Osmotic Dehydration and Microwave-Drying of Guava Fruit Part 1: Optimisation of Osmotic Dehydration Parameters

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This study investigated osmotic dehydration of guava fruit (Psidium guajava L.). Two mechanical pretreatments were tested - cutting in thin slices with (thickness of 4mm and diameter of 50mm) and cutting in spheres (diameter of 20mm). Two osmotic agents were tested: Sucrose solution and High Fructose Corn Syrup (HFCS), two concentrations of HFCS solution (66°Bx and 76°Bx) and five residence times for the osmotic process (1.5, 5, 10, 18 and 24 hours). It was demonstrated that cutting the fruits in slices and immersing them into HFCS at 76°Bx for 18 hours was the best way to significantly decrease the water content and maximise the sugar gain, thus facilitating subsequent drying.

Keywords: Drying pretreatment; fruit dehydration; guava; moisture loss; osmotic dehydration.

1. Introduction

Osmotic dehydration is the partial removal of water by direct contact of test material with a suitable hypertonic solution (highly concentrated sugar solutions, salt solutions or mixtures). Osmotic dehydration can be used to obtain intermediate moisture food, whose shelf life is extended but not stable, or it can be used as a pretreatment before drying, in order to reduce drying time and thus drying cost. The osmotic agent must not be toxic and must have good taste and high solubility.

Due to chemical potential gradients existing across the product-medium interface, two major countercurrent flows are created simultaneously:

- Water from product to medium.
- Solute from medium to product.

The third transfer process, solutes in fruits into the medium can be neglected in comparison to the first two. The energy consumption of the osmotic process is very low due to the absence of a change of phase. As osmotic dehydration is an oxygen-free process, there is no need to use sulphur dioxide or to blanch the product in order to avoid enzymatic and non-enzymatic processes. Colour and flavour retention are improved compared to conventional drying methods because of the low process temperature [1]. Organoleptic properties of the fruits are better preserved as there is less discoloration through enzymatic oxidative browning.

Some variables can influence water loss and solute uptake. Size and shape of the product have a significant role in mass exchange because of different specific surface areas or surface to thickness ratios.

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Pertinent discussion will be published in January, 2006 West Indian Journal of Engineering if received by November, 2005.

Lerici *et al* [7] peeled apples, cut them into radial slices, cubes, sticks and rings and immersed them in concentrated sucrose solutions for 16 hours under constant agitation. The water activity of final product depended on the water activity of osmotic solution and sugar gain (which was significantly affected with sample shape). In the same study, the authors showed the influence of the composition and concentration of the osmotic solution. These two parameters are the main influencing factors of chemical potential (the main driving force for mass exchange).

The size of molecule is also important for the osmotic solute - the smaller the solute, the larger the depth of penetration [1]. Therefore, absorption in the tissues is higher for HFCS than for sucrose solution [2]. HFCS is extremely soluble and hydroscopic. As fructose is a monosaccharide, it is 75% sweeter than sucrose [2]. HFCS has a lower viscosity, higher sweetness and higher osmotic pressure (compared to sucrose solution) which helps in controlling microbiological growth and penetration into cell membranes. Moreover, HFCS costs less than liquid sucrose. Generally, water loss and sugar gain increase with concentration of the solution [4, 5] but there is a maximum concentration above which water loss cannot be improved with increased concentration [3].

The process duration is also a significant variable affecting mass exchange. True equilibrium is reached after a long period (24 hours or more), but mass exchanged between the sample and medium is not significantly changed after several hours of process. A two hours' process using sugar syrup with 70°Bx is long enough to obtain partially dried cherries of acceptable quality with respect to chemical, physical and organoleptic properties during both processing and storage [11].

Tropical fruits like guavas are very fragile and they often have to be processed before export. Osmotic dehydration is a very common method used for the dehydration of tropical fruits prior to drying. **Panadés-Ambrosio *et al*** [10] used peeled guavas without the core and which were cut in 16 pieces. 65°Bx sucrose, 5:1 syrup/fruit ratio was used for the osmotic dehydration as a pretreatment under pulsed vacuum. Combinations of 2, 3 or 4 cycles of 5 minutes vacuum and 30, 55 or 80 minutes of atmospheric pressure were used. **Moy** [9] applied osmotic dehydration to guava slices dipped for 5-6 hours into sucrose syrup of 60-70°Bx and then dried under vacuum (at 2-4 mm Hg of absolute pressure). The economic feasibility of the process was recorded later [8].

The objectives of this study were to determine the feasibility of osmotic dehydration as a pretreatment to drying of guavas and to evaluate the process parameters, such as type and concentration of osmotic agent, as well as different fruit shapes that may influence the osmotic process. The aim was to select the best way to dehydrate guavas through an osmotic process before drying, to obtain the highest water loss and the highest sugar gain possible. The scarcity of available research studies on guavas, as well as the high nutritional quality [6] of this fruit justified further investigation on guava.

2. Materials and Methods

White-flesh guavas of unknown cultivar from Brazil were obtained from the local fruit and vegetable distributor. The fruits were deseeded, peeled and then cut in approximately 4 mm-thick slices or cut in spheres of 20 mm diameter with a melon spoon. Samples of 20-50 g (depending on the sample shape) were immersed in three types of osmotic solutions: 66°Bx sucrose solutions, 66°Bx and 76°Bx HFCS. The syrup/fruit ratio was always 2:1 as suggested by some authors [1]. Brix degree was measured with a hand-held refractometer. The sugar solution was prepared by blending the appropriate amount of sucrose with distilled water until the refractometer indicated the desired sugar concentration of 66°Bx. The 76°Bx HFCS was a commercial one (Invertose 2655, Van Waters & Rogers Ltd, Canada) and the 66°Bx HFCS was obtained by dilution with distilled water. The osmotic dehydration was carried out in small glass containers, without any agitation during the process. Three replicates of all tests were performed, all at ambient temperature (23±1°C) and pressure.

After osmotic dehydration, to avoid mass loss from fruit itself, the fruits were quickly rinsed with warm tap water to remove the adhering osmotic solution, dried with soft paper towel and then weighed. Weight and water content before and after dehydration were recorded for each sample and a mean was used for data representation. Water content of the samples was determined with an oven (Cole-Farmer Instrument Company) at 70°C until the sample mass became constant and expressed in kilogram of water per kilogram of wet sample.

Three variables were taken into account: weight reduction (ΔM) water loss (ΔM_w) and sugar gain (ΔM_s). They were calculated using the following expressions [1]:

$$\Delta M = \frac{M_0 - M_t}{M_0} \quad ....(1)$$

$$\Delta M_w = \frac{M_0 \cdot M_{w0} - M_t \cdot X_{wt}}{M_0 \cdot X_{w0}} \quad ....(2)$$

$$\Delta M_s = \frac{M_t \cdot X_{st} - M_0 \cdot X_{s0}}{M_0} \quad ....(3)$$

Where:

ΔM is the weight reduction (g/g of initial mass).

ΔM_w is the water loss (g of water per g of initial mass of water).

ΔM_s is the sugar gain (g of sugar per g of initial sample mass).

M_0 is the initial mass (g) of the sample and M_t (g) the final mass.

X_{w0} and X_{wt} are respectively the initial and final moisture content (kg/kg wet basis).

X_{s0} and X_{st} are respectively the initial and final solid content (kg/kg wet basis).

Transfer of solutes from fruits to medium was neglected, as mentioned before.

The effects of the variables (shape, time of dehydration, osmotic agent and osmotic solution concentration) on the final moisture content, weight reduction, water loss and sugar gain were analysed using Analysis of Variance (ANOVA). Differences were identified as significant or insignificant based on Duncan's multiple range tests for each variable. The significance level was set at 0.05 in all cases. Statistical analyses were carried out using Statistical Analysis Software (SAS) System, version 8.0.

3. Results and Discussions

3.1 *Shape of the Sample and Time of Dehydration*

Final moisture content (X_{wt}), weight reduction (ΔM), water loss (ΔM_w) and sugar gain (ΔM_s) were calculated after lh30, 5h, 10h, 18h and 24h for both slices and spheres immersed in 76°Bx HFCS at atmospheric pressure. Water and sugar transfers are very important parameters in the osmotic dehydration process and, therefore, these two parameters were combined into one: water loss + sugar gain ($\Delta M_w + \Delta M_s$).

The most important mass transfers took place during the first few hours of the process. **Figure 1** shows the behaviour of these four parameters for guava slices. Both solid gain and moisture loss increased with increasing dehydration time. Moisture loss is three to four times higher than sugar gain (**Table 1**), leading to a positive weight reduction. This behaviour depends on the variety of fruit and weight reduction can be close to zero and can even be negative for cranberries [1].

Significant differences were observed for the variable water loss + sugar gain ($\Delta M_w + \Delta M_s$) with respect to shape, time and interaction between shape and time. All of these parameters were significant but time was the most important parameter. As shown in **Table 1**, it can be seen that for both shapes, 18 hours were sufficient to reach an acceptable equilibrium for all parameters, as leaving the guavas six hours more in the osmotic solution did not increase significantly the values of the parameters. Sliced guavas had a significantly higher $\Delta M_w + \Delta M_s$ than spherical guavas when immersed into HFCS, when the time of dehydration was over five hours, mainly because of a higher water loss. These differences could be explained by a smaller surface/volume ratio for the spheres as compared to the slices. This is in agreement with the mass diffusion law, as the solid gain increases with higher surface/volume ratios [7].

3.2 Type of Osmotic Solution

21±1 g of sample was immersed into either 66°Bx sugar solution or 66°Bx HFCS at ambient pressure and temperature for 22 hours. The results (**Table 2**) showed that there was only a significant difference concerning the sugar gain. It was higher for the samples dipped in HFCS than for the ones immersed in sucrose

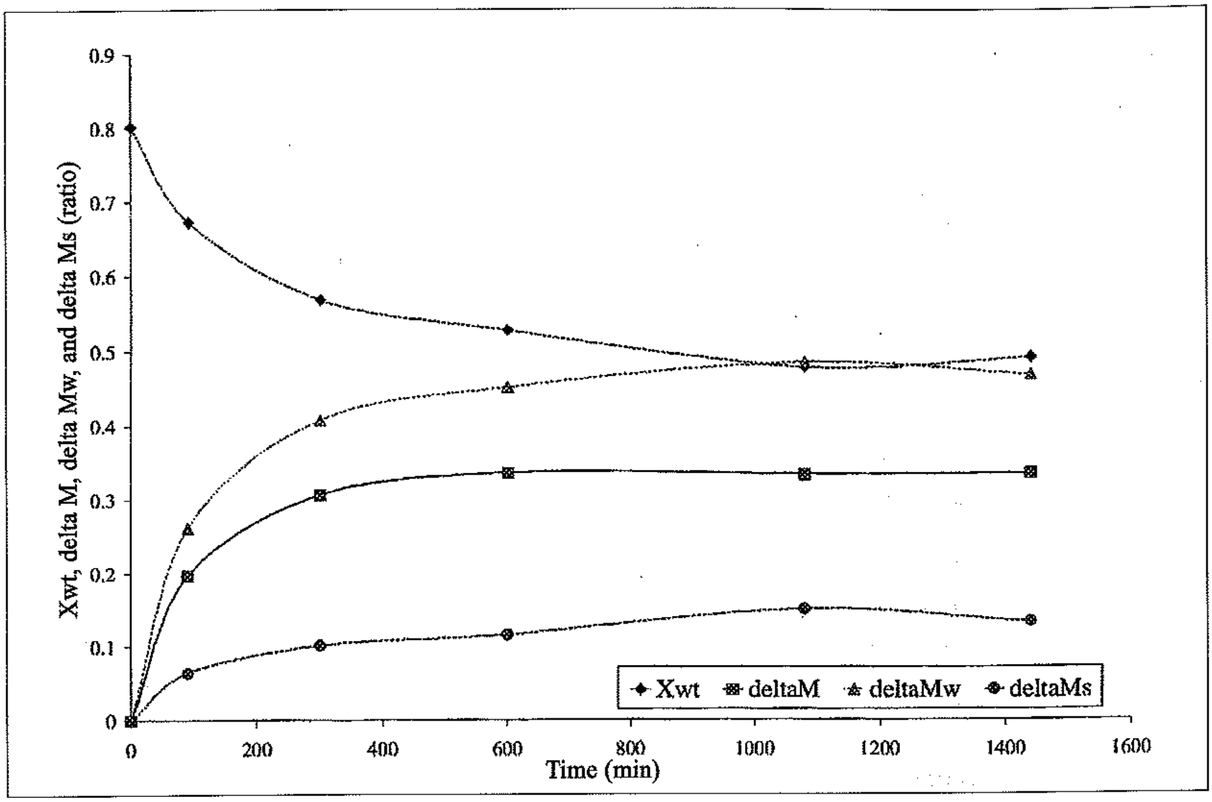

FIGURE 1: *Average Change of Moisture Content X_{wt}, Weight Reduction ΔM, Water Loss ΔM_w, and Sugar Gain ΔM_s with Time for Guava Slices dipped into 76°Bx HFCS at Atmospheric Pressure and Ambient Temperature*

solution. The results were not surprising as the extreme solubility and the hydroscopic properties of HFCS result in a higher osmotic pressure than sucrose, thus a deeper penetration into cell membranes.

3.3 Concentration of the Osmotic Solution

The efficiency of the osmotic dehydration was compared for two concentrations of HFCS. 50±1 g of samples were immersed in two concentrations (76°Bx and 66°Bx) for 24 hours. Results (**Table 3**) indicate that there is a significant difference for the weight reduction and the water loss. Both are higher for the 76°Bx HFCS. The sugar gain is not significantly different. Three of the five osmotic dehydration parameters increased significantly with the osmotic solution concentration. Hence, it is more convenient to use the 76°Bx HFCS, as it is the available commercial concentration, but further studies should be done to show whether it is also cost-effective.

4. Conclusions

Different pretreatments for osmotic dehydration of guavas were tested prior to drying. Firstly, two mechanical pretreatments were tested: cutting in either slices or spheres. Different parameters involved in osmotic dehydration were tested, such as the nature of osmotic agent, concentration of the osmotic solution and duration of dehydration. Sugar solution and HFCS were compared as osmotic agents.

The shape of the cut fruit had a significant effect on the dehydration of guavas through osmosis. Water loss is significantly higher using guava slices than guava spheres, being respectively 0.48 and 0.40 after 18 hours of dehydration in 76°Bx HFCS at ambient temperature. HFCS was found to be the best osmotic solution, as dipping guava slices into a 76°Bx HFCS resulted in a water loss of 0.4724 and a sugar gain of 0.1346 after 24 hours. HFCS at 76°Bx and a 2:1 syrup to fruit ratio were selected for the osmotic solution. Cut slices dipped in HFCS for

TABLE 1: *Dehydration Parameters for Different Shapes of the Guava Pieces dipped in HFCS (76°Bx) at Different Time Levels*

Shape	Time	Moisture Content (kg/kg)	Weight Reduction (Ratio)	Water Loss (Ratio)	Sugar Gain (Ratio)	Water Loss + Sugar Gain (Ratio)
Slices	1h30	0.6720[a]	0.1968[d]	0.2617[c]	0.0649[c]	0.3265[g]
	5h	0.5680[c]	0.3064[a,b]	0.4075[c]	0.1011[d]	0.5086[d]
	10h	0.5266[d]	0.3353[a]	0.4506[b]	0.1153[c]	0.5658[b]
	18h	0.4769[c]	0.3329[a]	0.4833[a]	0.1504[a]	0.6337[a]
	24h	0.4969[c]	0.3378[a]	0.4768[a]	0.1390[a,b]	0.6158[a]
Spheres	1h30	0.6946[a]	0.2175[d]	0.2829[c]	0.0654[c]	0.3483[f]
	5h	0.6285[b]	0.2736[b,c]	0.3804[d]	0.1068[c,d]	0.4872[c]
	10h	0.5933[c]	0.2617[c]	0.3965[c,d]	0.1349[b]	0.5314[c]
	18h	0.5952[c]	0.2651[c]	0.4009[c,d]	0.1357[b]	0.5366[c]
	24h	0.5664[c]	0.2662[c]	0.4130[c]	0.1469[a,b]	0.5600[b]

Means with the same letters are not significantly different.

TABLE 2: *Dehydration Parameters for Guava Slices Dipped in Either Sugar or HFCS at 66°Bx*

Type of Solution	Moisture Content (kg/kg)	Weight Reduction (Ratio)	Water Loss (Ratio)	Sugar Gain (Ratio)	Water Loss + Sugar Gain (Ratio)
Sugar	0.5387[a]	0.3247[a]	0.4681[a]	0.1434[a]	0.6114[a]
HFCS	0.5307[a]	0.2891[a]	0.4546[a]	0.1654[b]	0.6120[b]

Means with the same letters are not significantly different.

TABLE 3: *Dehydration Parameters of Guava Slices Dipped into Different Concentrations of HFCS (66°Bx and 76°Bx)*

Concentration (°Bx)	Moisture Content (kg/kg)	Weight Reduction (Ratio)	Water Loss (Ratio)	Sugar Gain (Ratio)	Water Loss + Sugar Gain (Ratio)
66	0.5352[a]	0.2929[a]	0.4364[a]	0.1435[a]	0.5799[a]
76	0.4969[a]	0.3378[b]	0.4724[b]	0.1346[a]	0.6070[b]

Means with the same letters are not significantly different.

18 hours led to significantly higher moisture content decrease and sugar intake compared to spheres.

Acknowledgements

The authors are most grateful to Natural Sciences and Engineering Research Council of Canada (NSERC) for their financial support to Dr. Valérie Orsat and Mr. Yvan Gariëpy for their technical assistance and suggestions during this research.

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