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Mass Transfer during Osmotic Dehydration of Banana Slices for Drying Process

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Abstract- Effects of Osmotic dehydration on water loss, solids gain, and weight reduction during osmotic dehydration were investigated in order to determine the usefulness of this technique as pre-treatment for further drying of bananas slices. Banana slices, 10 mm thick, were immersed in sucrose solutions with concentrations of 30, 40 and 50 Brix at 40, 50 and 60^0C for 60, 90 and 120 minutes. Water loss, weight reduction and solids gain increased with treatment time. Longer treatment time in high concentrations of sucrose resulted in a very soft product, which is difficult to handle and unsuitable for further drying. Increasing concentration at the same temperature did not cause significant increments in weight change. Higher concentrations of sucrose caused higher rates of water removal.

The effective Normalized moisture content for water and Normalized solid content were determined, considering banana as slices configuration. The temperature was controlled using constant temperature stirred water bath. The ratio of the volume of slices to that of the medium was maintained at 1:4, 1:5 and 1:10 in order to ensure that the concentration of the osmotic solution did not change significantly during the experiment. The samples were withdrawn, rinsed quickly in water, blotted gently with a tissue paper in order to remove adhering water and then dried in a hot air oven at 70 ^{0}C for 18 hours. The regression analysis was done by response surface method.

Index Terms- Osmotic dehydration, solid gain, moisture loss, solid gain, weight reduction, normalized moisture content, normalized solid content, response surface method.

I. INTRODUCTION

Banana is the common name for herbaceous plants of the genus Musa and for the fruit they produce. It is one of the oldest cultivated plants. They are native to tropical South and Southeast Asia, and are likely to have been first domesticated in Papua New Guinea. Today, they are cultivated throughout the tropics. They are grown in at least 107 countries, primarily for their fruit, and to a lesser extent to make fibre, banana wine and as ornamental plants. Its fruits, rich in starch, grow in clusters hanging from the top of the plant. They come in a variety of sizes and colours when ripe, including yellow, purple, and red. Almost all modern edible parthenocarpic bananas come from two wild species – Musa acuminate and Musa balbisiana. The scientific names of bananas are Musa acuminate, Musa balbisiana or hybrids Musa acuminate balbisiana, depending on their genomic constitution. The old scientific names Musa sapientum and Musa paradisiacal are no longer used.

Banana is one of the most important major fruit crops grown in India. In respect of area it ranks second and first in production only after mango in this country. India leads the world in banana production with an annual output of about 16.820 mt. In India Tamil Nadu leads in total area and production with 2514729 T from 71088 ha. The banana culture in India is as old as Indian civilization. It seems that it is one of the earliest fruit crops grown by mankind at the dawn of civilization. In India, bananas are so predominant and popular among people that poor and rich alike like the fruit. Considering the nutritive value and fruit value of bananas, it is the cheapest among all other fruits in the country. Considering the year round availability of fruits, unlike the seasonal availability of other tree fruits, it has become an inevitable necessity in any household in India, for all functions. The bananas were grown in Southern Asia even before the prehistoric periods and the world's largest diversity in banana population is found in this area. Hence, it is generally agreed that all the edible bananas and plantains are indigenous to the warm, moist regions of tropical Asia comprising the regions of India, Burma, Thailand and Indo China.

Bananas must be transported over long distances from the tropics to world markets. To obtain maximum shelf life, harvest comes before the fruit is mature. The fruit requires careful handling, rapid transport to ports, cooling, and refrigerated shipping. The goal is to prevent the bananas from producing their natural ripening agent, ethylene.

This technology allows storage and transport for 3–4 weeks at 13 °C (55 °F). On arrival, bananas are held at about 17 °C (63 °F) and treated with a low concentration of ethylene. After a few days, the fruit begins to ripen and is distributed for final sale. Unripe bananas cannot be held in home refrigerators because they suffer from the cold.

Osmotic dehydration is an operation used for the partial removal of water from plant tissues by immersion in a hyper-tonic (osmotic) solution. Water removal is based on the natural and non-destructive phenomenon of osmosis across cell membranes. The driving force for the diffusion of water from the tissue into the solution is provided by the higher osmotic pressure of the hyper-tonic solution. The diffusion of water is accompanied by the simultaneous counter diffusion of solutes from the osmotic solution into the tissue. Since the cell membrane responsible for osmotic transport is not perfectly selective, solutes present in the cells (organic acids, reducing sugars, minerals, flavors and pigment compounds) can also be leached into the osmotic solution, which affect the organoleptic and nutritional characteristics of the product. The rate of diffusion of water from any material made up of such tissues depends upon factors such

as temperature and concentration of the osmotic solution, the size and geometry of the material, the solution-to-material mass ratio and, to a certain level, agitation of the solution.
In osmotic dehydration, foods are immersed or soaked in a saline or sugar solution. This results in three types of counter mass transfer phenomenon (Ponting, 1973). First, water outflow from the food tissue to the osmotic solution, second, a solute transfer from the osmotic solution to the food tissue, third, a leaching out of the food tissue's own solutes (sugars, organic acids, minerals, vitamins) into the osmotic solution.

II. MATERIAL AND METHORD

Musa paradisiacal L varieties of bananas were obtained from the local market; Allahabad, Uttar Pradesh, India and experiment were conducted in Laboratory of Food Process Engineering Sam Higginbottom Institute of Agriculture technology and Sciences Deemed to be university, Allahabad. The tips of the bananas were first removed and its medium part, cut into slices of 1cm length with a knife. The average moisture content of fresh banana, determined by hot air oven drying at 70 ^{0}C, was found to be 75% on a wet weight basis. Commercial sugar was used as the osmotic agent.

The samples were taken from the same banana, blotted with tissue to remove external moisture, and then subjected to osmotic dehydration over a range of concentration (30-50 ^{0}B)s and temperature (40-60 ^{0}C) of osmotic solution. The temperature was controlled using a constant temperature stirred water bath. The ratio of the volume of the pieces to that of the medium was maintained at 1:4, 1:5, and 1:10 in order to ensure that the concentration of the osmotic solution did not change significantly during the experiment. The samples were withdrawn, rinsed quickly in water, blotted gently with a tissue paper in order to remove adhering water and dried in a vacuum oven at 70 ^{0}C for 18 hours. The moisture and solid content at any time are expressed as kg of water/kg of initial dry solids and kg of solid/kg of initial dry solid, respectively.

Banana
⇩
Peeling
⇩
Decoring
Cut into Slices (10mm Thickness)
⇩
Blotted with Tissue Paper
⇩
Weight of the Sample
⇩
Subjected to Osmotic Dehydration Solution in the Range of Concentration (30-50 ^{0}B) and Temperature (40-60 ^{0}C) of Osmotic Solution
⇩
Ratio of Volume of Slices to that of the Medium Maintained at 1:4, 1:5 and 1:10
⇩
Immersion Time (60, 90 And 120 Min.)
⇩
Weight of Immersion Sample
⇩
Put in Hot Air Oven Drier for 18 Hrs at 70 ^{0}C
⇩
Weight of the Dried Sample

Figure 1: Flow Chart for Banana Dehydration Process

Determination of process parameters
Moisture content

%, M.C = (Mass of moisture)/ (Mass of the sample)
$= \{(w_1 - w_{2)\,x}\ 100\}/\ (w_1)$

Where,
w_1 = weight of sample (g),
w_2 = weight of final dried mass (g).

Moisture loss

$$\%, \text{Moisture Loss} = \frac{\text{Initial Moisture-Final Moisture}}{\text{(Initial Moisture)}} \times 100$$

Solid Gain

$$\%, \text{Solid Gain} = \frac{\text{Initial Solid} - \text{Final Solid}}{\text{(Initial Mass Of Sample)}} \times 100$$

Weight loss

$$\%, \text{Weight Loss} = \frac{\text{Initial Sample Weight} - \text{Sample Weight After OD}}{\text{(Initial Sample Weight)}} \times 100$$

Normalized moisture content

$$\text{NMC} = \frac{\text{Moisture Content In The Sample After OD(G)}}{\text{Initial Moisture Content Of The Fresh Sample (G)}}$$

Normalized solid content

$$\text{NSC} = \frac{\text{Solid Content In The Sample After OD(G)}}{\text{Initial Solid Content In The Fresh Sample(G)}}$$

III. RESULT ANDDISCUSSION

The initial moisture content of the banana used during the study was in the range of 75% wet basis and 25% dry matter. In this present study osmotic dehydration of banana was investigated by immersion of banana slices (10mm thickness) in to sugar solution in the range of (30-50 Brix) held at 40 ^{0}C, 50 ^{0}C, 60 ^{0}C temperature processed for 60, 90 and 120 minutes respectively.

Effect of Time and Temperature on moisture loss in banana slices:

- Concentration=40 Brix
- Sample to solution ratio=1:5

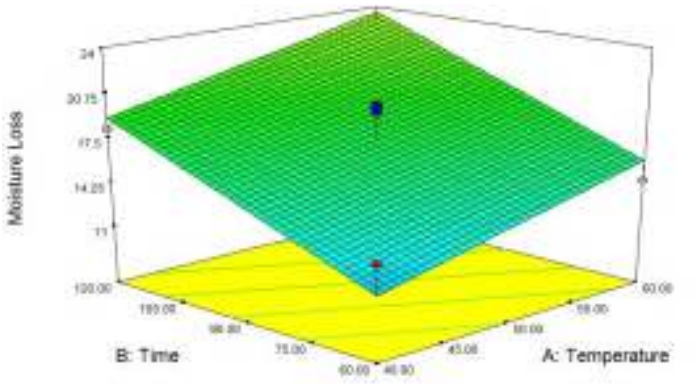

Figure 2: Moisture Loss Vs Temperature and Time

In Figure2 show the effect of time in moisture loss, According to this figure Concentration and sample to solution ratio are constant factors only time is varying. Here the moisture loss is increasing with increasing the time most efficient Moisture Loss occurred between 90 to 120 minute.

The effect of temperature in moisture loss. According to this FigureConcentration and sample to solution ratio are constant factors and temperature and time is varying. Here the moisture loss is increasing with increasing temperature. The higher temperature can effect on the texture of banana and it can be responsible for nutrition loss.

Effect of Concentration and Sample to Solution Ratio on moisture loss in banana slices:

- Temperature = 50 ^{0}C
- Time = 90 min

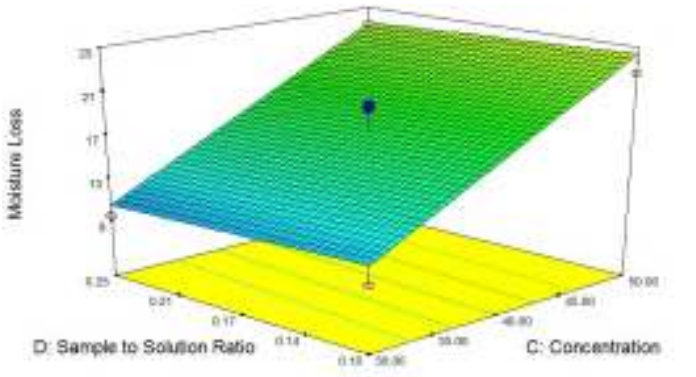

Figure 3: Moisture Loss Vs Concentration and Sample to Solution Ratio

In Figure3 show the effect of concentration in Moisture Loss. According to this Figure time and Temperature are constant factors only Concentration varies. Here the moisture loss is increasing with increasing Concentration.

The effect of Sample to Solution Ratio in moisture loss, according to this Figure time and Temperature are constant factors only Sample to Solution Ratio varies. Here the moisture loss is increasing with increasing Sample to Solution Ratio.

Effect of Temperature and Time on Solid Gain in banana slices:

- Concentration=40 Brix
- Sample to solution ratio=1:5

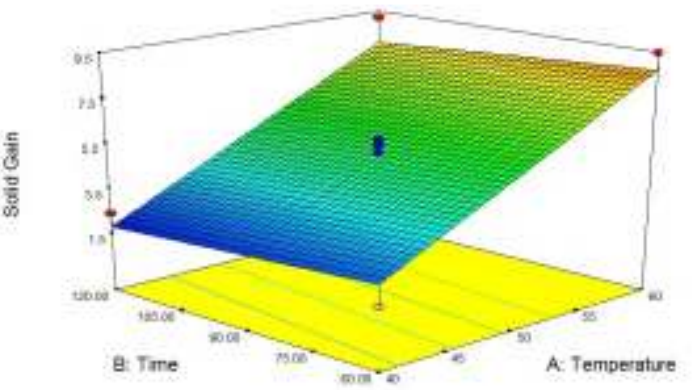

Figure 4: Solid Gain Vs Temperature and Time

In Figure 4 show the effect of temperature in solid gain, according to this Figure Concentration and sample to solution ratio are constant factors only temperature is varies. Here the solid gain is increasing with increasing the temperature .In osmotic dehydration temperature is important variable. The higher solid gain can effect on the texture of banana and it can be responsible for change in flavor.

The effect of time in solid gain, according to this figure Concentration and sample to solution ratio are constant factors only time is varies. Here the solid gain is increasing with increasing the time most efficient solid gain occurred between 60 to 90 minute indicating that it may not be necessary to carry out the osmotic treatment step for longer hours.

Effect of Concentration and Sample to Solution Ratio on Solid Gain in banana slices:

- Temperature = 50 0C
- Time = 90 min

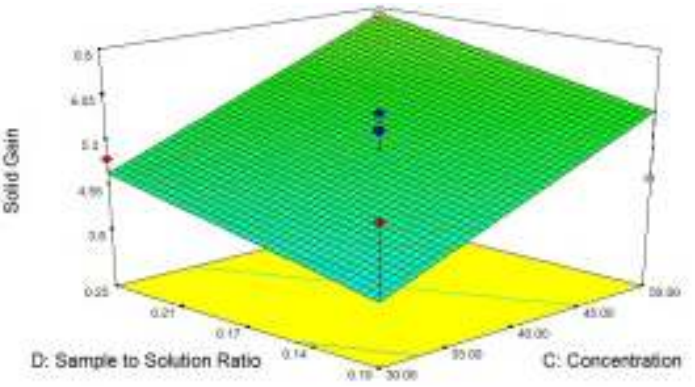

Figure5: Solid Gain Vs Concentration and Sample to Solution Ratio

In Figure5 show the effect of Concentration in solid gain, according to this Figure Time and Temperature ratio are constant factors only Concentration varies. Here the solid gain is increasing with increasing the Concentration.

The effect Sample to Solution Ratio in solid gain, according to this figure Time and Temperature are constant factors only Sample to Solution Ratio varies. Here the solid gain is increasing with increasing Concentration.

Effect of Temperature and Time on Weight Reduction in banana slices:

- Concentration=40 0B
- Sample to solution ratio=1:5

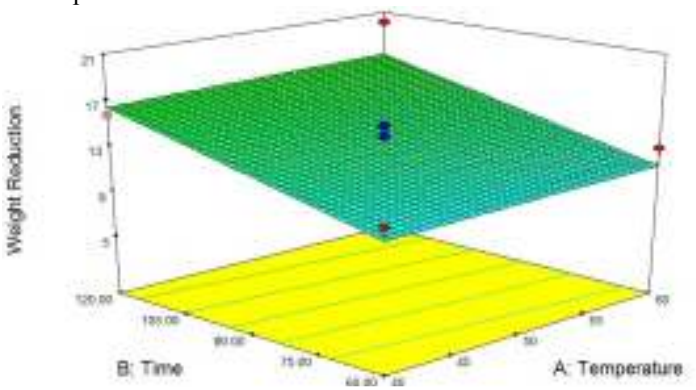

Figure 6: Weight Reduction Vs Temperature and Time

In Figure6 show the effect of temperature in weight reduction, according to this Figure Concentration and sample to solution ratio are constant factors only temperature is varies. Here the weight reduction is increasing with increasing the temperature. In osmotic dehydration the weight reduction depends on the moisture loss and solid gain in banana slices.

The effect of time in weight reduction, according to this figure Concentration and sample to solution ratio are constant factors only time is varies. Here the solid gain is increasing with increasing the time most efficient weight reduction occurred between 60 to 90 minute indicating that it may not be necessary to carry out the osmotic treatment step for longer hours.

Effect of Concentration and Sample to Solution Ratio on Weight Reduction in banana slices:

- Temperature = 50 0C
- Time = 90 min

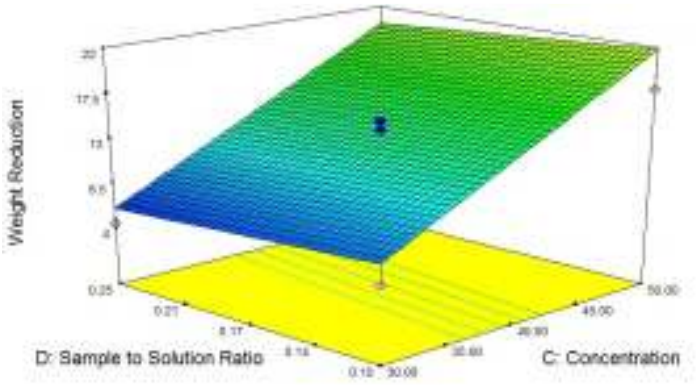

Figure7: Weight Reduction Vs Concentration and Sample to Solution Ratio

In Figure7 show the effect of Concentration in Weight Reduction. According to this Figure Time and Temperature are constant factors only Concentration varies. Here the Weight Reduction is increasing with increasing the Concentration.

The effect of Sample to Solution Ratio in weight reduction, according to this Figure Time and Temperature are constant factors only Sample to Solution Ratio varies. Here the weight reduction is increasing with increasing Concentration

Analysis of Normalized Moisture Content (NMC) during Osmotic Dehydration:

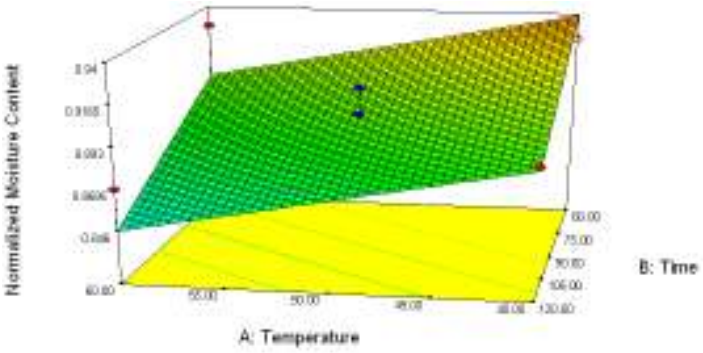

Figure 8: Normalized Moisture Content Vs Temperature & Time.

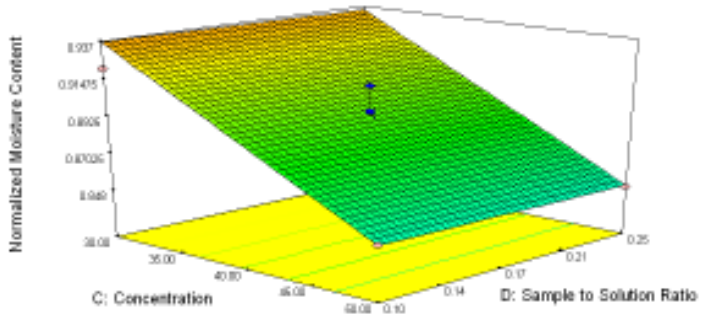

Figure 9: Normalized Moisture Content Vs Concentration & Sample to Solution Ratio.

Normalized Moisture Content (NMC); is ratio between Moisture Content in Banana before Osmotic Dehydration & Moisture Content in Banana after Osmotic Dehydration. From Figure No. 4.13, it is obtained that Moisture Content with in Banana sample is gradually decreasing with the increase of Time & Temperature. As well as from Figure No. 4.14, Moisture Content is decreasing within the Sample of banana taken for osmotic dehydration with increase of Concentration & Moisture Content is slightly increasing with Sample to Solution ratio.

Analysis of Normalized Solid Content (NSC) during Osmotic Dehydration:

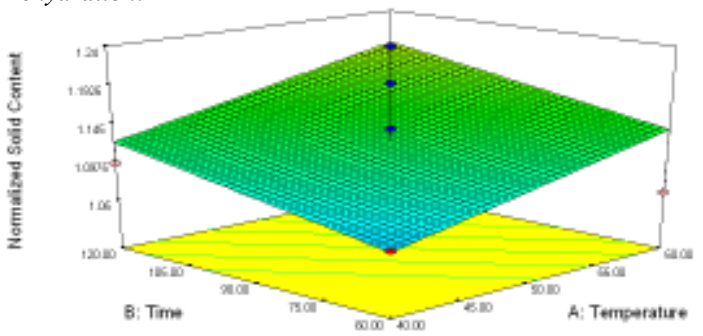

Figure 10: Normalized Solid Content Vs Temperature & Time.

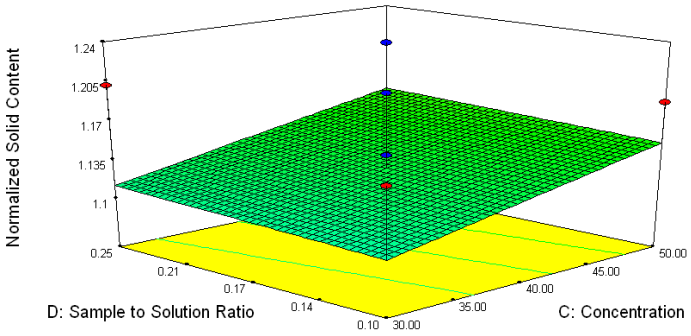

Figure 11: Normalized Solid Content Vs Concentration & Sample to Solution Ratio.

Normalized Solid (NSC); is ratio between initial Solid Content of Banana before Osmotic Dehydration & Solid Content of Banana after Osmotic Dehydration. From Figure No. 4.15, it is obtained that Solid Content with in Banana sample is gradually increasing with the increase of Time & Temperature. As well as from Figure No. 4.16, Solid Content is increasing within the Sample of banana taken for osmotic dehydration with increase of Concentration & slightly increasing with Sample to Solution ratio.

Analysis of Moisture Loss, Solid Gain &Weight Reduction during Osmotic Dehydration

Weight Reduction was attributed to the Moisture Loss and the Solid Gain it is observed from plots the experimental results. It helps to confirm whether the observed mass change (Weight Reduction) is due to Moisture Loss and Solids Gain or if there are other significant mass transfer changes taking place that are not being controlled.

This could be attributed to the softening of the banana slices after longer time of osmotic treatment at high temperature and high concentrated solution, leading to unaccounted for mass losses, during wiping the slices of the sugar solution and overall process inefficiency due to structural collapse. This implies that it should not be recommended to employ high temperatures and longer time during the osmotic dehydration of the banana slices since a firm texture is important for further handling during subsequent drying operations. Despite a general noticeable improvement in Moisture Loss due to increasing the osmotic solution concentration at the same temperature, appreciable increments were realized only at 40^{o}C. For other conditions the increments were not significant as expected.

The ratio between Solid Gain and Moisture Loss ($\Delta SG/\Delta ML$) is a very useful parameter to select the most appropriated process conditions to be use in the osmotic pretreatment. The values of $\Delta SG/\Delta ML$ ratio obtained at different working conditions were important differences can be appreciated during the 90 minutes of treatment. The results therefore suggest that treatments carried out at lower temperature are the ones were lower ratios of $\Delta SG/\Delta ML$ are obtained, and hence an optimal Moisture Loss without an excessive Solid Gain, being also advantageous in terms of energy saving.

Contreras and Smryl, (1981) reported that increasing the osmotic solution concentration to 65% did not result in faster weight. Higher concentration (50^{o}B) appreciably improves Moisture Loss with respect to Solid Gain.

Results obtained indicated though there was a general increase in Moisture Loss in samples treated with a Sample to Solution Ratio, the increments were not significant. There was, however, a significant increase in soluble solids content. This occurs because when a low pressure is applied to the sample capillary impregnation is promoted and when the atmospheric pressure is restored, pores are extensively flooded with external solution hence high soluble solids gain (Fito *et al.* 2001).

These results suggest that since the Sample to Solution Ratio did not appreciably improve Moisture Loss, and instead improved Solids gain. The primary objective of osmotic pretreatment is Moisture Loss.

IV. CONCLUSION

Osmotic dehydration of Banana was done using sugar solution for Banana slices; sugar osmotic solution has been reported to be more effective for Banana. Most efficient Moisture Loss occurred between 60 to 90 Minutes indicating that it may not be necessary to carry out the osmotic treatment step for longer hours. However, Moisture Loss, Solids Gain and Weight Reduction increased with longer time of treatment.

The results also suggest that for bananas, temperature is an important variable. Due to the soft texture of bananas, osmotic treatment of bananas needs not to be done at extreme conditions of temperature and concentration.

Results obtained suggest that a product for further drying could be obtained by treating the slices at temperatures not more than 40^{o}C and using osmotic solutions at 45 or 50 Brix.

- Osmotic dehydration rate increased with the concentration of osmotic solution and process temperature.
- The Moisture loss, Solid Gain and the Weight Reduction during osmotic dehydration of Banana slices were influenced positively by the temperature, concentration.
- The obtained models for the responses of Moisture loss and weight reduction were significant, while for Solid Gain this did not happen.
- Noramalized Moisture Content (NMC) is reduced within Banana slices with temperature, concentration and Time.
- Noramalized Solid Content (NSC) influenced positively within Banana slices with temperature, concentration and Time.

REFERENCES

[1] Brett, A., Cox, D.R.S., Simmons, R. and Anstee, G. 1996. "Producing solar dried fruits and vegetables for micro and small-scale rural enterprise development." Handbook 3: Practical aspects of processing.Chatham , NRI, UK.

[2] Contreras, J.E. and Smryl, T.G. 1981. "An evaluation of osmotic concentration of apple rings using corn syrup solids solutions." Canadian Institute of Food Science and Technology Journal, 14 (4), 310-314.

[3] Donsi, D.; Ferrari, G., Nigro, R. and Matteo P. di. 1999. "A combined technology for the production of dried fruits: Osmotic

dehydration/freeze drying." Italian Food and Beverage Technology; 15, 9-11, 17.

[4] FAO. 1994. FAO Agricultural Production Statistic Database. Food and Agricultural Organization of the United Nations, Rome, Italy.

[5] FAO. 1998. FAO Agricultural Production Statistic Database (FAOSTAT). Food and Agricultural Organization of the United Nations, Rome, Italy.

[6] Fito, P.; Chiralt, A, Barat, J.; Salvatori, D and Andrés, A. 1998. "Some advances in osmotic dehydration of fruit." Food Science and Technology International, 4, 329-338.

[7] Fito, P.; Chiralt, A, Barat, J.; Salvatori, D, Andrés, A., Martinez-Monzo, Martinez- Navarrete, N. 2001. "Vacuum impregnation for development of new dehydrated products." Journal of Food Engineering 49(2001) 297-302.

[8] Harris, N., Lazarides, Fito, P., Chiralt, A., Vassilis, G. and Lenart, A. 1999. "Osmotic dehydration. In: Advances in Osmotic Dehydration."175-199.

[9] Lazarides, H. N.; Fito, P.; Chiralt, A., C.; Vassilis, G and Andrzej, L. 1999. "Advances in osmotic dehydration. Processing foods: Quality optimization and process assessment" local1975-1997.

[10] Lescot, T. 1999. Banana production, trade and varieties. FruiTrop. 63:13:16.

[11] Pekke, M, Nowakunda, K and Tushemereirwe, W. 2001. "Overview of banana utilization in East Africa."

[12] Ponting, D. 1973. "Osmotic dehydration of fruits. Recent modifications and applications: Process Biochemistry" 8. 18-20.

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