Biological Forum – An International Journal 16(8): 77-81(2024)

ISSN No. (Print): 0975-1130
ISSN No. (Online): 2249-3239

Influence of Sugar and Jaggery Pretreatment on Drying Kinetics of Banana Slices

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(Received: 27 May 2024; Revised: 15 June 2024; Accepted: 04 July 2024; Published: 14 August 2024)
(Published by Research Trend)

ABSTRACT: Drying is a common method for preserving agricultural food products. Banana is one of the popular food. Due to its high nutrition, strong aroma, and the convenience for package, storage, and transportation, dried banana is in a growing demand in local and international market. The effects of different pretreatments and temperature on the drying characteristics of ripe banana slices were investigated. 7 mm thick slices of bananas were pretreated with two different pretreatments such as sugar solution, jaggery solution and a control for 1hour. Pretreated banana slices were dried in a tray dryer using a completely randomized design at 50°C and 60°C and their drying characteristics such as rate of drying, moisture ratio, moisture content (db) % were studied. The 7 mm thick slices at a drying air temperature of 60°C dried better than the other. The textural properties of banana slices were analysed with textural profile analyzer (TPA) at different drying condition and temperature. The osmotic treatments preserved the texture of banana slices. The sugar exhibited more hardness value when compared to the jaggery treated sample.

Keywords: Banana, Drying, Osmotic, Sugar, Jaggery, moisture.

INTRODUCTION

Bananas are a staple fruit in many countries. However, ripe bananas are highly perishable and deteriorate quickly after harvest, making it essential to apply appropriate technologies to extend their shelf life, whether in fresh or dried forms. Bananas have been a part of human diets for many years, and their production and consumption are widespread globally. Due to their high moisture content, around 80%, ripe bananas are particularly vulnerable to post-harvest losses, as well as significant weight loss during transportation and storage. This leads to serious economic losses due to reduced weight and quality. Post-harvest losses are a major challenge for tropical fruits like mango, pineapple, and banana. A fully ripened banana typically deteriorates within 4-7 days.

Drying is one of the oldest methods for preserving food. In recent years, newer drying techniques, such as heated air drying, have been developed due to hygienic and economic benefits (Hossain *et al.,* 2021). However, drying tropical fruits can lead to issues like cell shrinkage, browning, loss of redrying ability, reduced wet tability, and case hardening, all of which can decrease the market value and overall acceptability of the products (Singh *et al*., 2008).

Various pre-treatment methods have been developed for fruit drying, including lemon juice, salt solution, honey dip, ascorbic acid, sulfuring, osmotic pretreatment, and blanching. Osmotic dehydration (OD) is a commonly used pretreatment method before air drying. It involves partially removing water from the tissues of fruits and vegetables that are immersed in a hypertonic osmotic solution. This process causes the cellular surface to act as a functional semi-permeable membrane, facilitating mass transfer (Pei *et al*., 2022). Applying osmotic pretreatment to taikor slices resulted in a shorter drying time compared to untreated samples (Hossain *et al.,* 2021), as was also observed in pear slices (Tasova *et al.,* 2022). Additionally, OD pretreatment in the vacuum drying of kumquat slices enhanced color retention in the final product (Ozkan-Karabacak *et al.,* 2022).

In banana, Ali *et al.* (2019) conducted the drying experiment in foam mat drying and they revealed that the cost conditions were very efficient. The drying affects the quality of banana, and the different type of pretreatment increased the drying efficiency and quality retention of banana slices (Abd El-Wahhab *et al.,* 2023). Specifically, the study aimed to investigate the effect of osmotic pretreatment on the drying rate, moisture ratio, and moisture content (db) percentage. The objective of this study was

1. To examine the pretreatment effect on banana.
2. To investigate the effect of sugar and jaggery treatments on the drying kinetics of banana slices.
3. To evaluate the textural and sensory quality of dried banana slices.

MATERIALS AND METHODS

Raw materials: Table Sugar, Jaggery and Banana was purchased from local market of Varanasi city for this study.

Drying Procedure. The primary processes of cleaning, washing, peeling, and cutting were carried out first. The peeled bananas were manually sliced into 7 mm thickness using a sharp knife before pretreatment. For the pretreatment, 10 g of sugar was dissolved in 100 ml of water in one bowl, and 10 g of jaggery was dissolved in 100 ml of water in another bowl. The banana slices were then soaked in these different solutions for 1 hour and allowed to drain. Each pretreated sample was divided into two equal portions of 10 g for drying. The pretreated banana slices were placed on trays and arranged on racks in a tray dryer. The 7 mm thick slices were dried at temperatures of 50°C and 60°C until a constant mass was observed. The weight of the bananas was measured every hour until drying was complete. Once drying was finished, the samples were allowed to cool, packed into transparent, tightly zipped bags, labeled, and stored for further analysis.

Determination of Water Loss, Weight Reduction, and Solute Gain. During the osmotic dehydration process, solute gain and water loss happen simultaneously. Solute permeability leads to an increase in the initial mass, while water loss results in a reduction in mass. In summary, weight loss (WL) is the combined effect of solute gain (SG) and weight reduction (WR). The values for WL, WR, and SG were calculated using the procedure outlined by Arulkumar *et al.* (2023).

$$WR(g) = W_i - W_t \tag{1}$$

$$WL/100\,g\text{ of sample} = \frac{(W_i - W_t) + (S_t - S_i)}{W_i} \times 100 \tag{2}$$

$$SG/100\,g\text{ of sample} = \frac{(S_t - S_i)}{W_i} \times 100 \tag{3}$$

Where,

W_i represents the initial weight of the paneer (g); W_t represents the weight of the paneer after 12 h pretreatment(g); S_i represents the initial weight of the solids in the paneer (g) and S_t represents the weight of the solids of the paneer after 12 h pretreatment (g).

Ascertainment of moisture content

The moisture content of the banana slices was determined by applying equation (4).

$$M\% = \frac{W_w}{W_d} \times 100 \tag{4}$$

Where,

M represents the moisture content (% w.b.); W_w indicates the weight loss during drying in g, and W_d refers to the sample's weight before drying in g.

Ascertainment of the drying rate. The drying rate of the banana slices was calculated using equation (5).

$$Y = \frac{W_w}{t} \tag{5}$$

Where,

Y denotes the drying rate (g/h); W_w denotes the amount of weight reduced (g); t denotes the drying time (h).

Moisture ratio determination

The moisture ratio of the banana samples was determined from the equation (6) as reported by Arulkumar *et al*. (2023).

$$MR = \frac{M - M_e}{M_0 - M_e} \tag{6}$$

Texture profile analysis. The texture profile analysis of banana was done by TA. XT Plus texture analyzer (Micro stable systems) available at Banaras Hindu university, Varanasi. The load cell capacity was 50 kg and the universal probe P/75 (75 mm diameter) was used.

Sensory evaluation. The sensory properties of dried banana samples were judged by semi-trained judges from the Banaras Hindu university, Varanasi. Each panelist was served with a standard score card ('9' point hedonic scale) for recording score for sensory attributes such as colour & appearance, flavour, body & texture and overall acceptability of the product.

RESULTS AND DISCUSSION

Effect of sugar and jaggery treatment on banana before dehydration. It was observed that there was highly significant difference ($P \leq 0.01$) in the water loss, solute gain and weight reduction of different osmotic treated banana samples. The Water loss, solute gain and weight reduction during osmosis was depicted in Table 1. Values of water loss were noted higher at sugar treated banana sample and lower in jaggery solution treated sample with the values of -2.3524% and -2.6367 respectively. Osmotic pretreatment caused negative water loss in samples treated with both sugar and jaggery. The solute gain was highly observed in Jaggery treatment. The 10% level showed negative weight reduction value. A study by Rai *et al.* (2022) showed maximum weight reduction was observed at the highest levels in 65°Brix sucrose solution of sugar for banana.

Drying characteristics of Banana slices. Fig. 1 to 3 illustrate the drying characteristics of banana slices at different temperatures. Table 2 and 3 depict the moisture content and drying time of banana slices with respective to their treatment. For banana samples dried at 50°C, the equilibrium moisture content (EMC) ranged from 16.86% to 28.09% (dry basis), with drying times between 12 and 15 hours. For samples dried at 60°C, the EMC ranged from 15.03% to 19.63% (dry basis), and the drying time was between 11 and 13 hours. The highest drying rate was observed in the sugar treated samples and drying at 60°C with value of 0.1432 g/g.h as shown in Fig. 4.

At higher air-drying temperatures, the drying potential increases, leading to a reduction in drying time. These results are consistent with findings from several authors, such as those who observed shorter drying times for quinces and tomato pomace (Tzempelikos *et al.,* 2014; Al-Muhtaseb *et al.* 2010). The osmotic treated samples had a shorter drying time compared to the control samples due to their faster drying rate. Additionally, this pretreatment demonstrates energy savings by reducing processing time (Dehghannya *et al.,* 2015).

Sensory evaluation of dried banana. Table 4 shows highly significant differences (P≤0.01) in the sensory scores for color, flavor, body & texture, and overall acceptability of banana samples dried at different temperatures. When comparing flavor scores, the T3 sample received the highest rating, with a mean value of 6.77±0.13, while the T4 sample had the lowest score, with a mean value of 5.33±0.30. For color, the T2 sample scored the highest with a mean value of 7.87±0.22, whereas the T1 sample scored the lowest with a mean value of 5.77±0.17. In terms of overall acceptability, the T2 sample was rated "Like very much" on the 9-point hedonic scale, with a mean value of 7.43±0.13.

The osmotic pretreatment effectively preserved the color of the banana slices. Thesugar and jaggery treated samples had a significant impact on sensory evaluation, helping to preserve the natural color, body, and texture of the banana. Color and appearance play a crucial role in sensory evaluation. Similar type of observation was reported by Kwaw *et al.* (2023).

Texture analysis of dried banana. The mean values of textural parameters *viz.,* hardness, adhesiveness, springiness, cohesiveness, gumminess and chewiness of dehydrated banana samples analyzed with texture analyzer are presented in Table 5.

The drying conditions impacted the textural properties of the dried banana slices compared to the control slices before drying. The process led to an increase in hardness, gumminess, and chewiness. The control banana sample exhibited greater hardness than the sugar-treated and jaggery-treated samples. The sugar-treated sample was softer and had better texture properties. Elasticity refers to the ability of a material to stretch and return to its original length. The control banana sample had a very low springiness value, while the treated samples showed higher springiness values than the control. The results were comparable with Chauhan *et al.* (2011).

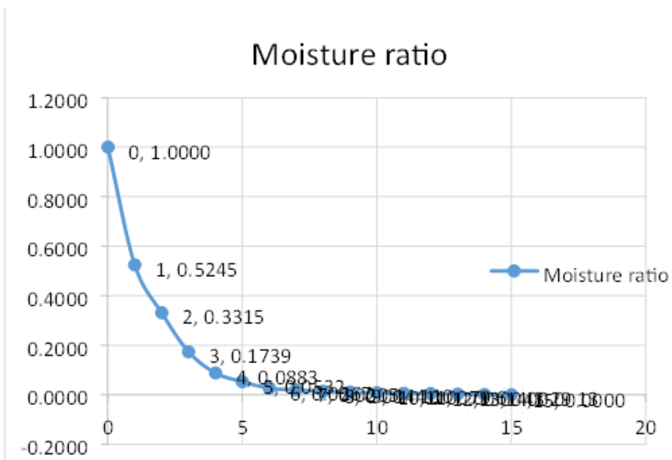

Fig. 1. Drying characteristics of control banana at 50°C

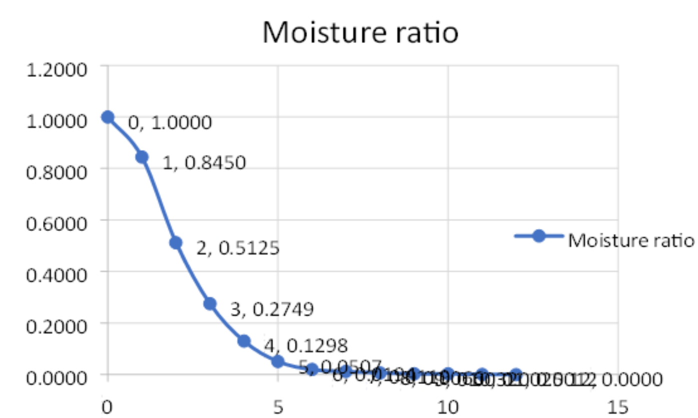

Fig. 2. Drying characteristics of sugar treated banana at 50°C

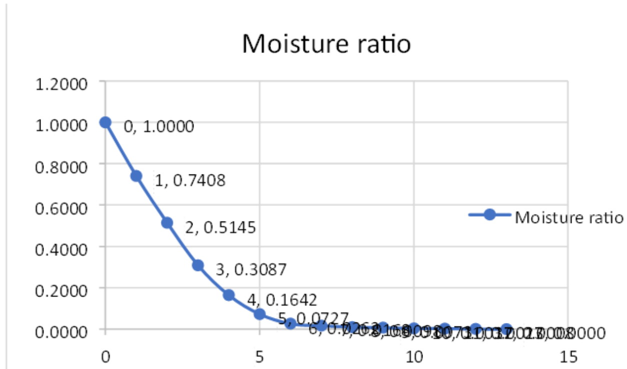

Fig. 3. Drying characteristics of jaggery treated banana at 50°C

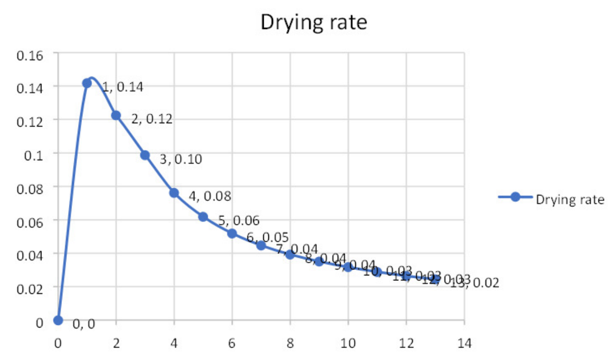

Fig. 4. Drying rate characteristics of sugar treated banana at 60°C.

Table 1: Water loss, solute gain and weight reduction during osmosis.

Sample	Water Loss, (%)	Solute Gain, (%)	Weight Reduction, (%)
Control	0	0	0
Sugar	-2.3524	10.3776	-12.7301
Jaggery	-2.6267	11.7679	-14.3946

Table 2: Drying characteristics of Banana at 50 °C temperature.

Sample	Initial Moisture Content % (d.b.)	Equilibrium Moisture Content % (d.b.)	Drying Time (h)
Control	121.72	28.09	15
Sugar	198.21	16.94	12
Jaggery	156.36	16.86	13

Table 3: Drying characteristics of Banana at 60 °C temperature.

Sample	Initial Moisture Content % (d.b.)	Equilibrium Moisture Content % (d.b.)	Drying Time (h)
Control	123.26	19.63	13
Sugar	173.53	15.03	11
Jaggery	175.10	16.83	12

Table 4: Sensory evaluation of dried banana slices.

Temperature	Sample		Colour and Appearance	Flavour	Body and Texture	Overall Acceptability
50°C	Control	T_1	5.77 ± 0.17^{b}	5.03 ± 0.22^{abc}	6.00 ± 0.30^{abcd}	5.91 ± 0.30^{cd}
	Sugar	T_2	7.87 ± 0.22^{c}	6.47 ± 0.31^{bc}	6.10 ± 0.29^{cde}	7.43 ± 0.13^{de}
	Jaggery	T_3	6.87 ± 0.04^{c}	6.77 ± 0.13^{c}	7.55 ± 0.26^{ef}	6.77 ± 0.33^{e}
60°C	Control	T_4	5.60 ± 0.41^{a}	5.33 ± 0.30^{ab}	5.73 ± 0.15^{abc}	5.33 ± 0.30^{bc}
	Sugar	T_5	6.43 ± 0.30^{b}	6.00 ± 0.36^{bc}	5.20 ± 0.31^{a}	5.33 ± 0.27^{bc}
	Jaggery	T_6	5.63 ± 0.28^{b}	5.33 ± 0.18^{ab}	6.93 ± 0.200^{def}	5.47 ± 0.36^{bc}

@Average of fifteen scores; **-Highly significant (P≤0.01) at intervals; $^{a\ to\ f}$ - superscripts with same letter indicates that the treatments are on par

Table 5: Texture profile analysis of banana samples (Mean±SE).

Sample	Hardness (g)	Springiness	Cohesiveness	Gumminess	Chewiness
Control	52410.65±2.87^{b}	0.158±0.11^{a}	0.015±0.05^{a}	3904.60±60^{c}	1059.83±83^{a}
Jaggery	17523.40±0.66^{a}	0.993±0.99^{b}	0.134±0.16^{b}	2179.67±67^{a}	1189.34±34^{b}
Sugar	13771.04±0.16^{a}	0.988±0.21^{b}	0.269±0.27^{b}	3736.73±73^{b}	2657.99±0.99^{c}

@Average of three replications; **-Highly significant (P≤0.01) at intervals; $^{a\ to\ c}$ - superscripts with same letter indicates that the treatments are on par

CONCLUSIONS

Osmotic dehydration proved to be an effective method for removing certain water from food materials without causing phase transformation, thereby reducing the physical, chemical, and biological changes that typically occur with drying at higher temperatures. The osmotic pretreated banana samples dried more efficiently than the control sample. Untreated banana samples experienced degradation in color and other sensory attributes. The sugar-treated banana sample dried at 50°C exhibited excellent drying and sensory properties. The sugar treated samples are far better than jaggery treated samples in pretreatment, drying time, and texture retention. In dried banana samples, the sugar-treated sample being soft and has good texture properties. In contrast, the jaggery-treated sample displayed a higher hardness value compared to the other two samples. The pretreatment didn't have so much impact on weight reduction but quality retention was appropriate. However, the concentration variation needs to be evaluate to improve the weight reduction in pretreatment.

FUTURE SCOPE

The osmotic treated banana slices reduce the processing time. The osmotic treated banana slices will be best to store and transport to other countries. It opens a wide window to produce quality dried slices in a short term at low cost.

Acknowledgement. The authors extend their appreciation to Banaras Hindu University, Varanasi.
Conflict of Interest. None.

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How to cite this article: Mahendra Kumar, Sudharsan M., Arulkumar M., Sapna Tomar, Sohan Lal Bajya and Yogeshwari R. (2024). Influence of Sugar and Jaggery Pretreatment on Drying Kinetics of Banana Slices. *Biological Forum – An International Journal, 16*(8): 77-81.