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OPTIMIZATIOIN OF OSMOTIC DEHYDRATION OF SAPOTA (MANILKARA ZAPOTA) SLICES

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Disclaimers

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Conflict of interest

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ABSTRACT

Background: Sapota *(Manilkara zapota*) is a tropical fruit of fabulous taste and excellent nutritional quality. It supplies a good quantity of essential vitamins and minerals, and it is an outstanding source of dietary fiber. However, the fruit is highly perishable and is therefore very difficult to market. This little-known delight of the tropics practically rots overnight once harvested. This characteristic adds urgency to the search for effective and efficient preservation techniques that can be applied at or near the harvest site without requiring refrigeration. Traditional methods of preservation such as drying or canning often compromise the sensory quality of the fruit, especially its taste, aroma, and texture, which take the fruit to its next level of greatness both before conservation and also after reconstitution when dehydrated or canned fruit is consumed. Myers (Mary Roberts), one of the few authorities on sapota, claims that the fruit has a consistency reminiscent of creamy milkshakes**.**

Approach: To obtain the best working conditions for osmotic dehydration of sapota, Response Surface Methodology (RSM) was used to perform a multi-factorial optimization. Fresh sapota, cut into pieces of uniform size, was treated with sugar solutions of differing concentrations. The sapota was then subjected to osmotic dehydration at several different temperatures (from 25°C to 60°C) and for several different time durations (from 60 to 300 minutes). The study used a central composite design within the RSM framework to see how well these factors worked alone and together in achieving a satisfactory osmotic dehydration result. The evaluations included retention of nutrients, texture, colour, and, most importantly, the sensory aspect of how the osmotic dehydrated sapota tasted**.**

Outcomes: Response Surface Methodology (RSM) was utilized to ascertain the basal parameters: temperature, time, and osmotic solution concentration. It was deduced from RSM that the optimal conditions for osmotic dehydration of sapota were: 47.36°C, 167.85 minutes, and 43.53°Brix. When applied under these optimum criteria, not only was sapota preserved, but significant enhancements were also noted in the aesthetic and gustatory properties of the fruit. The sensory and aesthetic evaluations indicated considerable improvements in several key areas: taste, colour, and texture. Moreover, when all these factors were considered collectively, there was a notable enhancement in the overall quality of the fruit, when compared to sapota preserved by more conventional means. Osmotic dehydration, sapota, response surface methodology, preservation, and shelf life are the essential terms associated with this science experiment.

Keywords: *Osmotic dehydration, sapota, response surface methodology, preservation, shelf life*

INTRODUCTION

Sapota (Manilkara zapota), often referred to as chikoo, is a tropical fruit primarily grown in India and regions such as southeastern Mexico and Guatemala. This fruit is known by various names, including sapodilla and chikoo. The term "zapote," which means "soft edible fruit" in Spanish, is derived from the name sapodilla (Bano and Ahmed, 2017). While sapota is mainly appreciated for its sweet flavour, it is also cultivated in some areas for chicle production, a latex gum used in chewing gum. Additionally, sapota powder is rich in fiber and can serve as a dietary supplement for both children and adults. It provides a good source of sugars, dietary fiber, carotene, and other bioactive compounds recognized for their antioxidant and laxative effects. Given its nutritional benefits, sapota powder can be regarded as a comprehensive food source, abundant in vitamins, carbohydrates, and proteins (Jangam et al., 2008).

However, despite its advantages, sapota is highly perishable and sensitive to cold storage, leading to significant post-harvest losses of approximately 25–40% due to improper handling. The commercial processing of the fruit is limited because it is sensitive to heat, which can affect its flavour and colour. Currently, only a small amount of sapota is processed into dried segments and flakes, while products like jams, jellies, squashes, and fruit drinks are made by combining sapota with other fruits. There is a pressing need to create more value-added products to stabilize prices for farmers and minimize waste.

Osmotic dehydration (OD) is an effective preservation method that removes moisture from fruits by utilizing osmotic pressure differences, typically through sugar or salt solutions. This technique lowers water activity, thereby extending the fruit's shelf life. Given its soft and perishable nature, sapota can greatly benefit from osmotic dehydration, which helps maintain its flavour, texture, and nutritional content while reducing spoilage. The osmotic dehydration process involves the use of sugar or salt syrups, which facilitate the transfer of water from the fruit to the solution, resulting in water loss and sugar absorption.

This study explores the osmotic behaviour of sapota by examining the effects of critical parameters such as temperature, osmotic solution concentration, and osmotic time on water loss, sugar gain, and mass reduction. Utilizing Response Surface Methodology (RSM) has enabled the optimization of these process parameters to enhance product quality. RSM is a valuable tool for experimental design and optimization, allowing for the identification of optimal conditions with fewer experimental trials. The goal of this research is to refine the dehydration process, improve product quality, and decrease post-harvest losses, thereby contributing to the development of a more effective and commercially viable preservation method for sapota.

MATERIALS AND METHODS

For the study, fresh, ripe sapota fruits, selected for their uniform size, colour, and firm texture, were used. The fruits were thoroughly washed to eliminate any impurities before being carefully peeled with a knife and sliced into thin, uniform pieces.

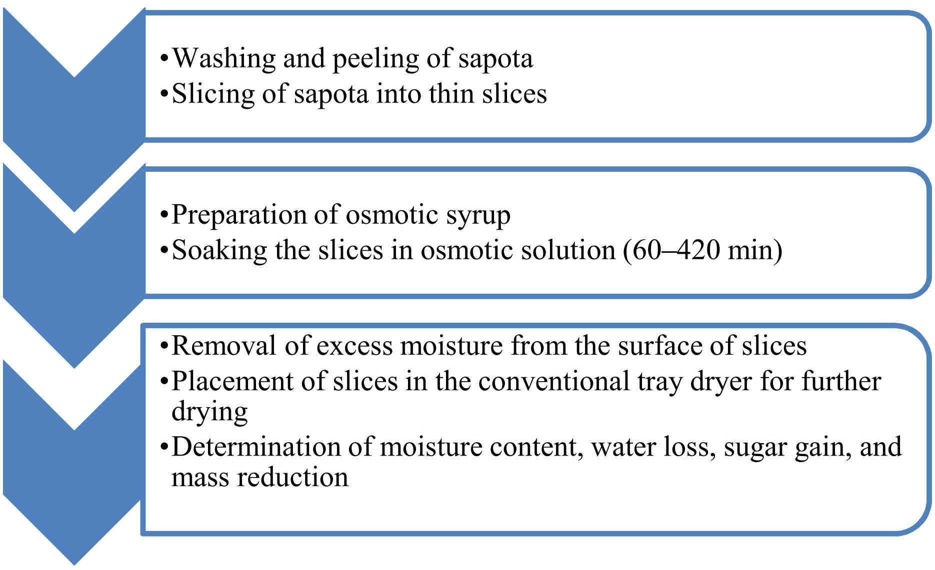
Preparation of Osmotic Solution

A sugar syrup served as the osmotic agent for the dehydration process. This syrup was created by dissolving a specific quantity of sugar in distilled water. To ensure effective osmotic dehydration, a fruit-to-syrup ratio of 1:5 was maintained. During the osmotic dehydration process, the sapota samples were immersed in the hypertonic solution, promoting the movement of water from the fruit to the syrup due to the concentration gradient. Concurrently, solid components were also transferred between the solution and the fruit. The study focused on various mass transport parameters, including water loss, mass reduction, moisture content, and solid gain.

Equipment Utilized

A conventional tray dryer was utilized for the dehydration experiments. This equipment consists of a drying chamber equipped with a blower, heaters, and a thermostat. The insulated chamber houses an air-circulating fan that distributes heated air to achieve uniform drying. To enhance consistency during the drying process, the trays with the sapota slices were rotated periodically.

Processing Flow Chart



Experimental Plan

Drying Process Parameters

The parameters for the drying process selected for this study are detailed in Table 1.

Measurement Tools and Techniques

Brix Measurement: The sugar concentration of the osmotic solution was determined using a refractometer to obtain the °Brix value.

Weight Measurement: The weights of the sapota slices were recorded before and after osmotic dehydration to evaluate mass reduction.

Tray Dryer Placement: After undergoing osmotic treatment, the slices were placed into a conventional tray dryer for dehydration.

Response Surface Methodology (RSM) and Experimental Design

To optimize the osmotic dehydration process, Response Surface Methodology (RSM) was utilized. RSM encompasses various experimental design and optimization techniques that help researchers explore the relationships between independent variables and their responses. This study specifically employed the Box-Behnken Design (BBD), involving three variables at three different levels, as presented in Tables 2 and 3. The experimental setup included 17 trials, with 5 central points to enhance the reliability of the results.

The independent variables (factors) considered for osmotic dehydration included:

1. Syrup Concentration (°Brix) - A
2. Osmotic Temperature (°C) - B
3. Drying Temperature (°C) - C

The three levels for each variable are as follows:

Syrup Concentration: 30, 40, and 50 °Brix

Osmotic Temperature: 30, 40, and 50 °C

Drying Temperature: 50, 60, and 70 °C

Mathematical Modelling

The osmotic dehydration process was represented using a second-order polynomial equation that connects the response variable (Yk) to the independent variables (ri). The general form of the equation used for modelling is as follows:

$$y_k = \beta_{k_0} + \sum_{i=1}^{i=3} \beta_{k_i x_i} + \sum_{i=1}^{i=3} \beta\, k_{ii} x_i^2 + \sum_{i=1}^{i=2} \sum_{j=i+1}^{j=1} \beta k_{ij} x_i x_j$$

Where:

- y_k is the response variable (e.g., water loss or sugar gain)
- β_{k_0},$\beta_{k_i x_i}$,$\beta k_{ii} x_i^2$,$\beta k_{ij} x_i x_j$ are the coefficients of the equation
- x_i and x_j are the coded independent variables (syrup concentration, osmotic temperature, and drying temperature)

This mathematical model was employed to analyse and anticipate how the process parameters impact the osmotic dehydration of sapota, as well as to identify the optimal conditions needed to achieve the greatest water loss and desired sugar gain.

Optimization and Analysis

Utilizing the experimental data, response surface methodology (RSM) was applied to optimize the osmotic dehydration process. The predicted outcomes derived from RSM were compared with the experimental results to validate the model's accuracy. Additionally, the desirability function in RSM was used to identify the optimal conditions for the osmotic dehydration process.

RESULTS AND DISCUSSION

Analysis of Results from Osmotic Dehydration of Sapota

This chapter discusses the analysis of results obtained from the osmotic dehydration of sapota, emphasizing the impact of varying operational parameters such as drying temperature, osmotic temperature, and syrup concentration on dependent variables including water loss, sugar gain, mass reduction, and moisture content.

Optimization of Operational Parameters

To optimize the dehydration process and minimize the number of experiments, a Box-Behnken design based on Response Surface Methodology (RSM) was utilized. The study focused on three independent variables: drying temperature, osmotic temperature, and syrup concentration. The experimental results, following the designed methodology, are summarized in Table 3.

The data revealed how changes in syrup temperature, syrup concentration, and osmosis duration influenced water loss, mass reduction, and sugar gain. It was observed that water loss increased with both syrup concentration and the duration of osmosis. This trend suggests that osmosis occurs most rapidly during the initial stages, with both water loss and sugar gain peaking early before gradually slowing. Higher syrup concentrations and longer osmotic durations resulted in increased water loss and sugar gain, although these rates decreased over time as the osmotic potential diminished.

The final product exhibited water loss ranging from 52% to 75%. **Figure 1** illustrates the relationship between water loss, drying temperature, and syrup concentration. As the drying temperature rose from 50°C to 70°C, water loss also increased. Elevated drying temperatures enhanced the evaporation rate due to a stronger driving force for moisture transfer. Similarly, higher syrup concentrations led to greater water loss, likely due to the increased osmotic pressure generated by the sugar syrup, which facilitated moisture removal from the sapota slices.

Positive interaction terms between syrup concentration, osmotic temperature, and osmosis duration indicated that increasing these variables further enhanced water loss. Elevated syrup concentrations and osmotic temperatures contributed to more rapid dehydration.

Figure 1 shows that water loss was most pronounced at high syrup concentrations (50°C) and elevated osmotic temperatures, attributed to the increased osmotic pressure and enhanced moisture transfer into the syrup. Initially, water loss increased rapidly, but this rate slowed as the osmotic potential decreased over time. The negative quadratic terms for syrup concentration and osmosis duration suggested that exceeding certain levels of concentration and time resulted in diminishing returns regarding water loss. In summary, higher syrup concentrations and osmotic temperatures significantly increased the rate of water loss from sapota slices, particularly during the early stages of osmotic dehydration.

Figure 2 illustrates the effect of syrup concentration and drying temperature on sugar gain. Sugar gain rose with increasing syrup temperature (from 0.5% to 0.7%), corresponding to a heightened osmotic driving force and improved membrane permeability. This facilitated greater sugar absorption into the sapota slices. Additionally, higher syrup concentrations resulted in increased sugar gain, as the greater osmotic pressure gradient promoted more sugar transfer from the syrup to the fruit. Sugar gain increased non-linearly over time, with the most significant rates occurring during the initial stages of osmosis, after which the rates slowed due to diminishing osmotic pressure. The rapid sugar uptake observed initially is a characteristic of osmotic dehydration, where osmotic potential is at its peak, but as sugar concentration within the fruit rises, the osmotic driving force diminishes.

Figure 3 shows that the moisture content of the final product ranged from 4% to 9%, depending on the processing parameters. As the drying temperature increased from 50°C to 70°C, the moisture content of the sapota slices decreased, driven by enhanced heat transfer that accelerated the drying process. Additionally, higher syrup concentrations contributed to reduced moisture content, likely due to the increased osmotic water loss from the fruit. Both moisture loss and sugar gain exhibited similar trends, with rapid increases in the initial stages of osmosis followed by a slowdown as osmotic potential decreased. This indicates that while the osmotic process is effective initially, its efficiency diminishes over time as the gradients of moisture and solute concentration decline.

CONCLUSION

The influence of syrup concentration and duration on the osmotic dehydration of sapota demonstrated that both water loss and sugar gain were significantly affected by these factors. Initially, there was a rapid increase in both water loss and sugar gain; however, this trend diminished over time as the osmotic potential decreased. Higher syrup concentrations and extended osmosis times led to greater water loss and sugar gain, although the rates of both declined over time due to a reduction in the osmotic pressure gradient.

The highest water loss recorded was 74%, observed in run 7, which involved a drying temperature of 50°C, a syrup concentration of 40°Brix, and an osmotic temperature of 30°C. The maximum sugar gains of 0.7% occurred in run 11, with a drying temperature of 70°C, syrup concentration of 40°Brix, and osmotic temperature of 50°C. Additionally, run 1, which had a drying temperature of 70°C, a syrup concentration of 50°Brix, and an osmotic temperature of 40°C, resulted in the greatest mass reduction of 77.5%. These results highlight the critical role of syrup concentration and osmosis time in optimizing the osmotic dehydration process for sapota.

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Table 1 Parameters for osmotic dehydration

Independent Variables	**Dependent Variables**
Sugar concentration	Water loss
Osmotic temperature	Sugar gain
Drying air temperature	Mass reduction
	Moisture content

Table 2 levels for variables

Parameters	**Notations**	**Coded Variables**	**-1**	**0**	**+1**
Concentration of syrup (°Brix)	A	-1	30	40	50
Osmotic Temperature (°C)	B	0	30	40	50
Drying Temperature (°C)	C	0	50	60	70

Table 3: Observed water loss and sugar gain under varying processing parameters

RUN	DRYING TEMP °C	SYRUP CON.°C	OSMOTIC TEMP °C	WATER LOSS %	SUGAR GAIN%	MASS REDUCTION %	MOISTURE CONTENT %
1	70	50	40	70.95	0.6	77.5	5.2
2	60	40	40	68.8	0.5	68.5	8
3	50	30	40	71.13	0.5	71	8.4
4	60	40	40	68.8	0.5	68.75	8.2
5	50	50	40	70.5	0.6	70.25	7
6	60	40	40	69.5	0.5	69.5	8.1
7	50	40	30	74	0.5	77.25	6.9
8	60	50	30	68.8	0.5	68.25	8.8
9	60	30	30	70.2	0.5	70	6.6
10	60	40	40	70.2	0.5	70.3	6.5
11	70	40	50	73.9	0.7	73.75	4.7
12	50	40	50	52.6	0.5	75.25	6.2
13	70	30	40	70.7	0.5	71.75	7.3
14	60	30	50	71.01	0.6	70	6.3
15	60	50	50	71.2	0.6	71.75	6.6
16	60	40	40	69.2	0.5	69.25	7
17	70	40	30	74.01	0.6	74	6.8

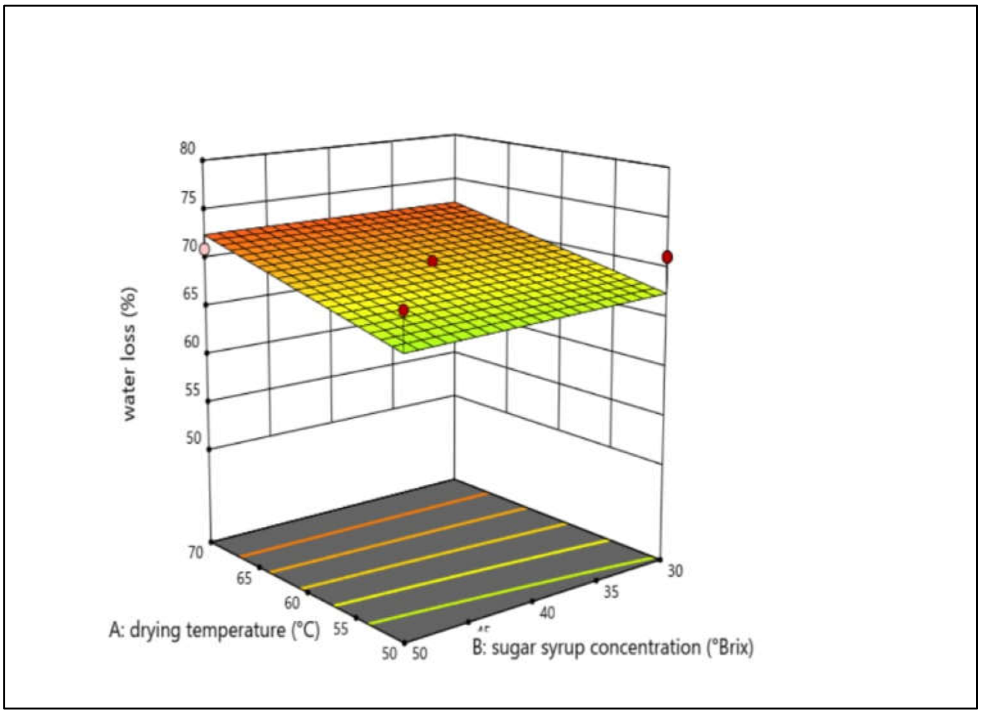

Fig. 1. Effect on Water Loss with Respect to Drying Temperature and Syrup Concentration

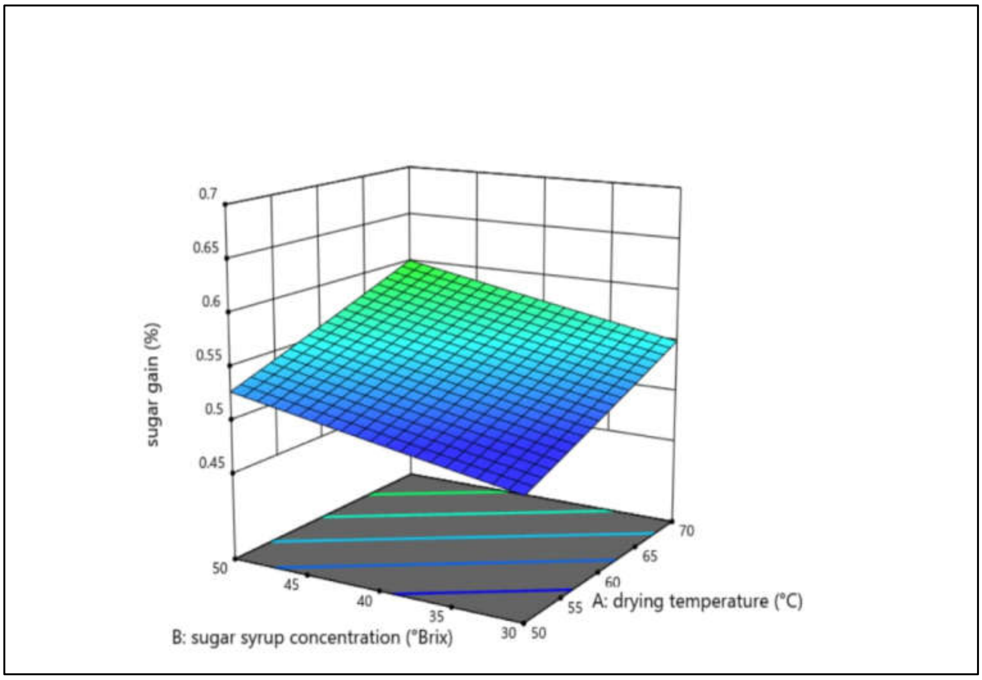

Fig. 2 Effect on Sugar Gain with Respect to Syrup Concentration and Drying Temperature

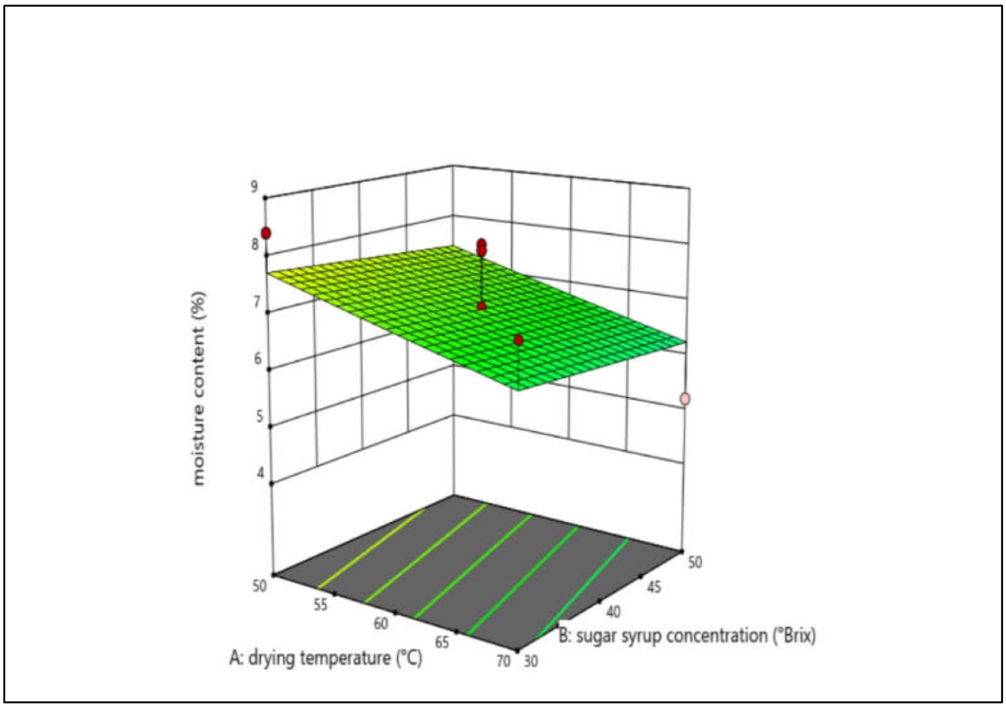

Fig. 3 Effect on Moisture Content with Respect to Osmotic Temperature and Drying Temperature