b	17.12 c	20.65 a	

Different letters in each factor and their interactions indicate a statistical difference between treatments according to Duncan's multiple ranges.

Also table 2 exhibited that the highest total solid content was found in the white mulberry or white shahtoot fruits were untreated with ascorbic acid 85.15 and 84.80% respectively, which were significantly superior on the other interaction treatments except white shahtoot fruits were treated with 20% ascorbic acid.

The data in the same table shows that the highest total solid content was found in the fruits were treated with 10% ascorbic acid and dried by the oven 88.83%, which was significantly superior on most other interaction treatments.

The data in the same table exhibited that the highest total solids content was found in the black mulberry fruits treated with 10% ascorbic acid and dried by the oven 89.87%, which was significantly superior on most other interaction treatments. However, the lowest total solids (60.50%) were observed in the black mulberry fruits treated with 30% ascorbic acid and solar dried.

Ash content (%)

The obtained results in table 3 appeared that the white shahtoot and white mulberry species significantly distinguished in ash content as compared with the black mulberry.

On the other hand, the fruits treated with 10% ascorbic acid had the highest ash content 0.968%, which was significantly superior compared to the other treatments.

The results indicated that the solar drying of mulberry fruits caused to higher significant ash content than oven drying.

The result shows that the white mulberry fruits that solar dried was significantly superior on the other interaction treatments in the ash content except for the white shahtoot fruits that were dried by the sun, which has the highest ash content 0.978%, whilst, the lowest percentage 0.929% was found in the black mulberry fruits that drying by the sun.

The data in the same table indicated that the highest ash content was noticed in the white mulberry fruits were treated with 10% ascorbic acid 0.992%, which was significantly superior on the other interaction treatments, while the lowest percentage 0.923% was noticed in the black mulberry fruits were treated with 30% ascorbic acid.

Table 2. Effect of ascorbic acid concentrations and drying methods and their interactions on total solids content (%) of three mulberry species

Drying Methods	Species	Ascorbic Acid (%)				Species X Drying Methods
		0	10	20	30	
Sun	White Shahtoot	80.83 c	78.30 d	77.93 de	75.83 de	78.23 b
	White Mulberry	81.90 c	72.67 g	76.80 de	75.27 ef	76.66 c
	Black Mulberry	76.47 de	73.10 fg	77.90 de	60.50 h	71.99 d
Oven	White Shahtoot	88.77 ab	86.79 b	89.08 ab	87.23 ab	87.97 a
	White Mulberry	88.40 ab	89.82 a	87.77 ab	88.61 ab	88.65 a
	Black Mulberry	83.30 c	89.87 a	87.79 ab	88.69 ab	87.41 a
Species X Ascorbic Acid	Species					Species
	White Shahtoot	84.80 a	82.55 bc	83.51 ab	81.53 cd	83.10 a
	White Mulberry	85.15 a	81.24 cd	82.29 bc	81.94 bc	82.65 a
	Black Mulberry	79.88 d	81.49 cd	82.85 bc	74.60 e	79.70 b
Drying Methods X Ascorbic Acid	Drying Methods					Drying Methods
	Sun	79.73 c	74.69 e	77.54 d	70.53 f	75.63 b
	Oven	86.82 b	88.83 a	88.21 ab	88.18 ab	88.01 a
Ascorbic Acid (%)		83.28 a	81.76 b	82.88 a	79.35 c	

Different letters in each factor and their interactions indicate a statistical difference between treatments according to Duncan's multiple ranges.

Also table 3 appeared that the highest ash content was found in the fruits were treated with 10% ascorbic acid and dried by the sun 0.972%, which was significantly superior on most other interaction treatments, while the lowest percentage 0. 946% was noticed in the fruits were treated with 30% ascorbic acid and dried by the oven.

The white mulberry fruits treated with 10% ascorbic acid that dried by the sun showed the highest significant 1.012% compared to all other interaction treatments. However, the lowest ash content 0.910% was observed in the black mulberry fruits treated with 30% ascorbic acid that oven-dried.

Total sugars content (%)

The data in table 4 shows that the fruits of black mulberry had significantly higher total sugar content than both white shahtoot and white mulberry.

Regarding with ascorbic acid, the result indicated that all concentrations of ascorbic acid significantly decreased the total sugar content compared with control and other treatments.

On the other hand, the results appeared that the highest total sugar content 16.22% was observed in the fruits that were dried by the sun, which was significantly superior to the fruits that were dried by the oven 14.15%.

The result shows that the highest total sugar content 28.02% appeared in black mulberry fruits that dried by the sun, which was significantly superior compared with other treatments, whilst, the lowest percentage was found in the white mulberry that dried by the sun 10.02%.

Table 3. Effect of ascorbic acid concentrations and drying methods and their interactions on ash content (%) of three mulberry species

Drying Methods	Species	Ascorbic Acid (%)				Species X Drying Methods
		0	10	20	30	
Sun	White Shahtoot	0.964 bcd	0.968 bcd	0.959 cd	0.984 b	0.969 ab
	White Mulberry	0.961 cd	1.012 a	0.967 bcd	0.971 bc	0.978 a
	Black Mulberry	0.927 fg	0.936 ef	0.930 ef	0.936 ef	0.932 c
Oven	White Shahtoot	0.964 bcd	0.971 bc	0.961 cd	0.966 bcd	0.965 b
	White Mulberry	0.957 cd	0.971 bc	0.964 bcd	0.963 cd	0.964 b
	Black Mulberry	0.922 fg	0.948 de	0.935 ef	0.910 g	0.929 c
Species X Ascorbic Acid	Species					Species
	White Shahtoot	0.964 bc	0.970 bc	0.960 c	0.975 b	0.967 a
	White Mulberry	0.959 c	0.992 a	0.966 bc	0.967 bc	0.971 a
	Black Mulberry	0.925 e	0.942 d	0.933 de	0.923 e	0.931 b
Drying Methods X Ascorbic Acid	Drying Methods					Drying Methods
	Sun	0.951 c	0.972 a	0.952 c	0.964 ab	0.960 a
	Oven	0.948 c	0.963 ab	0.953 bc	0.946 c	0.953 b
Ascorbic Acid (%)		0.949 b	0.968 a	0.953 b	0.955 b	

Different letters in each factor and their interactions indicate a statistical difference between treatments according to Duncan's multiple ranges.

Also, table 4 shows that the black mulberry fruits untreated with ascorbic acid has significantly higher total sugar content 29.50% compared with other treatments except for the black mulberry fruits treated with 20% ascorbic acid, while the lowest 8.25% was found in the white shahtoot fruits that treated 10% ascorbic acid.

The data in table 4 shows that the fruits untreated with ascorbic acid and sun-dried had the highest rate 23.85% of total sugar content, which was significantly superior on the other interaction treatments. Whilst, the lowest percentage 10.21% was found in the fruits treated with 30% ascorbic acid and dried by the sun.

The highest total sugar content 38.51% was obtained in the black mulberry fruits untreated with ascorbic acid sun-dried, while the lowest total sugar content 7.00% in the white shahtoot fruits treated with 10% ascorbic acid and sun-dried.

Table 4. Effect of ascorbic acid concentrations and drying methods and their interactions on total sugars content (%) of three mulberry species

Drying Methods	Species	Ascorbic Acid (%)				Species X Drying Methods
		0	10	20	30	
Sun	White Shahtoot	17.96 efg	7.00 k	9.42 hijk	8.16 jk	10.63 c
	White Mulberry	15.09 efgh	7.72 jk	9.36 hijk	7.93 jk	10.02 c
	Black Mulberry	38.51 a	27.50 bc	31.51 b	14.55 fghi	28.02 a
Oven	White Shahtoot	10.45 hijk	9.50 hijk	8.82 ijk	13.46 ghij	10.56 c
	White Mulberry	12.67 ghijk	9.61 hijk	15.09 efghi	8.73 ijk	11.52 c
	Black Mulberry	20.50 def	21.01 de	24.23 cd	15.70 efghi	20.36 b
Species X Ascorbic Acid	Species					Species
	White Shahtoot	14.20 cd	8.25 e	9.12 e	10.81 de	10.59 b
	White Mulberry	13.88 cd	8.66 e	12.22 cde	8.33 e	10.77 b
	Black Mulberry	29.50 a	24.26 b	27.87 ab	15.13 c	24.19 a
Drying Methods X Ascorbic Acid	Drying Methods					Drying Methods
	Sun	23.85 a	14.07 bc	16.76 b	10.21 d	16.22 a
	Oven	14.54 bc	13.37 bcd	16.05 bc	12.63 cd	14.15 b
Ascorbic Acid (%)		19.19 a	13.72 c	16.40 b	11.42 d	

Different letters in each factor and their interactions indicate a statistical difference between treatments according to Duncan's multiple ranges.

Polyphenol oxidase activity (units/ml)

The obtained results in table 5 appeared that the black mulberry fruits significantly distinguished in decreasing the polyphenol oxidase activity as compared with the white shahtoot and white mulberry fruits.

On the other hand, the lowest polyphenol oxidase activity was noticed in the untreated fruits with ascorbic acid than in treated fruits, which was significantly superior compared to the other treatments in decreasing the enzyme activity.

The results indicated that the oven drying of mulberry fruits caused to a significant decrease in polyphenol oxidase activity than solar drying.

The result shows that the black mulberry fruits that drying by the oven significantly decreased the polyphenol oxidase activity as compared to the highest activity were noticed in the white shahtoot or white mulberry fruits that were dried by the sun.

The data indicated that the lowest polyphenol oxidase activity was found in the black mulberry fruits that were untreated with ascorbic acid, while the highest activity was observed in the white mulberry fruits were treated with 30% ascorbic acid.

Table 5 appeared that the activity of polyphenol oxidase significantly decreased in the fruits that were untreated with ascorbic acid and oven dried, while the highest activity of this enzyme was noticed in the fruits were treated with 30% ascorbic acid and solar dried.

The black mulberry fruits that were untreated with ascorbic acid that dried by the oven showed the lowest polyphenol oxidase activity, moreover, the highest significant activity were observed in the white mulberry fruits treated with 30%

ascorbic acid that solar dried compared to all other interaction treatments.

Table 5. Effect of ascorbic acid concentrations and drying methods and their interactions on polyphenol oxidase activity of three mulberry species

Drying Methods	Species	Ascorbic Acid (%)				Species X Drying Methods
		0	10	20	30	
Sun	White Shahtoot	13.60 cde	110.00 bcd	115.60 bc	137.40 b	94.15 a
	White Mulberry	42.00 bcde	23.20 cde	53.40 bcde	248.40 a	91.75 a
	Black Mulberry	9.80 cde	15.80 cde	60.40 bcde	72.00 bcde	39.65 b
Oven	White Shahtoot	21.20 cde	142.40 b	53.40 bcde	17.00 cde	58.50 ab
	White Mulberry	7.80 de	8.40 de	18.80 cde	93.20 bcde	30.45 b
	Black Mulberry	1.40 e	28.00 cde	21.40 cde	19.20 cde	19.10 b
Species X Ascorbic Acid	Species					Species
	White Shahtoot	17.40 cd	126.20 ab	84.50 bc	77.20 bcd	76.33 a
	White Mulberry	21.70 cd	15.80 cd	36. cd	170.80 a	61.10 a
	Black Mulberry	8.80 d	21.90 cd	40.90 cd	45.90 cd	29.38 b
Drying Methods X Ascorbic Acid	Drying Methods					Drying Methods
	Sun	21.80 bc	49.67 bc	76.47 b	152.80 a	75.18 a
	Oven	10.13 c	59.60 bc	31.20 bc	43.13 bc	36.02 b
Ascorbic Acid (%)		15.97 c	54.63 b	53.83 b	97.97 a	

Different letters in each factor and their interactions indicate a statistical difference between treatments according to Duncan's multiple ranges.

Peroxides activity (units/ml)

The results in table 6 appeared that non-significant differences among the mulberry fruits species in the peroxidase activity.

Moreover, the results show that the treated fruits with all concentrations of ascorbic acid significantly distinguished in decreasing the peroxidase activity than in untreated fruits.

The obtained results indicated non-significant differences between the drying methods in the peroxidase activity.

The result shows that the white shahtoot fruits that drying by the sun significantly decreased the peroxidase activity as compared to all other interactions except the black mulberry fruits that were dried by the oven.

The data appeared that the lowest peroxidase activity was observed in the black mulberry fruits that were treated with 10% ascorbic acid, while the highest activity was found in the white mulberry fruits that were untreated with ascorbic acid.

Table 6 indicated that the activity of peroxidase significantly decreased in the fruits that were treated with 10% ascorbic acid and solar dried, while the highest activity of this enzyme was noticed in the fruits that were untreated with ascorbic acid and oven-dried.

The white mulberry fruits that were treated with 30% ascorbic acid that oven dried showed the lowest peroxidase activity, while, the highest significant activity was observed in the white mulberry fruits untreated with ascorbic acid that oven dried compared to most other interaction treatments.

Table 6. Effect of ascorbic acid concentrations and drying methods and their interactions on peroxidase activity of three mulberry species

Drying Methods	Species	Ascorbic Acid (%)				Species X Drying Methods
		0	10	20	30	
Sun	White Shahtoot	57.93 efg	31.00 fg	26.90 g	122.80 def	59.66 c
	White Mulberry	223.20 bc	49.07 edf	33.60 fg	230.13 abc	134.00 a
	Black Mulberry	45.80 efg	19.20 g	311.73 a	218.80 bc	148.88 a
Oven	White Shahtoot	276.80 ab	25.60 g	56.93 efg	134.60 de	123.48 a
	White Mulberry	313.53 a	50.33 efg	52.40 efg	13.80 g	107.52 ab
	Black Mulberry	83.23 defg	43.40 efg	147.93 cd	24.40 g	74.74 bc
Species X Ascorbic Acid	Species					Species
	White Shahtoot	167.37 b	28.30 d	41.92 d	128.70 b	91.57 a
	White Mulberry	268.37 a	49.70 d	43.00 d	121.97 bc	120.76 a
	Black Mulberry	64.52 cd	31.30 d	229.83 a	121.60 bc	111.81 a
Drying Methods X Ascorbic Acid	Drying Methods					Drying Methods
	Sun	108.98 b	33.09 d	124.08 b	190.58 a	114.18 a
	Oven	224.52 a	39.78 cd	85.76 bc	57.60 cd	101.91 a
Ascorbic Acid (%)		166.75 a	36.43 c	104.92 b	124.09 b	

Different letters in each factor and their interactions indicate a statistical difference between treatments according to Duncan's multiple ranges.

The variation of moisture content, total solid, total sugar and enzyme activity in mulberry fruits could be due to genetic factors, such as the species, cultivars, and rootstocks used, or attribute to environmental conditions and the nutritional status of the orchards. Additionally, it is clear that the PPO and POD activity are related to the phenolic acid content in the fruits. The variation of phenolic compounds in the fruits depends on many factors, such as the degree of maturity at harvest, genetic differences and environmental conditions during fruit development, etc. (Zadernowski *et al.*, 2005). Also exhibited that the ash content was effect by the ripening stage (Kim *et al.*, 2021).

Regarding ascorbic acid, the lowest moisture content in treated dried samples with ascorbic acid could be because of the leaching impact of the ascorbic acid, which affected the fruit tissues, making it easier for water to diffuse during drying (Abano *et al.*, 2013). This led to an increase in the total solid and ash content as shown in tables (2 and 3). On the other hand, our result is opposite to the results found by Prajapati *et al.*, (2011) that reported pretreatment with ascorbic acid exhibited faster moisture removal as compared to untreated control of dried products, thus enhancing their drying period.

Moreover, ascorbic acid suggested as an excellent antioxidant in the system of food, helps to preserve the active state of several bioactive components, such as flavonoids, vitamin E, and some phenolics (Burguieres *et al.*, 2007). The results obtained by Gomez *et al.* (2012) confirm our results that ascorbic acid can reduce the browning development in apple slices in fresh-cut Granny Smith. As caused to decrease in the POD activity (Table 6). On the other hand, ascorbic acid itself is not an inhibitor of polyphenol oxidase; it must be oxidized indirectly by the enzyme before it can inhibit enzyme activity. Therefore, if sufficient ascorbic acid is present, polyphenol oxidase will oxidize its natural substrate and the oxidation product will be immediately reduced by ascorbic acid (Ingraham, 1956; Schultz, 1960). Eskin *et al.* (1971) reported that food products must be treated with ascorbic acid by an appropriate amount, otherwise browning is only late slightly, until the point at which oxidization of all the ascorbic acid.

The quick increment of PPO activity is a typical response as a result of wounding; by the prompting of the pathway of phenylalanine ammonia-lyase (PAL), in which the key enzyme is PAL (Degl'Innocenti *et al.,* 2005). This process leads to increased phenols availability as a substrate for browning processes enzymes (PPO and POD), consequently incrementing the tendency to browning (Landi *et al.,* 2013). Several preservatives, including ascorbic acid, have been reported to efficiently control the browning and the PPO activity (Chiabrando and Giacalone, 2012; Jeong *et al.,* 2008; Landi *et al.,* 2013; Rocha and De Morais, 2005; *Tardelli et al.,* 2010).

As for drying methods effects, the results showed the lowest moisture content in the oven-drying fruits this may be due to the temperature being controlled in the oven, but not in the sun (Mwamba et al., 2017), thus maintaining the highest moisture content in the fruits. This may be as a result of the ambient air temperature variation during the sun-drying of mulberries under natural convection on a typical day in May 2021, at Halabja, the temperature of ambient air ranged from 26 to 35 ℃ during the drying process. Furthermore, reduced the sugar content of dried products as affected by pretreatments and drying methods (Prajapati *et al.,* 2011). These results agree with our result that exhibited solar drying fruits have higher sugar content as compared to oven drying (Table 4). Additionally, the results mentioned by Fung and Lim, (2016) showed that POD is less heat-sensitive. The dry treatment is a good method as it reduces PPO activity and has a minimal POD activity effect. However, this treatment would depend on the water content of the individual products being dried, as high water content (Table 1) would mean that the drying process would be longer and POD would have more time to reduce.

Conclusion

The results exhibited that the significantly lowest polyphenol oxidase activity in black mulberry and has higher moisture and total sugar content as compared to the two other species. In addition, the ascorbic acid treatment significantly decreased total sugars content and peroxidase activity, while significantly increasing moisture content and polyphenol oxidase activity in fruits as compared to untreated fruits. Furthermore, sun drying significantly increased the fruits content of moisture, ash, total sugars, and polyphenol oxidase activity as compared to oven drying

Conflict of Interest

We have no conflicts of interest to disclose.

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