Optimization of ultrasound-assisted osmotic dehydration of Ber (*Ziziphus mauritiana*)

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IN

BIOTECHNOLOGY

By

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DECLARATION

I, hereby declare that the experimental work introduced in this dissertation entitled "Optimization of ultrasound-assisted osmotic dehydration of ber (Ziziphus mauritiana)" for the degree of Master of Science in Biotechnology award is an authentic record of my work. The work has been performed under the supervision of Dr. Ovais Shafiq Qadri assistant professor at the Department of Biotechnology at Thapar Institute of Engineering and Technology (Patiala).

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CERTIFICATE

I certify that the project entitled “Optimization of ultrasound-assisted osmotic dehydration of ber (*Ziziphus mauritiana*)” was submitted by Sapanjot Khurana, Roll No. 302001021 for the fulfillment of the requirement for the award of the degree of Master of Science in Biotechnology. The work has been carried out under my supervision. It is also certified that the work of the present thesis or any part of this has not been submitted, to this university or any other university for the award of any other degree or diploma.

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LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS AND ABBREVIATIONS

Na_2CO_3	Sodium carbonate
UAOD	ultrasound-assisted osmotic dehydration
KMS	Potassium Metabisulphite
°C	degree centigrade
%	percent
°Brix	degree Brix
DPPH	2,2-diphenyl-1-picrylhydrazyl
WL	Water loss
MC	Moisture content
RSM	Response surface methodology
TPC	Total phenolic content
TSS	Total soluble solids
ha	Hectares
cm	Centimeter
m	Meter
ML	Moisture loss
SG	Solid gain
WR	Water retention
OA	Overall acceptability
aw	Water activity
g	grams
mg	milligrams
ml	millilitres
mm	millimolar
µg	Microgram
µl	microlitre
nm	nanometer
s	second
min	minutes
w/w	Weight by weight
v/v	Volume by volume

OD	Osmotic dehydration
BBD	Box Behnken design
:	ratio
M	Molar
abs	Absorbance
FCCCD	Face-Centered Central Composite Design
CCD	central composite design

ABSTRACT

The effect of ultrasound-assisted osmotic dehydration on drying kinetics of ber (Ziziphus mauritiana L.) was analyzed. Slices of ber samples were pre-treated using KMS and ultrasound-assisted osmotic dehydration (UAOD) and dried in a drying oven. An investigational design was developed to assess the effect of ultrasound time, amplitude, and osmotic solution concentration on the water loss and sugar gain during the drying time. The ultrasonic pre-treatment was carried out for 10,20,30 minutes and at 30,60,90% amplitude at 25°C. Osmotic solution concentration of 40,50,60 °Brix was applied in the treatments, the sample to solution ratio kept is (1:5), and air drying was carried out at 70°C. The effects of drying parameters (ultrasonication time, ultrasonication amplitude, syrup concentration) on the sample's drying kinetics and physicochemical properties were analyzed. Based on these physicochemical properties, the process parameters for osmotic dehydration of ber slices were optimized using response surface methodology. The physicochemical properties analyzed were DPPH (2,2-diphenyl-1-picrylhydrazyl) assay (antioxidant property), total phenolic content, total soluble salts, water activity, and acidity. The cell wall shape and connection between the cells are lost, and tissue breaks down due to osmotic dehydration. Ultrasound creates the formation of microscopic channels in the fruit structure. The changes due to osmotic dehydration and ultrasound reveal the effect on water diffusivity. Ultrasound treatment increases water diffusivity due to the formation of microscopic channels, which also offers lower resistance to water diffusion (Fabiano A.N. Fernandes, Maria Izabel Galla˜o, Sueli Rodrigues). In order to achieve the best-operating conditions for maximum WL, drying rate, and solid gain, MC of ber slices, RSM was helpful in optimizing process parameters for osmotic dehydration as pre-treatment of ber slices. The condition optimized for maximum WL, TSS and drying rate minimum MC, acidity and water activity were 90% ultrasonication amplitude, 30 minutes ultrasonication time, 60°Brix syrup concentration in order to get MC 0.84 and drying rate of 0.0046. The condition optimized for DPPH, and TPC, were 60% ultrasonication amplitude, 20 minutes ultrasonication time, 50°Brix syrup concentration. To cut energy costs and preserve the product's authenticity, osmotic dehydration of ber could be used as a pre-treatment prior to air-drying.

INTRODUCTION

Due to its high nutritional and economic significance, the jujube, also known as ber, is currently an important crop in India. It is a traditional and widespread fruit that grows in India's tropical and subtropical regions, and it is said to be native to the region that stretches from India to China. It is a member of the Rhamnaceae family and is known by the botanical name Ziziphus mauritiana Lamk. Indian jujube (Ziziphus mauritiana Lamk., 2n=48) and Chinese or common jujube (Ziziphus jujube Mill., 2n =24) are the main two domestic jujube species. About 50 varieties make up the genus Ziziphus, of which 18 to 20 are indigenous to India (Pareek, 2001). Ziziphus comprises 50 species, of which 18 to 20 are present in India, according to Baily (1947). Zizyphus is a genus of 135 species, of which around 90 are found in the ancient world, according to Bhansali (1975). Z. mauritiana is the primary species grown for commerce in India. It is distinct from Z. jujube, also referred to as "Chinese jujube."

- Domain: Eukaryota
- Kingdom: Plantae
- Phylum: Spermatophyta
- Subphylum: Angiospermae
- Class: Dicotyledonae
- Order: Rosales
- Family: Rhamnaceae
- Genus: *Ziziphus*
- Species: *mauritiana*

Although seed-based crop reproduction is not all that common, ber is typically propagated vegetatively. In India, budding is the preferred technique of spreading ber. Various forms of budding, such as eye or screen, rings, patches, and forkert (Jyotishi et al. 1967), have already been used with varying degrees of success. Ber fruits are indeed incredibly nutrient-dense and vitamin-rich. Animals can eat the nutritious leaves of the jujube tree. The tree's wood, which is strong, is used to make furniture. Although there are many ber plantations in our nation, systematic cultivation is uncommon. Although the precise area devoted to this fruit's cultivation is unknown, it is estimated that close to 2200 hectares are only used in the north Indian plains, central India, and peninsular India (Chadha, 1990). Due to the profitable revenue out of its orchard, ber production is currently performed throughout the nation, and the area planted with this crop is steadily growing. At Varanasi, Aligarh, Faizabad, and Agra in Uttar Pradesh, there are ber orchards. Sangrur and Patiala districts in Punjab contain ber orchards, and Rohtak, Hissar, Gurgaon, Jind, Panipat, and Mohindergarh districts in Haryana have ber orchards. Even at elevations of 1,000 meters above sea level, it thrives in hot, dry climes. Ber farming is best in both cold and heat, although in many regions of the country, high air humidity is thought to be a barrier to ripening that is sufficient. Ber serves as the main host for lac insect reproduction. In India, ber covers 49000 hectares and produces 481000 metric tonnes with an average yield of 9.8 tonnes/ha (Anon, 2017). The 'Indian Jujube', Z. mauritiana, is an evergreen tree with greenish-yellow to reddish-brown fruit. The ber plant has erect to extending leaves that are highly felted on the bottom side and deep green on the top side. A tiny, spiky tree with a trunk width of around 30 cm, a widespread crown, stipular spines, and numerous drooping branches, Ziziphus mauritiana Lamk. grows to a height of 15 meters. The flowering, which contains male and hermaphrodite flowers, is an axillary cyme on the main and lateral stems. Fruit is a delicate, juicy drupe that can be round, oval, ovate, or oblong in shape and ranges in size from 2.5 cm to 4.5 cm. The deep tap roots of the ber plant enable it to absorb water from the deep soil. The fact that ber is a resilient fruit crop and can be cultivated on a variety of soil types, including deep sandy loam having neutral and alkaline reactions, explains its significance. Even on soil with a pH as high as 9.2, it can thrive. This crop is well adapted to dry ground cultivation since it uses lesser groundwater than other crop species. Maharashtra, Gujarat, Uttar Pradesh, Tamil Nadu, West Bengal, Chhattisgarh, Punjab, Haryana, Rajasthan, Madhya Pradesh, Karnataka, Bihar, and Andhra Pradesh are significant regions for ber cultivation in our country (India). In northern India, ber start to develop in late June or early July as the monsoon arrives, followed by the blooming of the flowers. Fruit begins to set in October and, depending on the cultivar, matures in either February or April. Early February marks the beginning of the fruit season, and it lasts until mid-April.

In the Puranas and Vedas, Ber is noted as being ancient in India. It is stated that Saint Ved Vyas, the author of the Mahabharata, constructed his hut among ber trees in the hopes that the nutritious qualities of the ber fruits would only allow him to have a prolonged healthy life with exceptional creativity. The ancient sages' good health, lifespan, lofty intellect, and high imaginal capacity appear to have been greatly influenced by the tremendous strength of the food they consumed from the juicy ber fruits. Ber's requirements for soil are not particularly stringent. It may grow on a wide range of soil types, including clay, sand, gravel, and shallow to deep soils. The best soil for its production and fruit yield is neutral or slightly alkaline sandy loam. Ber fruits are extremely high in protein, minerals, phosphorus, calcium, carotene, and vitamins C and A, as well as a moderate amount of B-complex in mature fruits. The former outperforms the latter in terms of the amount of protein, phosphate, calcium, carotene, and vitamin "C," according to a comparison of the nutritional value of ber and apple (Bakshi and Singh, 1974). In terms of phosphate, iron, vitamin C, calorific content, and carbs, it surpasses oranges as well. The fully matured fruits have a 20.9-calorie food content (Singh et al., 1973). On a fresh weight basis, fruit contains 81–83 % moisture, approximately 19 percent carbohydrates, 0.8 percent protein, 0.07 percent fat, 0.76–1.8 percent iron, 0.03 percent calcium and phosphorus, 0.02 milligram of carotene and thiamine, 0.02-0.038 milligrams of riboflavin, 0.7–0.9 milligram of niacin, 0.2–1.1 milligram of citric acid, 65–76 milligram (Pareek et al., 2009). An adult man's daily vitamin C and vitamin B complex requirements could be satisfied by eating one ber fruit. The fruits can be turned into a variety of high-quality goods, including candies, pickles, preservatives, murabba, chhuhara, and ber powder (Singh, 1995).

The use of ber plant parts in the creation of Unani and Ayurvedic medicines has been reported by Shastri, Kirtikar, and Basu (1975). Ber's medicinal qualities have undoubtedly contributed to its varied usage as jam, jelly, lugdi, chutney, dried flakes, etc. According to Ayurvedic, the roots of ber have a calming effect and treat headaches, pile issues, and cough. Pregnant women who have nausea, vomiting, or stomach aches often consume the sedative seeds, often in combination with buttermilk.

Ber has a variety of therapeutic qualities (Bhandari, 1969). The fruit is thought to aid with metabolism and detoxify the blood. According to legend, the bark can treat diarrhea. The root is applied to ulcers and old wounds as a powder and used as a decoction for fever. The mature fruit relieves biliousness, a burning sensation, thirst, vomiting, and blood disorders. It is also a cooling, digestible, tonic, laxative, and energizing. The astringent seed quenches thirst and is a good tonic for the heart and brain. Fresh fruit from this plant helps with digestion, blood purification, and many other blood-related diseases. Its roots should be brewed into a decoction if you have fever and diarrhea, and applied to boils and pimples, the root extract is also beneficial. It’s traditionally used to treat conjunctivitis and other eye-related conditions.

In this investigation carried on ber to optimize the process, RSM is employed. KMS (Potassium Metabisulphite) treatment is given to preserve the color texture of the fruit. Ultrasound technology has been used directly in air-drying or as a pre-treatment. Earlier studies tell about the suitability of the ultrasound pre-treatment before drying processes (Ca'rcel et al. 2007; Fernandes and Rodrigues 2012; Correˆa et al. 2017). Ultrasound use in the food industry is new; only a few studies have addressed the use of ultrasound pre-treatment in drying processes (Tarleton 1992; Mason et al. 1996; Tarleton and Wakeman 1998; Gallego-Juárez et al. 1999; Fuente-Blanco et al. 2006; Zheng and Sun 2006; Rodrigues and Fernandes 2007; Fernandes et al. 2007; Rodrigues and Fernandes 2007), most of them were dealing with ultrasound-assisted spray-drying and ultrasound-assisted osmotic dehydration. Recent studies have evolved in studying the effect of the pre-treatment on quality aspects of dehydrated fruits and vegetables (Fernandes et al. 2016; Nascimento et al. 2016; Sangeeta 2016; Amami et al. 2017; Delgado et al. 2017; Soquetta et al. 2018). The ultrasonic pre-treatment reduces the processing time of the more expensive air-drying process when applied to fruits and vegetables (Fernandes et al. 2008a; Rodrı´guez et al. 2014; Dehghannya et al. 2015). It makes the technology suitable for application in less porous fruits, such as papayas and genipap (Rodrigues et al. 2009b; Fernandes and Rodrigues 2012). Ultrasonic waves may cause a swift series of alternative compressions and expansions, similar to a sponge when the sponge is squeezed and released repeatedly (the so-called sponge effect). The forces involved in this mechanical process are much higher than the forces involved due to surface tension. The moisture held in the capillaries of the fruit is easily removed due to the formation of microscopic channels. In addition, ultrasound produces cavitation which may help in removing the water that is strongly attached to the solid. These tiny channels diminish the diffusion boundary layer and increase the mass transfer in a sample. (Nowacka et al. 2014; La Fuente and Tadini 2017). In this investigation, we looked into the application of ultrasound-assisted osmotic dehydration as a pre-treatment to air-drying of ber. Osmotic dehydration is a standard pre-treatment used before air-drying. The technique consists of immersing the fruit in a hypertonic solution to remove part of the water from the fruit. The difference in osmotic pressure act as the driving force for the removal of water between the fruit and the hypertonic solution. The complex cellular structure of the fruit acts as a semi-permeable membrane producing an extra resistance to the diffusion of water within the fruit (Raoult-Wack et al., 1989; Torreggiani, 1993; Raoult-Wack, 1994; Simal et al., 1998). The application of osmotic dehydration changes fruit texture (Prothon et al., 2001; Torreggiani and Bertolo, 2001; Khin et al., 2007; Mayor et al., 2007).

The effect of processing time and osmotic solution concentration on various quality attributes was evaluated. Its effect on the drying kinetics throughout convective air-drying was evaluated.

The main advantage of ultrasound is it can be executed at room temperature and without any mechanical disturbance and heating, which decreases the chances of degradation of food (Mason, 1998). Employing distilled water in an ultrasonic experiment won't build in soluble solids, altering the original flavor of the fruit. This investigation looked into the application of ultrasound and osmotic dehydration as pre-treatment antecedents to air-drying. Various physicochemical properties (antioxidant property, total phenolic content, total soluble solids, water activity, and acidity) were analyzed in order to observe the effect of pre-treatments and air-drying.

This study looked into the drying kinetics of ber by altering the drying parameters (ultrasonication time, ultrasonication amplitude, syrup concentration) and, seeing the effect of drying parameters on physicochemical properties of dried ber to optimize the process.

Dehydration is optimized to produce a product of satisfactory grade of quality and including excessive throughput capacity under quick working circumstances. An optimization study technique that is often utilized is called response surface methodology (RSM). In order to ascertain and address multiple issues concurrently, it makes use of numerical data out of relevant investigational design. Equations identify links between test variables, show how test variables affect replies, and depict how every single test variable together has an impact on any given response. This strategy empowers a researcher to efficiently explore a proceeding. The main goal of this investigation was to look into the preparation of ber slices cut into a round shape with osmotic dehydration, pursued by air-drying. The study's precise goals were to look at how process factors (ultrasonication time, ultrasonication amplitude, syrup concentration) affected product quality throughout the osmotic dehydration and air-drying of ber slices and to optimize these process factors based on physicochemical tests.

Review of literature

The impact of solution temperature, sucrose concentration, and fruit-to-solution ratio on mass transfer kinetics of jujube was examined. Different models Magee, Azuara, and Peleg were used to understand the kinetics of jujube. The sucrose concentration and temperature were directly proportional to water loss and solid gain. Azuara was the best model for ML, and SG. The results inferred that sucrose concentration is inversely related to the activation energy. (Solgi et al. 2021)

The impact of time, concentration, sample thickness, and temperature was investigated on the osmotic dehydration of mango. Time, concentration, sample thickness, and the temperature were 3, 5, and 7 hours, 40-60%(w/w), 2-6 mm, and 20-40°C, respectively. RSM was used to optimize the process. The response evaluated were WR, SG, OA, and MC. WR was significantly affected by all four treatments, whereas OA was not significantly affected by any of the four treatments. Thickness has a significant effect on final MC. The conditions optimized time, concentration, sample thickness, and temperature were 6 hours, 65% (w/w), 5mm, and 35 degrees Celsius. (Madamba et al, 2002)

The impact of ultrasound-assisted osmotic dehydration on water diffusion and the drying period of strawberries was explored. Fruit samples were sopped in distinct sugar solution concentrations. Ultrasonic frequency and time were diverse to note the effect on WL, SG, and drying period. The more the concentration of sugar solution, the more WL in samples treated in 50% solution for 45 minutes. The treatment is done for 30 minutes in 50% solution concentration resulting in a large drying scale. A combined process of osmotic dehydration and ultrasound has a more significant effect on processing time than alone osmotic dehydration. (Garcia-Noguera et al. 2010)

The impact of ultrasound implemented for various periods at atmospheric pressure on melons was inspected. Ultrasound forms microchannels in fruit by breaking the connection between cells and distorting the cell wall's shape. Water diffusivity increases as the time increase from 30 minutes to 1 hour due to the ultrasound implemented. (Fernandes et al. 2008)

Fernandes et al., 2007 looked into the impact of air drying on the dehydrated banana. The data were used to validate the mathematical model, and simulations indicate how the operating circumstances impact the process. The process was optimized to get the most acceptable operational circumstances to decrease processing time. The range of sugar concentration used was a plus point to reduce processing time.

The impact of the type of sugar, concentration, sopped time, and the temperature was inquired on the mass transfer of pineapple slices. The sugars used were sucrose and glucose. Sugar concentration, time, and temperature were 50-70 %, 3-9 hours, and 30-70°C, respectively. The fruit sample was kept for drying for 48 hours at 70 degrees Celsius. The conditions optimized for high mass transfer were concentration, time, and the temperature at 70%, 9 hours, and 50°C, respectively. Fernandes (2009)

The consequences of numerous pre-treatments upon osmotic air-drying kinetics for apples and the modification to physical conditions in the course of dehydration were reviewed. At different time spans, apple slices were sopped in an osmotic solution making use of 30% of glucose and 45% sucrose. The apple slices sopped in sucrose were highly porous and had color retention, whereas those sopped in glucose were having tough texture rate. Mandala et al. (2005)

Anoar et al. (2006) looked into the impact of the osmotic solution, temperature, and osmotic time of osmotic dehydration of papaya slices. The osmotic solution is made of sugar and corn syrup. The osmotic solution concentration was 44-56% (w/w), the temperature was 34-46°C, and the osmotic time was 120-210 minutes. Using two factorial investigational designs, numerous factors like MR, SG, and ML were looked into. The values obtained for numerous factors were higher in the case of sucrose than in corn syrup.

Osmotic dehydration's impact on the kinetics of diffusion of water and solute of carambola was researched. The fruit was sopped in glucose, fructose, and sucrose solution having a concentration of 50g/100g. The temperature, osmotic time, and fruit to the solution were

45,60, and 75°C, 10 hours, and 1:15 respectively. The results describe to consider sucrose a best osmotic solution than others and it causes high water loss with respect to others. Ruiz et al. (2011)

The change in texture and kinetics while dealing with distinct combinations of osmotic solution and distinct temperatures was examined. The distinct osmotic solution and temperature used were 49.47% sucrose+0.25% $CaCl2$, 50% w/w sucrose solution, 40.52% w/w sucrose+0.50% w/w $CaCl2$+2% w/w NaCl, and 48.27% sucrose+0.5% $CaCl2$ and 20,40, and60°C respectively. It was found that tissue softness can be reduced using a distinct combination of osmotic solutions. The 60°C temperature gives rise to a greater extent of softness to the apple no matter what osmotic solution is used. Nikolaos et al. (2012)

Patchimaporn et al. (2015) researched the influence of drying air temperature (50 to 80°C), air velocity (0.2, 0.5, 0.7 m/s), and specific humidity (10, 25 g/kg dry air) of papaya cubes pre-treated in osmotic solution. The results exhibited a significant drop in water level and enzyme activity but increased the browning effect when the drying temperature was higher. This study confirmed that drying temperature was an essential parameter for preserving the color and biochemical properties of the Osmo-dehydrated products.

The impact of osmotic agents on partial dehydration in fruits was explored. It was confirmed that the use of sugar solution is better than using dry sugar due to the issue with disposing of leftover syrup if dried sugar is used. Ponting et al. (1966)

Guilbert and Raoult-Wack-Ac (1990) looked into dehydration by sopping in an osmotic solution. It was found that two processes occur simultaneously but in different directions. Water was transferred from the fruit to the sugar solution and solutes from the sugar solution to the fruit. This help in removing approximately 70% (w/w) of water from the fruit without heat.

The energy consumption in drying fresh and solute sopped fruit was inspected. Fruit drying efficiency was evaluated based on kinetics and energy use. More energy is consumed in the case of fresh fruit than the fruit sopped in sugar solution. Collignan et al. (1992)

The statement that dehydration before drying improves the quality of fruit and saves energy was reviewed. He assessed that fruits in 60% sugar solution had impeded mass transfer due to the high viscosity of sugar solution. Raoult-Wack (1994)

The employment of ultrasound and ultrasound-assisted osmotic dehydration was inquired in drying fruits that were banana, papaya, sapota, pineapple, genipap, Jambo, and melon on effective diffusivity of water, sugar gain, and water loss. It was wrapped up that ultrasound influences osmotic dehydration and marked-up water diffusivity on tissue structure. Fernandes and Rodrigues (2008)

Saxena et al. (2009) generated a technique to stabilize the jack fruit by practicing osmotic dehydration, in-pack pasteurization, and acidification. Bring into play response surface methodology to optimize the process. Osmosis time, temperature, and concentration were the process variables. The fluctuating elements optimized for a minimum solid gain, maximum water loss, and overall acceptability were 180.6 min of osmosis time, 65.9°Brix concentration, and 68.5°C temperature. After studying the micro-structure of fruit, it was discovered under optimal circumstances, that tissue's structural intactness was preserved.

Campos et al. (2012) studied the effect of process parameters during osmotic dehydration on slices of star fruit. The process parameters were solution concentration, blanching, fruit to solution ratio, and temperature. For blanching, a collaboration of Citric acid and ascorbic acid in the company of contrasting concentrations came into play. On application of the Box-Wilson central composite design, osmotic dehydration was accomplished by using orbital shaking at a speed of 120 rpm and different temperatures. It was discovered water loss and solid gain were affected by two factors those are concentration and temperature. Given economic viability 1:2.1 ratio was approved as fruit to solution ratio showing an insignificant impact Whereas, the blanching medium constituting the ideal cost-benefit analysis was 0.75% citric acid

The mass exchange was researched in the course of osmotic dehydration of sapota in sugar solution at three different sugar concentrations of 30, 40, and 50°Brix, at osmotic time 0-1 hour, at three different temperatures of 30,40, and 50°C. All these three parameters were discovered to affect the kinetics of O.D of sapota. It was found that change in temperature and concentration was directly proportional to weight reduction and water loss during osmosis. Kedarnath et al. (2013)

The osmotic dehydration of sapota slices was examined in three different syrup solutions of 30,40, and50 °Brix for 1 hour at three different temperatures of 30, 40, and 50 °C. The parameter studied were solid gain, water loss, and weight reduction After one hour, the effect on solid gain, water loss, and weight reduction was reported. Kedarnath et al. (2014)

Osmotic dehydration of cubes of seedless guava was inquired in sucrose solutions. Utilizing the Box Behnken design of RSM, the process at different concentrations (30-50% w/w), different temperatures (30-50°C), and immersion time (15-240 min) for SG WR and WL was optimized. The desirability function method was used to optimize sucrose concentration (33.79% w/w), osmosis time- 240 min, and temperature-30°C. Optimized conditions of WL, SG AND WR were 0.237 (g/g), 0.050 (g/g), and 0.189 (g/g) respectively. Ganjloo et al. (2014)

The optimization of parameters such as the temperature of 40,50,60°C, osmotic time of (60-240 min), and sugar concentration of 40,50,60°Brix were explored by making use of RSM(BBD), and the osmotic dehydration of sapota. The optimized conditions were sugar concentration, temperature, and osmosis time, 48.17 °Brix, 49.13°C, and 139.74 minutes respectively. The optimized conditions removed moisture with sugar gain of 26.50% and 6.95%, respectively, in sapota. Gupta et al., 2014

The effect of calcium lactate and sucrose on fruit quality and the kinetics of osmotic dehydration of pineapple were inspected. Evaluated parameters were water activity, fruit composition, color, and texture. Sucrose with calcium lactate solutions 40% and 50% and 0%, 2% and 4%, respectively were utilized for osmotic dehydration for the osmotic time of 1,2,4,6 hour. Due to the addition of calcium, sucrose impregnation of pineapple because of high M.wt. and water content get reduced, and efficiency of the process is enhanced. The firmness of pineapple is refined with the addition of calcium. Silva et al., 2014

The two-stage optimization of Osmo-vacuum drying of pear (Pyrus communis L.) was examined using RSM (FCCCD). For osmotic dehydration, optimized conditions were temperature, osmosis time, and syrup concentration valued at 55°C, 115 minutes, and 50%, respectively. Optimize conditions for vacuum drying were vacuum pressure, temperature, and time, which was 10kPa, 55°C, and 250 minutes of drying was signified. It was verified that energy cost was reduced, and the quality of fruit was preserved by osmotic dehydration. Amiripour et al., 2015

The impact of parameters was reviewed on Osmotic Dehydration of Mapara (Hypophthalmus edentatus) fillet. Time, temperature, brine concentration, and pressure were the parameters of the process and were optimized by RSM. Reduced vacuum pressure shows insignificant change ($p > 0.05$) in solid gain, water activity, and water loss. The above-mentioned parameters are affected the most by NaCl concentration in brine. 25% NaCl, 25°C, 120 minutes, and atmospheric pressure were the condition optimized. Optimized conditions modelling was executed with Azuara's model and showed the finest fit for solid gain and water loss. Maciel et al.,2015

The impact of parameters was inquired on osmotic dehydration of sapota. The parameters were sugar concentration (40,50, and 60°Brix), osmotic time (120, 180, and 240 minutes), and solution temperature (40,50, and 60°C). The change in water loss and solid gain is directly proportional to the change in sugar concentration and solution temperature. it was found that water loss and solid gain increased with an increase in syrup concentration and temperature. The effect of sugar concentration is more on water loss and solid gain than solution temperature. Wankhede et al., 2015

The optimization of process blanching and salt curing of the bitter gourd was inspected by using RSM. It was discovered that blanching has a substantial effect ($p< 0.001$) on water reduction (WR), water loss (WL), water activity (aw), firmness, and solids gain (SG) of bitter gourd. For achieving maximum WL and WR, minimum SG and water activity, and minimum changes in firmness, the conditions optimized were 15% concentration of the solution, osmosis time of 5 hours, and blanching was done at 800°C for 5.26 minutes. Nambi et al., 2016

Sirousazar, 2017 looked into osmotic dehydration in cone-shaped fruits and vegetables. The kinetics of water loss was studied using Fick's second rule. The factors considered were moisture content, coefficient of water diffusion, geometrical characteristics, and solution concentration. The dehydration rate was directly proportional to the coefficient of water diffusion and moisture content and inversely proportional to the concentration of a solution and geometrical characters. Time of osmosis was inversely proportional to the coefficient of water diffusion and moisture content and was directly proportional to the concentration of a solution and geometrical characters.

Energy Aspects

Making use of energy when the samples are osmotically dehydrated comes from (Lewicki and Lenart, 1992, Ramya and Jain, 2016):

- Temperature-dependent homogenizing, jiggling, and revolutions of the substance and solution.
- The material disintegrates in a diluted solution.

Economics

Osmotic dehydration is an economical process (Ponting et al., 1966; Jackson and Mohammed, 1971; Hawkes and Flink, 1978; Chaudhari et al., 1993, Ramya and Jain, 2016) as

- An osmotic solution could be used again.
- This process is economically better than freeze drying and vacuum drying.
- Due to the lack of a phase shift, the process uses less energy.

Concentration and Configuration of Osmotic Solution

The osmotic agent's kind, molecular weight, and ionic nature significantly impact WL, SG, and MC. Frequently used osmotic agents are sucrose and sodium chloride. Sodium chloride is an osmotic agent for vegetables, whereas sucrose is an osmotic agent for fruits. Sodium chloride retards both oxidative browning and enzymatic browning in vegetables, whereas sucrose retards oxidative browning in fruits. Sucrose also decreases the leaching of salt on colorful fruits. (Ponting et al., 1966; Ponting, 1973; Flink, 1975, Ahmed et al., 2016).

Fruit sample to sugar Solution Ratio

Considering economic factors, adopting the ideal sugar solution to the fruit sample ratio is crucial. With the rise in fruit sample to sugar solution ratio, the rate of osmosis also rises to a specific level; after that, it remains steady. (Chaudhary et al., 1993, Ramya and Jain, 2016, Ahmed et al., 2016).

The significant osmotic impact is obtained at a fruit sample to sugar solution ratio of 1:4 to 1:6 at the time WL and SG were taken into account. Lenart and Flink (1984)

The foremost fruit sample to sugar solution ratio between 1:4 to 1:8 was 1:6. In this osmotic dehydration, *Agaricus bisporus* was operated. Kar (1998)

Most researchers tell fruit sample to sugar solution ratio scale between 1:4-1:5 (Islam and Flink, 1982; Grabowski et al., 1994; Welti et al., 1995; Erketin and Cakaloz, 1996; Pokharkar, 2001; Ghosh, 2002; Sutar, 2003, Ahmed et al. 2016, Ramya and Jain, 2016)

Stirring or Movement of Osmotic Solution

As there is minor mass transfer hindrance at the fruit's exterior, osmotic dehydration occurs more quickly while the fruit is stirred. Though stirring might injure the sample, it is not relevant to try mixing. (Chaudhary et al., 1993, Ramya and Jain, 2016, Ahmed et al., 2016).

Activity period

Moisture loss increases at a decreasing rate as the osmosis time lengthens. (Chaudhary et al., 1993, Ahmed et al., 2016, Ramya and Jain, 2016).

From 4 hours to 20 hours, water loss remains constant, but solid gain did rise Lenart and Flink (1984).

Dimensions and appearance of the sample

The sample's size and shape impact dehydration. However, sample size and form are chosen based on the product's intended usage following further processing (Ahmed et al., 2016, Chaudhary et al., 1993, Ramya and Jain, 2016).

Therefore, this detailed analysis of optimization of ultrasound-assisted osmotic dehydration of ber (*Ziziphus mauritiana*) was attempted with the objectives follow as:-

- Study the effect of drying parameters (ultrasonication time, ultrasonication amplitude, syrup concentration) on drying kinetics of ber slices.
- Study the effect of drying parameters on physiochemical properties of dried ber slices.
- Optimize the process parameters for osmotic dehydration of ber slices based on various quality attributes using response surface methodology.

MATERIAL AND METHODS

Preparation of Samples

Ber (Ziziphus mauritiana L.) was bought from the local market. Ber was cut along the diameter in round shape slices of the thickness of 6mm. The moisture content of ber is measured by (ACZET MB-50). The initial soluble solids content of the fruit (°Brix) was determined by refractometry (ERMA INC.). The Ber's were stored at 4°C in the refrigerator until further use.

Fig1 – preparation of ber samples

Fig2 - measuring the moisture content

KMS (Potassium Metabisulphite) pre-treatment

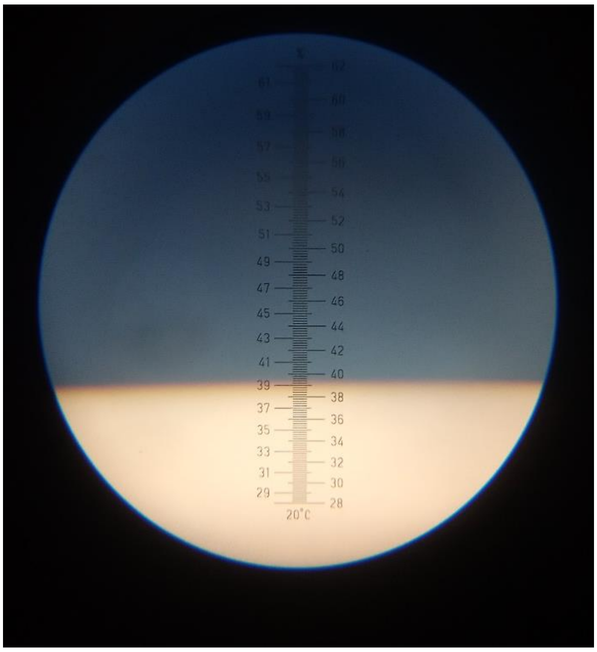
Potassium Metabisulphite is also known as E224. The slices are given a 2% (v/v) KMS treatment. Weigh KMS according to the volume of distilled water used to dip the sample. It is used as a preservative. It protects the natural color of fruit during an ultrasound and osmotic dehydration. It also protects against micro-organisms. After KMS treatment, samples were given an ultrasound treatment.

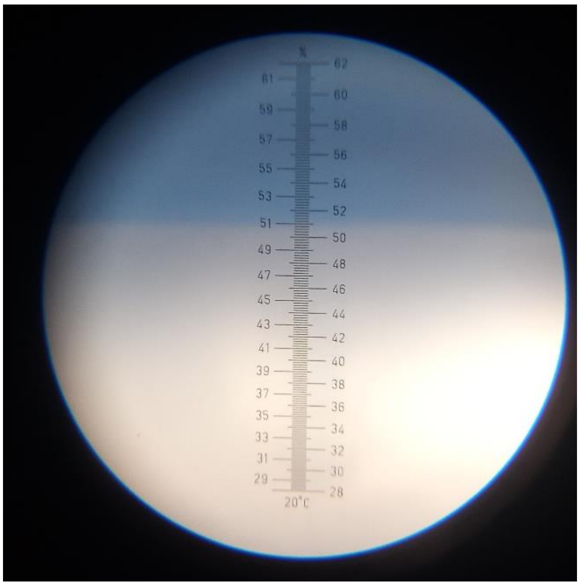
Ultrasound pre-treatment

In this treatment, samples each 200g were dipped in distilled water and subjected to ultrasonic waves for different 1) time (10,20,30 minutes) and 2) Amplitude (30,60,90%). The ultrasound treatment is carried out in a flask to avoid any disturbance. The treatment was accomplished at ambient temperature (25°C) without the application of mechanical forces. As at higher temperature the effects of ultrasound is not enhanced (simal et al.,1998). The model used is VCX750. The ultrasound power and frequency were 750 Watts and 20KHz, respectively. After the completion of the experiment, the sample is weighed to check the effect of ultrasound on moisture content. The experiment was executed in duplicates.

Osmotic dehydration

In this experiment, a sample of 200 g was sopped in a sugar solution with a concentration (of 40,50,60 °Brix). The fruit-to-sugar solution ratio was (1:5) Islam and Flink, 1982; Grabowski et al., 1994; Welti et al., 1995; Erketin and Cakaloz, 1996; Pokharkar, 2001; Ghosh, 2002; Sutar, 2003, Ahmed et al. 2016, Ramya and Jain, 2016. The sugar solution was prepared by dissolving the required sugar in a definite amount of distilled water (Preservation of fruits and vegetables Girdhari Lal, G. S. Siddappa, G. L. Tandon). The concentration of sugar solution is checked by a refractometer. The sample sopped in sugar solution is kept on shaking for 3 hours at a constant speed and at room temperature. After 3 hours of shaking, the solution is removed. The absorbent paper blotted the fruit sample to remove excess sugar solution, and the sample was weighed using a weighing machine to measure weight loss due to the removal of water.





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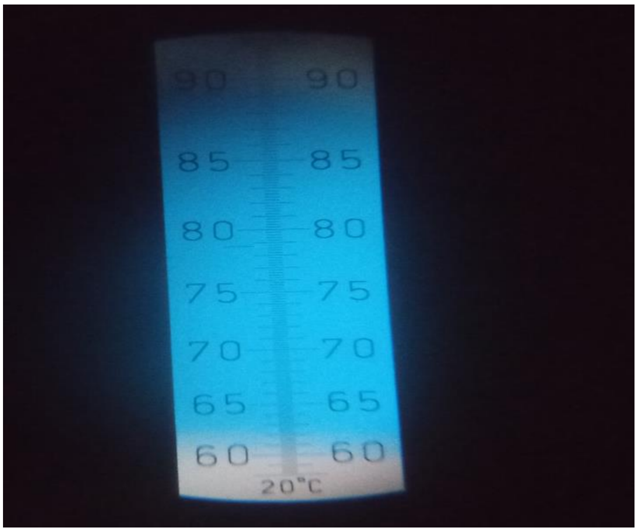

fig3- measuring osmotic concentration of osmotic solution a) 40°Brix b)50°Brix c)60°Brix

Air-drying

After the osmotic treatment, the samples were weighed and kept in an air-drying oven. A wave of hot circulating air is being circulated in the air-drying oven. The temperature of the hot air-drying oven is set at 70 °C. Air drying is done for 7 hours continuously. After every 30 minutes interval, the weight of the sample was weighed. The drying kinetics of the Ber was analyzed by the experimental data of air drying. After air-drying, some tests are performed to check physicochemical properties.

Fig4 – Drying of pre-treated ber samples

Antioxidant Property

The DPPH assay was exercised to check the antioxidant property of dehydrated ber. DPPH assay is also called a free radical scavenging activity. DPPH radical scavenging activity is the methanolic extracts' ability to scavenge free radicals. It was determined spectrometrically against a very stable free radical DPPH.

Preparation of DPPH Solution (0.1 M)

0.1M DPPH solution was formed by mixing 0.39 mg of DPPH in 100 ml of methanol. The purple-colored DPPH solution was stored at −20°C in the refrigerator for further use.

Evaluation of Antioxidant Potential

Ber fruits were crushed with the aid of methanol. Weigh the crushed ber (1gram). The sample was diluted (1:4) using water and vortexed for a few minutes. 0.1 ml of diluted sample was taken in a falcon. The falcon was covered with foil paper. 3.9 ml of 0.1 mm methanolic DPPH was added to the falcon in the dark. The falcon was kept for 30 minutes in the dark at room temperature. The absorbance was recorded at 517 nm wavelength. Methanol was employed as blank. The experiment was carried out in duplicates. Control of Ascorbic acid, DPPH, and methanol was formed in a ratio of 1:15:4. The Antioxidant Property was calculated by the formula-

Anti-oxidant Property = [Abs(control)-Abs(sample)] *100/Abs(control)

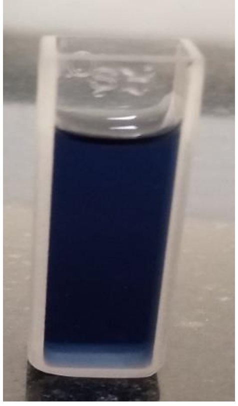

Fig5 – Measuring the absorbance of pre-treated ber samples

Total Phenolic Content

Preparation of Standard Gallic Acid for Calibration Curve

According to Singleton et al., 1999 to calculate the total phenolic content (TPC) folin-ciocalteu method is operated. The stock solution of gallic acid was prepared by dissolving 100mg gallic acid in 100 mg methanol which is 1mg per ml. Different concentrations of gallic acid were prepared from a stock solution which was 1, 2.5, 5, 10, 25, 50, and 100 µg per ml in different test tubes. To each test tube, distilled water was added to make up the volume to 1000 µl. 5ml of Folin–Ciocalteu reagent and 4ml of sodium carbonate (Na2CO3) were added to every test tube. The mixture obtained was shaken and incubated for 30 minutes at ambient temperature in the dark. After 30 minutes, absorbance was computed at a wavelength of 754nm, making use of a UV- spectrometer. As the readings were obtained, a calibration curve was plotted.

Table 1 Preparation of gallic acid as a standard

S.No.	Concentration of gallic acid (µg/ml)	Amount of distilled water (µl)	Amount of Folin–Ciocalteu reagent (ml)	Amount of sodium carbonate (ml)
1.	1	999	5	4
2.	2.5	997.5	5	4
3.	5	995	5	4
4.	10	990	5	4
5.	25	975	5	4
6.	50	950	5	4

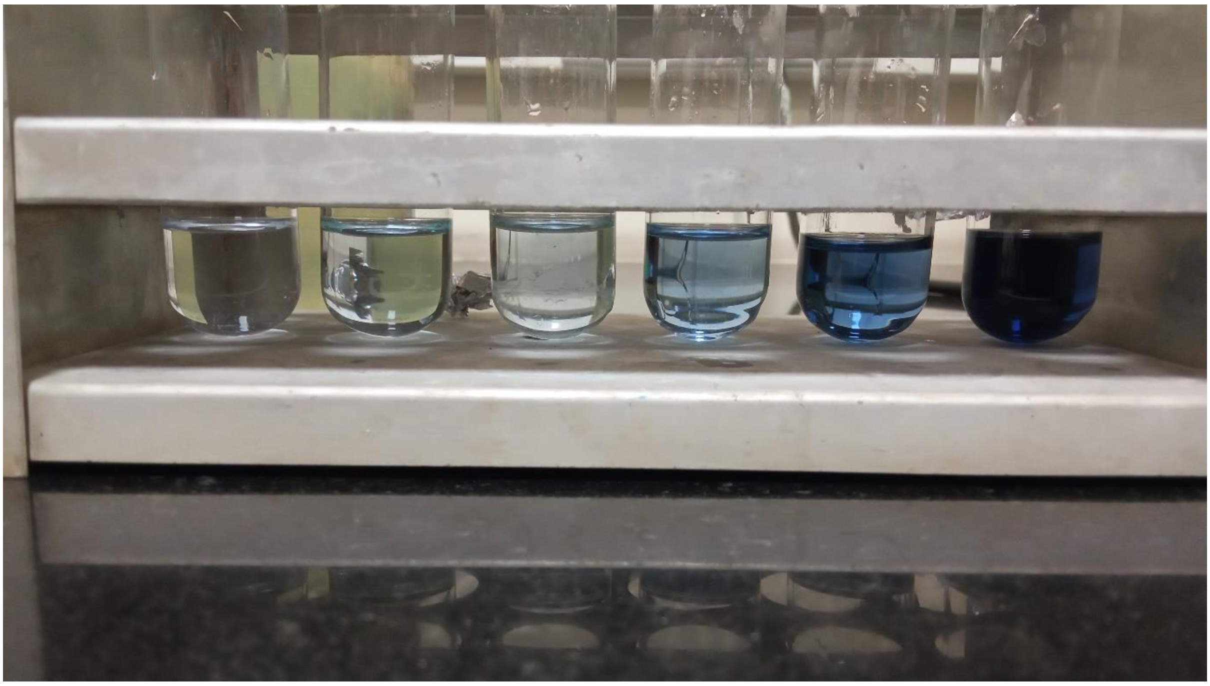

Fig6 – Preparation of Gallic acid as a standard

Preparation of Samples for Total Phenolic Content

A piece of ber was crushed with the aid of water. Weigh of crushed ber (1gram) was measured. The sample was diluted by the dilution of 1:4 (fruit to water). The diluted sample was vortexed for a few minutes. 0.2 ml of diluted sample was taken in a falcon. The falcon was covered with foil paper. 2.5 ml of Folin-ciocalteu reagent was added. The falcon was kept in dark for 5 minutes. After 5 minutes 2ml of sodium carbonate was added to the same falcon. The falcon was incubated for 2 hours at room temperature in the dark. The absorbance was computed at 754 nm wavelength. Deionized water was employed as blank. The experiment was carried out in duplicates. The Total Phenolic Content was calculated by the formula-

$$C = x*(v/m)$$

Where,

C = total phenolic content

X = concentration of the sample

V = volume of a sample taken

M = mass of sample taken

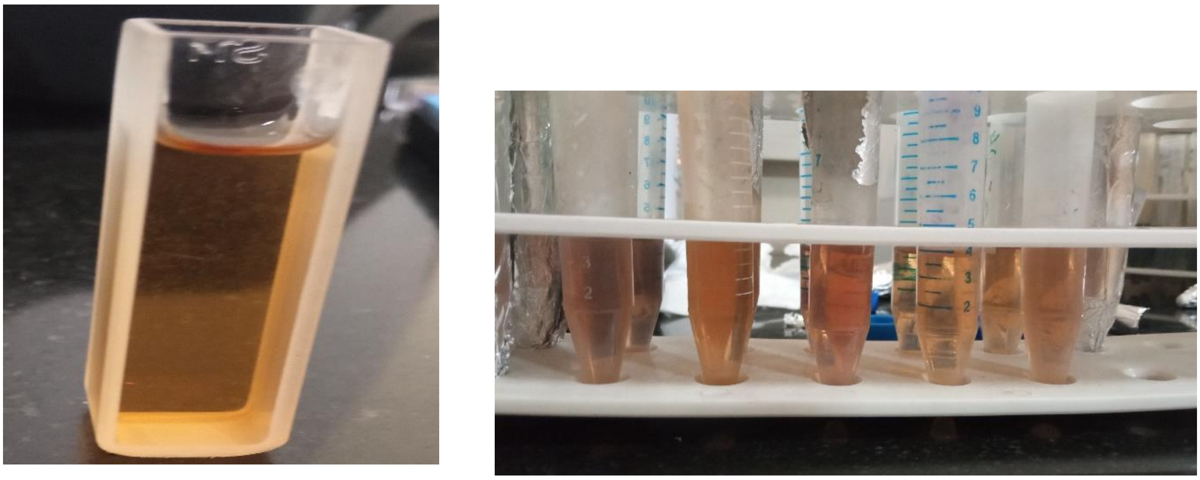

Fig7 – Measuring TPC absorbance for pre-treated ber samples

Acidity

A piece of ber was crushed with the aid of water. Weigh of the crushed ber (1gram)was measured. The sample was diluted by the dilution of 1:4(fruit to water). The diluted sample was vortexed for a few minutes. 2 ml of diluted sample was taken in a beaker. The burette was filled with 0.1N NaOH. A few drops of phenolphthalein indicator were added to the sample. The sample was titrated with 0.1N NaOH. The endpoint is colorless to pink color. The reading were marked down at which the colorless solution changed to pink. The experiment is carried out in duplicates. The titratable acidity was calculated as citric acid percent -

$$\text{Citric Acid \%} = \frac{\text{Titre} * \text{normality of alkali} * \text{volume made up} * \text{Equivalent weight of acid} * 100}{\text{Volume of sample taken for estimation} * \text{wt./volume of sample taken} * 100}$$

Fig8 – Titration of pre-treated ber slices

Total Soluble Solids (TSS)

The pieces of ber were put in distilled water. The pieces of ber were sopped in the water for 10-15 minutes. After 10-15 minutes, the pieces were taken out and squeezed. The total soluble solid content was computed by a refractometer. The readings were pen down. The experiment was carried out in duplicates.

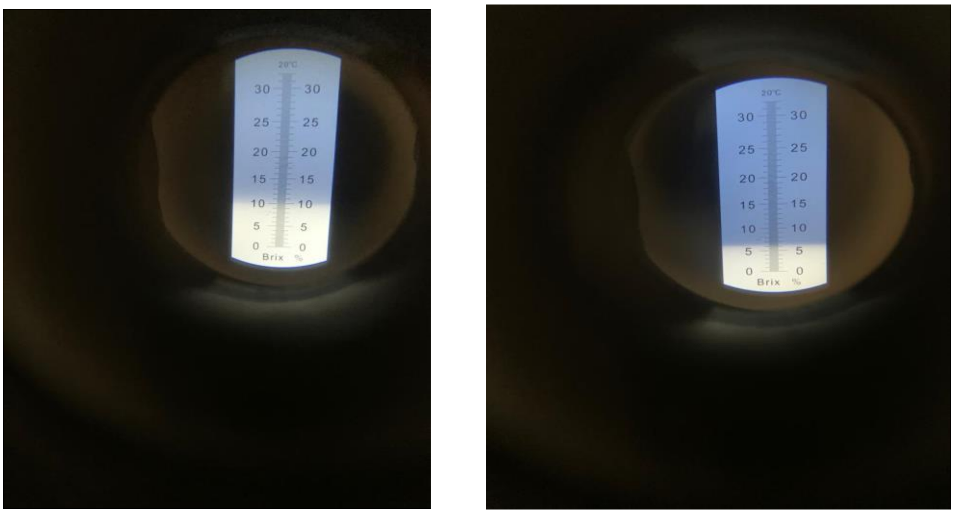

Fig – Measuring the TSS of ber samples

Water Activity

The piece of ber was placed on a small round plate. Measure its water activity by ERMA INC.

Fig11- Measuring the water activity of ber slices

After analyzing these physicochemical properties, the drying parameters (ultrasonication time, ultrasonication amplitude, syrup concentration) for osmotic dehydration of ber were optimized.

Sensory Analysis-

It was analyzed as per the 'Hedonic scale' (1-9 points), and the scores were given by a group of 10 people for the color, taste, overall acceptability, and texture of the fruit. Each sample was kept before every person. For each sample, scores granted were –

Table 2- Hedonic rating

Scores	Hedonic Rating
1.	Like Extremely
2.	Like Very Much
3.	Like Moderately
4.	Like Slightly

5.	Neither Like nor Dislike
6.	Dislike Slightly
7.	Dislike Moderately
8.	Dislike Very Much
9.	Dislike Extremely

Results and discussion

The analysis was aimed to review the impact of ultrasound amplitude, ultrasound time, and sugar solution concentration on drying kinetics of ber. The ultrasound amplitude, ultrasound time, and syrup concentration stretch selected were 30%, 60%, and 90%, 10, 20, and 30 minutes, 40ºBrix, 50ºBrix, and 60ºBrix respectively. The ber samples were dried for 7 hours at 70ºC to reduce the moisture content of the fruit samples. RSM (CCD)was operated to optimize drying parameters. The ANOVA table was generated with the help of RSM. Additionally, the entire optimization was carried out with the replies' anticipated outcomes in mind.

Fresh ber fruit was copped in loads from the native market of Patiala (Punjab). Ber was cut into a diametrically round shape of 6mm thick. The seed is removed from the fruit. The cut samples were given KMS, ultrasound treatments, and osmotic dehydration. The fruit-to-solution ratio kept was 1:5 (Islam and Flink, 1982; Grabowski et al., 1994; Welti et al., 1995; Erketin and Cakaloz, 1996; Pokharkar, 2001; Ghosh, 2002; Sutar, 2003, Ahmed et al. 2016, Ramya and Jain, 2016). The osmotic treatment was given for 3 hours as after that time period water loss get constant till 20 hours Lenart and Flink (1984). The other responses antioxidant property, color, taste, acidity, water activity, texture, TPC, and TSS were evaluated and equated to fresh ber fruit, similar properties. The following parts provide a presentation and discussion of the study's findings.

The analytical review emphasizes on optimization of ultrasound-assisted osmotic dehydration of ber (Ziziphus mauritiana). The results of this study were divided into parts. Part 1-study the effect of osmotic air drying on the drying kinetics of fruit. Part 2-study the impact of osmotic air drying on the fruit's physicochemical properties and osmosis's impact on percentage water loss from fruit samples. Part 3- sensory analysis of pre-treated ber samples.

Effect on Moisture Content:

As can be seen, each of the three parameters chosen—ultrasound amplitude, ultrasound time, and osmotic concentration—had a different impact on the drying of ber (Ziziphus mauritiana). The impact of ultrasound amplitude and ultrasound time is shown on moisture content at 40, 50, and 60 °Brix concentrations of the osmotic solution. It is clear from the graphs that as drying time increases, the MC of ber the sample decreases. In the beginning, the decrease in MC is rapid, whereas in the later stage the decrease in MC is slow. (Fernandes, et al., 2019). The effect of osmotic concentration, ultrasonication amplitude, and ultrasonication time was recorded by which MC gets reduced. More significant influences on moisture content than ultrasonication time came from osmotic concentration, and ultrasonication amplitude. Figure 1 represents the effect of ultrasonication amplitude and ultrasonication time at an osmotic concentration of 40°Brix, Figure 2 represents the effect of ultrasonication amplitude and ultrasonication time at an osmotic concentration of 50°Brix, and Figure 3 represents the effect of ultrasonication amplitude and ultrasonication time at an osmotic concentration of 60°Brix on moisture content. The MC drastically shifted as the osmotic concentration increased from 40 °Brix to 60 °Brix. In 7 hours, the reduction in MC from 5.4-0.84 was noticed in 60 °Brix, the reduction in MC from 5.89-0.85 g of water/g of dry matter was noticed in 50°Brix, and the reduction in MC from 5.9- 1.02 g of water/g of dry matter in 40°Brix. (Fernandes, et al., 2019). The fastest drying rate is seen in the sample treated with ultrasonication time, ultrasonication amplitude, and syrup concentration is 30 minutes, 90%, and 60°Brix respectively. The slowest drying rate is seen in the sample treated with ultrasonication time, ultrasonication amplitude, and syrup concentration is 10 minutes, 30%, and 40°Brix respectively. The eye-catching grounds, higher the all three parameters more water is lost due to osmosis, and low is the moisture content. Although it was the least significant of the three characteristics, ultrasonication had a favorable impact on the moisture content. The early increase in drying rate demonstrates the existence of a heat-up stage. In 60 °Brix osmotic concentration heat-up stage is quickly succeeded by the falling rate stage whereas in 40 °Brix, and 50°Brix there is little stability for a while. It is due to the loss of water during osmotic dehydration. The rapid reduction in moisture content is due high concentration of syrup and high ultrasonication time and amplitude which creates microchannels that help in the removal of water. The earlier review tells that ultrasound-assisted osmotic dehydration boost WL and SG (Bozkir, Ergün, Serdar, et al., 2019). The use of ultrasound catalyzes the change in WL, color, and SG (Corrêa, Justus, de Oliveira, & Alves, 2015). Ultrasonication amplitude and ultrasonication time also have a significant effect on moisture content. The higher the ultrasonication amplitude higher is the rate of WL, whereas lower the ultrasonication amplitude rate of WL is slow. Higher the ultrasonication time higher is the rate of WL, whereas lower the ultrasonication time rate of WL is slow (Fernandes, et al., 2019).

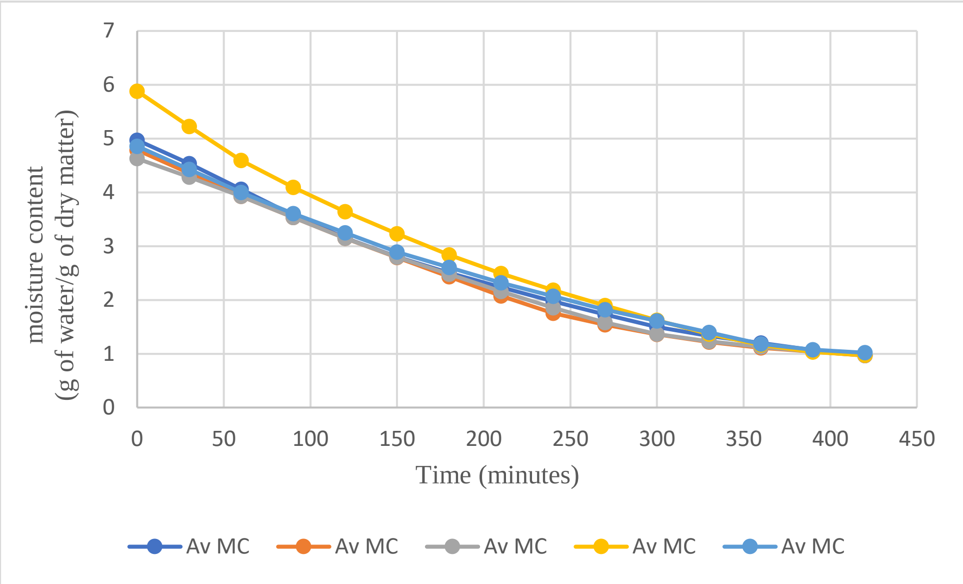

Fig 11 – Effect on moisture content at 40°Brix syrup concentration.

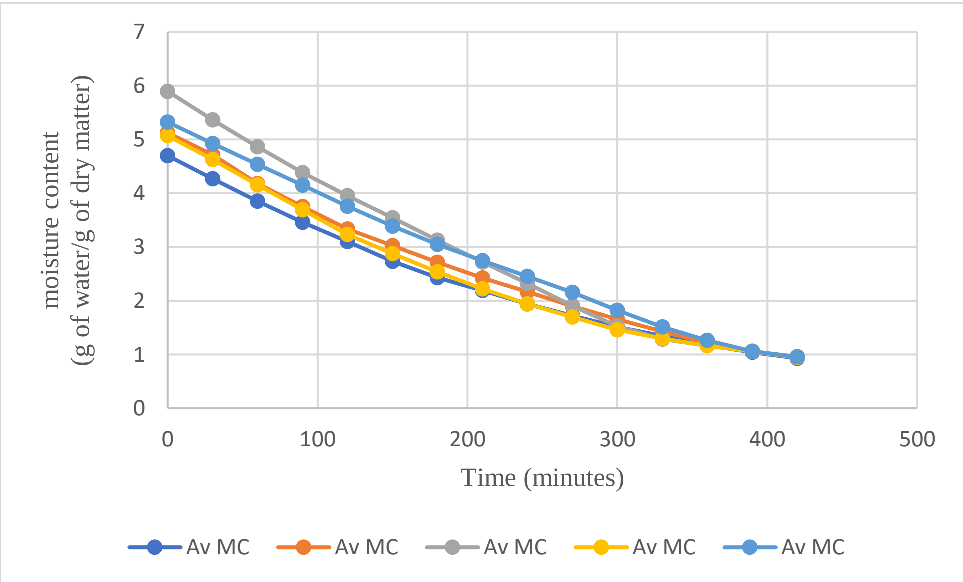

Fig 12 – Effect on moisture content at 50°Brix syrup concentration.

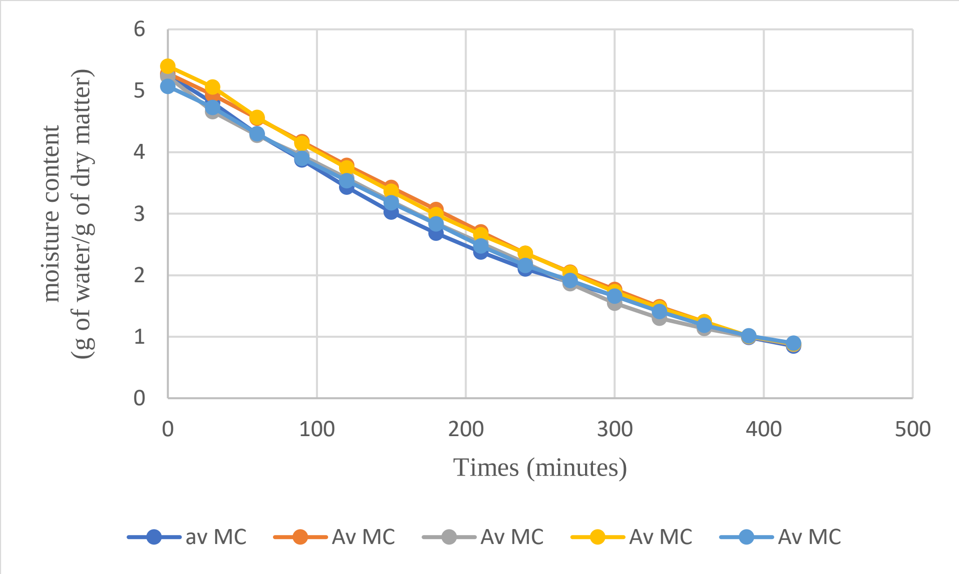

Fig 13 – Effect on moisture content at 60°Brix syrup concentration.

Effect on drying rate

The drying rate during osmotic dehydration was calculated as moisture loss per time. The effect of ultrasonication time, ultrasonication amplitude, and osmotic solution concentration on the drying rate of ber slices are represented in figures 4-6. The data represented in graphs depict that the drying rate increases first to the max and then declines. While the drying rate gradually decreased, it increased quickly. More significant influences on drying rate than ultrasonication time came from osmotic concentration, and ultrasonication amplitude. Figure 4 represents the effect of ultrasonication amplitude and ultrasonication time at an osmotic concentration of 40°Brix, Figure 5 represents the effect of ultrasonication amplitude and ultrasonication time at an osmotic concentration of 50°Brix, and Figure 6 represents the effect of ultrasonication amplitude and ultrasonication time at an osmotic concentration of 60°Brix on drying rate. The fastest drying rate of 0.00463 (g of water/g of dry matter) was noticed where the ber samples were treated in conditions of 90% ultrasonication amplitude, 30 minutes ultrasonication time, and 60°Brix osmotic concentration. The slowest drying rate of 0.001786 (g of water/g of dry matter) was found where the ber samples were treated in conditions of 30% ultrasonication amplitude, 10 minutes ultrasonication time, and 40°Brix osmotic concentration. The medium drying rate of 0.003685 (g of water/g of dry matter) was noticed where the ber samples were treated in conditions of 60% ultrasonication amplitude, 20 minutes ultrasonication time, and 50°Brix osmotic concentration. The eye-catching grounds, higher the all three parameters more water is lost due to osmosis, and faster is the drying rate. Although it was the least significant of the three characteristics, ultrasonication had a favorable impact on the drying rate. The early increase in drying rate demonstrates the existence of a heat-up stage. In 60 °Brix osmotic concentration heat up stage is quickly succeeded by the falling rate stage whereas in 40 °Brix, and 50°Brix there is little stability for a while. It is due to the loss of water during osmotic dehydration. The earlier review tells that ultrasound-assisted osmotic dehydration boost WL and SG (Bozkir, Ergün, Serdar, et al., 2019). The use of ultrasound catalyzes the change in WL, color, and SG (Corrêa, Justus, de Oliveira, & Alves, 2015). The drying rate is directly proportional to WL. The higher the ultrasonication amplitude higher is the rate of WL, whereas lower the ultrasonication amplitude rate of WL is slow. Higher the ultrasonication time higher is the rate of WL, whereas lower the ultrasonication time rate of WL is slow (Fernandes, et al., 2019).

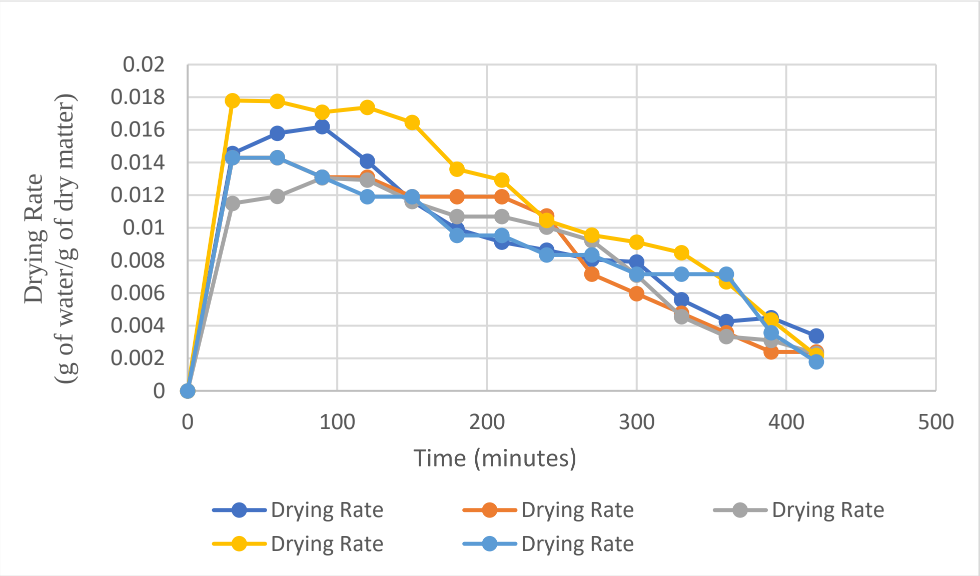

Fig 14 – Effect on drying rate at 40°Brix syrup concentration.

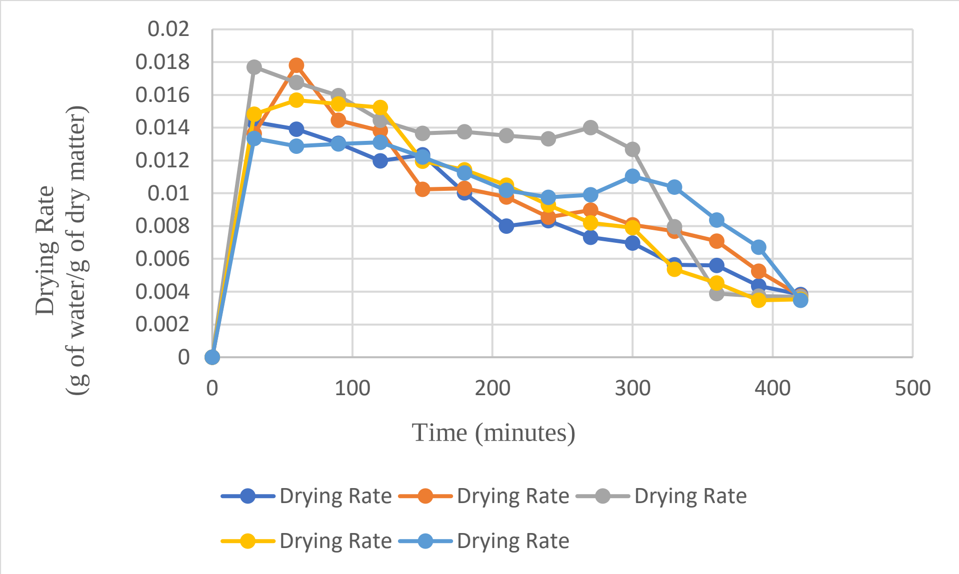

Fig 15 – Effect on drying rate at 50°Brix syrup concentration.

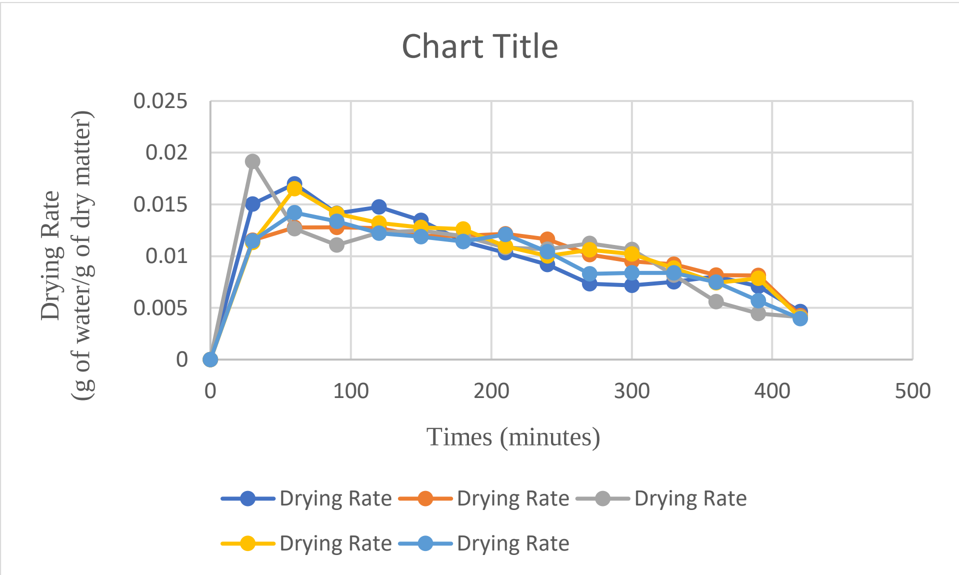

Fig 16 – Effect on drying rate at 60°Brix syrup concentration.

The physicochemical properties reviewed were water activity, antioxidant property, Total Phenolic Content, total soluble salts, and acidity. Effects of osmotic air drying on physicochemical properties were

1. Water activity- Water activity is the amount of water available in fruit for the micro-organism to use. The water activity of fresh fruit was 0.985. After the treatment of

ultrasound and osmotic air-drying the water activity decrease as the ultrasound time, amplitude, and osmotic concentration increase (Zhang et al., 2017, Amami et al., 2017).

Table 3.1- Effect of ultrasound-assisted osmotic air drying on water activity

S.no.	Amplitude	Time	Degree Brix	Water activity
1	60	20	60	0.51
2	60	20	50	0.56
3	60	30	50	0.52
4	90	30	60	0.49
5	60	20	40	0.71
6	30	10	60	0.53
7	30	30	40	0.66
8	90	20	50	0.54
9	60	20	50	0.59
10	90	30	40	0.69
11	30	10	40	0.74
12	60	10	50	0.62
13	90	30	60	0.47
14	60	10	50	0.59
15	60	20	60	0.49
16	30	20	50	0.63
17	30	20	50	0.58
18	60	20	40	0.67
19	60	20	50	0.6
20	60	20	50	0.57
21	30	30	60	0.5
22	90	10	40	0.68
23	30	10	40	0.79
24	90	30	40	0.64
25	60	20	50	0.61
26	90	20	50	0.58
27	30	30	60	0.48

28	30	10	60	0.5
29	60	30	50	0.57
30	90	10	40	0.73
31	90	10	60	0.52
32	90	10	60	0.48
33	30	30	40	0.7

The data obtained from the effect of osmotic air drying on water activity is represented in table 3.1.

The ultrasound-assisted osmotic air drying significantly impacts water activity ($p<0.0001$). Among time, amplitude, and concentration, concentration remarkably impacts water activity. In the quadratic equation, the most remarkable effect is the quadratic term concentration and concentration, and the least remarkable effect is the quadratic term of time. The quadratic model was created using processing factors in their coded format at a 0.01% level of significance. The F-value of the model is 41.32 which means the model is significant. Lack of fit is not significant. The R-squared value is 0.9418.

$$\text{Water Activity} = +\ 0.58 - 0.015 * A - 0.023 * B - 0.010 * C + 6.250\text{E-}003 * A * B + 6.250\text{E-}003 * A * C + 0.010 * B * C + 4.360\text{E-}003 * A^2 - 3.140\text{E-}003 * B^2 + 0.017 * C^2$$

Table 3.2- ANOVA for the effect of ultrasound-assisted osmotic air drying on water activity

Source	Sum of Square	df	Mean Square	F value
Model	0.23	9	0.025	41.32
A-Amplitude	4.205E-003	1	4.205E-003	6.85
B-Time	0.011	1	0.011	17.24
c-Syrup concentration	0.21	1	0.21	339.04
AB	6.250E-004	1	6.250E-004	1.02
AC	6.250E-004	1	6.250E-004	1.02
BC	1.600E-003	1	1.600E-003	2.61
A^2	1.011E-004	1	1.011E-004	0.16
B^2	5.243E-005	1	5.243E-005	0.085

C^2	1.512E-003	1	1.512E-003	2.46
Residual	0.014	23	6.137E-004	
Lack of fit	1.446E-003	5	2.892E-004	0.41
Pure Error	0.013	18	7.039E-004	
Significance- $p<0.0001$			$R^2 = 0.9418$	

Gianotti et al. (2001) noted a decrease in microbial growth of the kiwi fruit samples. This was because sucrose assimilation amplifies the viscosity of fruit(kiwi) impacting the growth kinetics of micro-organisms. Moreover, it is proved by Birmpa, Sfika, and Vantarakis (2013), that ultrasound treatment depletes the numeric of chosen bacteria.

2. Antioxidant properties- DPPH assay is best to measure the antioxidant property. DPPH gets reduced in the presence of free radical. After the treatment of ultrasound and osmotic air-drying, the antioxidant properties were best reported at ultrasound time, amplitude, and osmotic concentration of 20 minutes, 60%, and 50ºBrix respectively. The range of scavenging properties lies between 80.09- 15.35. The antioxidant activity depletes due to the loss of TPC in the process (Rahaman et al., 2019). The early studies tell that the use of ultrasound depletes the bioactive compound in the process of osmotic dehydration [8], [46].

Table 4.1- Effect of ultrasound-assisted osmotic air drying on Antioxidant Property

S.no.	Amplitude	Time	Degree Brix	Antioxidant property
1	60	20	60	37.39
2	60	20	50	80.09
3	60	30	50	68.61
4	90	30	60	17.99
5	60	20	40	37.07
6	30	10	60	46.98
7	30	30	40	37.19
8	90	20	50	73.43
9	60	20	50	75.89
10	90	30	40	41.33

11	30	10	40	15.35
12	60	10	50	56.29
13	90	30	60	21.4
14	60	10	50	51.92
15	60	20	60	41.33
16	30	20	50	70.51
17	30	20	50	71.77
18	60	20	40	38.95
19	60	20	50	79.03
20	60	20	50	77.47
21	30	30	60	25.33
22	90	10	40	22.87
23	30	10	40	17.15
24	90	30	40	43.49
25	60	20	50	76.66
26	90	20	50	70.51
27	30	30	60	30.21
28	30	10	60	48.72
29	60	30	50	51.33
30	90	10	40	29.47
31	90	10	60	42
32	90	10	60	44.89
33	30	30	40	39.74

The data obtained from the effect of ultrasound-assisted osmotic air drying on Antioxidant Property is represented in table 4.1. The osmotic air drying significantly impacts the Antioxidant property ($p<0.0001$). Among time, amplitude, and concentration, concentration has a remarkable impact on the antioxidant property. In the quadratic equation, the most remarkable effect is, the quadratic term of amplitude, and the least remarkable effect is, the quadratic term of concentration and time. The quadratic model was created using processing factors in their uncoded format at a 0.01% level of significance. The F-value of the model is 57.78 which means the model is significant. The R-squared value is 0.9576.

DPPH = +72.58 + 0.22 * A + 0.050 * B + 1.68 * C – 1.20 * A * B – 3.29 * A * C – 10.28 * B * + 2.25 * A^2 – 12.27 * B^2 – 30.62 * C^2

Table 4.2- ANOVA for the effect of ultrasound-assisted osmotic air drying on Antioxidant Property

Source	Sum of Square	df	Mean Square	F value
Model	12728.12	9	1414.24	57.78
A-Amplitude	0.99	1	0.99	0.040
B-Time	0.050	1	0.050	2.043E-003
c-Syrup concentration	56.62	1	56.62	2.31
AB	23.21	1	23.21	0.95
AC	173.38	1	173.38	7.08
BC	1692.29	1	1692.29	69.15
A^2	26.86	1	26.86	1.10
B^2	800.92	1	800.92	32.72
C^2	4988.48	1	4988.48	203.82
Residual	562.91	23	24.47	
Lack of fit	325.20	5	65.04	4.93
Pure Error	237.71	18	13.21	
Significance- $p<0.0001$				$R^2 = 0.9576$

3. Total Phenolic Content-The total phenolic content (TPC) was calculated by making use of the Folin-Ciocalteu colorimetric method the oxidation-reduction reaction employing gallic acid as a standard. After the treatment of ultrasound and osmotic air-drying, the TPC was best reported at ultrasound time, amplitude, and osmotic concentration of 20 minutes, 60%, and 50ºBrix respectively. The range of TPC varies from 2.47-0.15mg GAE/g of dry extract. Considering the previous experimental work, with the use of ultrasound TPC content is lost as compared to non-ultrasound-treated samples. (Nowacka et al., 2018; Siucińska, Mieszczakowska-Frac, Polubok, & Konopacka, 2016). The TPC content gets depleted with the use of divergent osmotic solutions, rabbit eye blueberries [49], and strawberries [27].

Table 5.1- Effect of ultrasound-assisted osmotic air drying on total phenolic content

S. No.	Amplitude	Time	Degree Brix	TPC
1	60	20	60	0.91
2	60	20	50	2.47
3	60	30	50	1.75
4	90	30	60	0.19
5	60	20	40	0.72
6	30	10	60	1.02
7	30	30	40	0.69
8	90	20	50	2.04
9	60	20	50	2.36
10	90	30	40	0.99
11	30	10	40	0.15
12	60	10	50	1.3
13	90	30	60	0.17
14	60	10	50	1.29
15	60	20	60	0.87
16	30	20	50	1.47
17	30	20	50	1.5
18	60	20	40	0.73
19	60	20	50	2.31
20	60	20	50	2.44
21	30	30	60	0.65
22	90	10	40	0.58
23	30	10	40	0.16
24	90	30	40	0.98
25	60	20	50	2.45
26	90	20	50	2.01
27	30	30	60	0.67
28	30	10	60	1.01

29	60	30	50	1.73
30	90	10	40	0.59
31	90	10	60	0.85
32	90	10	60	0.83
33	30	30	40	0.75

The data obtained from the effect of ultrasound-assisted osmotic air drying on total phenolic content is represented in table 5.1. The osmotic air drying significantly impacts total phenolic content ($p<0.0001$). Among time, amplitude, and concentration, amplitude remarkably impacts the total phenolic content. In the quadratic equation, the most remarkable effect is, the linear term of amplitude, and the least remarkable effect is, the quadratic term of syrup concentration. The quadratic model was created using processing factors in their uncoded format at a 0.01% level of significance. The F-value of the model is 22.83 which means the model is significant. The R-squared value is 0.9031.

$TPC = +2.07 + 0.058 * A + 0.039 * B + 0.042 * C – 0.059 * A * B – 0.17 * A * C – 0.25 * B * C – 0.097 * A^2 – 0.33 * B^2 – 1.04 * C^2$

Table5.2- ANOVA for the effect of ultrasound-assisted osmotic air drying on total phenolic content

Source	Sum of Square	df	Mean Square	F value
Model	14.92	9	1.66	23.83
A-Amplitude	0.067	1	0.067	0.97
B-Time	0.031	1	0.031	0.45
c-Syrup concentration	0.034	1	0.034	0.50
AB	0.055	1	0.055	0.79
AC	0.46	1	0.46	6.55
BC	0.98	1	0.98	14.09
A^2	0.050	1	0.050	0.72
B^2	0.59	1	0.59	8.55
C^2	5.80	1	5.80	83.4
Residual	1.60	23	0.070	

Lack of fit	1.58	5	0.32	245.57
Pure Error	0.023	18		
Significance- p<0.0001				$R^2 = 0.9031$

4. Total Soluble Solids – TSS is a measure of total solute content present in dissolved form in the fruit. After the treatment of ultrasound and osmotic air-drying the TSS increases as the ultrasound time, amplitude, and osmotic concentration increase. The TSS stretch from 5-10ºBrix. The earlier review tells that ultrasound-assisted osmotic dehydration boost WL and SG (Bozkir, Ergün, Serdar, et al., 2019). SG gets boosted with time as well as the concentration of osmotic dehydration (Fernandes and Rodrigues 2007; Garcia-Noguera et al. 2010; Kek et al. 2013; Thippanna and Tiwari 2017).

Table 6.1- Effect of ultrasound-assisted osmotic air drying on total soluble solids

S. No.	Amplitude	Time	Degree Brix	TSS
1	60	20	60	10
2	60	20	50	8
3	60	30	50	8
4	90	30	60	10
5	60	20	40	6
6	30	10	60	8
7	30	30	40	6
8	90	20	50	8
9	60	20	50	8
10	90	30	40	7
11	30	10	40	5
12	60	10	50	7
13	90	30	60	10
14	60	10	50	7
15	60	20	60	9
16	30	20	50	7
17	30	20	50	8

18	60	20	40	6
19	60	20	50	8
20	60	20	50	8
21	30	30	60	9
22	90	10	40	6
23	30	10	40	5
24	90	30	40	7
25	60	20	50	8
26	90	20	50	8
27	30	30	60	10
28	30	10	60	9
29	60	30	50	9
30	90	10	40	6
31	90	10	60	9
32	90	10	60	9
33	30	30	40	6

The data obtained from the effect of ultrasound-assisted osmotic air drying on total soluble solids is represented in table 6.1. The osmotic air drying significantly impacts total soluble solids ($p<0.0001$). Among time, amplitude, and concentration, the syrup concentration remarkably impacts total soluble solids. In the quadratic equation, the most remarkable effect is, the linear term of syrup concentration and the least remarkable effect is, the quadratic term of amplitude and time. The quadratic model was created using processing factors in their uncoded format at a 0.01% level of significance. The F-value of the model is 56.35 which means the model is significant. Lack of fit is not significant. The R-squared value is 0.9566.

$$TSS = +7.91 + 0.035 * A + 0.055 * B + 1.65 * C + 0 * A * B - 0.12 * A * C + 0 * B * C - 0.099 * A^2 - 0.099 * B^2 - 0.099 * C^2$$

Table 6.2- ANOVA for the effect of ultrasound-assisted osmotic air drying on total soluble solids

Source	Sum of Square	df	Mean Square	F value
Model	63.66	9	7.07	56.35

A-Amplitude	2.45	1	2.45	19.52
B-Time	6.05	1	6.05	48.2
c-Syrup concentration	54.45	1	54.45	433.76
AB	0	1	0	0
AC	0.25	1	0.25	1.99
BC	0	1	0	0
A^2	0.052	1	0.052	0.41
B^2	0.052	1	0.052	0.41
C^2	0.052	1	0.052	0.41
Residual	2.89	23	0.13	
Lack of fit	0.39	5	0.077	0.56
Pure Error	2.50	18	0.14	
Significance- $p<0.0001$				$R^2 = 0.9566$

5. Acidity – Acidity is measure of citric acid percentage. The acidity of fresh fruit was 0.161. the acidity increased to 0.966. The acidity stretch is 0.322-0.966. After the treatment of ultrasound and osmotic air-drying the acidity decreases as the ultrasound time, amplitude, and osmotic concentration increase. In osmosis the substance with low molecular weight ooze out which further impacts the overall nutritive value of fruit (Lenart, 1996). The less ph of arils is because of organic acids which further are accountable for sensory analysis and storage (Poyrazoglu et al., 2002).

Table 7.1- Effect of ultrasound-assisted osmotic air drying on acidity

S. No.	Amplitude	Time	Degree Brix	Acidity
1	60	20	60	0.322
2	60	20	50	0.644
3	60	30	50	0.483
4	90	30	60	0.322
5	60	20	40	0.805
6	30	10	60	0.483
7	30	30	40	0.805
8	90	20	50	0.483

9	60	20	50	0.644
10	90	30	40	0.644
11	30	10	40	0.966
12	60	10	50	0.644
13	90	30	60	0.322
14	60	10	50	0.805
15	60	20	60	0.483
16	30	20	50	0.644
17	30	20	50	0.805
18	60	20	40	0.805
19	60	20	50	0.644
20	60	20	50	0.644
21	30	30	60	0.322
22	90	10	40	0.805
23	30	10	40	0.966
24	90	30	40	0.805
25	60	20	50	0.644
26	90	20	50	0.644
27	30	30	60	0.483
28	30	10	60	0.483
29	60	30	50	0.644
30	90	10	40	0.805
31	90	10	60	0.322
32	90	10	60	0.483
33	30	30	40	0.805

The data obtained from the effect of ultrasound-assisted osmotic air drying on acidity is represented in table 7.1. The osmotic air drying significantly impacts acidity ($p<0.0001$). Among time, amplitude, and concentration, syrup concentration has a remarkable impact on acidity. In the quadratic equation, the most remarkable effect is, the quadratic term of amplitude and time, time and concentration, amplitude and concentration and the least remarkable effect is, the linear term of amplitude and time. The quadratic model was created using processing factors in their uncoded format at a 0.01% level of significance. The F-value of the model is 23.29 which means the model is significant. Lack of fit is not significant. The R-squared value is 0.9011.

Acidity = + 0.64 – 0.056 * A - 0.056 * B - 0.21 * C + 0.01 * A * B + 0.01 * A * C + 0.01 * B * C + 4.056E-003 * A^2 + 4.056E-003 * B^2 – 0.036* C^2

Table 7.2- ANOVA for the effect of ultrasound-assisted osmotic air drying on acidity

Source	Sum of Square	df	Mean Square	F value
Model	1.02	9	0.11	23.29
A-Amplitude	0.064	1	0.064	13.10
B-Time	0.064	1	0.064	13.10
c-Syrup concentration	0.88	1	0.88	180.69
AB	1.620E-003	1	1.620E-003	0.33
AC	1.620E-003	1	1.620E-003	0.33
BC	1.620E-003	1	1.620E-003	0.33
A^2	8.752E-005	1	8.752E-005	0.018
B^2	8.752E-005	1	8.752E-005	0.018
C^2	6.969E-003	1	6.969E-003	1.44
Residual	0.11	23	4.849E-003	
Lack of fit	7.839E-003	5	1.568E-003	0.27
Pure Error	0.10	18	5.760E-003	
Significance- $p<0.0001$				R^2 = 0.9011

6. Percentage (%) water loss- it is measure of loss of water in percent during osmosis. The % WL varies from 15.64%- 37.04%. After the treatment of ultrasound and osmotic air-drying the water loss increases as the ultrasound time, amplitude, and osmotic concentration increase. The earlier review tells that ultrasound-assisted osmotic dehydration boost WL and SG (Bozkir, Ergün, Serdar, et al., 2019). The use of ultrasound catalyzes the change in WL, color, and SG (Corrêa, Justus, de Oliveira, & Alves, 2015).

Table 8.1- Effect of ultrasound-assisted osmotic air drying on percentage water loss

S. No.	Amplitude	Time	Degree Brix	% water loss
1	60	20	60	17.43
2	60	20	50	20
3	60	30	50	20.59
4	90	30	60	16.35
5	60	20	40	32.67
6	30	10	60	18.63
7	30	30	40	26.72
8	90	20	50	19.61
9	60	20	50	23.66
10	90	30	40	28.97
11	30	10	40	35.25
12	60	10	50	25
13	90	30	60	15.09
14	60	10	50	23.53
15	60	20	60	16.35
16	30	20	50	25.21
17	30	20	50	21.74
18	60	20	40	27.27
19	60	20	50	24.11
20	60	20	50	20.49
21	30	30	60	15.64
22	90	10	40	28.57
23	30	10	40	37.04
24	90	30	40	25.44
25	60	20	50	24.41
26	90	20	50	21.57
27	30	30	60	17.12
28	30	10	60	16.96

29	60	30	50	17.82
30	90	10	40	34.4
31	90	10	60	17.86
32	90	10	60	15.69
33	30	30	40	29.93

The data obtained from the effect of ultrasound-assisted osmotic air drying on percentage water loss is represented in table 8.1. The osmotic air drying significantly impacts percentage water loss ($p<0.0001$). Among time, amplitude, and concentration, the amplitude remarkably impacts the percentage water loss. In the quadratic equation, the most remarkable effect is, the quadratic term of amplitude and syrup concentration and the least remarkable effect is, the linear term of syrup concentration. The quadratic model was created using processing factors in their uncoded format at a 0.01% level of significance. The F-value of the model is 32.08 which means the model is significant. Lack of fit is not significant. The R-squared value is 0.9262.

Percentage water loss = + 22.14 – 1.03 * A – 1.96 * B – 6.96 * C + 0.49 * A * B + 0.51 * A * C + 1.2 * B * C + 0.14 * A^2 – 0.15 * B^2 + 1.54 * C^2

Table 8.2 – ANOVA for the effect of ultrasound-assisted osmotic air drying on percentage water loss

Source	Sum of Square	df	Mean Square	F value
Model	1116.40	9	124.04	32.08
A-Amplitude	21.40	1	21.40	5.54
B-Time	77.07	1	77.07	19.93
c-Syrup concentration	968.00	1	968	250.35
AB	3.8	1	3.80	0.98
AC	4.2	1	4.20	1.09
BC	23.18	1	23.18	6
A^2	0.11	1	0.11	0.028
B^2	0.13	1	0.13	0.033
C^2	12.63	1	12.63	3.27

Residual	88.93	23	3.87	
Lack of fit	7.42	5	1.48	0.33
Pure Error	81.51	18	4.53	
Significance- $p<0.0001$				$R^2 = 0.9262$

SENSORY ANALYSIS

1. Color- it is measure of change in shade of the fruit after the treatment given to it. The use of ultrasound catalyzes the change in WL, color, and SG (Corrêa, Justus, de Oliveira, & Alves, 2015, Aadil et al., 2013, Wiktor et al., 2016, Bermudez-Aguirre, Mobbs, & Barbosa-Canovas, 2011)

Table 9.1 - Effect of ultrasound-assisted osmotic air drying on color

S. No.	Amplitude	Time	Degree Brix	Color
1	60	20	60	6
2	60	20	50	7.5
3	60	30	50	8
4	90	30	60	6.6
5	60	20	40	6.5
6	30	10	60	6.5
7	30	30	40	6.5
8	90	20	50	5.5
9	60	20	50	7.5
10	90	30	40	3
11	30	10	40	7.5
12	60	10	50	8.5
13	90	30	60	6.6
14	60	10	50	8.5
15	60	20	60	6
16	30	20	50	7
17	30	20	50	7
18	60	20	40	6.5
19	60	20	50	7.5

20	60	20	50	7.5
21	30	30	60	5.5
22	90	10	40	5
23	30	10	40	7.5
24	90	30	40	3
25	60	20	50	7.5
26	90	20	50	5.5
27	30	30	60	5.5
28	30	10	60	6.5
29	60	30	50	8
30	90	10	40	5
31	90	10	60	8
32	90	10	60	8
33	30	30	40	6.5

The data obtained from the effect of ultrasound-assisted osmotic air drying on color is represented in table 9.1. The osmotic air drying significantly impacts color ($p<0.0001$) of the ber fruit. Among time, amplitude, and concentration, the concentration remarkably impacts the color of the ber fruit. In the quadratic equation, the most remarkable effect is, the quadratic term of amplitude and syrup concentration and the least remarkable effect is, the quadratic term of syrup concentration as well as amplitude. The quadratic model was created using processing factors in their coded format at a 0.01% level of significance. The F-value of the model is 42.83 which means the model is significant. Lack of fit is not significant. The R-squared value is 0.9437.

$$Color = + 7.42 - 0.49 *A - 0.59 *B + 0.41 *C - 0.17 *A*B + 1.08 *A*C + 0.075 *B*C - 1.12 * A^2 + 0.88 * B^2 - 1.12 * C^2$$

Table 9.2- ANOVA for the effect of ultrasound-assisted osmotic air drying on color

Source	Sum of Square	df	Mean Square	F value
Model	54.46	9	6.05	42.83
A-Amplitude	4.8	1	4.8	33.99
B-Time	6.96	1	6.96	49.28

c-Syrup concentration	3.36	1	3.36	23.8
AB	0.49	1	0.49	3.47
AC	18.49	1	18.49	130.87
BC	0.09	1	0.09	0.64
A^2	6.66	1	6.66	47.15
B^2	4.13	1	4.13	29.22
C^2	6.66	1	6.66	47.15
Residual	3.25	23	0.14	
Lack of fit	3.25	5	0.65	
Pure Error	0	18	0	
Significance- $p<0.0001$				$R^2 = 0.9437$

2. Texture- It is measure of change in appearance of the fruit after the treatment given to it. According to this study, the dried kiwi fruits' organoleptic qualities diminished as the ultrasonic duration increased. Additionally, the findings demonstrated that when ultrasound time increased from 20 to 40 minutes, the samples' look and texture considerably degraded in quality. Sanhua plum's softer texture is thought to be the cause of the decrease in chewiness. Chickpeas that underwent ultrasonic treatment yielded a comparable outcome (Yildirim, Öner, & Bayram, 2013).

Table 10.1- Effect of ultrasound-assisted osmotic air drying on Texture

S. No.	Amplitude	Time	Degree Brix	Texture
1	60	20	60	6.5
2	60	20	50	7.5
3	60	30	50	8
4	90	30	60	6
5	60	20	40	4.5
6	30	10	60	6.5
7	30	30	40	7
8	90	20	50	6.5
9	60	20	50	7.5

10	90	30	40	3
11	30	10	40	5.5
12	60	10	50	8.5
13	90	30	60	6
14	60	10	50	8.5
15	60	20	60	6.5
16	30	20	50	7
17	30	20	50	7
18	60	20	40	4.5
19	60	20	50	7.5
20	60	20	50	6
21	30	30	60	6.5
22	90	10	40	5
23	30	10	40	5.5
24	90	30	40	3
25	60	20	50	6
26	90	20	50	6.5
27	30	30	60	6.5
28	30	10	60	6.5
29	60	30	50	8
30	90	10	40	5
31	90	10	60	7.5
32	90	10	60	7.5
33	30	30	40	7

The data obtained from the effect of ultrasound-assisted osmotic air drying on Texture is represented in table 10.1. The osmotic air drying significantly impacts texture ($p<0.0001$) of the ber fruit. Among time, amplitude, and concentration, the concentration remarkably impacts the color of the ber fruit. In the quadratic equation, the most remarkable effect is, the quadratic term of time and the least remarkable effect is, the quadratic term of syrup concentration. The quadratic model was created using processing factors in their coded format at a 0.01% level of significance. The F-value of the model is 30.23 which means the model is significant. Lack of fit is not significant. The R-squared value is 0.9221.

Texture= + 7.10 - 0.45 * A - 0.25 * B + 0.80 * C - 0.62 * A * B + 0.63 * A * C - 0.12 * B * C - 0.48 * A^2 + 1.02 * B^2 - 1.73 * C^2

Table 10.2- ANOVA for the effect of ultrasound-assisted osmotic air drying on Texture

Source	Sum of Square	df	Mean Square	F value
Model	53.49	9	5.94	30.23
A-Amplitude	4.05	1	4.05	20.6
B-Time	1.25	1	1.25	6.36
c-Syrup concentration	12.8	1	12.8	65.1
AB	6.25	1	6.25	31.79
AC	6.25	1	6.25	31.79
BC	0.25	1	0.25	1.27
A^2	1.24	1	1.24	6.3
B^2	5.51	1	5.51	28.01
C^2	15.97	1	15.97	81.22
Residual	4.52	23	0.2	
Lack of fit	1.82	5	0.36	2.43
Pure Error	2.7	18	0.15	
Significance- $p<0.0001$				R^2 = 0.9221

3. Taste – It is measure of flavor of the fruit after treatment given to it.

Table 11.1 - Effect of ultrasound-assisted osmotic air drying on taste

S. No.	Amplitude	Time	Degree Brix	Taste
1	60	20	60	6.5
2	60	20	50	7.5
3	60	30	50	8
4	90	30	60	6.5
5	60	20	40	5
6	30	10	60	7
7	30	30	40	5
8	90	20	50	6

9	60	20	50	7.5
10	90	30	40	3
11	30	10	40	6.5
12	60	10	50	8.5
13	90	30	60	6.5
14	60	10	50	8.5
15	60	20	60	6.5
16	30	20	50	8
17	30	20	50	8
18	60	20	40	5
19	60	20	50	7.5
20	60	20	50	6
21	30	30	60	6.5
22	90	10	40	5
23	30	10	40	6.5
24	90	30	40	3
25	60	20	50	6
26	90	20	50	6
27	30	30	60	6.5
28	30	10	60	7
29	60	30	50	8
30	90	10	40	5
31	90	10	60	6.5
32	90	10	60	6.5
33	30	30	40	5

The data obtained from the effect of ultrasound-assisted osmotic air drying on taste is represented in table 11.1. The osmotic air drying significantly impacts taste ($p<0.0001$) of the ber fruit. Among time, amplitude, and concentration, the concentration remarkably impacts the color of the ber fruit. In the quadratic equation, the most remarkable effect is, the linear term of syrup concentration and the least remarkable effect is, the quadratic term of syrup concentration. The quadratic model was created using processing factors in their coded format at a 0.01% level of significance. The F-value of the model is 25.88 which means the model is significant. The R-squared value is 0.9101.

Taste = + 7.26 - 0.60 * A -0.45 * B + 0.85 * C + 0.000 * A*B + 0.38 *A*C + 0.38 * B*C - 0.48 * A^2 + 0.77 * B^2 - 1.73 * C^2

Table 11.2 – ANOVA for the effect of ultrasound-assisted osmotic air drying on taste

Source	Sum of Square	df	Mean Square	F value
Model	53.71	9	5.97	25.88
A-Amplitude	7.20	1	7.2	31.22
B-Time	4.05	1	4.05	17.56
c-Syrup concentration	14.45	1	14.45	62.66
AB	0	1	0	0
AC	2.25	1	2.25	9.76
BC	2.25	1	2.25	9.76
A^2	1.25	1	1.25	5.41
B^2	3.12	1	3.12	13.52
C^2	16	1	16	69.4
Residual	5.3	23	0.23	
Lack of fit	2.6	5	0.52	3.47
Pure Error	2.7	18	0.15	
Significance- $p<0.0001$				$R^2 = 0.9101$

4. Overall Acceptability – It is measure grounded on hedonics.

Table 12.1 - Effect of ultrasound-assisted osmotic air drying on overall acceptability

S. No.	Amplitude	Time	Degree Brix	Overall acceptability
1	60	20	60	6.2
2	60	20	50	6.99
3	60	30	50	8
4	90	30	60	6.69
5	60	20	40	5.3

6	30	10	60	6.67
7	30	30	40	6.31
8	90	20	50	6
9	60	20	50	6.99
10	90	30	40	3
11	30	10	40	6.33
12	60	10	50	8.5
13	90	30	60	6.69
14	60	10	50	8.5
15	60	20	60	6.2
16	30	20	50	7.33
17	30	20	50	7.33
18	60	20	40	5.3
19	60	20	50	6.99
20	60	20	50	6.99
21	30	30	60	6.165
22	90	10	40	5
23	30	10	40	6.33
24	90	30	40	3
25	60	20	50	6.99
26	90	20	50	6
27	30	30	60	6.166
28	30	10	60	6.67
29	60	30	50	8
30	90	10	40	5
31	90	10	60	7.33
32	90	10	60	7.33
33	30	30	40	6.31

The data obtained from the effect of ultrasound-assisted osmotic air drying on overall acceptability is represented in table 12.1. The osmotic air drying significantly impacts overall acceptability ($p<0.0001$) of the ber fruit. Among time, amplitude, and concentration, the concentration remarkably impacts the color of the ber fruit. In the quadratic equation, the most remarkable effect is, the quadratic term of time and the least remarkable effect is, the quadratic term of syrup concentration. The quadratic model was created using processing factors in their coded format at a 0.01% level of significance. The F-value of the model is 68.31 which means the model is significant. The R-squared value is 0.9639.

Overall acceptability = + 7.18 - 0.48 * A - 0.37 * B + 0.71* C - 0.26 * A*B + 0.73 * A*C + 0.11 * B*C -0.63 * A^2 + 0.96 * B^2 - 1.54 * C^2

Table 12.2 – ANOVA for the effect of ultrasound-assisted osmotic air drying on overall acceptability

Source	Sum of Squares	df	Mean square	F- value
Model	47.61	9	5.29	68.31
A-Amplitude	4.58	1	4.58	59.14
B-Time	2.69	1	2.69	34.68
c-Syrup concentration	10.13	1	10.13	130.75
AB	1.12	1	1.12	14.45
AC	8.48	1	8.48	109.51
BC	0.19	1	0.19	2.47
A^2	2.09	1	2.09	26.96
B^2	4.89	1	4.89	63.10
C^2	12.64	1	12.64	163.23
Residual	1.78	23	0.077	
Lack of fit	1.78	5	0.36	1.282E+007
Pure Error	5.000E-007	18		
Significance- p<0.0001				R^2 = 0.9639

Optimization

1. Overall Optimization:

   RSM is used to optimize the factors to get desirable results of responses. Each component and response on the menu were assigned the desired aim. The choices for potential objectives are within range for factors whereas, minimum, maximum, and within range for responses. Every response was given equal importance. The option that scored highly for desirability out of all the options was chosen. The replies' predictive values and ideal optimized factors ultrasonication amplitude, ultrasonication time, and osmotic concentration were 64.60%, 10 minutes, and 54.44°Brix respectively. The best-case scenario is shown in the table with overall desirability of 0.933 for the UAOD system.

Table 13 - Overall optimization for the UAOD system

S.no.	Name	Goal	Lower Limit	Upper Limit	Importance
1	Amplitude	is in range	30	90	3
2	Time	is in range	10	30	3
3	Syrup concentration	is in range	40	60	3
4	Water activity	Minimize	0.47	0.79	3
5	TSS	is in range	5	10	3
6	Acidity	is in range	0.322	0.966	3
7	DPPH	is in range	15.35	80.09	3
8	TPC	is in range	0.15	2.47	3
9	Percentage water loss after osmosis	is in range	15.09	37.04	3
10	Color	maximize	3	8.5	3
11	Texture	maximize	3	8.5	3
12	Taste	maximize	3	8.5	3
13	Overall acceptability	maximize	3	8.5	3
Desirability - 0.933					

2. Individual Optimization:
    - Water activity- The choices for potential objectives are within range for factors whereas, none for responses except water activity. Water activity desired aim was minimum. The importance given to water activity was 3. The option that scored highly for desirability out of all the options was chosen as follows ultrasonication amplitude, ultrasonication time, osmotic concentration 69.03%, 30 minutes, and 60°Brix respectively. The best-case scenario is shown in the table with desirability of 0.97 for the water activity.

- TSS- The choices for potential objectives are within range for factors whereas, none for responses except TSS. TSS desired aim was maximum. The importance given to TSS was 3. The option that scored highly for desirability out of all the options was chosen as follows ultrasonication amplitude, ultrasonication time, osmotic concentration 90%, 30 minutes, and 60°Brix respectively. The best-case scenario is shown in the table with desirability of 1 for the TSS.
- Acidity- The choices for potential objectives are within range for factors whereas, none for responses except acidity. Acidity desired aim was minimum. The importance given to water activity was 3. The option that scored highly for desirability out of all the options was chosen as follows ultrasonication amplitude, ultrasonication time, osmotic concentration 30%, 10 minutes, and 40°Brix respectively. The best-case scenario is shown in the table with desirability of 1 for the acidity.
- DPPH- The choices for potential objectives are within range for factors whereas, none for responses except DPPH. DPPH desired aim was in range. The importance given to water activity was 3. The option that scored highly for desirability out of all the options was chosen as follows ultrasonication amplitude, ultrasonication time, osmotic concentration 60%, 20 minutes, and 50°Brix respectively. The best-case scenario is shown in the table with desirability of 1 for the DPPH.
- TPC- The choices for potential objectives are within range for factors whereas, none for responses except TPC. TPC desired aim was in range. The importance given to TPC was 3. The option that scored highly for desirability out of all the options was chosen as follows ultrasonication amplitude, ultrasonication time, osmotic concentration 60%, 20 minutes, and 50°Brix respectively. The best-case scenario is shown in the table with desirability of 1 for the TPC.
- Percentage water loss after osmosis- The choices for potential objectives are within range for factors whereas, none for responses except percentage water loss after osmosis. Percentage water loss after osmosis desired aim was maximum. The importance given to the percentage water loss after osmosis was 3. The option that scored highly for desirability out of all the options was

chosen as follows ultrasonication amplitude, ultrasonication time, osmotic concentration 90%, 30 minutes, and 60°Brix respectively. The best-case scenario is shown in the table with desirability of 1 for the percentage water loss after osmosis.

- Color- The choices for potential objectives are within range for factors whereas, none for responses except the color. Color desired aim was maximum. The importance given to color was 3. The option that scored highly for desirability out of all the options was chosen as follows ultrasonication amplitude, ultrasonication time, osmotic concentration 60%, 10 minutes, and 50°Brix respectively. The best-case scenario is shown in the table with desirability of 1 for the color.
- Texture- The choices for potential objectives are within range for factors whereas, none for responses except texture. Texture desired aim was maximum. The importance given to texture was 3. The option that scored highly for desirability out of all the options was chosen as follows ultrasonication amplitude, ultrasonication time, osmotic concentration 66.41%, 10.01 minutes, and 53.25°Brix respectively. The best-case scenario is shown in the table with desirability of 1 for the texture.
- Taste - The choices for potential objectives are within range for factors whereas, none for responses except taste. The taste desired aim was maximum. The importance given to taste was 3. The option that scored highly for desirability out of all the options was chosen as follows ultrasonication amplitude, ultrasonication time, osmotic concentration 36.29%, 10.07 minutes, and 50.33°Brix respectively. The best-case scenario is shown in the table with desirability of 1 for the taste.
- OA- The choices for potential objectives are within range for factors whereas, none for responses except OA. OA desired aim was maximum. The importance given to OA was 3. The option that scored highly for desirability out of all the options was chosen as follows ultrasonication amplitude, ultrasonication time, osmotic concentration 60%, 10 minutes, and 50°Brix respectively. The best-case scenario is shown in the table with desirability of 1 for the OA.

CONCLUSION

From this investigation, it is concluded that ultrasound is indeed the best pre-treatment to study the drying kinetics of fruits. An intriguing technique that complements traditional air-drying in processing is the use of ultrasonic. Shorter air-drying times result from the fruit's increased water diffusivity following ultrasonic pre-treatment. This might be brought on by the microchannels that are created when ultrasound is applied. To comprehend the creation of microchannels and the alteration in fruit’s cell membrane and cell structure during the process, further research needs to be done on this phenomenon. The outcomes demonstrated that ultrasonication as pre-treatment is intriguing when significant volumes of water from the fruit must be eliminated. The time utilized before air drying in osmotic dehydration is more than the cumulative processing time, whereas to eliminate less water from fruit only osmotic dehydration is utilized prior to air-drying. In order to achieve the best-operating conditions for maximum WL, drying rate, and solid gain, MC of ber slices, RSM helped optimize process parameters for osmotic dehydration as pre-treatment of ber slices. The overall optimization for the UAOD system were 64.60%, 10 minutes, and 54.44°Brix ultrasonication amplitude, ultrasonication time, and osmotic concentration respectively. The condition optimized for maximum WL, TSS, and drying rate minimum MC, acidity, and water activity were 90% ultrasonication amplitude, 30 minutes ultrasonication time, 60°Brix syrup concentration in order to get MC 0.84 and drying rate of 0.0046. The condition optimized for DPPH, and TPC, were 60% ultrasonication amplitude, 20 minutes of ultrasonication time, and 50°Brix syrup concentration. The product was not adversely affected in terms of color, acidity, or bioactive compounds. To cut energy costs and preserve the product's authenticity, osmotic dehydration combined with ultrasonication of ber could be used as a pre-treatment prior to air-drying.

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