Tianjin Daxue Xuebao (Ziran Kexue yu Gongcheng Jishu Ban)/
Journal of Tianjin University Science and Technology
ISSN (Online): 0493-2137
E-Publication: Online Open Access
Vol:55 Issue:12:2022
DOI 10.17605/OSF.IO/N6T8F

INFLUENCE OF ULTRASOUND-ASSISTED OSMOTIC DEHYDRATION OF FIG (FICUS RACEMOSA) FRUIT WITH NATURAL HYPERTONIC SOLUTIONS FOR PREPARATION OF CANDIED PRODUCTS

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Abstract

The osmotic dehydration of Fig (*Ficus racemosa***)** fruit was performed using sucrose, grape, and mulberry syrup in ultrasound for 10 to 30 minutes. The effect of different osmotic solutions and ultrasound time on solid gain, water loss, moisture content, color (L*a*b*), firmness and vitamin C of dehydrated fig was studied. The findings showed that the ultrasound-assisted osmotic dehydration of figs using grape syrup increased water loss, firmness, a solid gain, and vitamin C considerably while less reduction in the color, moisture content, and shrinkage in comparison to other pretreatments was observed. Furthermore, the moisture content and vitamin C decreased as ultrasonic time increased from 10 to 30 minutes, while the firmness of the fig increased. The study showed that grape syrup significantly improved the chemical and nutritional properties as compared to the sugar and mulberry syrups for the development of functional candid fig products.

Keywords: Fig; osmotic dehydration; ultrasonication; mulberry; sucrose; grapes; candid products

1) INTRODUCTION

Fruits played an important role in maintaining human health and improving the quality of human life for thousands of years (Jangde, 2015). Figs (*Ficus racemose*) are essential for health because they contain a variety of bioactive compounds including polyphenols, anthocyanins flavonoids, carotenoids, and polysaccharides. Fig fruit contains good amounts of vitamins including C, E and K and also has high antioxidant potential due to a wide number of phytonutrients (Shah et al., 2016; Walia et al., 2022; Singh et al., 2019). The major use of fig is when it is fresh because of its high perishability and low shelf-life (hardly 7-10 days) dehydration is considered to be important for the development of fig-based, ready-to-eat products so that the shelf-life of fig can be increased.Osmotic dehydration can be utilized as an alternative to conventional ovens and sun drying for the processing of fruit and vegetables. Osmotic dehydration is a technique used for the partial removal of water from plant tissues by submerging them in a hypertonic solution. The process is mediated to remove the water by a difference in osmotic pressure among the fruit and osmotic solutions, as well as the permeability of the membrane (Gupta et al., 2012). Studies have shown that osmotic dehydration aided by ultrasound is a realistic and inexpensive technique to reduce operational costs and drying times further it can prolong the shelf life and is used for the preparation of ready-to-eat food products

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(Nowacka et al., 2014). It is also used as a pre-processing step before drying, freezing, pasteurization and canning. This approach is relying on the diffusion of the moisture content of the food by absorption into the osmotic solution.Ultrasound-assisted osmotic dehydration causes changes in the internal structure of fruits by extension and pressure, which can lead to increased surface tension, the formation of micro-channels and helps in water removals.It was shown that the samples submerged in water showed considerably fewer changes in ultrasonic waves than those immersed in a sucrose solution. (Fernandes & Rodrigues, 2008).The hypertonic (osmotic) solutions used in osmotic dehydration should be non-toxic and of high quality, as they lower moisture content and improve the nutritional and functional properties of the product. Glucose, sucrose, and sodium chloride are the most commonly used hypertonic solutions, as the demand for nutritious foods increased, alternate media such as concentrated fruit juices were utilized in osmotic dehydration (Bchir et al. 2012). Mulberry and grapes are rich in nutrients, including vitamins, minerals, carbohydrates, dietary fibers, and antioxidants that are essential for human health. These syrups have a significant amount of sugar, minerals, and organic acids that are essential for infants, children, and athletes. They are also used as an emergency source of energy because mulberry and grape syrups quickly enter the blood without digestion as most of their carbohydrates are fructose and glucose (Sani, 2013). These products are manufactured because monosaccharides can be used as a natural sweetener and a viable substitute for sucrose in the food industry (Rezaul et al., 2014). Mulberry and grape are simply used as osmotic solutions because India is the second-largest producer of fruits and vegetables in the world. Thus, the main objective of this study was to explore how natural syrups (mulberry and grapefruit) affected the nutritional and functional properties of figs during ultrasound-assisted osmotic dehydration.

2) MATERIAL AND METHODS

2.1) Preparation of candied figs

Mulberry and grape syrups were procured from Jaipur, Rajasthan, India. Fig fruits were collected from Kangra district of Himachal Pradesh, India, and stored in refrigeration conditions (4-7^{0}C) till further use. The good quality, uniform shape, and color fruits were selected for the preparation of candied figs. The fruit was clean and then sliced into 0.6 cm thick slices. To reduce the browning the fig fruit slices were submerged in 1%citric acid for 5 minutes., then cleaned with distilled water and air dried so that its weight could be estimated. After that, the fig fruit slices were pre-treated using ultrasound and the moisture content was determined.

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2.2) Ultrasound-assisted osmotic dehydration pre-treatment sucrose, mulberry, and grape syrups (55^0 Brix) were used as osmotic solutions.

Fig slices, osmotic solutions, and distilled water were added to the beaker in a ratio of 1 to 10 (Fig slice weight to solution volume ratio) from 1 to 10. Then, the beaker was placed in an ultrasonic bath for 10, 20, and 30 minutes (LAB MAN LMUC-4, India) at 40 kHz and 65°C. The temperature, fruit weight- to volume s ratio, and Brix of the osmotic solutions were selected basis on preliminary results.

2.3) Final Drying

After dehydration, the samples were taken out from the osmotic solutions, cleaned with distilled water, and then the surface water was dried using absorbent paper. Finally, the samples were dried to a 20% moisture level using a tray drier (BPL-27, BP Lab Solutions, India) at 50°C.

2.4) Physicochemical properties of osmotic reagents

Total soluble solids (TSS) of sucrose, mulberry, and grape syrups were estimated using a digital refractometer. (Erma. INC Tokyo, Japan)., Furthermore, titratable acidity, ash, pH, and protein were and estimated using AOAC official methods (AOAC 2008).

2.5) Physico-chemical properties of candied figs

2.5.1) Moisture Content

The moisture content was determined using the oven method given by AOAC, 2008. The samples were oven dried (Prolab Instruments, India) at 105°C, and precisely weighed until they reached the constant weight, the moisture content was calculated based on the difference in weight between the samples at the beginning and end of the experiment.

2.5.2) Mass transfer: Soluble Solid Gain (SG) and Water Loss (WL)

The mass transfer was calculated in terms of water loss (WL) and solid gain (SG) according to the procedure followed by Rahaman et al.(2019).

$$WL = (Mo - mo) - \frac{M - m}{mo}$$

$$SG = \frac{m - mo}{mo}$$

Where M_0 is the initial mass of the fresh sample before the osmotic treatment, M is the mass of samples after time t of osmotic treatment, m is the dry mass of samples after time t of osmotic treatment, and m_0 is the dry mass of fresh material.

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2.5.3) Shrinkage

The shrinkage in the samples caused by osmotic dehydration was determined by measuring sample volume change. Volume was measured gravimetrically using the displacement of toluene in a pycnometer (Sette et al. 2015).

2.5.4) Firmness

A penetration test was carried out to determine the firmness of the sample using a TA-XT plus texture analyzer (Stable Micro Systems, Surrey, UK), which was fitted with a 25 N load cell. The experiment was carried out using a probe made of stainless steel with a diameter of 6 millimeters and a speed of 1 millimeter per second. The results were presented as a measure of firmness in Newtons (N), with 1 N representing the greatest force required to break through candied figs (Hamedi et al., 2018).

2.5.5) Color

The intensity of the color of fresh and dehydrated fig candy was analyzed using (CR-400,

Minolta Corp., Japan). Color information is provided in the form of CIE L*a*b* coordinates, which define color in three dimensions. L* denotes lightness, with values ranging from 0 (black) to 100 (white), and a* and b* are green-red and blue-yellow coordinates, respectively. Furthermore, a* is positive for reddish colors and negative for greenish colors, whereas b* is positive for yellowish colors and negative for bluish colors (Abraão et al., 2013).

2.5.6) Ascorbic acid

The ascorbic acid content of fig slices was estimated by the 2,6 -Dichloroindophenol titration method, which was described by Huang et al.(2017).

2.6) Statistical analysis

The data represented in this study is the mean of truiplicate readings shown as standard deviation (SD) was calculated using Microsoft Excel 2016.

3) RESULTS AND DISCUSSION

3.1) Physicochemical properties of osmotic reagents

The physicochemical characteristics of mulberry and grape syrup are shown in Table 1. The chemical values of these syrups were nearly identical. As described in Table 1, pH, protein, soluble dry matter, total sugar, ash, and titratable acidity were calculated to be 72.26±0.58 (%), 61.78±0.47 (g/100 g), 2.13±0.11 (%), 5.33±0.57,1.60± 0.30 (%),0.58±0.04% for the grape syrup and 73.05±0.82 (%), 57.88±0.67 (g/100 g), 2.44±0.21 (%), 4.66±0.57, 1.75±0.21 (%), and 0.56±0.09 (%) for the mulberry syrup, respectively. The prepared syrups had high levels of total sugars which were determined to be 61.78±0.47 and 57.88±0.67 (g/100 g) for the mulberry and grape syrups, respectively. The findings are similar to the previous study where properties of pekmez studied

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prepared from grape and mulberry (Tukben et al, 2016). Sengul et al. (2005) confirmed that the maillard reactions or caramelization of sugars are non-enzymatic browning reactions responsible for the dark color of syrups. As a result, the syrups did not have a high lightness (L*) index.

Table 1-Physicochemical properties of grape and mulberry syrup

Parameters	Grape syrup	Mulberry syrup
Soluble dry matter	72.23±0.58	73.05±0.82
Total sugar	61.78±0.47	57.88±0.67
Ash%	2.13±0.11	2.44±0.21
pH	5.33±0.57	4.66±0.57
Protein %	1.60±0.30	1.75±0.21
Titratable acidity	0.58±0.04	0.56±0.09
L*	23.67±0.18	28.15±0.60
a*	8.38±0.14	7.29±0.24
b*	1.30±0.18	3.32±0.19

3.2) Physico-chemical properties of candied figs

3.2.1) Moisture Content

The moisture content of the processed samples is indicated in Table 2. The results showed that the osmotic solutions and ultrasonication treatments significantly affect the moisture content of the samples. The moisture content of fig slices decreased with the increase in the ultrasonic time. Fig slices dipped in the grape syrups have the lowest moisture content as compared to the slices dipped in the mulberry syrups. This is might be due to the presence of a large number of monosaccharides (glucose and fructose) in the grape syrups, which created a higher osmotic pressure (Hamedi et al., 2018). However, prolonged osmotic drying will alter the absorption characteristic of the cell wall and decrease the moisture content of the sample and the water loss (Zhang et al., 2017)

Table 2: The effect of type of osmotic solution and ultrasonic time on the moisture content (%) on candied figs

Ultrasound time	Mulberry Syrup	Grape syrup	Sugar	Distilled water
10	41.92±0.29	42.34±0.30	56.48±0.36	68.11±0.17
20	31.05±0.10	32.60±0.29	41.6±0.23	61.49±0.27
30	22.61±0.22	23.99±0.13	40.30±0.26	52.4±0.22

3.2.2) Water loss

The results of WL after they are shown in Table 3, It has been demonstrated that adding the natural osmotic agents (mulberry and grape syrups) substantially increased the level of WL in the fig fruit. This issue is caused by monosaccharides such as fructose and glucose in natural osmotic solutions. Monosaccharides (fructose and glucose) found in natural osmotic solutions are likely to be responsible for this condition. Consequently, it increases osmotic pressure and induces more WL in the samples (Panagiotou et al., 1999). Using grape syrup as the osmotic solution results in more WL during the drying process than other treatments. This is because the grape syrup contains more glucose and fructose, which results in increased WL in the samples throughout the drying process. These results are in accordance with the dehydration of peach fruit reported by Zhang et al. (2017). Additionally, the amount of WL in the samples was raised as ultrasonic time was increased. Furthermore, as the ultrasonication time increased, they create holes and channels in the samples thereby increasing the water loss of the sample (Amami et al., 2017).

Table 3: The effect of type of osmotic solution and ultrasonic time on the water loss on candied figs

Ultrasound time	Mulberry Syrup	Grape syrup	Sugar	Distilled water
10	14.42±0.57	17.13±0.18	8.53±0.42	7.55±0.55
20	18.63±0.46	20.32±0.31	9.32±0.26	7.86±0.06
30	36.56±0.32	37.72±0.42	11.26±0.31	9.36±0.34

3.2.3) Solid Gain (SG)

The osmotic solutions have a significant effect on the levels of solid gain in the samples. The results are shown in Table 4. The grape and mulberry syrup increased the quantity of solid gain in the fig slices. The absorption process is facilitated by the use of osmotic reagents with lower molecular weight, such as mulberry and grape syrup, as opposed to osmotic reagents with higher molecular weight, like sucrose solution. This is because fructose has a greater capacity to bind to water, increasing the osmotic pressure in tissues (Panagiotou et al., 1999). Consequently, sugary molecules are assimilated into the tissues after drying fluids. In such an instance, the content of solid gain increases.

Table 4- The effect of the type of osmotic solution and ultrasonic time on the Solid gain on candied figs

Ultrasound time	Mulberry Syrup	Grape syrup	Sugar	Distilled water
10	5.42±0.23	7.48±0.32	4.35±0.28	3.32±0.14
20	6.38±0.21	8.46±0.32	5.29±0.15	4.46±0.12
30	9.31±0.23	9.54±0.16	5.54±0.36	4.6±0.28

3.2.4) Shrinkage

Variations in the shrinkage of the dried fig fruit slices are displayed in Table 5. According to the findings, shrinkage increased as the ultra-sonication time increased. Additionally, the shrinkage decreased after treatment with the osmotic solutions. The samples with the greatest reduction in shrinkage were dried fig fruit slices that had first been treated with grape syrup before drying, as samples soaked in distilled water showed the greatest shrinking. The holes in the fruit slices were filled by the absorbed particles, which prevented further shrinkage (Fathi et al., 2011). When compared to alternative treatments that use sucrose, grape syrup (glucose and fructose) has smaller molecular weights, hence their absorption significantly reduces shrinkage (Yadav & Singh, 2014). In dried bananas, Chavan et al., (2010) examined the effects of osmotic and ultrasonic pre-treatments. They claimed that WL and shrinkage were affected by the kind of osmotic solution, duration, and solution concentration.

Table 5- The effect of the type of osmotic solution and ultrasonic time on the shrinkage of candied figs

Ultrasound time	Mulberry Syrup	Grape syrup	Sugar	Distilled water
10	35.55±0.34	30.46±0.20	46.86±0.24	50.47±0.31
20	50.44±0.33	44.56±0.16	63.51±0.38	67.33±0.20
30	55.56±0.22	48.46±0.31	78.34±0.27	79.64±0.32

3.2.5) Vitamin C

The variety of osmotic reagents and duration of the ultrasonic treatment substantially affected the vitamin C content, as indicated in Table 6. As a result, the vitamin C content of fig slices declined as the ultrasonic time increased. This is most likely because of the micro-channels that were created during the cavitation process. Due to the water solubility of the Vitamin C leached out from the samples (Vissers et al., 2013). Additionally, the amount of vitamin C was enhanced when utilizing the mulberry and grapefruit syrup as an alternative to the sugar solution and distilled water. This might be because sugar can protect vitamin C, the grape syrup shows the greatest ability to protect Vitamin C in the fig fruit in comparison to other treatments

Table 6- The effect of the type of osmotic solution and ultrasonic time on Vitamin C on candied figs

Ultrasound time	Mulberry Syrup	Grape syrup	Sugar	Distilled water
10	55.57±0.37	68.65±0.55	45.35±0.15	33.44±0.23
20	47.41±0.25	58.42±0.23	36.34±0.24	28.63±0.26
30	38.43±0.24	56.31±0.40	30.80±0.29	19.50±0.17

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3.2.6) Firmness

The hardness of the samples was influenced by treatment type and ultrasonic time, as shown in Figure 1. As a result, firmness increased with an increase in ultrasonic time. In other words, the texture became softer and more elastic as the ultrasonic time increased while the firmness decreased. Additionally, the firmness was increased when utilizing the osmotic solutions rather than pure water, and this effect was more pronounced when the grape syrup was used. When utilizing osmotic solutions, the samples hardness is likely caused by an increase in solid matter and a reduction in moisture levels (Nieto et al., 2013). Osmotic solutions, mulberry, and grape syrups increased the osmotic pressure, which raise the quantity of solid matter while lowering the moisture level. In this, way fig candies acquire a firm texture (Nowacka et al., 2018).

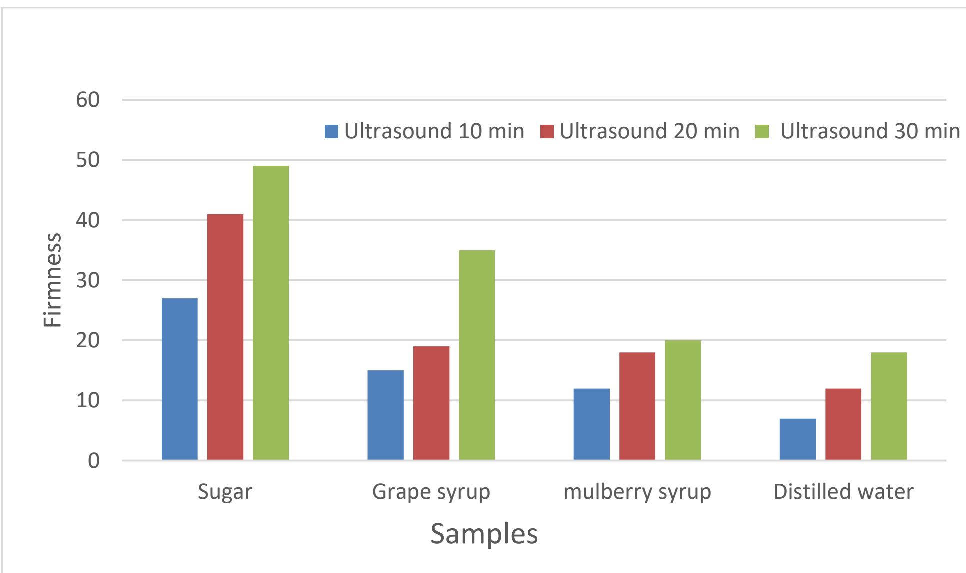

Fig 1-The effect of type of osmotic solutions and ultra-sonication time on the firmness of candied fig slices.

3.2.7) Color

The L*, a*, and b* values were significantly different among the fig slices immersed in distilled water as well as those treated with other solutions, as shown in Table 7. Additionally, employing osmotic solutions (like sugar solution, mulberry syrup, and grape syrup) in place of distilled water altered the samples' colorimetric indices throughout the procedure. Due to the higher temperature and monosaccharide absorption, the fruit slices immersed with mulberry and grape syrup solutions displayed the highest colorimetric alterations in the color parameters. Syrups of mulberry and grape produce more noticeable color index variations as osmotic solutions. The formation of melanoidin, colorful chemical reactions like Milliard's reaction between protein sugar, and colored

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pigments in osmotic solutions are all likely responsible for variations in the color index during the process. Due to their chemical characteristics, glucose and fructose play a more significant role in the interactions and synthesis of color pigments (Wiktor et al., 2016).

Table-7 The effect of type of osmotic solution and ultrasonic time on the color characteristics of the candied fig slices

Ultra sound time	L*				a*				b*			
	Mulberry syrup	Grape Syrup	Sugar	Distilled water	Mulberry syrup	Grape Syrup	Sugar	Distilled water	Mulberry syrup	Grape Syrup	Sugar	Distilled water
20	42.57 ±0.19	43.53±0.29	48.71±0.34	43.50±0.31	-1.82±0.12	1.58 ±0.14	-4.58 ±0.19	-4.64 ±0.39	15.54 ±0.19	9.75 ±.0.08	13.43±0.24	16.40±0.23
30	38.12 ±0.25	36.19±0.27	40.21±0.33	37.70±0.23	-1.44±0.15	2.32 ±0.15	-4.15 ±0.06	-3.27 ±0.13	15.14 ±00.07	9.44 ±0.14	11.95±6.89	10.43±0.11
40	27.55 ±0.37	24.84±0.21	24.71±0.38	28.50±0.22	-1.11±0.07	2.76 ±0.17	-3.02 ±0.08	-2.38 ±0.23	11.50 ±0.17	8.41 ±0.33	8.41 ±0.33	9.54 ±0.06

L* is the vertical coordinate of a three-dimensional system of colors, which has values from 0 (black) to 100 (white).

a* is the horizontal coordinate the values of which range from 280 (green) to 180 (red).

b* is the horizontal coordinate the values of which range from 280 (blue) to 180 (yellow).

CONCLUSION

In this study, the impact of osmotic solutions (sucrose solution, mulberry syrup, grape syrup, and water) and ultra-sonication time (10, 20, and 30 min) on the physicochemical characteristics of the dried fig fruit were investigated. These findings suggested that the application of ultrasound during osmotic dehydration in mulberry and grape syrups would be the better osmotic solution to decrease the moisture content, and hardness while increasing the water loss, and solid gain in the fig slices. The ultrasonic-assisted osmotic dehydration using the mulberry and grape syrups enhanced the Vitamin C content and reduced the shrinkage in the dried fig slices. These findings suggested that natural sugars such as grapes would be the most suitable osmotic solution to increase the firmness of dried food. The study showed that grape syrups significantly improved the chemical and nutritional properties as compared to sucrose and mulberry syrups for the development of functional candid fig products.

Conflict of Interest

The authors declared no conflict of interest.

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ISSN (Online): 0493-2137
E-Publication: Online Open Access
Vol:55 Issue:12:2022
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