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ORIGINAL RESEARCH ARTICLE

Effect of osmodehydration on the quality attributes of plum (*Prunus domestica*)

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ABSTRACT

Plum (*Prunus domestica*) is a seasonal nutraceutical fruit rich in many functional food nutrients such as vitamin C, antioxidants, total phenolic content, and minerals. Recently, researchers have focused on improvised technologies for the retention of bioactive compounds during the processing of perishable fruits; plum is one of these fruits. This study looked at how the percentage of moisture content and percentage of acidity were affected by conventional drying and osmotic dehydration. Total phenolic content (mg GA/100 g of plum), total anthocyanin content (mg/100 g), and vitamin C (mg/100 g) Conventional drying of fruit was carried out at 80.0 ℃ for 5 h. At various temperatures (45.0 ℃, 50.0 ℃, and 55.0 ℃) and hypertonic solution concentrations (65.0 B, 70.0 B, and 75.0 B), the whole fruit was osmotically dehydrated. It was observed that the osmotically treated fruit retains more nutrients than conventionally dried fruit. The total phenolic content of fruit significantly increased with the increase in process temperature. However, vitamin C and total anthocyanin content of the fruit decreased significantly with process temperature, and hypertonic solution concentration was observed. Hence, it was concluded that osmodehydration could be employed for nutrient retention in plum fruit over conventional drying. This process needs to be further refined, improvised, and optimised for plum processing.

Keywords: antioxidants; preservation; anthocyanin; osmotic dehydration; hypertonic solution

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1. Introduction

In India, there is a huge production of fruits. But the real challenge starts after harvesting because fruits are a highly perishable commodity. Preservation and processing are the arts employed to process fruits and increase their shelf-life. There are lots of techniques available to preserve the fruits; dehydration is one of the best ways of all. Dehydrated foods have lost heat-sensitive volatile ingredients like flavour, ascorbic acid, and pigment oxidation. Dehydration is the simultaneous application of heat and the removal of moisture from foods. A key unfavourable result of using traditional drying techniques is simultaneous alterations to the texture of the food. To minimize this dehydration loss, osmotic dehydration is the most beneficial pre-treatment. Osmotic dehydration is the movement of hypertonic solutions through the semipermeable membrane. Generally, sugar is used as a hypertonic solution for fruits. The osmotic dehydration process generally reduces 30%–50% of the moisture content of the fruits[1]. In

India generally, Murabba, a traditional Indian fruit jam (prepared from mango and amala), and pickles are commonly found in osmotically dehydrated products.

There are various natural materials that have been explored for the osmotic dehydration of fruits recently. One such method was explored by Leandro Levate Macedo and co-workers in Brazil. They used coconut sugar for the osmotic dehydration of strawberries instead of sugar. It was observed that the use of coconut sugar instead of sucrose does not show any significant difference in its properties except pH and colour responses. The optimum results were observed with a 60% solution of coconut sugar[2]. To decrease the duration of osmotic dehydration and increase the efficiency of moisture removal from the fruits, ultra-sound assisted osmotic dehydration (UAOD) was explored by Salehi and his co-workers in Iran[3]. This study was performed with kiwi fruits by making its slices, and this study resulted in satisfactory results[3]. A novel method of osmotic dehydration of Jambolan fruits was explored by Araújo and co-workers in Brazil[4]. For the preservation of Jambolan fruits, they investigated the combined use of vacuum osmotic dehydration using pulse and air-drying using convection. This study was found to be satisfactory and required less time for process completion[4].

Plum is one of the most important nutritional fruits for the human diet. Near about 200 varieties of the plum are available, but few are commercially important[5]. Plum is a significant source of bioactive substances that have a positive impact on human health and function as a nutraceutical. Generally, plums are consumed fresh, the processing of plum includes drying, juice preparation, and canning. Bioactive substances such as phenolic acids, anthocyanins, carotenoids, minerals, and pectin are all abundant in plums. As far as nutrition and dietary value go, plums are an important part of the human diet. Plums have been utilized for many years in Indian medicine as a component of herbal remedies for leukorrhea, irregular periods, and miscarriage[5]. Thus, this study aims to compare the physical and biochemical attributes like moisture, acidity, vitamin C, anthocyanin, and total phenolic content of conventional dried plum and Osmo dried plum (whole fruit osmosis) and drain sugar syrup. The objective of this study was to identify whether osmotic dehydration is the best way to preserve plums as compared to other preservation techniques and to understand the nutritional and other health benefits of dried plum and drain syrup.

2. Material and methods

2.1. Preparation of sample

Fresh plums (*Prunus domestica*) that were fully mature and had dark crimson outer skin were bought at the market. To ensure the removal of surface adhesion, chlorinated water was used to wash the fruits. Additional blanching (100.0 ℃) was done to soften the tissue, inactivate enzymes, remove tissue gasses, and facilitate osmosis by rupturing cell walls. By combining 0.5% salt (NaCl) and 1% citric acid throughout the blanching process, the colour was retained.

2.2. Osmotic dehydration

Whole blanched fruit was osmosed under a variety of process parameters, including temperature (45.0 ℃, 50.0 ℃, and 55.0 ℃) and hypertonic solution (sucrose) concentration (65.0 °B, 70.0 °B, and 75.0 °B), respectively, during a constant 24-h contact period. The whole blanched fruit was immersed in a sucrose hypertonic solution at a fruit-to-hypertonic solution ratio of 1:6, with an initial moisture content of 87.63% and TSS of 14.0 °B. Fruits were taken out of the solution after each treatment, kept at room temperature for 15 min to drain the syrup, and then gently wiped with tissue paper. Washing fruit with water after osmosis may cause the fruit's TSS to decrease; hence, it should be avoided.

2.3. Conventional drying of fruit

Conventional drying of whole fruit was carried out under controlled conditions (80.0 °C) for 7–8 h by using a hot air oven manufactured by REMI and having model no. RDHO 50.

2.4. Analysis of physiochemical parameters

Moisture, total acidity measurement, vitamin C, total anthocyanin, and total phenolic content are all included in the physiochemical examination of each batch. Each reading is made in three copies.

2.4.1. Estimation of moisture content

The moisture content of each sample was assessed using the AOAC's recommended methodology[6]. The sample (5 g) was dried in an oven at 110.0 °C, and its moisture content was determined.

2.4.2. Estimation of total acidity

Using the method described in Ranganna's article[7], total acidity was calculated. An aliquot (10 mL) of oxalic acid (0.1 N) and phenolphthalein as an indicator were used to standardize NaOH (0.1 N). The plum was homogenized with sterile distilled water after being osmotically dehydrated. Whatman filter paper No. 1 was used to filter the extract. 100 mL of additional volume was created using distilled water. Titration was done with a 5-mL aliquot of (0.1 N) NaOH. The titration is finished when the pink colour remains for at least 15 sec. There were three copies of each determination.

2.4.3. Estimation of ascorbic acid (vitamin C)

With a few adjustments, the 2,6-dichlorophenol-indophenol visual titration method[8] was used to evaluate the ascorbic acid in the osmotically dehydrated plum. 2,6-dichlorophenol-indophenol was used to normalize the ascorbic acid concentration (0.1 mg mL^{-1}). Plum that had been osmotically dehydrated was crushed in a mortar and mixed with HPO_3. Whatman filter paper No. 1 was used to filter the extract. Using HPO_3, more volume was created, reaching 100 mL. With the use of 2,6-dichlorophenol-indophenol, Aliquot was titrated. When the pink colour remained for at least 15 sec, the endpoint was noted. Every measurement was made three times.

2.4.4. Estimation of total anthocyanin content

The method published by Fuleki and Francis[9] with modifications was used to determine the total anthocyanin content of the osmotically dehydrated plum. A 15 g piece of osmotically dehydrated plum was ground in a mortar and pestle before being mixed with 15 mL of ethanolic HCl, transferred into a glass bottle with a stopper, and kept overnight in a controlled refrigerator (40 °C). Using a Buchner funnel, further filter on Whatman filter paper No. 1. The residue was continuously washed with ethanolic HCl until 90 mL of extract was collected. In the same volumetric flask, ethanolic HCl was then used to bring the final volume up to 100 mL. A sample (6.24 mL) was obtained for spectrophotometric (Labman Scientific Instrument) analysis, and 25 mL of ethanolic HCl was used to make up the volume.

2.4.5. Estimation of total phenolic content

With few changes, Folin Ciocalteu's technique was used to calculate the sample's total phenolic content. Plums that had been osmotically dehydrated (5 g) were crushed in a mortar with 80% ethanol before the sample was kept in a controlled refrigerator (at 40 °C) for 2 h. The material was then centrifuged for 20 min at 3000 rpm before being filtered using Whatman filter paper No. 1. For further investigation, the clean extract was kept in a freezer at 40 °C. Gallic acid (GA) (20, 40, 60, and 80 L) solution and 0.4 mL of osmotically dehydrated plum extract were put into the test tube, and 5 mL of water was then added. 0.5 mL of the Folin Ciocalteu (FC) (10-fold) reagent was then added. 20% Na_2CO_3 was added to the 10 mL volume and shook after 3 min. After that, the sample spent one minute in a water bath heated to 100.0 °C, following room-temperature cooling. A

UV visible spectrophotometer (Labman Scientific Instrument) was used to detect absorbance at 640 nm. For comparison purposes, the spectrophotometric absorbance was plotted against the gallic acid (GA) calibration curve. Results were given in milligrams of GA per kilogram of osmotically dehydrated plum. Every measurement was carried out three times.

2.4.6. Statistical analysis of the experimental findings

The factorial experimental design method was employed for this experiment. GraphPad Prism 5.00.288 was used to conduct an analysis of variance (ANOVA) on each quality parameter to determine the impact of temperature and sugar syrup content. The least significant difference (LSD) test was used to analyse variations in the mean values with a significance threshold of 0.05 and a confidence interval of 95% ($P < 0.05$). In addition, the statistical program's built-in Bonferroni test was utilized to compare every column to every other.

3. Results and discussion

The average values of moisture content (%), acidity (%), vitamin C (mg/100 g), total anthocyanins (mg/100 g), and total phenolic content (mg GA/100 g) are displayed in **Table 1**, and **Figure 1** displays the standard deviation. Relationship between traditionally dried fruit and osmotically dried fruit (fruit and effluent syrup) with various operational parameters and (confidence level 95%) temperature (45.0, 50.0, and 55.0 °C) and hypertonic solution concentrations (65.0, 70.0, and 75.0 °B).

Table 1. Raw and Conventional dried fruit analysis.

Sample parameters	Raw fruit analysis		Conventional dried fruit analysis	
	Dry basis	Wet basis	Dry basis	Wet basis
Moisture content (%)	295.6 ± 0.52^{b}	85.22 ± 0.52^{b}	155.4 ± 0.122^{b}	7.77 ± 0.012^{a}
Acidity (%)	8.18 ± 0.45^{b}	1.21 ± 0.05^{a}	1.40 ± 0.102^{b}	1.30 ± 0.102^{b}
Vitamin C (mg/100 gm)	339.78 ± 0.55^{b}	50.22 ± 0.26^{b}	8.72 ± 0.05^{a}	8.05 ± 0.05^{a}
Anthocyanin (mg/100 gm)	759.13 ± 0.51^{b}	112.2 ± 0.005^{a}	43.02 ± 0.05^{a}	39.68 ± 0.025^{a}
TPC (mg GA/100 g)	835.59 ± 0.49^{b}	123.5 ± 0.087^{a}	1952.94 ± 0.002^{a}	1801.20 ± 0.002^{a}

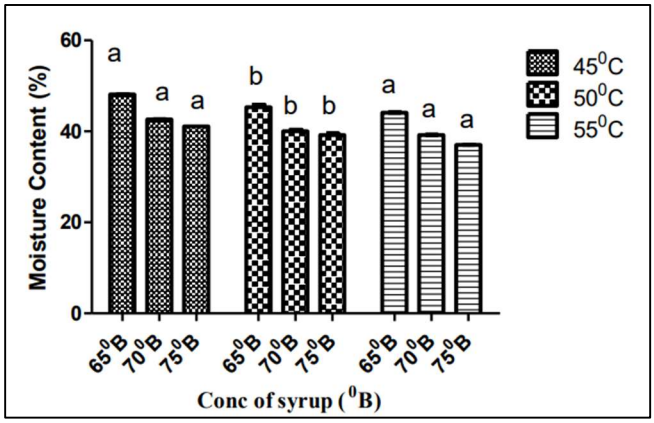

Figure 1. Changes in moisture content in the percentage of osmo-dried fruit with respect to temperature and sugar syrup concentration in Brix (ºB).

From **Table 1,** it was observed that the acidity of the conventional dried fruit is not that much affected as compared to raw fruit. Vitamin C and anthocyanin content of the fruit were significantly decreased[10,11]. As the drying temperature rose, the fruit's total phenolic content rose as well[12]. From this observation, it was found that the conventional drying process produces more losses as compared to other drying technologies. Thus, the osmotic dehydration process is preferred for dehydration.

3.1. Findings for moisture content

The initial moisture content of raw fruit was presented in **Table 1**, and the osmotically dehydrated fruit moisture content was presented in **Figure 1**. A significant decrease in moisture content was observed for the osmotically dehydrated plum (**Figure 1**) concerning different operating parameters temperature (45.0, 50.0 and 55.0 °C) and sugar syrup concentration (65.0, 70.0 and 75.0 °B) at the level of $P < 0.005$ and 95% CL. Similar results for moisture content were reported by Nuñez-Mancilla et al.[13] for osmotically dehydrated strawberries (*Fragaria vesca*).

3.2. Acidity

Figure 2(a,b) presents the combined bar graph for acidity content (%) of both osmotically dehydrated plum and drain syrup. This led researchers to conclude that the acidity of osmotically dehydrated plums has not significantly changed (**Figure 2(a)**). Additionally, it was noted that the addition of citric acid during the manufacture of the syrup for colour retention caused a substantial rise (0.1%–0.15%) in the acid content of the drained syrup (**Figure 2(b)**).

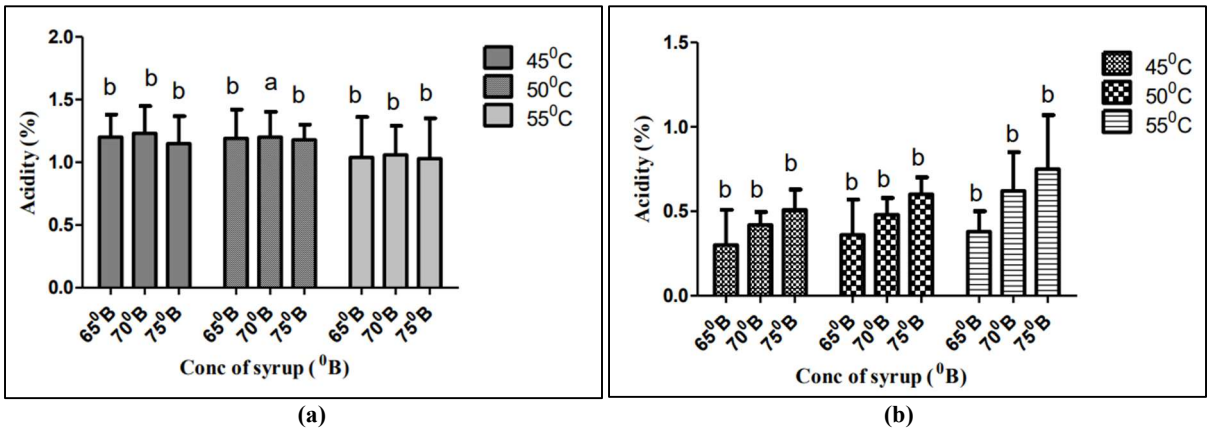

Figure 2. (a) Changes in the acidity of osmo-dried fruit concerning temperature and sugar syrup concentration; **(b)** Changes in acidity drain syrup concerning temperature and sugar syrup concentration.

3.3. Vitamin C

Figure 3(a,b) presents the combined bar graph of sugar syrup concentration (0 °B) versus ascorbic acid content (mg/100 g) at different temperatures (45.0, 50.0, and 55.0 °C) for the different samples of osmotically dehydrated fruit and drain syrup. About the different operating parameters of temperature (45.0, 50.0, and 55.0 °C) and sugar syrup concentration (65.0, 70.0, and 75.0 °B), a considerable reduction in vitamin C content was seen for osmotically dehydrated plum and drain syrup at the levels of $P < 0.005$ and 95% CL. The sample treated at 45.0 °C has better vitamin C retention than samples treated at 50.0 °C and 55.0 °C. It was observed that there was a 12% reduction in ascorbic acid content in the case of osmotically dehydrated plums and a 40% reduction in ascorbic acid content in the case of conventionally dehydrated plums. With processing temperature and hypertonic solution concentration, ascorbic acid concentration dropped[10]. Leaching is also one of the most important factors to consider in the decrease in ascorbic acid concentration in osmotically dehydrated fruit.

Due to its extreme heat sensitivity, vitamin C is readily damaged during processing[14]. The decrease in ascorbic acid concentration with the increase in osmosis temperature shows its instability at higher temperatures[15]. However, other enzymes present in fruits, such as cytochrome oxidase, ascorbic acid oxidase, and peroxidase, are also in charge of the breakdown of ascorbic acid[8,13].

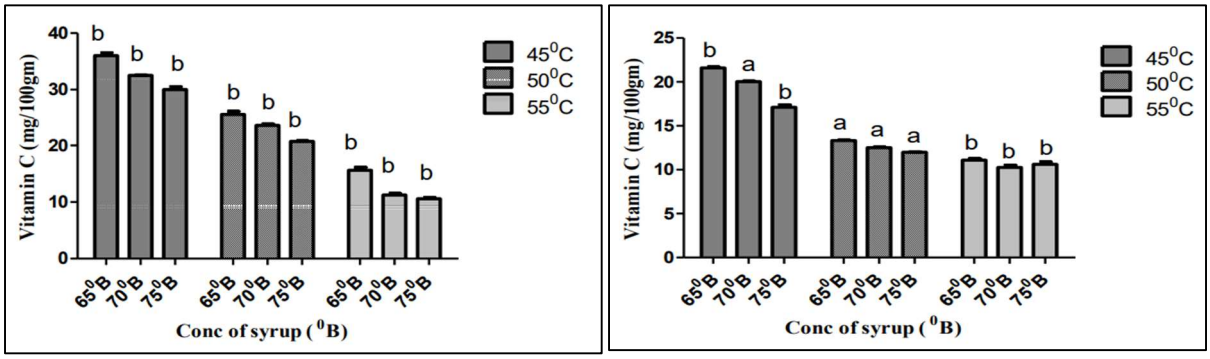

Figure 3. (a) Changes in vitamin C content of osmo-dried fruit and drain syrup with respect to temperature and sugar syrup concentration; **(b)** Changes in vitamin C content of drain syrup with respect to temperature and sugar syrup concentration.

3.4. Anthocyanin content

From **Figure 4(a)**, according to various operating settings, a considerable drop in the anthocyanin content of osmotically dehydrated plums was seen, like temperature (45.0, 50.0, and 55.0 °C) and sugar syrup concentration (65.0, 70.0, and 75.0 °B) at the level of $P < 0.005$ and 95% CL. The sample processed at 45.0 °C and 65.0 °B has a higher anthocyanin content (90.32 mg/100 g) than the sample processed at 50.0 °C and 55.0 °C for osmotically dehydrated fruit. It was found that in the case of osmotically dehydrated plums, there were 20%–22% anthocyanin content losses, and in the case of conventionally dehydrated plums more than 50% losses as compared to fresh plum fruit.

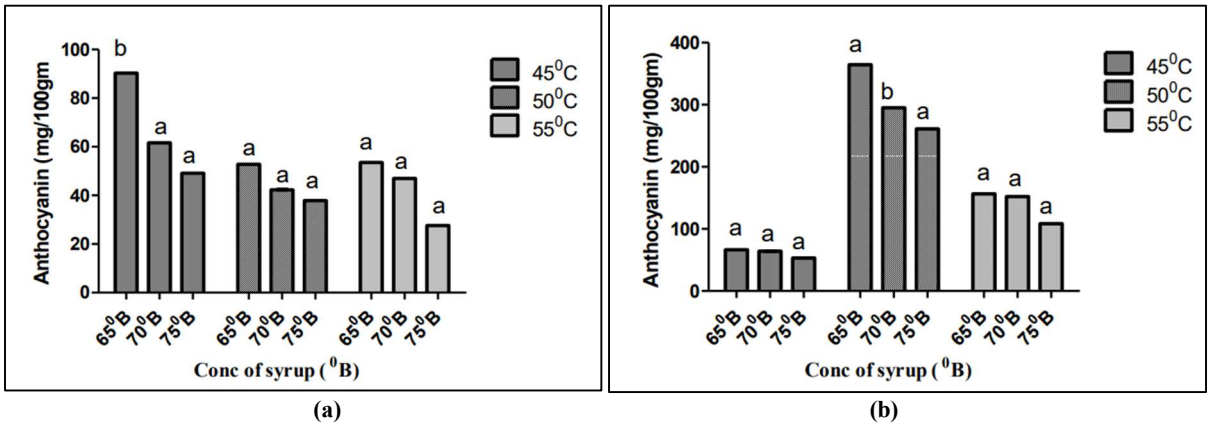

Figure 4. (a) Changes in anthocyanin content of osmo-dried fruit concerning temperature and sugar syrup concentration; **(b)** Changes in anthocyanin content of osmo-dried drain syrup concerning temperature and sugar syrup concentration.

No significant change in the anthocyanin content of drain syrup was observed (presented in **Figure 4(b)**) concerning temperature (45.0, 50.0, and 55.0 °C) and sugar syrup concentration (65.0, 70.0, and 75.0 °B). The anthocyanin content of drain syrup was dependent on the amount of anthocyanin leaching out from fruit during 24-h osmosis.

Sugar is one of the critical factors for anthocyanin stability. Ngo et al.[16] reported that total anthocyanin in strawberries canned at 20.0 °B at room temperature. Similarly, the temperature and duration of blanching strongly at the anthocyanin. In the study of Brownmiller et al.[17], they observed that a higher temperature of blanching (95.0 °C for 3 min) resulted in 43% anthocyanin losses compared to the original level found in fresh fruit. Numbers of factors are responsible for anthocyanin degradation during processing, such as heat, pH, light, oxygen, and the duration of exposure of these factors to the product[18]. Anthocyanin pigment is a heat-sensitives described by Oancea et al.[11] for the effect of extraction conditions on total anthocyanin content from *Vaccinium corymbosum*. Markaris et al.[19] reported anthocyanin degradation concerning temperature.

3.5. Total phenolic content (TPC)

Figure 5(a,b) shows the impact of processing temperature and hypertonic solution concentration on the total phenolic content of fruit. The change in the total phenolic content of the fruit and syrup is depicted in this image as a combined bar graph. From it, it was found that the concentration of sugar syrup and processing temperature were correlated with a considerable rise in TPC content. Similar results were reported by Izli et al.[12] for osmotically dehydrated mango, and Jeong et al.[20] for citrus peels. The sample processed at 55.0 °C shows higher TPC content than the sampling process at 45.0 °C and 50.0 °C.

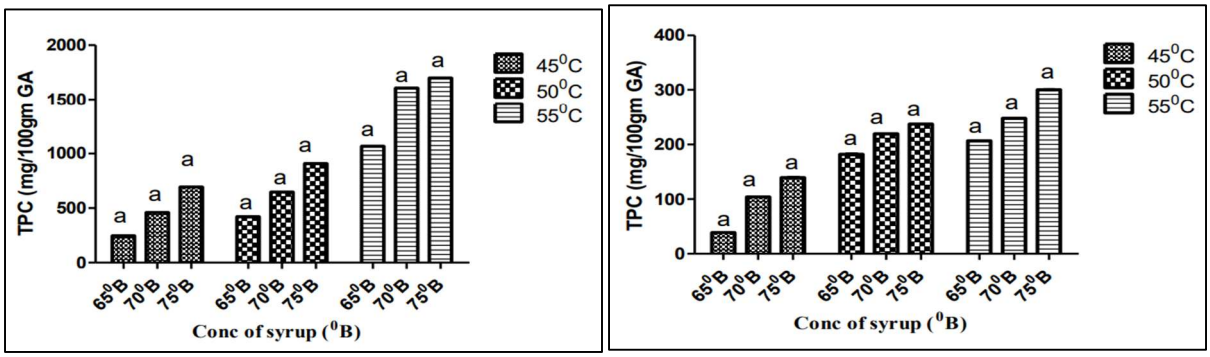

Figure 5. (a) Changes in the total phenolic content of osmo-dried fruit with respect to temperature and sugar syrup concentration; **(b)** Changes in the total phenolic content of drain syrup with respect to temperature and sugar syrup concentration.

Temperature, pH, sugar syrup content, enzymes, organic acids, and many other variables are among those that affect TPC. TPC breakdown occurs during drying due to polyphenol oxidase and other enzymes, although these enzymes become inactive as a result of high processing temperatures and prolonged exposure. Djendoubi Mrad et al.[21] and Que et al.[22] found that non-enzymatic interconversion transforms the precursor of phenolic compounds contained in fruits into phenolic compounds, causing the production of phenolic compounds to occur after drying. Drying enhanced the phenolic content of grapes that had been osmotically treated with a hypertonic solution of NaCl, as reported by Carranza-Concha et al.[23]. Possible causes include structural modifications in drying and skin damage brought on by pre-treatment.

Additionally, some research claims that phenolic compounds are reduced during the thermal processing of food items, while others claim that the TPC has not changed much. With an increase in temperature, the TPC content of dried pears decreased considerably, reported by Djendoubi Mrad et al.[21]. Similar results for TPC decrease were reported by Santos[24] for pears, and Vega-Gálvez et al.[25] for apples, and Michalczyk et al.[26] for berries.

4. Conclusion

A comparison between osmotically dehydrated fruit (at different temperatures and hypertonic solution concentrations) and conventionally dehydrated fruit (80.0 °C for 5–6 h) and drain syrup was represented in this research work. Vitamin C content and anthocyanin content of the fruit were significantly decreased with an increase in processing temperature. The total phenolic content of the fruit increased as the processing temperature increased. The osmotically treated fruit shows more vitamin, anthocyanin, and acidity content retention than conventionally dried fruit. Thus, osmotic dehydration is the best process for the preservation of fruits.

Author contributions

Conceptualization, SVK and PSL; methodology, PSL and PS; software, PS; validation, SVK, PSL and PS; formal analysis, PSL and PS; investigation, SVK; resources, PSL, PS and RK; data curation, PSL and PS;

writing—original draft preparation, SVK; writing—review and editing, PSL; visualization, PSL and PS; supervision, SVK; project administration, PSL; funding acquisition, SVK and PSL. All authors have read and agreed to the published version of the manuscript.

Conflict of interest

The authors declare no conflict of interest.

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