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Studies on Mass Transfer Kinetics of Kokum based anthocyaninin fused osmo-Dehydrated Pineapple Cubes

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ABSTRACT: Bioactive compounds play an important role in functional food. Various bioactive compounds can be successfully infused into the solid food matrix by means of osmotic dehydration. The current experiment focused on the use of anthocyanin as a food colourant to infuse into pineapple cubes via osmotic dehydration and evaluated for changes in mass transfer kinetics and anthocyanin infusion. A study was conducted to develop kokum-based anthocyanin-infused osmo-dehydrated pineapple cubes using 5 levels (0, 40, 50, 60 and 100%) of kokum extract, 4 levels (6, 12, 18 and 24 h) of infusion time followed by 2 drying methods (solar tunnel drying and tray drying) to optimize the process parameters. Pineapple cubes infused with 60% kokum extract for 24 h followed by tray drying were found acceptable with superior sensory quality and anthocyanin content.

Keywords: Pineapple, infusion, kokum, anthocyanin, Osmo-dehydration, mass transfer, drying.

INTRODUCTION

Pineapple (*Ananas comosus.* L.) belongs to the family Bromeliaceae (Nazaneen *et al*., 2015). It is one of the most prominent tropical fruits and is known as the "Golden Queen" all over the world due to its excellent taste and flavour (Sarkar *et al*., 2018). After banana and citrus fruits, pineapple is the world's third most important tropical fruit. India in stands sixth position (Nazaneen *et al*., 2015) among the world largest producer of pineapple contributing 8 per cent of global trade with the annual production of 1799 thousand metric tonnes (Anon., 2020). This fruit is highly perishable and only available during the season. Mature fruit contains 14 per cent sugar, bromelain- a protein digesting enzyme and a good amount of malic acid, citric acid, vitamin A and B. Pineapples can be eaten or served fresh, cooked, juiced, or preserved. Pineapple is used to make a variety of foods such as syrup, squash, jelly, and candy (Chaudhary *et al*., 2019). Osmotic dehydration, in combination with other drying technologies, allows for the production of novel shelf-stable types of high-quality pineapple products for both the domestic and export markets.

Osmotic dehydration is a processing method used to obtain partially dehydrated foods. Food is placed in a concentrated hypertonic solution in such a way that a driving force for removal of water is established due to an osmotic pressure difference between the food and the solution in this operation. The food acts as a semipermeable nonselective membrane, allowing leaching of solutes from the fruit tissue into the osmotic solution. Osmotic processes are not only used to dehydrate products; they can also be used to introduce physiologically active components such as calcium, iron, or selenium, as well as preservatives or nutritional or sensory important compounds, into a product to improve its nutritional or functional properties without compromising their integrity.

Anthocyanins are the most numerous and likely the important class of water-soluble natural pigments which imparts orange, red, purple and blue colours in many fruits, vegetables, flowers, leaves, roots and other plant organs. Anthocyanins are well-known for their pharmacological properties, which include antioxidant, anti-inflammatory and anti-carcinogenic activity. Phenolic from diverse sources are used as a food colouring agent. Anthocyanin's eye-catching colour and water solubility allow it to be incorporated into aqueous food systems, as well as potential health benefits, which considered anthocyanin as a potential replacement for synthetic colour (Nayak *et al*., 2009). The ripe kokum fruits of dark purple colour or red with yellow tinge having a pleasant flavour and a sour taste are good source of anthocyanins.

Kokum (*Garcinia indica*) is an underexploited tree also known as 'Cool King' of Indian foods, belongs to the botanical family Clusiaceae. The ripe fruits are sour to taste and have a short shelf life of approximately a week. The rind contains moisture (80.0 g/100 g), protein (1%), tannin (1.7%), pectin (0.9%), total sugars (4.1%) and fat (1.4%). The fresh fruit kokum contains 2.4 g per 100 g anthocyanins (Nayak *et al*., 2010). The main anthocyanins found in kokum are cyanidin-3-sambubioside and cyanidin-3-glucoside.

From the past research it has been found that various bioactive compounds can be successfully infused into the solid food matrix by means of osmotic dehydration. The current study focused on the use of anthocyanin as a food colourant to infuse into pineapple cubes via osmotic dehydration therefore a study was conducted to optimize the process parameters for development of kokum-based anthocyanin infused osmo-dehydrated pineapple cubes.

MATERIALAND METHODS

The investigation was carried out in the Department of Post Harvest Technology, College of Horticultural Engineering and Food Technology, Devihosur, Haveri (UHS, Bagalkot), Karnataka, during the year 2020-21.

Procurement of raw materials: Pineapple variety Gaint Kew fruits were collected from the farmers field at Thogarsi, Shivamogga. Kokum rind was procured from Kadamba Marketing Souharda Sahakari Niyamita, Sirsi for infusion of kokum extract into the osmosed pineapple cubes.

Preparation of sample: Fresh pineapple fruits with uniform maturity (60-70%), good colour and shape were selected. The fruits washed, weighed and de-crowned before the central core was removed with a pineapple corer, hand peeled with a knife and individual eyes were removed with scissors. The fruit is then cut into 15 mm thick uniform slices, which are further cut into 6-8 uniform cubes.

Preparation of kokum anthocyanin extract: Dried kokum rind was washed and immersed in R.O. purified water in a 1:2 ratio. The mixture was slightly heated and left for 24 h to extract anthocyanin. The extract was filtered using muslin cloth. Total soluble solids in the kokum extract was found to be 22.5°Brix, which was raised to 60°Brix by adding sugar. The extract was stored in the refrigerator at 4-5°C and was drawn as needed for the experiment.

Osmotic treatment for candy making process: Sugar syrup of 60ºBrix were prepared. To make 60°Brix concentration sugar syrup, 1.2 kg of sugar was mixed with 0.8 kg of water. While boiling the sugar syrup solution, citric acid (0.2%) was added and 0.1 per cent of potassium metabisulfite was added to sugar syrup after dissolving in little sugar syrup once the syrup was cooled. The pineapple cubes were subjected to osmotic treatment by boiling in prepared sugar solution for 15-20 min, followed by cooling for 24 h at room temperature. Cubes to sugar syrup ratio followed was 1:1.

Osmotic treatment for anthocyanin infusion: The osmosed pineapple cubes were further subjected to impregnation with anthocyanin solution having 60°Brix at different concentration (40, 50, 60 and 100%) for a period of 6, 12, 18 and 24 h in each solution

Osmotic treatment for anthocyanin infusion: The anthocyanin infused pineapple cubes were subjected to solar tunnel drying and tray drying to attain the optimum moisture level. The cubes subjected to drying in tray drier at temperature of 60°C for a period of 8 to 10 h. While, in solar tunnel drier with recorded average temperature of 35 and 55°C during morning and evening respectively, dried for 2 days. The methodology used for the preparation of kokum-based anthocyanin-infused osmo-dehydrated pineapple cubesare mentioned in Fig. 1.

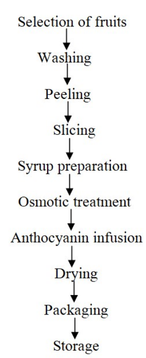

Fig. 1. Flow chart for anthocyanin infusion and osmotic dehydration of pineapple cubes

Treatment details:

Factors	Levels
Factor 1: Kokum Extract concentration (%)	C_1: 0% C_2: 40% C_3: 50% C_4: 60% C_5: 100%
Factor 2: Infusion time	T_1: 6 h T_2: 12 h T_3: 18 h T_4: 24 h
Factor 3: Method of drying	D_1: Solar tunnel dryer D_2: Tray dryer

Design: 3 Factorial CRD with 40 treatments and 2 replications.

Constant Factors: 60°Brix Sugar syrup, 0.2 per cent citric acid and 0.1 per cent KMS

Observation recorded: The following physico-chemical parameters were recorded immediately after preparation of kokum-based anthocyanin-infused osmo-dehydrated pineapple cubes.

Water loss (%): The weight of fresh fruit before and after osmosis was recorded in an electronic balance. The dry mass of fresh fruit and dry mass after osmosis were measured, and per cent water loss was calculated using the formula given by Sridevi and Genitha (2012).

$$WL\,(\%) = \frac{(W_o - W_t) + (S_t - S_o)}{W_o} \times 100$$

W_O = Initial weight of fruit slices, W_t = Weight of fruit slices after osmotic dehydration

S_0 = Initial dry mass of fruit slices, S_t = Dry mass of fruit slices after osmotic dehydration

$$SG\,(\%) = \frac{m - m_o}{m_o} \times 100$$

Solid gain (%): It was determined using the procedure followed by Chavan *et al*. (2010).

m = Dry mass of fruit after osmosis, m_o= Initial dry mass of fresh fruit prior to osmosis

Weight reduction (%): Weight reduction was calculated in terms of percentage using the method described by Yadav *et al*. (2011).

$$WR\,(\%) = \frac{M_o - M}{M_o} \times 100$$

M_o= Initial mass of fruit slices prior to osmosis (g), M = Mass of fruit slices after osmosis (g)

Moisture content (%) and total solids (%). The moisture content of fresh slices, osmosed slices, and osmotically dehydrated samples was calculated as a percentage. Ten grammes of sample were placed in a pre-weighed China dish and placed in a hot air oven at temperature of 105° for a period of 6 hour, with the weight recorded using an electronic balance. Drying was continued until consistent weights were observed between two subsequent weightings. Moisture content was determined on fresh

$$\text{Moisture content}\,(\%) = \frac{\text{Moisture loss}}{\text{Sample weight}} \times 100$$

weight basis. Total solids were calculated by subtracting moisture content from 100.

Total solids (%) = 100 - moisture content

Determination of Anthocyanin content (mg/100 g): Total anthocyanin content was estimated by using the method given by AOAC (1990**).**

$$\text{Total O.D./100 g} = \frac{\text{O.D.} \times \text{Vol. made up}}{\text{Wt. of sample}} \times 100$$

$$\text{Total anthocyanin (mg/100 g)} = \frac{\text{Total O.D.} / 100\text{ g}}{\text{Wt. of sample}} \times 98.2$$

Organoleptic evaluation: The organoleptic characters were evaluated by a panel of semi-trained judges consisting of teachers and post-graduate students of CHEFT, Devihosur, on a nine-point hedonic scale as per the method of Ranganna (2003).

Experimental design: The data obtained from the experiment was analysed by using factorial Completely randomized design (FCRD). The interpretation of data was carried out in accordance with Panse and Sukhatme (1985). The level of significance used in the 'F' test was p=0.05.

RESULT AND DISCUSSION

A. Effect of treatments on mass transfer of water loss

Table 1 shows data on percent water loss during osmotic infusion as influenced by different treatments. The pineapple cubes infused for 12 h with 40 per cent kokum extract recorded maximum water loss (47.44%). Further, mean value for maximum water loss (45.79%) was recorded in pineapple cubes infused with C_2 (kokum extract 40%) for the factor concentration of kokum extract. During osmotic dehydration over the period of increase in infusion time increased the water loss (44.63%) upto 18 h of infusion for the factor infusion time. A close perusal of data indicates that increase in water loss percentage may be due to combination of dewatering and infusion which can modify the functional properties of food materials and also due to higher solute water exchange due to increase in concentration and duration of infusion. Similar results were reported by Katke *et al*. (2018) in sugarless amla (*Phyllanthus emblica*) candy, Tippanna *et al*. (2019) in pineapple slices.

B. Effect of treatments on mass transfer of weight reduction

The kinetics of osmotic dehydration is affected by geometry and size of the food material. Maximum weight reduction of 27.50 per cent was obtained for cubes infused with C_2 (kokum extract 40%) for the duration of T_2 (12 h).Whereas, for the factor kokum extract concentration pineapple cubes infused with 40% kokum extract showed maximum weight reduction (26.13%) (Table 1). Increase in infusion time of pineapple cubes showed the decreasing trend in weight reduction up to T_3 (18 h of infusion) with minimum weight reduction (21.65%) (Table 1). These results were in accordance with Khanom *et al*. (2015) in osmotic dehydration of pineapple cubes, Tippanna *et al*. (2019) in effect of osmotic dehydration on mass transfer kinetics in pineapple slices.

C. Effect of treatments on mass transfer of solid gain

Solid gain is an index of solute diffusion into the pineapple cubes and it has increased with increase in concentration of kokum extract and time. The highest solid gain (24.11%) was obtained in pineapple cubes with combination of treatments $C_4T_{4.}$ Whereas, for the factor concentration of kokum extract maximum per cent of solid gain (22.59%) was observed in C_4 (Table 2). Increase in surrounding solution concentration decreased the moisture content and significantly increased the solid content in osmotic dehydration process (Adsare *et al*., 2016; Chaudhary *et al*., 2018). Considering the factor time maximum solid gain (22.98%) was observed in $T_{3.}$ It may be due to mass transfer and final product quality of osmotically dehydrated products depends on several factors, such as tissue properties (Saurel, 1994; Fernandes *et al*., 2009); process time (Germer *et al*., 2010), apricot (Ispir and Togrul, 2009), cantaloupe (Fazli *et al*., 2006).

D. Effect of treatments on mass transfer of total solid

Maximum total solid of 37.05% was obtained for pineapple cubes with combination of treatments C_1T_3 (Table 2). Maximum per cent of total solid (33.41%) was observed in pineapple cubes infused with C_2. Osmosis decreased the moisture content of pineapple cubes on the contrary facilitated the absorption of sugar and kokum extract by the cubes which ultimately increased the total solid content of osmosed pineapple cubes infused with kokum extract. Maximum total solid content (34.29%) was observed in T_2 (12 h of infusion) (Table 2). These findings are also in conformity with observations made by other workers in case of mango (Duduyemi *et al*., 2016), apple (Abbasi *et al*., 2014), sapota (Gupta *et al*., 2014), strawberry (Nores *et al*., 2010).

E. Moisture content

The pineapple cubes infused with plain sugar syrup (0% kokum extract) for 18 h recorded minimum moisture content (62.96%) (Table 3) pineapple cubes infused with kokum extract 40 per cent recorded minimum moisture content (66.59%). In the same way pineapple cubes osmosed for 12 h showed the minimum values for moisture content (65.71%). Similar results were noticed by Adsare *et al*. (2016) in osmotic treatment for the impregnation of anthocyanin in candies from Indian gooseberry (*Emblica officinalis*); sapota (Gupta *et al*., 2014), strawberry (Nores *et al*., 2010).

F. Overall acceptability and Anthocyanin (mg/100 g)

Pineapple cubes infused with 60% kokum extract for 24 h followed by tray drying exhibited superior quality with respect to sensory values overall acceptability (8.75) (Table 5) and anthocyanin content (4.07mg/100 g) (Table 4). Increase in concentration of kokum extract significantly increased the anthocyanin content in pineapple cubes. Similar results reported by Adsare *et al*. (2016) in osmotic treatment for the impregnation of anthocyanin in candies from Indian gooseberry (*Emblica officinalis*), Bellary *et al*. (2016) in anthocyanin infused watermelon rind and its stability during storage.

Table 1: Effect of kokum extract concentration and infusion time on water loss (%) and weight reduction (%) of pineapple cubes.

Parameter	Water loss (%)					Weight reduction (%)				
Treatment	Time (h)					Time (h)				
C- Kokum extract (%)	T_1	T_2	T_3	T_4	Mean	T_1	T_2	T_3	T_4	Mean
C_1-0%	36.37	37.92	37.88	41.49	38.41	18.13	17.25	16.00	21.88	18.31
C_2-40%	41.53	47.44	47.17	47.00	45.79	25.63	27.50	25.38	26.00	26.13
C_3-50%	42.27	45.24	45.73	44.89	44.53	23.69	22.94	22.00	22.50	22.78
C_4-60%	44.64	45.31	46.00	46.36	45.58	25.13	21.94	22.63	22.25	22.98
C_5-100%	47.00	44.89	46.36	42.07	45.08	26.00	22.50	22.25	21.38	23.03
T Mean	42.36	44.16	44.63	44.36		23.71	22.43	21.65	22.80	

	S.Em ±	C.D. @ 5%	S.Em ±	C.D. @ 5%
C	0.11	0.33	0.22	0.65
T	0.10	0.30	0.20	0.58
C X T	0.23	0.66	0.44	1.29

Note: C- Kokum extract concentration
C_1 – kokum extract 0% + sugar syrup 100%
C_2 – kokum extract 40% + sugar syrup 60%
C_3 – kokum extract 50% + sugar syrup 50%
C_4 – kokum extract 60% + sugar syrup 40%
C_5 – kokum extract 100% + sugar syrup 0%

T- Infusion time
T_1- 6 h of infusion
T_2- 12 h of infusion
T_3- 18 h of infusion
T_4- 24 h of infusion

Table 2: Effect of kokum extract concentration and infusion time on solid gain (%) and total solid (%) of pineapple cubes.

Parameter	Solid gain (%)					Total solid (%)				
Treatment	Time (h)					Time (h)				
C- Kokum extract (%)	T_1	T_2	T_3	T_4	Mean	T_1	T_2	T_3	T_4	Mean
C_1-0%	18.24	20.67	21.88	19.61	20.10	26.93	32.00	37.05	29.49	31.36
C_2-40%	15.91	19.94	21.79	21.00	19.66	28.62	36.45	32.58	35.99	33.41
C_3-50%	18.58	22.30	23.73	22.39	21.75	27.61	36.18	28.32	33.78	31.47
C_4-60%	19.52	23.37	23.38	24.11	22.59	33.08	33.04	30.90	28.12	31.28
C_5-100%	21.00	22.39	24.11	20.70	22.05	35.99	33.78	28.12	34.74	33.15
Mean	18.65	21.73	22.98	21.56		30.44	34.29	31.39	32.42	

	S.Em ±	C.D. @ 5%	S.Em ±	C.D. @ 5%
C	0.14	0.56	0.14	0.58
T	0.12	0.50	0.13	0.38
C X T	0.28	1.12	0.29	0.84

Note: C- Kokum extract concentration
C_1 – kokum extract 0% + sugar syrup 100%
C_2 – kokum extract 40% + sugar syrup 60%
C_3 – kokum extract 50% + sugar syrup 50%
C_4 – kokum extract 60% + sugar syrup 40%
C_5 – kokum extract 100% + sugar syrup 0%

T- Infusion time
T_1- 6 h of infusion
T_2- 12 h of infusion
T_3- 18 h of infusion
T_4- 24 h of infusion

Table 3: Effect of kokum extract concentration and infusion time on moisture content (%) of pineapple cubes.

Parameter	Moisture content (%)				
Treatment	Time (h)				
C- Kokum extract (%)	T_1	T_2	T_3	T_4	Mean
C_1-0%	73.07	68.01	62.96	70.52	68.64
C_2-40%	71.39	63.56	67.42	64.01	66.59
C_3-50%	72.39	63.83	71.68	66.22	68.53
C_4-60%	66.93	66.96	69.10	71.89	68.72
C_5-100%	64.01	66.22	71.89	65.27	66.85
Mean	69.56	65.71	68.61	67.58	

	S.Em ±	C.D. @ 5%
C	0.14	0.42
T	0.13	0.38
C X T	0.29	0.84

Note: C- Kokum extract concentration
C_1 – kokum extract 0% + sugar syrup 100%
C_2 – kokum extract 40% + sugar syrup 60%
C_3 – kokum extract 50% + sugar syrup 50%
C_4 – kokum extract 60% + sugar syrup 40%
C_5 – kokum extract 100% + sugar syrup 0%

T- Infusion time
T_1- 6 h of infusion
T_2- 12 h of infusion
T_3- 18 h of infusion
T_4- 24 h of infusion

Table 4: Effect of kokum extract concentration, infusion time and drying method on anthocyanin content (mg/100 g) of pineapple cubes.

Treatments	Time (h)												C × D Mean		C Mean
	T_1			T_2			T_3			T_4					
	Drying		Mean	Drying		Mean	Drying		Mean	Drying		Mean			
C- Kokum extract (%)	D_1	D_2		D_1	D_2		D_1	D_2		D_1	D_2		D_1	D_2	
C_1-0%	0.66	0.78	0.72	0.53	0.63	0.58	0.52	0.56	0.54	0.47	0.50	0.49	0.55	0.62	0.58
C_2-40%	2.05	2.68	2.36	2.68	2.83	2.75	2.21	2.82	2.51	2.36	2.45	2.41	2.32	2.69	2.51
C_3-50%	2.21	3.09	2.65	2.92	3.17	3.04	2.81	3.53	3.17	3.11	3.36	3.23	2.76	3.29	3.02
C_4-60%	3.20	3.22	3.21	3.86	3.23	3.54	3.27	3.56	3.41	4.03	4.07	4.05	3.59	3.52	3.55
C_5-100%	4.47	4.21	4.34	6.00	5.21	5.61	5.60	6.28	5.94	6.66	7.73	7.20	5.68	5.86	5.77
T X D Mean	2.52	2.80		3.20	3.01		2.88	3.35		3.33	3.62				
T Mean	2.66			3.11			3.12			3.48					
Drying	D_1							D_2							
D Mean	2.98							3.20							

	S.Em ±	C.D. @ 5%		S.Em ±	C.D. @ 5%
C	0.02	0.07	C X D	0.04	0.10
T	0.02	0.06	T X D	0.03	0.09
D	0.02	0.05	C X T X D	0.07	0.20
C X T	0.05	0.14			

Note: C- Kokum extract concentration
C_1 – kokum extract 0% + sugar syrup 100%
C_2 – kokum extract 40% + sugar syrup 60%
C_3 – kokum extract 50% + sugar syrup 50%
C_4 – kokum extract 60% + sugar syrup 40%
C_5 – kokum extract 100% + sugar syrup 0%

T- Infusion time
T_1- 6 h of infusion
T_2- 12 h of infusion
T_3- 18 h of infusion
T_4- 24 h of infusion

D- Drying method
D_1- Solar tunnel drying
D_2- Tray drying @ 60°

Table 5: Effect of kokum extract concentration, infusion time and drying method on overall acceptability (score out of 9) of pineapple cubes.

Treatments	Time (h)												C × D Mean		C Mean
	T_1			T_2			T_3			T_4					
	Drying		Mean	Drying		Mean	Drying		Mean	Drying		Mean			
C- Kokum extract (%)	D_1	D_2		D_1	D_2		D_1	D_2		D_1	D_2		D_1	D_2	
C_1-0%	7.00	7.58	7.29	7.79	7.73	7.76	8.25	8.00	8.13	8.20	8.45	8.33	7.81	7.94	7.88
C_2-40%	7.15	7.68	7.42	7.38	7.69	7.53	7.75	8.30	8.03	8.00	8.25	8.13	7.57	7.98	7.77
C_3-50%	7.85	7.72	7.78	7.63	7.73	7.68	7.20	8.30	7.75	7.60	8.15	7.88	7.57	7.97	7.77
C_4-60%	8.10	8.10	8.10	8.19	7.90	8.04	7.45	7.75	7.60	8.45	8.75	8.60	8.05	8.13	8.09
C_5-100%	6.48	7.25	6.87	7.13	8.03	7.58	6.65	7.00	6.83	6.60	6.63	6.61	6.71	7.23	6.97
T X D Mean	7.32	7.67		7.62	7.81		7.46	7.87		7.77	8.05				
T Mean	7.49			7.72			7.67			7.91					
Drying	D_1							D_2							
D Mean	7.54							7.85							

	S.Em ±	C.D. @ 5%		S.Em ±	C.D. @ 5%
C	0.07	0.22	C X D	0.10	NS
T	0.06	0.19	T X D	0.09	NS
D	0.04	0.14	C X T X D	0.21	NS
C X T	0.15	0.44			

Note: C- Kokum extract concentration
C_1 – kokum extract 0% + sugar syrup 100%
C_2 – kokum extract 40% + sugar syrup 60%
C_3 – kokum extract 50% + sugar syrup 50%
C_4 – kokum extract 60% + sugar syrup 40%
C_5 – kokum extract 100% + sugar syrup 0%

T- Infusion time
T_1- 6 h of infusion
T_2- 12 h of infusion
T_3- 18 h of infusion
T_4- 24 h of infusion

D- Drying method
D_1- Solar tunnel drying
D_2- Tray drying @ 60°
NS- Non significant

CONCLUSION

Among different combination of treatments pineapple cubes infused with 40% kokum extract for the duration of 12 hours recorded the maximum water loss, weight reduction and total solid. While, the superior quality pineapple cubes were prepared using 60% kokum extract infused for 24 h followed by tray drying with respect to overall acceptability and good amount of anthocyanin content.

FUTURE SCOPE

Pineapple is a potential fruit for infusion of bioactive compounds other than anthocyanin such as curcumin, lycopene and beta- carotene to develop novel products with nutritional enrichment. Application of high hydrostatic pressure, high intensity electric field and ultrasound can be tried to enhance the infusion of bioactive compounds during osmotic dehydration.

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