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Influence of concentration of sugar on mass transfer of pineapple slices during osmotic dehydration

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Abstract

Osmotic drying is a partial dehydration process to give the product a quality improvement over the conventional drying process. The experiment was conducted for studying water loss(WL), sugar gain(SG), weight reduction(WR) and total solid(TS) during osmotic dehydration of pineapple slices (10 mm thick) in different concentration of sugar (40%, 50% and 60%) up to 6 hours at room temperature. It was found that increasing the concentration of the sugar solution used resulted in increased rates of water loss. The water loss at 40% sugar solution of pineapple slices were found to be significantly lower (p=0.05) than that of at 60% sugar solution. It was found there were rapid rates of water loss, sugar gain, weight reduction for first four hour of the osmotic process.

Keywords: Pineapple slices, Sugar, Osmotic dehydration

Introduction

Pineapple (*Ananas comosus*) is a delicious and popular fruit of our country. It is one of the most common tropical and sub tropical fruit, consumed largely because of its attractive flavour and refreshing sugar-acid balance and a very rich source of vitamin C and organic acids (Bartolomew *et al*., 1995). Pineapple contains sucrose, fructose and glucose in concentration that, in combination with acids and other compounds, determine the typical flavour of this fruit (Gherardi *et al.,* 1994). The three varieties of pineapple grown in Bangladesh are Giankew, Calendar and Juldubi. The major pineapple growing areas in Bangladesh are Madhupur, Ghorashal and Chittangong Hill tracts. Osmotic dehydration is a method for the partial dehydration of water-rich foods, such as fruits and vegetables by immersing them in a concentration of sugar and salt. It results in two simultaneous crossed flows: a water out flow, from the food to the solution and a solute inflow from the solution into the food (Hough *et al*., 1993: Raoult-Wack *et al*., 1994: Spiazzi and Mscheroni, 1997). The main problem is availability of adequate and sufficient processing technologies. Development of new technologies to process the pineapple products may promote the round year availability of pineapple and also serve the interest of the farmers.

The objectives of this study were to investigate the influence on water loss, sugar gain, weight reduction, normalised solids content during osmotic dehydration.

Materials and Methods

The experiment was conducted in the Department of Food Technology and Rural Industries, Bangladesh Agricultural University, Mymensingh. The pineapples, having 10-30% coloration from base was collected from local market. Collected samples (*Ananas comosus*) were washed thoroughly in clean water to remove the adhering soil and organism, outer skin were peeled manually by using knife and cut into pieces of 10 mm thickness. The core of the slices was also removed by using core remover.

Osmotic dehydration

The dehydration solute used was sucrose (food grade, commercial granulated cane sugar manufactured by Lenart and Flink in 1984. Solutions of 40%, 50% and 60% (w/w) sucrose concentrations were prepared by blending an amount of sucrose with distilled water on a weight to weight basis. The weight pineapple slices were dipped in different concentration of sugar. The ratio of the fruits and sugar solution was 1: 6 in order to ensure proper soaking of the samples. Samples were taken at half an hour interval up to six hours, drained quickly and wiped gently with tissue paper and analyzed for different process variables like water loss, sugar gain, weight reduction, and total solid.

Calculation of water loss

Percent Water Loss (%WL) was defined as the net loss of water from the fresh pineapples after osmotic dehydration based on the initial sample weight and was calculated from the following equation:

$$\% \text{ WL} = \frac{(M_1)(1-TS_i)-(M_0)(1-TS_0)}{(M_1)} \times 100$$

Calculation sugar gain

Sugar Gain (%SG) was defined as the net uptake of sugar by the osmosed pineapples based on the initial sample weight and was calculated by the following equation:

$$\% \text{ SG} = \frac{(M_0)(TS_0)-(M_i)(TS_i)}{(M_i)} \times 100$$

Calculation of weight reduction

Weight Reduction (WR) was defined as the net difference in weight between the initial sample weight of the pineapples and the weight of the osmosed fruit based on the initial sample weight and was calculated by the following equation:

$$\% \text{ WR} = \frac{(M_i)-(M_0)}{M_i} \times 100$$

where, M_i = initial weight of the raw pineapples; M_0 = weight of the osmosed pineapples; TS_i = initial total solids content of the raw pineapples; and TS_0 = total solids content of osmosed pineapples (% dry weight basis).

Calculation of total solid

Amount of total solids in the fruit was determined gravimetrically by vacuum oven drying at 70°C for 24 hours. The slices were transferred to a preweighed aluminium dish, weighed and dried in the vacuum oven. After cooling in a dessicator, the dish and the dried samples were reweighed. The percentage total solids (% TS) was calculated as follows:

$$\% \text{ TS} = \left(\frac{W_3 - W_1}{W_2 - W_1}\right) \times 100$$

where, W_1 = Weight of aluminium dish; W_2 = Weight of dish and sample; W_3 = Weight of dish and the vacuum dried samples.

Results and Discussion

Influence of osmotic solution concentration on mass transfer

The study of the influence of osmotic solution concentrations on mass transfer behavior during osmotic dehydration of pineapple slices was carried out using three different sugar solution concentrations of 40%, 50% and 60% (w/w). This experiment was carried out at temperature of 40°C and using of 10 mm pineapple slices throughout the experiment.

Fig. 1 to 4 illustrate plots of each of the respective mass transfer parameters (% WL, % SG, % WR and % TS) as a function of osmotic times due to the influence of three different sugar solution concentrations. It was observed from these figures that for all the three sugar solution concentrations (40%, 50% and 60%) studied, there were rapid rates of water loss (WL), sugar gain (SG) and weight reduction (WR) for the first hour of the osmotic process, after which the rate of these mass transfer parameters gradually slowed down with time towards equilibrium end-point. Contreras and Smyrl (1981) as well as Lu and Brennan (1987a) have also reported rapid removal of water and uptake of solids in the early stages of the osmotic process for apples. It was also found that both sugar solution concentration and osmotic time have highly significant effects (*p = 0.001*) on values of water loss, sugar gain, weight reduction and total solids of the osmosed pineapple.

For water loss, the higher the concentration of the sugar solution used, the greater was its rate of water loss. When 40% sugar solution was used, the water loss values of the pineapple were found to be significantly lower (*p = 0.05*) than those of 60% sugar solution.

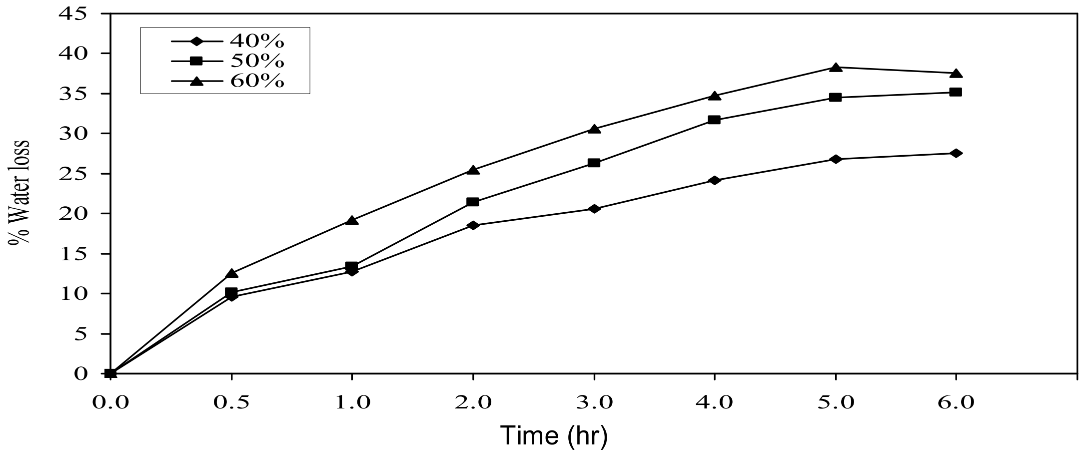

Fig. 1. Influence of different sugar solution concentration at 40°C on %water loss (WL) of pineapple slices of 10mm thickness

In the case of sugar uptake, Fig. 2 shows that sugar gain significantly increased (*p = 0.05*) with increasing sugar solution concentration. However, values sugar gain of the fruit obtained by using 40% sugar solution was not significantly different (*p = 0.05*) from that obtained when 50% sugar solution was used. This was observed in Figure 2 by the closeness of the two curves depicting changes of sugar gain of pineapple with osmotic time due to the 40% and 50% sugar solution concentrations.

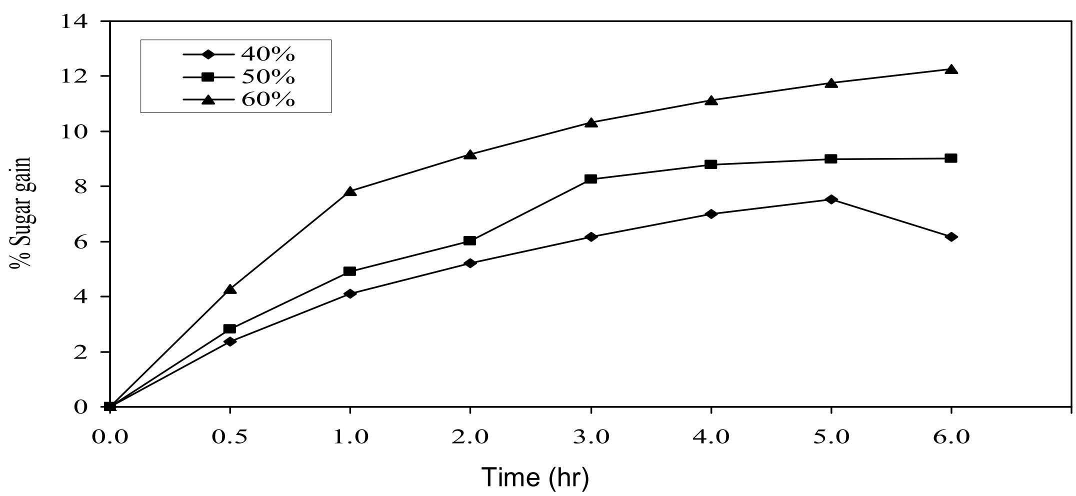

Fig. 2. Influence of different sugar solution concentration at 40°C on % sugar gain (SG) of pineapple slices of 10mm thickness

Fig. 3 shows that increasing the sugar concentration of the osmotic solution from 40% to 60% increased the weight reduction values of the osmotically-dried fruit. Ponting *et al.* (1966) using apples, noticed that at high sugar concentrations (above 65%) additional increase in concentration did not promote further weight loss. Similar responses to concentration increases were observed by Contreras and Smyrl (1981) although there was a difference regarding the concentration cut point; that is, the point above which an increase in concentration was not followed by a significant increase in weight loss. This difference can be explained on the basis of differences in experimental setup among the above workers (Lazarides, 1994).

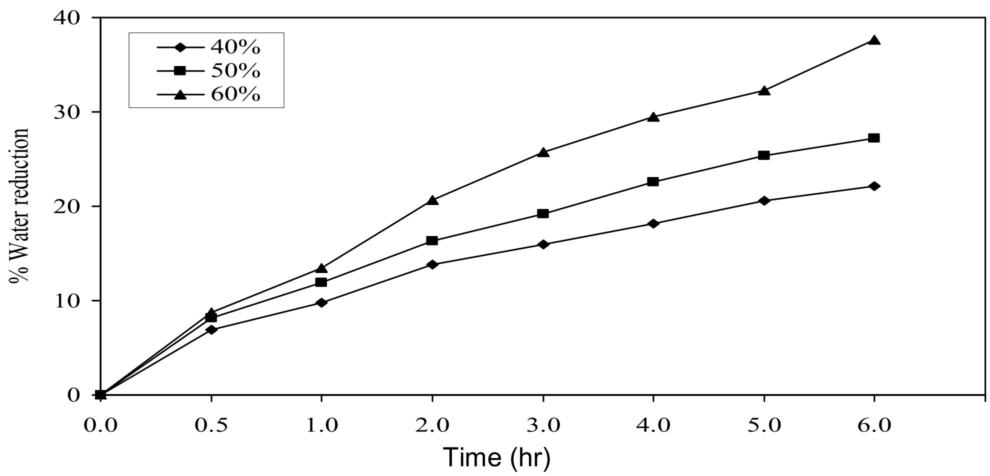

Fig. 3. Influence of different sugar solution concentration at 40°C on %weight reduction (WR) of pineapple slices of 10mm thickness

Fig. 4 shows that amount of total solids in the osmosed fruit significantly increased (*p=0.001*) with increase in sugar solution concentration. Thus, the use of very high sugar solution concentration (60% sugar) resulted in higher amount of sugar uptake by the fruit at the expense of lower water loss values as evidence by the low WL/SG ratio and higher TSo /TSi ratio (Normalized Solids content) in Table 1.

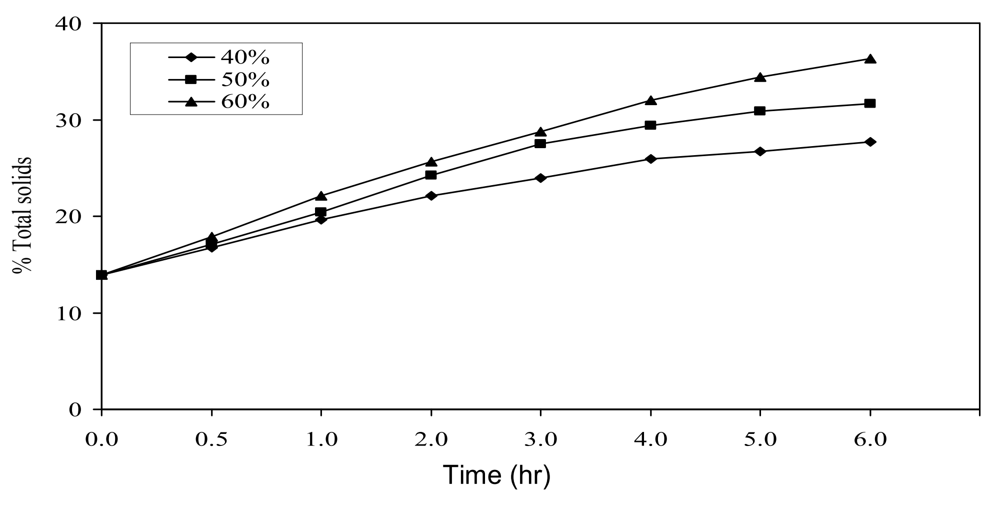

Fig. 4. Influence of different sugar solution concentration at 40°C on % total solids (TS) of pineapple slices of 10mm thickness

The higher amount of sugar uptake probably resulted in rapid development of a concentrated sugar layer under the surface of the fruit pieces, upsetting the osmotic pressure gradient across the fruit-sugar solution interface and therefore decreasing the driving force for water flow (Hawkes and Flink, 1978). Hughes *et al.* (1958) working on the penetration of maltosaccharides in processed Clingstone peaches, reported that the rate of solute penetration was directly related to the solution concentration and inversely related to the size of the sugar molecule. At lower concentrations of sugar (40 to 50% sugar), WL/SG ratios were the highest for the first 30 minutes of osmosis indicating the rate of water loss from the pineapple was the highest during the first half hour of the osmotic process before the ratios began to drop and then increased or decreased slightly with time (Table 1). The TSo/TSi ratio (NSC) of the three sugar solution concentrations studied increased with increase in both sugar concentrations and osmotic time.

Furthermore, the WL/SG and TSo/TSi ratios (Table 1) for the 60% sugar concentration after 6 hours of osmotic process were 3.79 and 2.73, respectively (second highest in both cases). Sankat (1992) found that in the case of banana slices immersed in 50° Brix sugar solution for 36 hours, the reduction in weight of the fruit slices was only 24.2%.

Table 1. WL/SG ratio and normalised solids content (NSC) of osmosed pineapple as a function of fruit blanching treatments and osmotic time and sugar solution concentrations

Osmotic time (hours)	WL/SG ratio			NSC = TSo/TSi		
	Sugar solution concentrations			Sugar solution concentrations		
	40%	50%	60%	40%	50%	60%
0.5	4.04	3.61	2.94	1.20	1.22	1.28
1.0	3.10	2.73	2.46	1.41	1.46	1.58
2.0	3.55	3.55	2.78	1.59	1.74	1.84
3.0	3.34	3.18	2.96	1.72	1.97	2.06
4.0	3.45	3.61	3.12	1.86	2.11	2.29
5.0	3.56	3.84	3.26	1.91	2.21	2.47
6.0	3.46	3.90	3.22	1.98	2.27	2.60
Mean*	3.5	3.48	2.96	1.66	1.85	2.01

* Mean of WL/SG ratios determined at seven osmotic time

Several researchers working with other fruits and vegetables (Hawkes and Flink, 1978; Moy *et al.,* 1978; Islam and Flink, 1982; Conway *et al.,* 1983; Lenart and Flink, 1984a and Pavasovic *et al.,* 1986) have also reported increased water loss with increase in osmotic solution concentrations. However, they did not point out the occurrence of reduced WL/SG ratio when high osmotic solution concentration (≥ 60% sugar solution) was used.

Hawkes and Flink (1978) in investigating the mass transport in the osmotic concentration of apples found that the mass transfer coefficient increased with sucrose concentration and was also influenced by agitation when the concentration of the sugar solution was 50% or greater. It should also be pointed out that, if the levels of sugar uptake into the fruit slices need to be a certain desired level, the sugar solution concentration that can maximize the rates of water loss and weight reduction and at the same time minimize the rate of sugar uptake had to be found.

Conclusion

- Six hours of osmotic process, using 60% sugar solution is recommended for the osmotic dehydration of pineapples due to its high rates of water loss (39.56%) and weight reduction (37.63%) as compared to those of 50% sugar solution (35.18% water loss; 27.18% weight reduction) and 40% sugar solution (27.58% water loss; 22.15% weight reduction).
- The level of sugar uptake in 6 hours of osmotic process in 60%, 50% and 40% sugar solutions were 12.26%, 9.02% and 6.18%, respectively.

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