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Mass transfer characters during osmo dehydration of red banana (*Musa* spp.)

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Abstract
Drying and dehydration are most popular age old practices of food processing and osmo dehydration is an improvement over the traditional method which retains higher nutritional and sensory qualities of dried product. The efficiency of osmo dehydration depends on the mass transfer characters which occur during the osmotic process. In order to standardise the process variables such as shape of fruit slices, osmotic solution concentration and immersion time for osmo dehydration of Red Banana, an experiment was conducted to study the effect of these process variables on mass transfer characters *viz*., water loss, solid gain, percentage weight reduction and water loss to solid gain. Osmo dehydration was carried out using optimally ripened red banana sliced into three shapes (ring, round and chunks) of thickness 5 mm and osmosed in sucrose syrup of 40 ºBrix, 60 ºBrix and 80 ºBrix concentration for immersion time of 60, 120 and 180 minutes. Maximum solid gain (8.90%), water loss (9.59%) and weight reduction (10.00%) with water loss to solid gain ratio of 1.07 was observed in osmo dehydrated red banana chunks immersed in osmotic solution concentration of 80°Brix and immersion time of 180 minutes. The solid gain, water loss and percentage weight reduction increased with increase in osmotic concentration and immersion time irrespective of fruit shapes.

Keywords: Osmo dehydration, water loss, solid gain, percentage weight reduction, red banana

Introduction
Fruits contain more than 75% water and get spoiled very quickly due to their high water content. Drying and dehydration are important low cost method of processing and are widely employed in fruit and vegetable processing. Osmotic dehydration is one of the best and suitable methods to increase the shelf life of fruits and vegetables and the process is preferred over others due to its vitamins, minerals, color, flavor and taste retention property and prevention of microbial spoilage. Osmotic dehydration is a concentration process in which water is removed from the plant tissue to a hypertonic solution and solutes flow from the solution into the food (Ahmed *et al*., 2016) [1]. Osmotic dehydration, preceding the air-drying preserves fruits and vegetables from undesirable colour changes and increases the retention of flavour during drying. The products obtained by osmotic dehydration are more stable during storage due to low water activity imparted by solute gain and water loss (Akbarian *et al*., 2014) [2].

Banana (*Musa* spp.) is one of the most important tropical fruit crop well known for its high nutritional value, being rich in starch, sugars, vitamins and minerals. However, its high moisture content leads to a rapid deterioration and causes a postharvest loss of about 40% in main producer countries (Silva *et al.*, 2014) [11]. Among the different species of banana, Red banana is most popular in South India, known for its characteristic flavour and colour. However its high perishability signifies a vast potential for processing into value added products. Most predominant preservation method such as solar drying techniques results in poor quality and product contamination. Thus osmotic dehydration has immense scope for the production of quality dehydrated product especially for highly perishable fruit like red banana.

Materials and methods
The experiment was conducted at Department of Post Harvest Technology, College of Agriculture, Vellayani, Kerala Agricultural University, during the year 2017-19.

Osmo dehydration of red banana
Outer peel of optimally ripened red banana was removed and the edible fruit portion was made into slices of 5 mm thickness, in three shapes *viz*., ring, round and chunks. Sucrose syrup of three different concentrations *viz*. 40°Brix, 60°Brix, 80°Brix were prepared and 0.1% potassium metabisulphite, 0.1% citric acid and 0.2% ascorbic acid were added to the osmotic solution.

Prepared red banana slices of three different shapes; ring (S_1), round (S_2) and chunks (S_3) were osmosed in 40°Brix (C_1), 60°Brix (C_2) and 80°Brix (C_3) for different immersion time of 60 minutes (T_1), 120 minutes (T_2) and 180 minutes (T_3) with three replications. The ratio of fruits to osmotic solution was maintained at 1:1 w/w. After the osmotic treatment, solution was drained quickly and the samples were analysed for different mass transfer characters.

Treatments
Shape of fruit slices: 3
Osmotic solution concentration: 3
Immersion time: 3
Total treatments: 27
Replications: 3

Mass transfer parameters
Mass transfer involves water out flow from the product to solution and solute transfer from the solution to product; thus possible to improve sensory quality of the product. These characters include water loss, solid gain, percentage weight reduction and water loss to solid gain were determined using standard procedure.

Water loss (%)
Weight of fresh red banana slices and weight after osmosis was recorded in electronic balance (Cyber Lab-0.01mg to 1000mg). Dry mass of fresh fruit and dry mass after osmosis were recorded and water loss in terms of percentage was calculated by the method described by Sridevi and Genitha (2012) [12] using following formula:

$$WL(\%) = \frac{(Wo - Wt) + (St - So)}{Wo} x100$$

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

Solid Gain (%)
Solid gain (%) of osmo dehydrated red banana was determined as per the procedure described by Kowalski and Mierzwa, (2011) [6].

$$SG(\%) = \frac{St - Si}{mi} X\ 100$$

Where, S_t = dry mass at time t, S_i = Initial dry mass (of fresh) and m_i= initial mass of wet sample.

Weight Reduction (WR)
Weight reduction of red banana slices after osmosis in terms of percentage was calculated using the method described by Yadav *et al.* (2012) [14].

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

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

Water Loss to Solid Gain (WL/SG)
Water loss to solid gain is expressed as ratio of calculated value of water loss and solid gain.

$$\frac{WL}{SG} = \frac{\%waterloss}{\%solidgain}$$

Results and discussion
Results revealed that mass transfer characters increased with increase in osmotic solution concentration and immersion time.

Water loss (%)
Osmosed red banana slices showed varied water loss values with respect to different shape, osmotic solution concentration and immersion time, and are depicted in Table 1. Osmotically dehydrated red banana chunks (S_3) showed the highest water loss of 4.51% (Fig.1), followed by ring shaped red banana (S_1) with a water loss of 3.52% and the lowest water loss of 3.19% was observed for round shaped red banana slices (S_2). With respect to osmotic concentration, 80ºBrix (C_3) showed the highest water loss (5.35%) followed by 60ºBrix (C_2) having a water loss of 3.59% and the lowest water loss of 2.28% was observed for 40ºBrix (C_1). Among the different immersion time, T_3 (180 min) showed the highest water loss of 4.50% followed by T_2 (120 min) with 3.61% water loss and the lowest water loss of 2.61% was recorded for T_1 (60 min). According to Ispir and Togrul (2009) [4], during osmo dehydration of apricot, higher sucrose concentration favoured greater osmotic pressure gradients thereby leading to higher water loss throughout the osmotic treatment period.

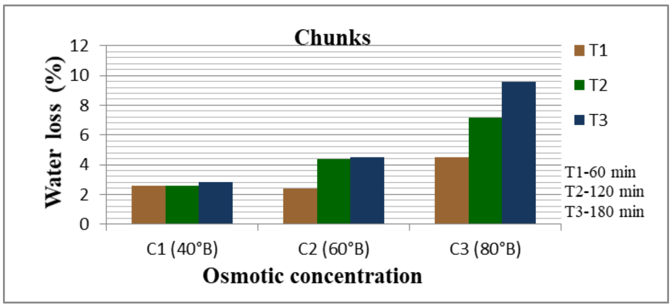

Fig 1: Water loss of osmo dehydrated red banana chunks with respect to osmotic concentration and immersion time

Solid gain (%)
Solid gain during osmotic process of red banana slices influenced by shape, osmotic concentration and immersion time are given in Table 2. Osmo dehydrated ring shaped red banana slices (S_1) recorded the highest solid gain of 7.01% (Fig.2) followed by chunks shape (S_3) with a solid gain of 6.35% which was found to have no significant difference with round shaped osmo dehydrated red banana (S_2). When different osmotic concentration is considered, the highest solid gain of 7.02% was recorded for 80ºBrix (C_3) followed by 60ºBrix (C_2) with 6.41% solid gain which showed no significant difference with 40ºBrix (C_1). Among different immersion time, the highest solid gain of 8.25% was observed for 180 min immersion time (T_3) whereas 7.31% was recorded for T_2 (120 min) and the lowest solid gain of 4.02% was recorded for T_1 (60 min). Azoubel and Murr (2004) [3] indicated that increase in osmotic solution concentration resulted in an increase in pressure gradient and thereby increased water loss which lead to a much greater solid gain.

Similar trend of increase in solid gain with increase in osmotic concentration and immersion time was observed during osmo dehydration of pomegranate arils (Mundada *et al.*, 2011) [7], pineapple (Zapata *et al.*, 2011) [15] and banana (Shukla *et al.*, 2018) [10].

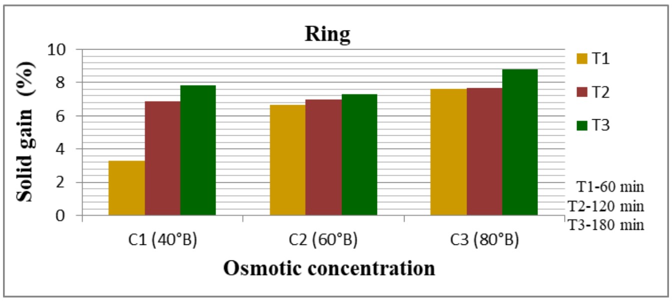

Fig 2: Solid gain of osmo dehydrated red banana rings with respect to osmotic concentration and immersion time

Percentage weight reduction (%)

Percentage weight reduction of osmo dehydrated red banana slices at different osmotic concentration and immersion time are given in Table 3. Osmo dehydrated round shaped red banana (S_2) recorded the highest percentage weight reduction of 7.97%, followed by ring shaped osmo dehydrated red banana (S_1) with 6.69% which statistically showed no significant difference with red banana chunks (S_3). When different osmotic concentration was considered, the highest percentage weight reduction of 8.99% was recorded for 80ºBrix (C_3) which has no significant difference with 60ºBrix (C_2) and 40ºBrix (C_1) showed the lowest reduction in weight (3.52%). Among different immersion time, highest percentage weight reduction of 8.47% was observed for 180 min immersion time (T_3) whereas 7.18% was recorded for T_2 (120 min) and the lowest of 5.61% was recorded for T_1 (60 min). The results were similar to the findings observed during osmo dehydration of pineapple (Khanom *et al.*, 2014) [5] and red pitaya (Najafi *et al.*, 2014) [8].

Water loss to Solid Gain (WL/SG)

Water loss to solid gain values of osmo dehydrated red banana slices in different osmotic concentration and immersion time is depicted in Table 4. Highest water loss to solid gain ratio of 0.80 was noticed in osmo dehydrated red banana chunks (S_3) followed by osmo dehydrated round shaped red banana (S_2) with 0.52 water loss to solid gain which showed no significant difference with ring shaped red banana slices (S_1). When different osmotic concentration was considered, the highest water loss to solid gain (0.82) was recorded for 80ºBrix (C_3) followed by 60ºBrix (C_2) with a water loss to solid gain ratio of 0.58 whereas 40ºBrix (C_1) recorded the lowest water loss to solid gain of 0.42. With respect to immersion time, the highest water loss to solid gain of 0.72 was observed for 60 min immersion time (T_1) whereas 0.60 was recorded for T_3 (180 min) and the lowest ratio of water loss to solid gain (0.49) was recorded for T_2 (120 min). Increase in WL/SG with increase in osmotic concentration were reported in mango and pineapple by Tiwari and Jalali, (2004) [13] and in banana by Renu *et al.* (2012) [9].

Table 1: Effect of shape, osmotic concentration and immersion time on water loss (%) of osmo dehydrated red banana

Immersion time (min)	Osmo dehydrated red banana											
	S_1(Ring)				S_2 (Round)				S_3 (Chunks)			
	Osmotic concentration				Osmotic concentration				Osmotic concentration			
	C_1 (40°B)	C_2 (60°B)	C_3 (80°B)	Mean	C_1 (40°B)	C_2 (60°B)	C_3 (80°B)	Mean	C_1 (40°B)	C_2 (60°B)	C_3 (80°B)	Mean
T_1	1.09	3.41	4.16	2.89	1.15	1.48	2.68	1.77	2.58	2.40	4.52	3.17
T_2	1.93	3.52	4.39	3.20	1.42	2.84	4.28	2.85	2.60	4.40	7.14	4.71
T_3	2.90	4.48	5.81	4.40	3.97	5.30	5.56	4.94	2.84	4.52	9.59	5.65
Mean	1.98	3.80	4.79		2.18	3.21	4.17		2.67	3.77	7.08	
Mean	S_1 - 3.52 S_2 - 3.19 S_3 - 4.51		C_1 - 2.28 C_2 - 3.59 C_3 - 5.35		T_1 - 2.61 T_2 - 3.61 T_3 - 4.50							
SE(±m)	S - 0.106 S×C - 0.184		C - 0.106 S×T - 0.184		T - 0.106 C×T - 0.184		S×C×T - 0..318					
CD (0.05)	S - 0.300 S×C - 0.520		C - 0.300 S×T - 0.520		T - 0.300 C×T - 0.520		S ×C×T - 0.901					

Table 2: Effect of shape, osmotic concentration and immersion time on solid gain (%) of osmo dehydrated red banana

Immersion time	Osmo dehydrated red banana											
	S_1(Ring)				S_2 (Round)				S_3 (Chunks)			
	Osmotic concentration				Osmotic concentration				Osmotic concentration			
	C_1 (40°B)	C_2 (60°B)	C_3 (80°B)	Mean	C_1 (40°B)	C_2 (60°B)	C_3 (80°B)	Mean	C_1 (40°B)	C_2 (60°B)	C_3 (80°B)	Mean
T_1	3.29	6.64	7.63	5.85	3.10	3.35	3.30	3.25	2.75	3.07	3.02	2.95
T_2	6.90	7.00	7.68	7.19	7.32	6.75	7.75	7.27	7.53	7.41	7.49	7.48
T_3	7.84	7.30	8.80	7.98	8.19	7.64	8.62	8.15	8.41	8.56	8.90	8.62
Mean	6.01	6.98	8.04		6.20	5.91	6.56		6.23	6.35	6.47	
Mean	S_1 - 7.01 S_2 - 6.23 S_3 - 6.35		C_1 - 6.15 C_2 - 6.41 C_3 - 7.02		T_1 -4.02 T_2 -7.31 T_3 -8.25							
SE(±m)	S - 0.106 S×C - 0.184		C - 0.106 S×T - 0.184		T - 0.106 C×T - 0.184		S×C×T – 0.319					
CD (0.05)	S - 0.301 S×C - 0.522		C - 0.301 S×T - 0.522		T - 0.301 C×T - 0.522		S×C×T – 0.904					

Table 3: Effect of shape, osmotic concentration and immersion time on percentage weight reduction (%) of osmo dehydrated red banana

Immersion time (min)	Osmo dehydrated red banana											
	S_1(Ring)				S_2 (Round)				S_3 (Chunks)			
	Osmotic concentration				Osmotic concentration				Osmotic concentration			
	C_1 (40°B)	C_2 (60°B)	C_3 (80°B)	Mean	C_1 (40°B)	C_2 (60°B)	C_3 (80°B)	Mean	C_1 (40°B)	C_2 (60°B)	C_3 (80°B)	Mean
T_1	2.25	8.00	7.00	5.75	2.40	6.71	7.75	5.62	1.63	7.50	7.25	5.46
T_2	2.38	8.63	8.50	6.50	4.85	10.00	10.28	8.38	3.38	8.25	8.38	6.67
T_3	4.38	9.13	10.00	7.83	6.41	11.57	11.75	9.91	4.00	9.00	10.00	7.67
Mean	3.00	8.58	8.5		4.55	9.43	9.93		3.00	8.25	8.54	
Mean	S_1 - 6.69 S_2 - 7.97 S_3 - 6.60		C_1 - 3.52 C_2 - 8.75 C_3 - 8.99		T_1 -5.61 T_2 -7.18 T_3 -8.47							
SE(±m)	S - 0.181		C - 0.181		T - 0. 181		S×T - 0.314					
CD (0.05)	S - 0.514		C - 0.514		T - 0.514		S×T - 0.890					

Table 4: Effect of shape, osmotic concentration and immersion time on water loss to solid gain of osmo dehydrated red banana

Immersion time (min)	Osmo dehydrated red banana											
	S_1(Ring)				S_2 (Round)				S_3 (Chunks)			
	Osmotic concentration				Osmotic concentration				Osmotic concentration			
	C_1 (40°B)	C_2 (60°B)	C_3 (80°B)	Mean	C_1 (40°B)	C_2 (60°B)	C_3 (80°B)	Mean	C_1 (40°B)	C_2 (60°B)	C_3 (80°B)	Mean
T_1	0.35	0.51	0.55	0.49	0.39	0.46	0.82	0.55	0.99	0.86	1.52	1.12
T_2	0.29	0.50	0.57	0.45	0.20	0.44	0.55	0.40	0.35	0.60	0.95	0.63
T_3	0.37	0.61	0.66	0.55	0.49	0.70	0.65	0.61	0.34	0.53	1.07	0.65
Mean	0.33	0.54	0.59		0.36	0.53	0.67		0.56	0.66	1.18	
Mean	S_1 - 0.49 S_2 - 0.52 S_3 - 0.80		C_1 - 0.42 C_2 - 0.58 C_3 - 0.82		T_1 - 0.72 T_2 - 0.49 T_3 - 0.60							
SE(±m)	S - 0.032 S×C - 0.055		C - 0.032 S×T - 0.055		T - 0.032							
CD (0.05)	S - 0.091 S×C - 0.157		C - 0.091 S×T - 0.157		T - 0.091							

Conclusion

On the basis of the finding of the present study it can be concluded that there was remarkable effect of fruit slice shape, osmotic solution concentration and immersion time on osmo dehydration of red banana slices. Based on the results, it can be concluded that mass transfer characters viz. water loss, solid gain and percentage weight reduction increased with increase in osmotic solution concentration and immersion time. Solid gain were higher during initial period of osmotic dehydration treatment than in the later period. The optimal mass transfer characters during osmo dehydration of red banana was recorded for osmotic solution concentration of 80⁰ Brix for an immersion time of 180 min in all the three fruit slice shape *viz.* ring, round and chunks.

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