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Effect of process parameters on the effectiveness of osmotic dehydration of summer onion

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Abstract

The present study was carried out to investigate the effects of solution concentration, immersion time and temperature on the osmotic dehydration (OD) of summer onion. OD was done using sucrose, salt and combined (sucrose-salt) solution. In this study three sucrose (40,50 and 60%), five salt (5,10,15,20 and 25%) and five sucrose- salt (combine) solution (40:15, 45:15, 45:20 50:15 and 55:15 %) were used. Among different solution concentration and temperature for 6 hrs contact time 55:15°brix at 40°C gave water loss (50.05%), solid gain (16.25%) and normalized solid content (2.34), while 60 °brix sucrose solution gave 35.60%, 9.32%, 1.81 and 25°brix salt solution gave 33.50%, 12.21%, 2.25 water loss, solid gain and normalized solid content respectively. It was also found that at ambient temperature (25°C) 55:15°brix for 24 hrs contact time gave the highest water loss (56%) and solid gain (17.80%). It can be concluded from this study that solution temperature, time and concentration were the most pronounced factors affecting solid gain, water loss and normalized solid content of onion slice during osmotic dehydration.

Introduction

Onion (*Allium cepa* L.) is an important spice crop grown in Bangladesh and ranked second in acreage and first in production (BBS, 2007). A global review of area and production of major vegetables shows that onion ranks second in area of vegetables and third in production in the world, among seven vegetables, namely onion, garlic, cauliflower, green peas, cabbage, tomato and green beans (FAO, 2003). Bangladesh produces onion in season, summer and winter. The yield of summer onion is 4-5 times more than winter onion. The summer onion is more perishable than winter onion and can not be keep more up to 30 days due to its perishable nature. About 40-50% post-harvest losses are observed of onion during storage, transportation and marketing (BARI, 2003). Dehydrated bulb or onion powder is in great demand which reduces transportation cost and storage losses. Dried onion flakes can be reconstituted by cooking in water. Recent studied suggested that onions in the diet may play a part in preventing heart disease (Augusti, 1990). Osmotic dehydration preceding air drying decreases colour changes and increase flavour retention in dried fruits and vegetables (Lenart and Lewicki, 1988). The resulting product has generally better quality than the dried one without pretreatment. Osmotic dehydration is a method for the partial dehydration of water-rich foods, such as fruits and vegetables, by immersing them in a concentrate solution of sugar or salt. It results in two simultaneous crossed flows: a water outflow, from the food to the solution and a solute inflow from the solution into the food (Hough *et al*., 1993; Spiazzi and Mascheroni, 1997). Water loss and solute gain are usually measured as average values in the piece of food. There are a few papers published about the concentration profiles developed in structured foods during osmotic dehydration. There is information about the concentration profiles developed during osmotic dehydration of apple tissue (Salvatori *et al*., 1998). The product thus loses water and gains solid from the external solution. Therefore, it is being widely used to reduce the water content of many fruits and vegetables (Li and Ramaswamy 2006). For achieving high yield of final product, the kinetics of solid gain is more important than that of water loss. Kinetics of water loss in osmotic dehydration has been extensively studied for many fruits, including blueberries (Dermesonlouoglou

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et al., 2005; Sodhi and Komal 2006). The quality traits and nutritional value of osmo dried fruits and vegetables can be modified depending on the parameters of the dehydration process and osmotic agent used (Mandala *et al*., 2005; Chiralt and Talens, 2005). The dehydrated material becomes impregnated with the osmotic agent that enhances not only its sensory properties, but also has an impact on its dietary value (Torreggiani and Bertolo, 2001). This study is limited to investigation regarding the effects of certain process parameters such as solute, solute concentration, immersion time, temperature on the effectiveness of osmotic dehydration of summer onion so that optimization technique could be used at a later stage for developing shelf-stable products.

Materials and Methods

Experimental procedure for osmotic dehydration

Selection of raw materials

The fresh summer onion was collected from the spices research center Bogra, Bangladesh Agricultural Research Institute.

Preparation of sample and solution

The selected variety of summer onion was peeled and washed with water and unwanted material like dust, dirt, and surface adhering were removed. The onion bulbs were sliced with an electrical slicer of approximate 7 mm ± 1mm thickness. Each slice was weight and subsequently individually marked by using different clour threads, the ratio of solute to onion slices was 5:1 w/w.

Measurement of initial moisture content

The moisture content of fresh as well as osmotically dehydrated onion samples was determined by using air oven method and calculated by using following equation (Ranganna, 2000).

$$\text{Percent moisture content (db)} = \frac{W1 - W2}{W2} x100$$

Measurement of total soluble solids

The total soluble solids of prepared solution were found out by using hand refracto meter of various ranges, which give the reading directly in Brix. (Ranganna, 2000).

Osmosis of onion slices

In osmotic dehydration the prepared samples (onion slices) were weighed approximately 100 gm for every experiment and immersed in sucrose and salt solution (40, 50, 60 sucrose 5, 10, 15, 20, 25 °Brix salt and of 40:15, 45:20 50:15 and 55:15°Brix sucrose-salt combine) contained in a 1000 ml glass beaker. The beakers were placed inside the constant temperature of refrigerator (5°C) ambient (25°C) and water bath (40°C). The solution in the beakers was manually stirred at regular intervals to maintain uniform temperature (5, 25 and 40°C). Every concerned sample was removed from each keeping condition at designed time (0.5, 1, 2, 4, 6, 8, 12, 16 and 24 hours), samples were taken out and placed on absorbent paper for 5 minute or were immediately rinsed in flowing water and placed on tissue paper to remove the surface moisture to eliminate excess solution from the surface before weighing. Finally the samples were weighted and their moisture contents were determined.

Osmotic dehydration characteristics

Water loss

Water loss is the quantity of water lost by food during osmotic dehydration. The water loss (WL) is defined as the net weight loss of the onion slice on initial weight basis and will be estimated as, (Hawkes and Flink, 1978)

$$\text{Water loss, \% WL (wb)} = \frac{WWO - (TW - WS)}{WWO + WSO} x100, \text{ g } H_2O/100g \text{ initial wt of sample}$$

Solid gain

The solids from the osmotic solution get added to the samples during osmotic dehydration. The loss of water from the sample takes place in osmotic dehydration consequently it increases the solid content. The solid gain is the net uptake of solids by the slices on initial weight basis and computed using following expression (Hawkes and Flink, 1978)

$$\text{Solid gain, \% SG (wb)} = \frac{WS - WSO}{WWO + WSO} x100, \text{ g solids/100g initial wt. of sample}$$

Normalized solid content (NSC)

The overall Normalized solid content of the sample do affect the final weight of the sample ((Hawkes and Flink, 1978).

$$\text{Normalized solid content, NSC} = \frac{\text{Total solid at any time}}{\text{Initial total solid}} = \frac{TSt}{TSi}$$

Where;

TW = Total weight of the sample upon removed from the osmosis solution

WS = Total weight of solid content of the sample determined after removal from the osmosis solution

WSO = Solid content of the initial sample

WWO = Water content of the initial sample

Results and Discussion

Effect of solution concentration and time on water loss, solid gain and normalized solid content at ambient temperature

Effect of sucrose solution concentration (40, 50 and 60%) on percent water loss, solid gain and normalized solid content (NSC) at different time of 7 mm thick onion slices is shown in Fig. 1 and 2. It is seen from the figure that as percent sucrose concentration increased, the percent water loss is (WL) also increased. Simultaneously, percent solid gain (SG) increased with increasing percent sucrose concentration but comparatively water loss is quite higher than solid gain at similar solution concentration. It is also observed that water loss and solid gain increased with increasing immersion time at similar concentration of sucrose. For 6 hr osmosis period the highest water loss (32.127%) and solid gain (8.301%) are given by 60% sucrose solution and is closely followed by 50% sucrose solution with (26.083% WL and 7.234% SG), while the lowest water loss (15.74%) and solid gain (5.07) are given by 40°Brix sucrose solution. The highest normalized solid content (NSC) 1.71 was observed for 60% sucrose solution and was followed by 50°brix sucrose solution (1.5); while the lowest normalized solid content (1.39) was given by for 40°Brix sucrose solution. This behaviour is in agreement with (Bohuon *et al*., 1997; Falade, 2003).

Effect different salt solution concentration (5, 10, 15, 20 and 25°Brix) is presented in (Figure 3- 4). The results shows that for 6 hr osmotic dehydration the highest water loss and solid gain and NSC were found for 25% salt solution which were 28.42%, 11.24% and 2.08; closely followed by 25.82%, 8.98% and 1.77 respectively for 20% salt solution. The lowest water loss, solid gain and normalized solid content were found for 5% salt solution which were 19.73%, 2.61% and 1.15 followed by 20.43%, 4.13%, 1.36 and 23.56%, 7.86%, 1.75 for 10% and 15% salt solution respectively. In this study water loss and solid gain and thus also normalized solid content increased with increase in concentration of solute. This is expected since the solute and water activity gradient increased with increasing solution concentration. Several other researchers (Krokida *et al*., 2000; Ravaskar, 2007) also showed that increase in concentration of sucrose or salt gave increased amount of water loss and solid gain.

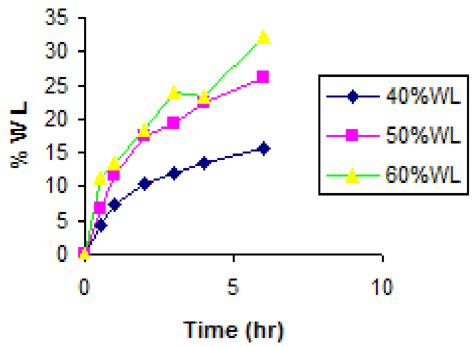

Figure1. Change in water loss of onion slice (7mm) with time in different sucrose solution

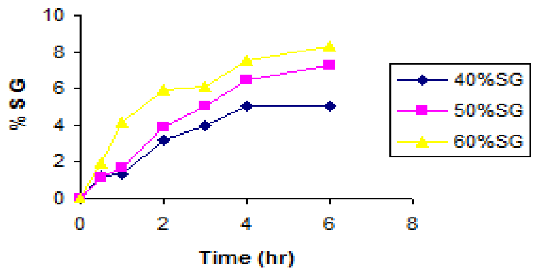

Figure 2. Change in solid gain of onion slice (7mm) with time in different sucrose solution

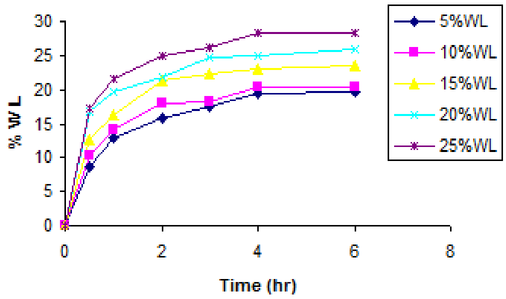

Figure 3. Change in water loss of onion slice (7mm) with time in different salt solution

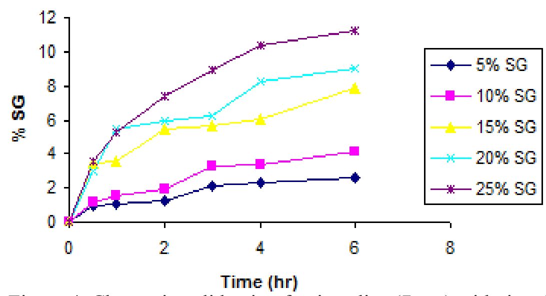

Figure 4. Change in solid gain of onion slice (7mm) with time in different salt solution

Comparison of water loss, solid gain and NSC between sucrose, salt and combined osmotic dehydration at ambient temperature

From (Figures 5-6) it is clearly observed that for 40:15, 45:15, 45:20, 50:15 and 55:15°Brix sugar-salt solution water loss and solid gain increases with the increase in time and the rate of increase is rapid at the

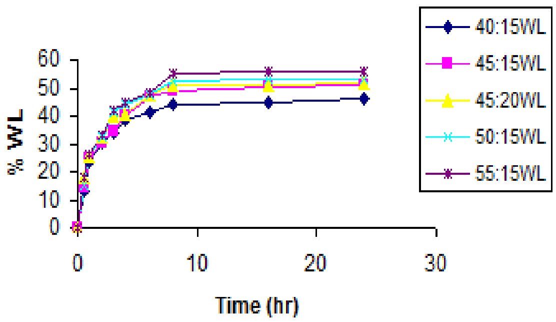

Figure 5. Change in water loss of onion slices (7mm) within 24 hours time in different sucrose-salt solution

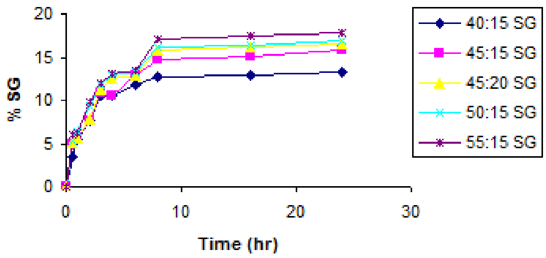

Figure 6. Change in solid gain of onion slices (7mm) within 24 hours time in different sucrose-salt solution

beginning period (up to 4-8, or 4 to 6 hr), after which the rate falls presumably due to reduction of osmotic potential gradient. In other words, an equilibrium stage is being approached. Cruz and Florencia (2004) observed that the sodium chloride achieves a constant value after 6 hours of osmotic treatment and attaining equilibrium condition. The approach to equilibrium stage is also evidently different for different solution concentration. The results also show that more time is needed to approach equilibrium at higher concentration and this behaviour may be attributed to the viscous nature of the concentrated solution. As concentration of solution increases the mass transfer resistance in the solution adjacent to surface of samples also increases (Nieuwenhuijzen *et al*., 2001). That is why, for concentrated solution more time is required to achieve equilibrium stage. The higher the solution concentration the higher is the equilibrium stage. In (Figure 5-6) it is also observed that at a given immersion time (6hr) water loss and solid gain increase with increase in solution concentration and 55:15 sugar-salt solution gives highest water loss (48.083%) and solid gain (13.534%), for a specific immersion time while 40:15 sugar-salt solution gives lowest water loss (41.71%) and solid gain (11.806%) for passage of same immersion time. In solution concentration 45:20 (sugar-salt) this gives 47.369 % water loss and 12.999 % SG for an immersion period of 6 hr this due to increase in salt concentration.

During 24 hr period the highest water loss was record (56.002%) and solid gain (17.802%) was given by 55:15 (sugar-salt) solution and is closely followed by 50:15 (sugar-salt) solution (53.110 %WL and 16.850 %SG) and 45:20 (sugar-salt) 51.558% water loss and 16.505% solid gain, while the lowest water loss (46.101%) and solid gain (13.202%) was given by 40:15 (sugar-salt) solution. Tsamo *et al*., (2005) found the same result in case onion slices and tomato fruits. He reported that a mixed solution of sugar and salt showed the highest dehydration capacity with predominance of water removal and gain of solutes over solute loss. For 18 hr osmosis period using 50:10 (sugar-salt) solution Tortoe *et al*. (2007) reported 69.25% water loss and 8.5% solid gain for 1/8 thick tomato dice. Thus by changing the type of solute concentration and time, the desired degree of dehydration or concentration can be achieved. The observation that higher solution concentration and time results in increased water loss and solid gain for identical sample for a given time is attributable to the fact that as solution concentration increases osmotic potential gradient also increases with resultant increase in diffusivity. Osmotic dehydration has been termed as a two way diffusion process (Marouzé *et al*., 2001; Jannot *et al*., 2004), and in this case mass transfer parameters such as %WL and %SG are dependent on the osmotic potential gradient. Above observations were also made by (Bohuon *et al*., 1998; Falade, 2005).

In (Figures 5-6) it is observed that 45:15°brix (sucrose-salt) osmosed sample for 6 hrs gave 47.00% water loss, 12.982% sugar gain and 1.899 normalized solid content and 60°brix sucrose osmosed sample for similar period gave 32.127% water loss, 8.301% solid gain and 1.71 normalized solid content. Although 45:15°brix (sugar-salt) solution and 60°brix sugar solution contain 60% of total solute concentration and 60% sugar solution is more viscous than 45:15°brix (sugar-salt) solution due to presence of higher proportion of sucrose. Thus resistance to mass transfer is higher for the case of 60°brix sugar solution. These results are similar to those reported by who found that 45:15 °brix (sucrose-salt) osmosed potato gave the highest normalized solid content (3.94) as compared to 50:10 °brix (sucrose-salt) osmosed potato but contrary to those however, showed that 55:15°brix (sucrose-salt) solution is more effective compared to both 50:10 (sucrose-salt) and 45 :15°brix (sucrose-salt) osmosed papaya (Kowalska and Lenart, 2001). This difference in effectiveness may be attributed to difference in product characteristics. The highest normalized solid content, water loss and solid gain given by 55:15°brix (sucrose-salt) solutions is probably due to the highest solution concentration and membrane effectiveness of onion.

Table1. Effect of immersion time and osmotic solution concentration (60°brix salt) on behavior of summer onion slices at different temperature

Temperature (°C)	Immersion time (hr)	Size	Init. Solid (%)	WL (%)	SG (%)	NSC
5	2	7	10.634	13.136	3.359	1.307
	4			15.731	3.987	1.228
	6			18.860	3.997	1.205
25	2	7	10.634	18.412	5.892	1.504
	4			23.189	7.511	1.643
	6			32.127	8.301	1.710
40	2	7	10.634	18.450	5.899	1.574
	4			24.120	8.250	1.673
	6			35.601	9.325	1.810

Table2. Effect of immersion time and osmotic solution concentration (25°brix salt) on behavior of summer onion slices at different temperature

Temperature °C	Immersion time (hr)	Size	Init. Solid (%)	WL (%)	SG (%)	NSC
5	2	7	10.634	18.841	5.098	1.304
	4			20.035	6.416	1.382
	6			20.448	7.987	1.476
25	2	7	10.634	24.960	7.418	1.714
	4			28.398	10.327	1.995
	6			28.423	11.241	2.083
40	2	7	10.634	26.800	9.246	1.734
	4			32.402	9.873	2.05
	6			33.500	12.214	2.25

Table 3. Effect of immersion time and osmotic concentration (55:15°brix sucrose-salt) on behavior of summer onion slices at different temperature

Temperature (°C)	Immersion time (hr)	Size	Init. Solid (%)	WL (%)	SG (%)	NSC
5	2	7	10.634	25.385	6.323	1.409
	4			35.823	8.155	1.528
	6			40.453	8.292	1.534
25	2	7	10.634	33.177	9.999	1.675
	4			44.852	13.020	1.990
	6			48.083	13.534	2.300
40	2	7	10.634	33.20	10.950	1.775
	4			48.085	14.025	2.100
	6			50.05	16.250	2.340

Influence of temperature on osmotic dehydration behavior

Study the effect of temperature on osmotic dehydration behavior of onion slices, 7 mm thick slices were immersed in 60°brix sugar, 25°brix salt and 55:15°brix sucrose- salt solutions and immersion temperature was 5, 25 and 40°C. The data of ambient temperature for 60°brix sugar, 25°brix salt and 55:15°brix sucrose salts reused for comparison in Table 1-3. The results (Table 1-3) shown that as the solution temperature increases, the moisture content at any given time decreases. In other words, the rate of mass transfer increases with the increase in temperature. Thus water loss, solid gain and normalized solid content increased with increasing temperature. Ramallo *et al*., (2004) found that equilibrium sugar content increased from 45 to 54 % as the temperature rose from 30 to 50°C. Maximum water loss at 40°C for 55:15°brix (55.05%) sucrose salt solution followed by 60°brix sucrose solution (35.601%) while minimum was observed for 25°brix salt solution (33.5%). The highest solid gain and normalized solid content were found at the same temperature for 55:15°brix sucrose-salt solution (16.25%, 2.34) followed by 25°brix salt-solution (12.214%, 2.25) while minimum increase was observed for 60% sucrose solution (9.325%). In case of low temperature (5°C) the highest water loss (40.45%) and solid gain (8.29%) and normalized solid content (1.53) were found in 55:15°brix sugar salt followed by 25°brix salt solution (20.45,7.98 and 1.48) and 60°brix sucrose solution (18.86, 3.99 and 1.20) respectively. This is expected since osmotic dehydration is a two way diffusion process which is strongly dependent on temperature. Similar observations as to the influence of temperature on osmotic dehydration rate were made by Farkas and Lazar (1969); Hope and Vital (1972); Beristain *et al*., (1990). While temperature can be advantageously used to complete osmotic dehydration rapidly, it should be noted that higher temperature may adversely affect colour and flavour. Consideration of these and other factors such as tissue integrity lead Pointing *et al*., (1966) to suggest a maximum temperature limit of 49°C for osmotic dehydration.

Conclusions

It can be concluded from this study that solution temperature, time and concentration were the most pronounced factors affecting solid gain, water loss and NSC of onion slice during osmotic dehydration. While for certain products, it would be desirable to use single solute such as sucrose, salt etc., there would be other products where mixed solutes such as salt-sucrose would be even more desirable from the view point of product throughput, cost and consumer acceptability. By processing summer onion post-harvest loss can be minimized, its market value can be increased and production can be maximized. Further research is needed to optimize process variables for high quality products produced for export market.

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