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MOISTURE – SOLID TRANSFER DURING OSMOTIC DEHYDRATION OF BANANA (MUSA SAPIETUM) VARIETIES.

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ABSTRACT

Moisture-Solids transfer during the osmotic dehydration of three banana (Musa sapietum) varieties was investigated. Cavendish, Omini-red and Cooking banana were transversely sliced into 10, 15 and 20mm thicknesses. Sample of each thickness were immersed in 52^0, 60^0 and 68^0B sucrose solutions. A fruit: solution ratio of 1:20 (w/w) was maintained. The fruit-solution mixtures were kept at 27^0, 34^0 and 40^0C for 12 hours. Samples were evaluated gravimetrically at 2 hours interval. Moisture and total solids contents were determined and expressed as g water/g dry matter (DM) and g solids/g initial mass respectively.

Moisture contents on dry basis of the banana slices were found to decrease with increased immersion time, solution concentration and temperature. However, moisture contents decreased with decreased slice thickness. Total solids content increased with increased immersion time, solution concentration and temperature, but decreased with decreased slice thickness. Omini red cultivar had the lowest moisture content and the highest total solids content at the end of 12 hours of osmotic treatment. Complex polynomial equation showing the relationship with moisture and total solids contents with immersion time showed high correlation ($R^2 = 0.9919 - 1.000$).

Keywords: Cavendish, Cooking banana, Mass transfer, Omini red, Osmotic Dehydration

INTRODUCTION

Osmotic dehydration is used for partial removal of water from materials such as fruits and vegetables when immersed in a concentrated solution of sugar or salt. The osmotic solute diffused from the solution into the product and water is transported from the material into the solution due to osmotic pressure differential between the food and the solution (Rastogi and Niranjan, 1998; Rastogi, Estiaghi & Knorr, 1999; Beristain et al., 1990; Barat, Chipalt & Fito, 1996). The main advantages of osmotic dehydration include inhibition of enzymatic browning, retention of natural colour without addition of solutes, higher retention of volatile compounds during further dehydration with no phase change involved, and therefore, less energy consumed during dehydration (Beristain et al., 1990). Poor understanding of the counter – current water extraction and solute penetration during osmotic dehydration has limited its commercial application in tropical fruits. Moisture – solid transfer during osmotic dehydration modifies product characteristics and stability, giving a more plastic texture and reduced moisture to be removed during the subsequent dehydration. According to Lazarides and Mavroudis (1995) almost 50% of initial moisture was lost in the first 2 hours, while an additional 20% was lost within the next 3 hours of osmotic treatment of apples. Prolonged osmotic treatment, will lead to excessive soluble solid leaching, extensive solids uptake and drop in water loss rates. Water rates dropped to half their initial value within an hour of immersion of apple slices in sucrose solution (Lazarides, Nickolaidis & Katsandidis , 1994). The objective of this study is to investigate the effects of slice thickness, immersion time, solution concentration and temperature, and variety on moisture – solid changes in banana during osmotic dehydration.

MATERIALS AND METHODS

Procurement and preparation of materials

Samples of mature green banana were obtain from a local market at Iware. The bananas were stored at 26°C until the attained stage 5. Firm ripe – Omini red, Cavendish and Cooking banana at stage 5 on banana ripening chart (United Fruit Sales Corporation, 1964) were used for the experiment. Commercial sucrose was used as the osmotic agent. Osmotic sugar solutions of 52°, 60° and 68°B were prepared by dissolving a weighed amount of sucrose in a known amount of distilled water with gentle heating to facilitate complete sugar dissolution. To each of the osmotic solution 0.25% sodium metabisulphite was added.

Osmotic dehydration of banana varieties

Bananas were peeled and transversely cut into 10, 15 and 20mm slices, and were packed into wire mashes. These were then immersed into the prepared osmotic solutions while maintaining a 1:20 (w/w) fruit: syrup ratio. A set of fruit-solution mixtures was kept at 27°C, another set at 34°C and a third set at 40°C. Osmotic solution concentration was monitored with Abbe refractometer and the solutions were maintained at the required concentration by addition of solute when necessary.

Banana samples were removed from the solution at regular intervals of 2 hours, quickly rinsed and gently blotted with tissue paper to remove the adhering syrup solutions. The samples were then weighed and dried in a Gallenkamp oven (Model OV – 160) at 100°C for 24 hours as described by Sankat, Castaigne & Maharaj (1996). Moisture and total solids contents were determined according to the method of Ruck (1969), and expressed in terms of g water/g dry matter and g solids/g of initial mass respectively. All experiments were done in triplicates and average values were reported.

RESULTS AND DISCUSSION

Effect of Slice Thickness on the Moisture and Total Solids Content During Osmotic Dehydration

The slice thickness of banana varieties affected the response to osmotic dehydration. The moisture content attained by banana soaked in sucrose solution decreased with decreased slice thickness. Figure 1 show the variation of moisture content with slice thickness of Omini red banana. Similar trends were noted with Cavendish and Cooking bananas. Moisture content of Cavendish decreased from 3.878 g water/g D.M. to 0.791, 1.516 and 1.844, respectively, for 10, 15 and 20mm slices immersed in 60°B sucrose solution. And, moisture content of Cooking banana decreased from 3.388 g water/g D.M. to 1.108, 1.276 and 1.394, for 10, 15 and 20mm slices, respectively immersed in 60°B sucrose solution. Total solids content increased with decreased slice thickness, as shown for Omini red banana (Figure 2). A similar trend was observed for Cavendish and Cooking banana. Total solids content of Cavendish increased from 0.2051 g solid/g initial mass to 0.5585,0.3974 and 0.3773 for 10, 15 and 20mm slices, respectively, immersed in 60°B sucrose solution. And, total solids content of Cooking banana increased from 0.2279 g solid/g initial mass to 0.4640, 0.4211 and 0.4068, for 10, 15 and 20mm slices, respectively, immersed in 60°B sucrose solution. Decreased moisture and total solids contents of banana with decrease slice thickness is due to increase in exposed surface area per unit mass. The increase in surface area of contact with the osmotic solution as the slice thickness decreased, allowed for greater contact with osmotic solution (Yao and Le Maguer, 1996;
Lazarides and Mavroudis, 1995). It has similarly been found for pineapple that one of the factors affecting mass transfer during osmotic dehydration is the size and geometry of the solid (Rastogi and Niranjan, 1998; Rastogi et al., 1999).

Effect of Osmotic Solution Concentration on Moisture and Total Solids Content During Osmotic Dehydration.

Moisture contents attained by banana slices decreased with increasing osmotic concentration. Increasing osmotic solution concentration facilitated the extraction of moisture from the fruits resulting in lower moisture contents in the fruit pieces. Figure 3 shows the variation of moisture contents with solution concentration of Omini red banana. Similar trends were noted for Cavendish and Cooking bananas. The moisture content of fresh of Cavendish and Cooking banana were 3.878 and 3.3888 g water/g D.M., respectively. Moisture content of Cooking banana decreased to 1.375, 1.276 and 1.063 g water/g D.M. in 52°,60° and 68°B sucrose solutions, respectively, after 12 hours of immersion. The moisture content of Cavendish banana decreased to 1.815, 1.516 and 1.235 g water/g D.M. in 52°, 60° and 68°B. The total solids content of osmosed bananas increased with increasing osmotic solution concentration. Consistently higher total solids were obtained in the bananas osmosed in 68°B sucrose solution. Figure 4 shows the variation of total solids with osmotic solution concentration of Cavendish banana. Similar results were obtained for Omini red and Cooking banana varieties. The total solids of fresh Omini red and Cooking banana were 0.2671 and 0.2279 g solid/g initial mass, respectively. Total solids of Omini red increased to 0.3961, 0.4006 and 0.4337 g solid/g initial mass in 52°, 60° and 68°B. Moreover, the total solids of Cooking banana increased to 0.4211, 0.4393 and 0.4847 g solid/g initial mass in 52°, 60° and 68°B, after 12 hours of immersion. The differential in concentration of solution and the fruit solids, affected water–solid transfer. As sucrose concentration of the solution was increased, more sugar migrated into the fruit. Similarly, Beristain et al., (1990) reported that water loss from pineapple slice increased with increased sugar concentration and temperature. Higher water extractions from apple and kiwi fruits were recorded as the solution concentration increased (Panagiotu, Karanthanos & Maroulis, 1999).

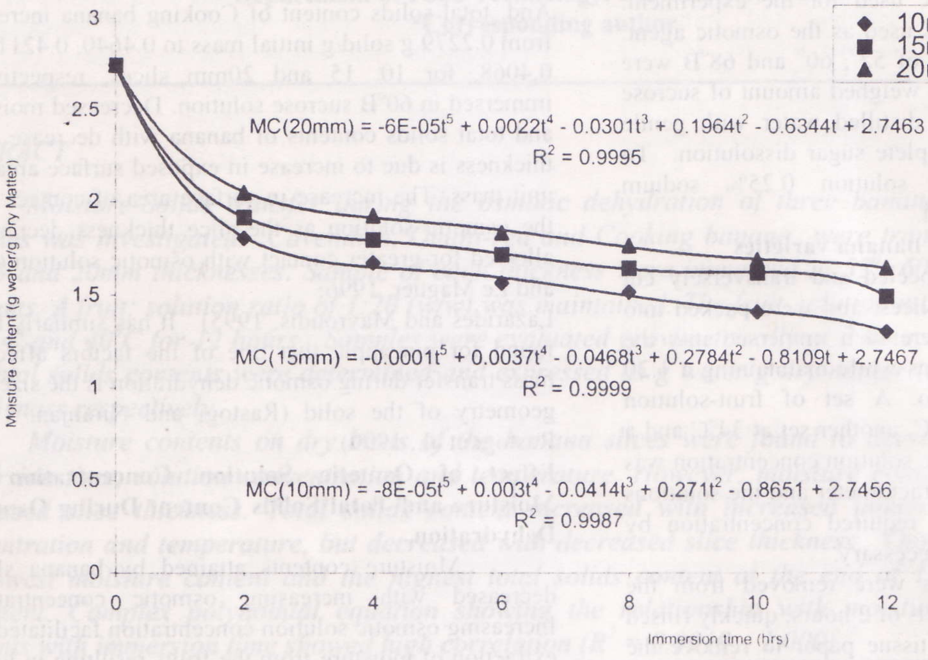

Fig. 1 Variation of Moisture Content with Thickness of Omini Red Banana Immersed in 60°B Sucrose Solution.

Effect of Varietal Difference on Moisture and Total Solids Contents During Osmotic Dehydration.

The variation of moisture contents attained by 10mm slices of Omini red, Cavendish and Cooking bananas in 52°B sucrose solution is shown in Figure 5. Cooking and Cavendish bananas had higher initial moisture content than Omini red banana. For all the banana varieties, moisture contents declined rapidly in the first 2 hours of immersion. Between 2 and 12 hours of immersion, an almost linear relationship occurred between moisture content and immersion time. Although the Omini red variety (2.747 g water g D.M.) had the lowest initial moisture content, attained the highest moisture content among the three varieties after 12 hours of osmotic dehydration. This is due to the higher initial soluble solids (23°B) content of Omini red prior to osmotic treatment. According to Saurel et al. (1994) the overall cause of water extraction from the product into the solution is the internal concentration gradient. After 4 hours of osmotic dehydration there was no further appreciable reduction in moisture content of the banana. More than 50% of the moisture reduction took place in the first 2 hours of osmotic dehydration. This agrees with the work of Lazarides and Mavroudis (1994) on apples.

Fresh Omini red (0.2671 g solids/g initial mass) and Cooking banana (0.2279 g solid/g initial mass) varieties had higher total solids than the Cavendish banana (0.2051 g solid/g initial mass). Total solids content of Cooking banana increased rapidly and attained the maximum total solids, but consistently lower total solids were recorded for Cavendish and Omini red bananas (Figure 6). Omini red had the lowest change in total solids content after 12 hours of osmotic treatment. This showed that solute uptake of the Omini red was lower compared to the other 2 varieties. This is advantageous, since lower solute infusion would limit solute depletion in the osmotic solution, thus enhancing sugar economy during the process.

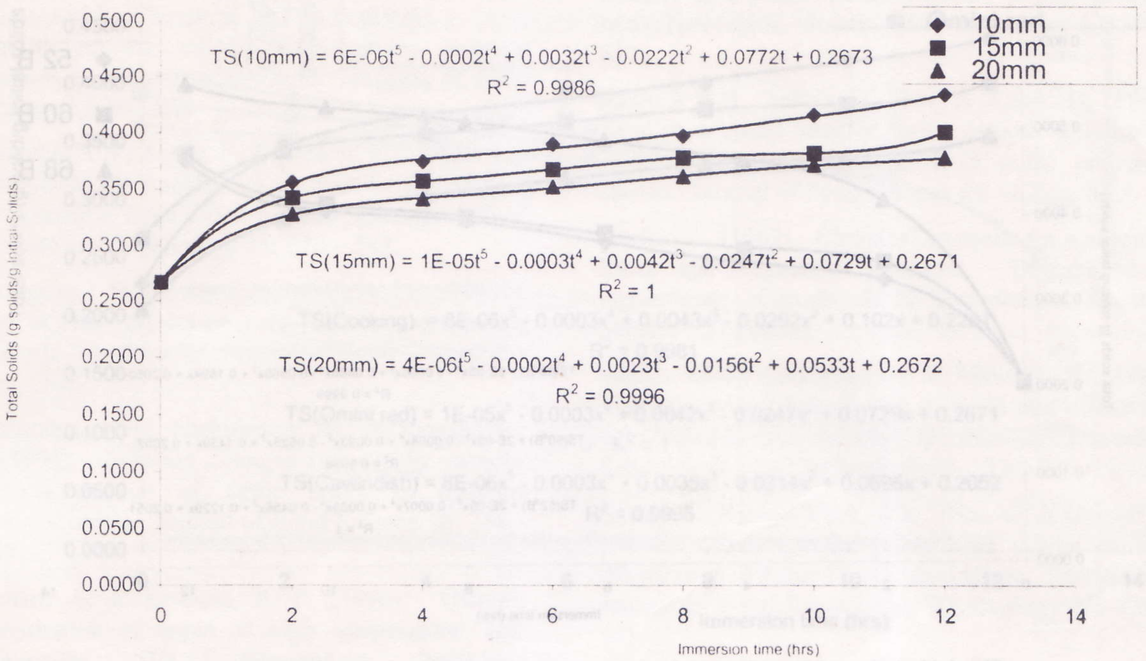

Fig. 2 Variation of Total Solids with Thickness of Omini Red Banana Immersed in 60°B Sucrose Solution at 27°C.

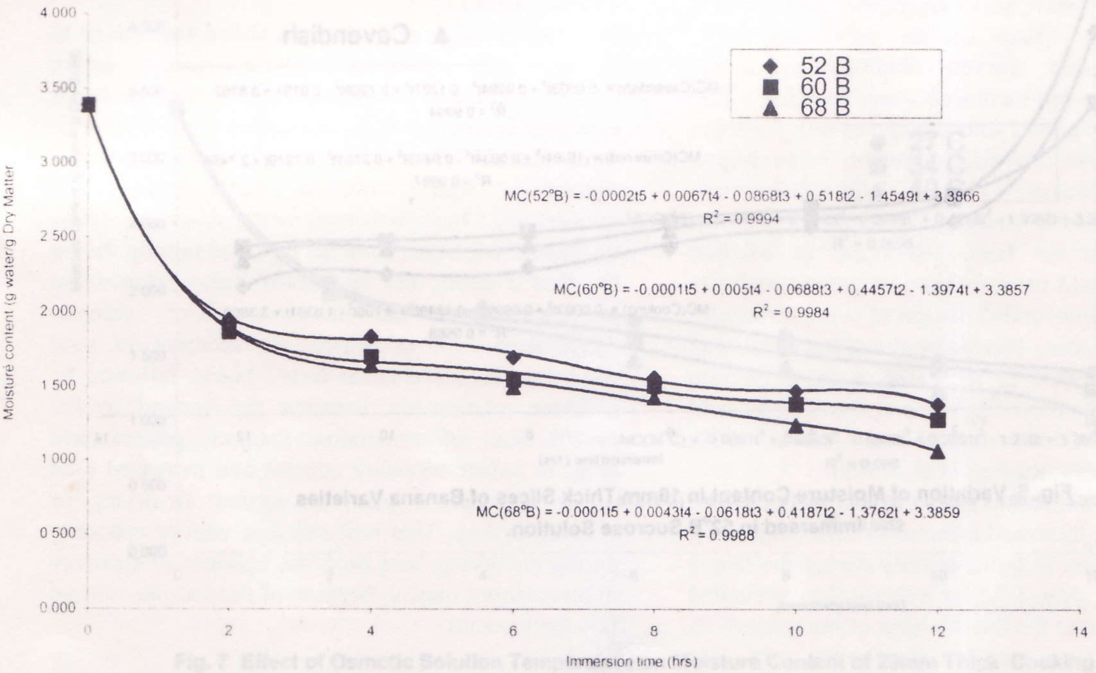

Fig. 3 Variation of Moisture Content with Sucrose Solution Concentration in 15mm Thick Cooking Banana at 27°C.

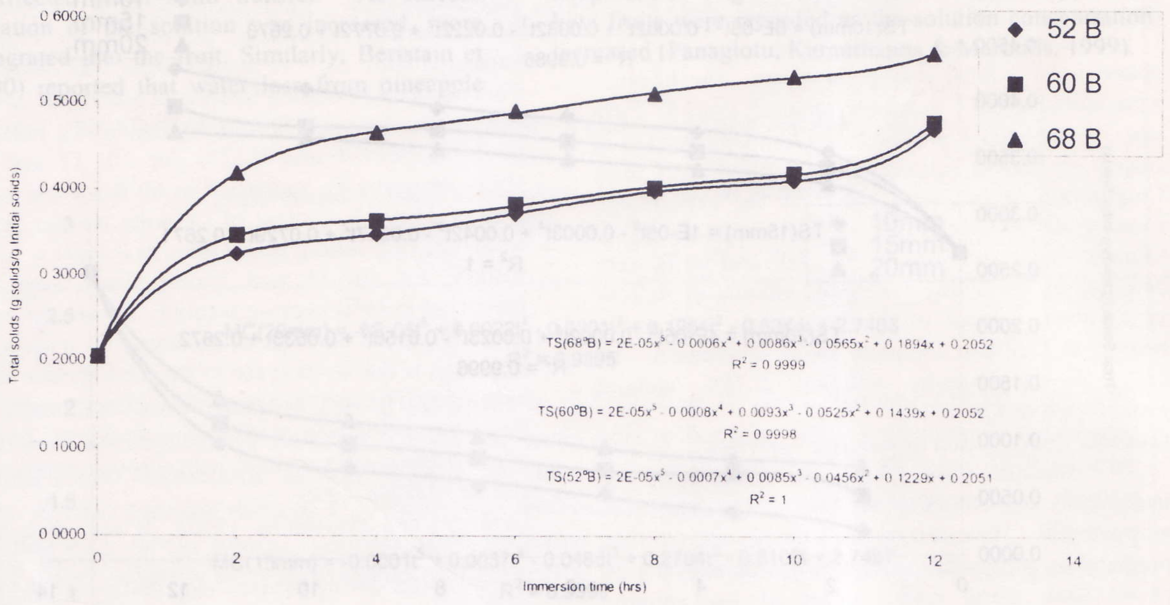

Fig. 4 Variation of Total Solids Content with Sucrose Concentration in 15mm thick Cavendish Banana Slices at 27°C.

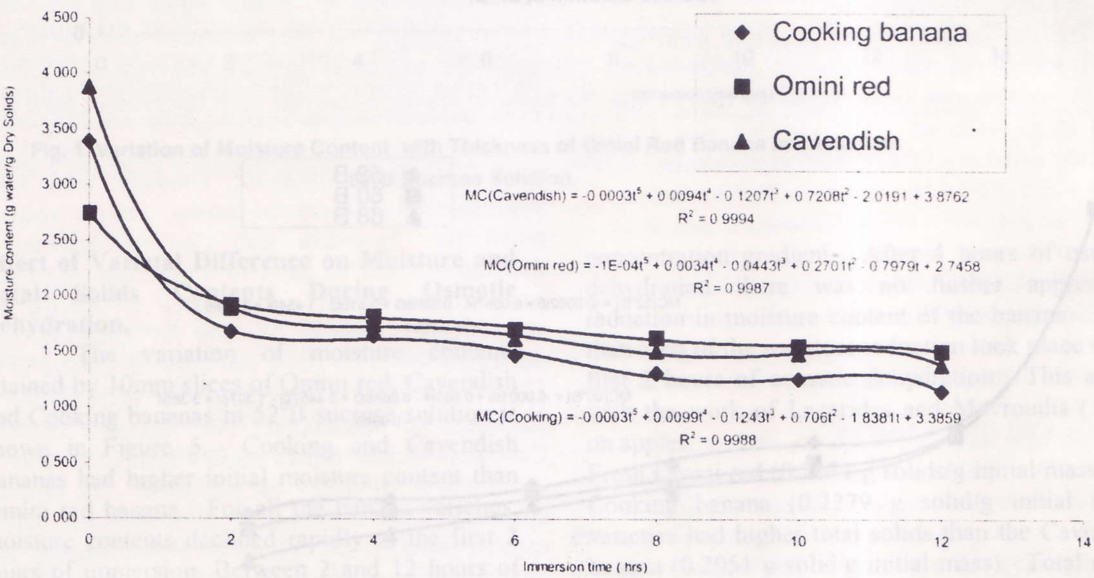

Fig. 5 Variation of Moisture Content in 10mm Thick Slices of Banana Varieties Immersed in 52°B Sucrose Solution.

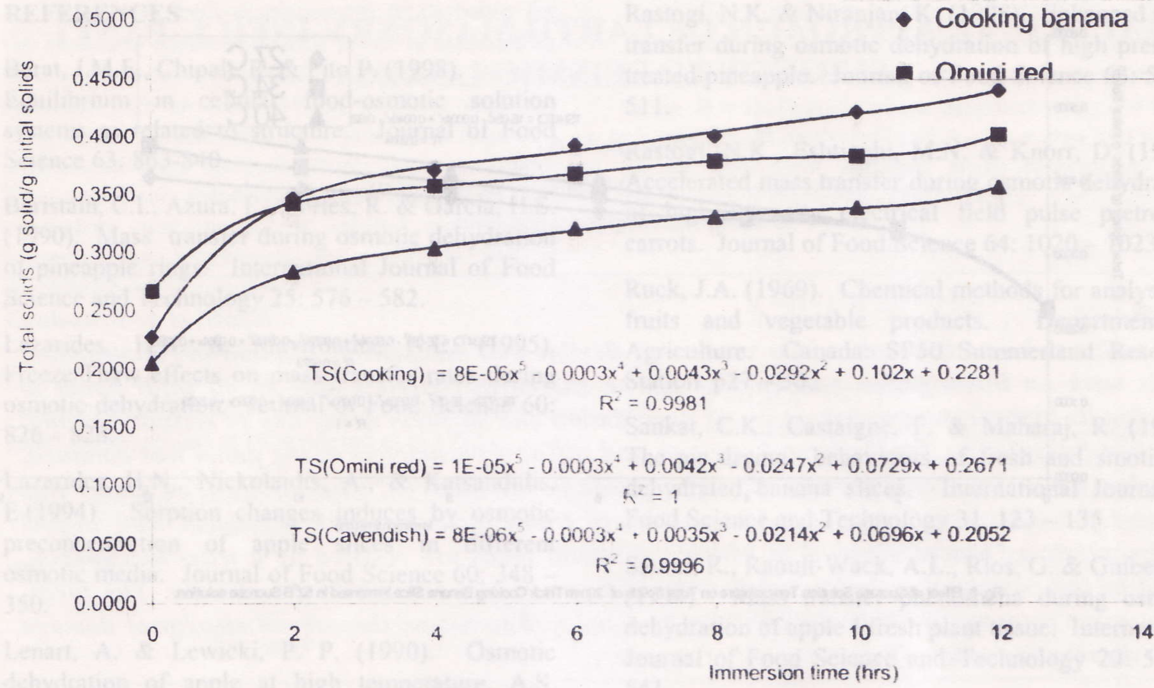

Fig. 6 Variation of Total Solids Content with Varietal Difference of 15mm Thick Banana Slice Immersed in 60°B Sucrose Solution.

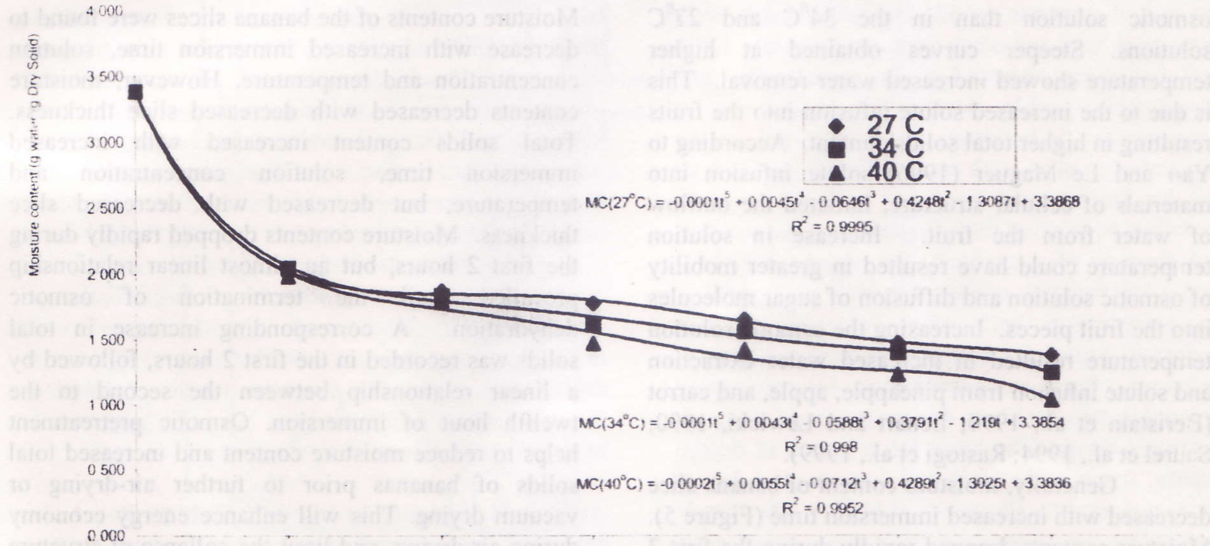

Fig. 7 Effect of Osmotic Solution Temperature on Moisture Content of 20mm Thick Cooking Banana Slice Immersed in 52°B Sucrose Solution.

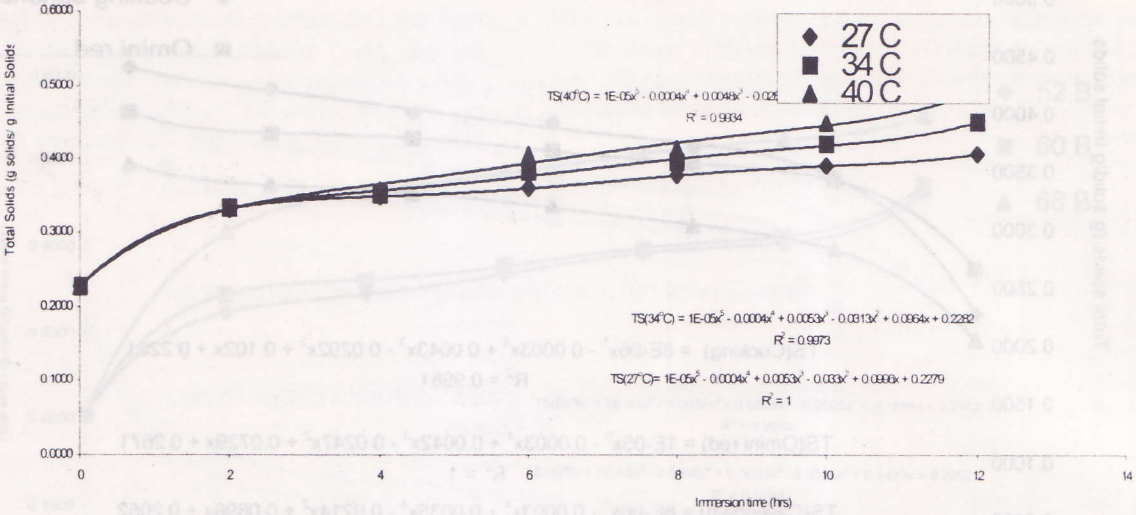

Fig. 8 Effect of Sucrose Solution Temperature on Total Solids of 20mm Thick Cooking Banana Slice Immersed in 52°B Sucrose solution.

Effect of Osmotic Solution Temperature and Immersion Time on Moisture and Total Solids Contents During Osmotic Dehydration.

Figure 7 and 8 show the effect of osmotic solution temperature on the moisture and total solids contents respectively. There was higher decline of moisture content of banana slices immersed in the 40°C osmotic solution than in the 34°C and 27°C solutions. Steeper curves obtained at higher temperature showed increased water removal. This is due to the increased solute infusion into the fruits resulting in higher total solids content. According to Yao and Le Maguer (1996) solute infusion into materials of cellular structure, initiated the outflow of water from the fruit. Increase in solution temperature could have resulted in greater mobility of osmotic solution and diffusion of sugar molecules into the fruit pieces. Increasing the osmotic solution temperature resulted in increased water extraction and solute infusion from pineapple, apple, and carrot (Beristain et al., 1990; Lenart and Lewicki, 1990; Saurel et al., 1994; Rastogi et al., 1999).

Generally, moisture content of banana slice decreased with increased immersion time (Figure 5). Moisture contents dropped rapidly during the first 2 hours, but an almost linear relationship prevailed from the second to the twelfth hour of immersion. A corresponding increase in total solids was also recorded in the first 2 hours, followed by a linear relationship between the second to the twelfth hour of immersion. Complex polynomial equations showing the relationship between experimental and predicted values of moisture and total solids content during osmotic dehydration are shown on the Figures 1-8. Predicted and experimental values of moisture and total solids content showed high correlation (R^2 = 0.9919 – 1.000).

CONCLUSIONS

Moisture contents of the banana slices were found to decrease with increased immersion time, solution concentration and temperature. However, moisture contents decreased with decreased slice thickness. Total solids content increased with increased immersion time, solution concentration and temperature, but decreased with decreased slice thickness. Moisture contents dropped rapidly during the first 2 hours, but an almost linear relationship prevailed until the termination of osmotic dehydration. A corresponding increase in total solids was recorded in the first 2 hours, followed by a linear relationship between the second to the twelfth hour of immersion. Osmotic pretreatment helps to reduce moisture content and increased total solids of bananas prior to further air-drying or vacuum drying. This will enhance energy economy during air-drying, and limit the collapse of structure in preosmosed banana because of the sucrose infused into the bananas.

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