



Studies on Impact of Processing on Physiochemical and Biochemical Properties of Osmodehydrated Pineapple (*Ananas comosus* (L) Merr.) Cuboid and Its Storage Stability

Arjuma Sultana ^a and Uma Ghosh ^{a*}

^a *Department of Food Technology and Biochemical Engineering, Jadavpur University, Kolkata-700032, India.*

Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

Article Information

DOI: 10.9734/EJNFS/2022/v14i111262

Open Peer Review History:

This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: <https://www.sdiarticle5.com/review-history/92624>

Original Research Article

Received 06 August 2022
Accepted 11 October 2022
Published 13 October 2022

ABSTRACT

Osmotic dehydration of pineapple cuboids were conducted to study the effect of sugar concentration of osmotic solution on mass transfer, weight reduction, vitamin-C, total phenol content and antioxidant property of samples pretreated with steam blanching and microwave heating. As treatment time went on, there was an increase in water loss, weight loss, and solids accumulation. The sample treated with 60°B experienced the highest mass transfer during the osmotic dehydration of pineapple cuboids, whereas the sample treated with 30°B experienced the lowest mass transfer. The pineapple cuboids immersed in 60°B sugar syrup and dried in a tray drier resulted maximum weight loss. Microwave heated samples dipped in 60°B sugar syrup showed better retention of nutritive value (total phenol content, vitamin C and antioxidant activity) as well as better color, texture, taste and mouth feel. According to the sensory analysis, the samples treated with 60°B solution received the highest acceptability for color, flavour, texture, mouth feel, and taste. Osmodried samples were stored for 3 months at ambient condition without any adverse effect on sensory and nutritional parameters.

Keywords: *Osmodehydration; pineapple; kinetic study; bioactive compound; storage stability.*

1. INTRODUCTION

Pineapple (*Ananas comosus* (L.) Merr., Family: Bromeliaceae) is one of the industrially most important fruits in the world. After citrus and bananas, pineapple is the third most significant tropical fruit in the world [1]. Fresh, cooked, juiced, and preserved pineapples are all consumed or served. This fruit is seasonal and extremely perishable. The fruit contains organic acids like malic acid and citric acid, vitamin-A and vitamin-B, protein degrading enzyme bromelin, sugar [2], calcium, potassium and other minerals, carotene along with significant amount of dietary fiber. The fruit with all these ingredients will support better nutrition and health benefits.

In recent years much attention has been focused on maintaining the freshness of fruits and vegetables by immersion of cellular materials containing water in an osmotic solution, which will help to develop intermediate moisture products with low water activity. During the process, chemical, physical and biological activities, which deteriorate the foods, are lowered considerably; hence extends the shelf life of food products. In this process moisture is withdrawn from the product at ambient temperature by diffusion, so phase change has been avoided. Besides, it helps to improve the nutritional and sensory attributes of food products and is less energy intensive process as compared to other drying techniques. Osmotic dehydration is influenced by various factors such as osmotic agent, time and temperature, solute concentration, solution to sample ratio, agitation and geometry of the materials. Recently, osmotic dehydration has been combined with several other methods namely, pulsed high electric field, high hydrostatic pressure, microwave heating, pasteurization, ultrasound, centrifugal force, vacuum and gamma irradiation, blanching. These techniques have been employed during or after osmotic treatment to enhance osmotic dehydration performance by increasing the cell membrane permeability and mass transfer rate [3,4]. These combined operations reduce the drying time, minimizing further energy costs as well as improving the quality of fruits and vegetables during storage.

Osmotic dehydration of foods has gained attention recently due to its potential for the food process industry. Osmotic dehydration is widely used for the partial removal of water from plant tissues by immersion in a hypertonic solution [5-7]. Osmotic dehydration generally will not give

a product of sufficiently low moisture content for it to be considered shelf-stable. Osmotic dehydration is a conventional interaction applied to food dewatering. It prompts alluring items that are prepared to eat or can be applied as a pretreatment to the following system, for example, drying or freezing [8-10]. Water is a principal constituent of food sources, which influences food security, microbial as well as compound. It is liable for the customer view of quite a large number organoleptic qualities like juiciness, elasticity, tenderness and texture. In food industry, food and food products are preserved by using dehydration process to remove the water from the raw materials. The bringing down of water action can be accomplished in two ways, either by the expansion of humectants or by the expulsion of dissolvable, for example, water [11-13]. Currently, researcher focused on the improvement of product quality of preserved food products. Osmotic dehydration results better food products as removal of water takes place at low temperature [14]. It requires less energy consumption than conventional drying process. And this process is applied as pretreatment step for preservation of fruits and vegetables by dehydration process [15].

Pineapple is an important fruit of India. It is cultivated in an area of 89 thousand hectare and total production is 1,415.00 thousand tons. It is native to Central and South America. The pineapple cultivation was started in Brazil and Paraguay and subsequently proliferated in tropical countries. The all out region under pineapple development on the planet is 1.05 million hectare with creation around 25.81 million hectare [16]. The agro-climatic and physio-geographical conditions of some parts of India is most suitable for the pineapple plant growth, such as the entire North-Eastern states including Assam, Meghalaya, Tripura and Manipur, northern part of West Bengal, coastal parts of Andhra Pradesh, Orissa, Kerala, Tamil Nadu and Goa, and some parts of Maharashtra, Gujarat and Karnataka. With over 0.11 million hectare area, India stands at second position just after Nigeria (0.18 million hectare) in terms of area under pineapple cultivation by contributing more than 10 percent of the total pineapple producing area of the world. While, in terms of production India is sixth largest producer of pineapple with a production value of 1.74 million tonnes, the first being Costa Rica (2.92 million tonnes). There are more than ninety variety of pineapple cultivated all around the world. However, only three

varieties are commercially grown in India, these are; *Giantkew*- big size fruit with broad and flat eyes and colour varies from yellow to coppery yellow (12-14 orbix); *Queen*- small in size with small and raised eyes and colour is flesh deep golden yellow (15-16 orbix); and *Mauritius*- fruit size is medium and yellow and red in colour. Pineapple is known by so many names throughout India, such as *Keehom* (Manipur), *Ananus* (Marathi), *Annasahannu* (Kannada), *Anasipazham* (Tamil), *Kaitachchakka* (Malayalam) and *Annasapandu* (Telegu). The sunny field of north-east India having pure tropical rain brings peak flavour to our pineapple. They are then packed and sent to store houses, where they are protected for transportation and marketing (pineapplesinIndia.com, 2018). The total area under pineapple cultivation in the world is 909.84 thousand hectare with production around 19412.91 thousand tons.

According to the USDA nutrient database, each 100 g of edible pineapple includes 50 Kcal. A study published in 'Alternative Therapies in Health and Medicine' states that pineapple has a therapeutic effect for allergies and asthma. It also alleviates anxiety and calms the heart. Generally, ripen pineapple is consumed by people in India and after extraction of juice the dried waste is used as animal feed [17,18]. Besides this, pineapple is useful for making pickles, squash, jelly, vinegar, alcohol and syrup [19]. Up to 40% of agricultural produce is wasted in developing countries, mainly due to the lack of storage and processing facilities, as well as to a limited knowledge of processing technologies [20]. Osmotic dehydration is widely used to remove part of the water content of fruit to obtain a product of intermediate moisture or as a pre-treatment before further processing [21,22] (Lenart, 1996). Pineapple organic product is viewed as an exceptionally nutritious natural product since it contains an elevated degree of L-ascorbic acid, a characteristic cell reinforcement which might restrain the improvement of major clinical circumstances including coronary illness and certain malignant growths [23]. The organic product likewise contains phenolic compounds and β -carotene [19,16] which comprise normal wellsprings of cell reinforcements. Consequently data in regards to cancer prevention agents and cell reinforcement limit of "Phulae" and "Nanglae" pineapples is required to serve purchasers. The data acquired from this study will be helpful for advancing and expanding organic product utilization and their financial worth.

The objective of this study is to investigate the physicochemical and biochemical characteristics of the osmotically dehydrated pineapple cuboids.

2. MATERIALS AND METHODS

2.1 Preparation of Osmo-dehydrated Pineapple Cuboid

Raw pineapples were obtained from Jadavpur market near Jadavpur University, Kolkata, India. Well matured and ripe pineapples were selected for this study. Cleaned thoroughly with distilled water to remove adhering, dust, foreign matter and wiped with a muslin cloth. The selected pineapples were peeled using stainless steel knife. The edible portion was cut into cuboids after removing the core. Size of the pineapple cuboid is $(5 \times 2 \times 2)$ cm³. The treatments prior to osmo-dehydration consisted of-

- a. Control sample(A₁)
- b. Steam blanching (A₂)
- c. Microwave heating(A₃)

2.2 Pretreatment

2.2.1 Control

Pineapple cuboid without any treatment were considered as control.

2.2.2 Microwave heating

Pineapple cuboids were put into microwave at 300W for 5 min

2.2.3 Steam blanching

Steam was generated in a steamer. Samples were exposed in steam for 5 min for steam blanching.

2.3 Osmo-dehydration Procedure

Pineapple cuboids were weighed approximately 15 g for every experiment and immersed in 100 ml sugar syrup and left undisturbed for 24 hours at room temperature (28^o C) for osmosis. The samples were separately dipped in sugar solution of 30^oB and it was measured using a hand refractometer (Erma Inc. Tokyo, Japan). The concentration of sugar solution increased to 50^oB and finally to 60^oB. At the end of the process, the fruit slices were taken out of the osmotic solution and were drained in order to remove the sugar coating adhering to the surface

of the fruit pieces. After that pineapple cuboids were spread uniformly over stainless steel trays and were kept in a conventional tray drier for dehydration with intermittent turning of cuboids for quick drying. Pineapple cuboids were dried at 40°C air temperature for overnight to get the desired moisture content and product quality. Osmodehydrated cuboids were packed in (20×15) cm² low density polyethylene pouch and stored under ambient condition for three months. Samples were analyzed to determine total phenol content and FRAP analysis was done for antioxidant activity.

2.4 Analytical Parameters

2.4.1 Moisture content

Moisture content was calculated according to the method described by Ranganna [24]. 10g sample was weighed accurately in a dry petridish and dried at 105°C until weight was constant. The moisture content was determined using the following equation-

$$\text{Moisture Content (\%)} = \left(\frac{A-B}{B} \right)$$

Where, A = the weight of the sample
B = the weight of the dry sample

2.4.2 Determination of total polyphenolic content (TPC)

Total phenol content was determined using the Folin-ciocalteu's reagent as described by Singleton and Rossi (1965). The sample extract (200µL) was mixed with 1.5ml of Folin-ciocalteu reagent (Previously diluted tenfold with distilled water). The mixture was allowed to stand for 5min at room temperature. Then 1.5ml sodium bicarbonate solution (60gm/L) was added to the mixture. Mixture was vortexed, covered and allowed to stand for 120 min in a dark place. Triplicate measurements were carried out and the absorbance was measured by spectrophotometer (Hitachi U- 2000) at 765nm against a blank containing all the reagents without the sample and plotted in a standard calibration curve of Gallic Acid. The results expressed as Gallic Acid equivalents per gram of dry sample.

2.4.3 Determination of total antioxidant content (FRAP)

The FRAP assay was carried out according to Benzie & Strain, [25]. The FRAP reagent was prepared from sodium acetate buffer (300 mM,

pH 3.6), 10 mM TPTZ solution (dissolved in 40 mM HCl) and 20 mM Fe (III) chloride solution in a ratio (v/v) of 10:1:1, respectively. The freshly prepared FRAP reagent was warmed to 37°C in a water bath before use. 100 µl of the sample solution was added to 3 ml of the freshly prepared FRAP reagent. The absorbance was measured at 593 nm using spectrophotometer after 4 min and plotted in a standard calibration curve of FeSO₄ solution. The results expressed as µmol Fe (II)/g dry sample.

2.4.4 Determination of water loss (WL) and solid gain (SG)

Osmotic dehydrated samples were blotted with tissue paper and later weighed for determination of WL and SG as shown by the following equation [26].

$$WL = \frac{W_{wo} - W_w}{W_o} \times 100$$

$$SG = \frac{W_s - W_{so}}{W_o} \times 100$$

Where, WL and SG are water loss and solid gain in %, respectively.

Wwo is the initial water mass,
Ww is the mass of water at time t,
WS is the solid mass at time t,
Wso is the initial solid mass

2.4.5 Dehydration and rehydration ratios

Dehydration ratio was determined as the ratio of weight of the sample before drying to the dried weight of sample. Whereas rehydration ratio was determined as the ratio of the weight of the rehydrated sample to that of dehydrated (Kalra, Tandon, & Singh, 1995).

Dehydration ratio=W/WD
Rehydration ratio=WR/WD

Where, W and WD are the weight of the sample before and after drying respectively, and WR is the rehydrated sample weight in (g).

2.5 Sensory Evaluation of Osmodehydrated Pineapple Cuboids

Sensory evaluation was carried out to determine the effect of osmodrying on the quality attributes of osmotically dehydrated pineapple cuboides. A

6-member sensory panel was used to evaluate the various descriptors for colour, texture and taste of samples. Sensory evaluation was done for color appearance, flavor, texture, taste and overall acceptability by a panel of semi trained judges on the basis of 9 point hedonic scale [24]. Attributes were scored for degree of liking on 9-point hedonic scale of 1 to 9 (1=dislike extremely, 9=like and extremely) and the average value was recorded. Scores of 5.5 and above were considered acceptable. The average of all the sensory parameters was recorded.

3. RESULTS AND DISCUSSION

Table 1. Physicochemical properties of fresh pineapple

| Characteristics | Value |
|---------------------------------------|-------|
| Average weight(g) | 1500 |
| Pulp (%) | 70 |
| Peel (%) | 50 |
| Core (%) | 17 |
| Waste Index (%) | 58 |
| Total Soluble solids (°B) | 11 |
| Moisture Content (%) | 88 |
| Vitamin C (% mg) | 38 |
| Total phenol Content (mg GAE/ 100 FW) | 51.1 |
| Antioxidant Activities(FRAP) | 62.4 |

Table 2. Effect of sugar concentrations on weight loss (%), dry weight (g/100g), dehydration ratio (%), rehydration ratio (%) on osmotically treated dry pineapple cuboids

| Sugar Concentration (°B) | Treatment | Weight loss (%)(gm) | Dry weight (%)(gm) | Dehydration Ratio | Rehydration Ratio |
|--------------------------|-----------------------|---------------------|--------------------|-------------------|-------------------|
| 30° B | Control(A1) | 69 | 30.75 | 3.25 | 3.43 |
| | Steam blanching(A2) | 60 | 34.06 | 2.94 | 2.97 |
| | Microwave heating(A3) | 65 | 40 | 2.5 | 2.63 |
| 50° B | Control(A1) | 80 | 20.43 | 4.89 | 4.8 |
| | Steam blanching(A2) | 76 | 25.49 | 3.92 | 2.61 |
| | Microwave heating(A3) | 75 | 24.14 | 4.14 | 4.86 |
| 60° B | Control(A1) | 75 | 24.89 | 4.01 | 3.88 |
| | Steam blanching(A2) | 66 | 21.30 | 4.69 | 4.31 |
| | Microwave heating(A3) | 79 | 33.84 | 2.95 | 2.84 |

3.1 Effect of Different Concentration of Sugar Syrup on Mass Transfer

Effect of different concentrations of sugar syrup on mass transfer as a function of time was studied during standardization process. The results obtained are shown in Fig. 1 to Fig. 3. The weight was continuously reduced upto 3 hours of dipping and then slightly decreased for all the concentrations. Initially the rate of mass transfer was higher but it was reduced gradually as time progressed. Maximum mass transfer was found in case of sample treated with 60°B at room temperature of sugar syrup while minimum mass transfer was observed in sample treated with 30°B and 50°B sugar syrup.

3.2 Drying Kinetics of Osmo dehydrated Pineapple Cuboids

Table 3 represents the effect of sugar syrup concentration on moisture content. After the sample was removed from the sugar syrup, then its moisture content was calculated. The moisture content was found to be decreased when concentration of syrup increased. 60° B sample showed the maximum reduction in moisture content.

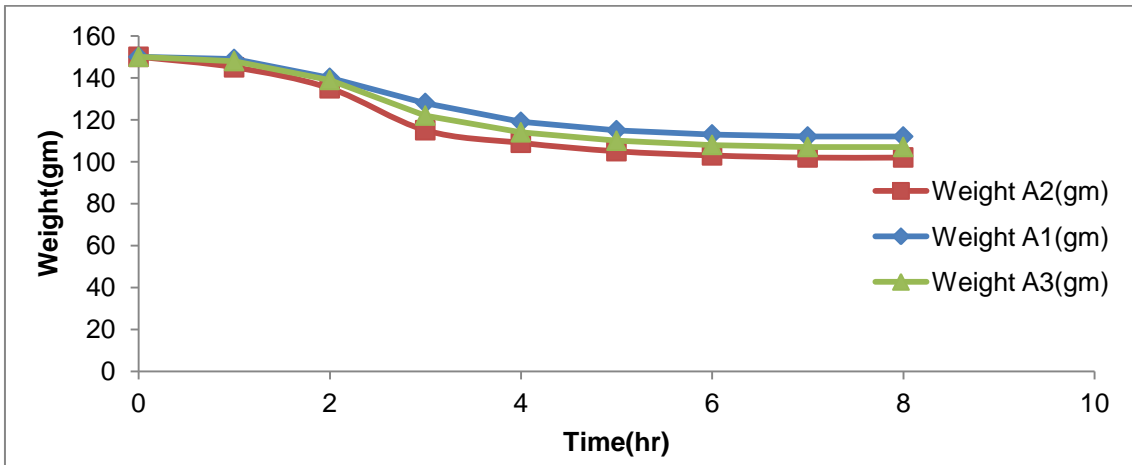


Fig. 1. Effect of sugar syrup concentration 30°C on mass transfer at room temperature

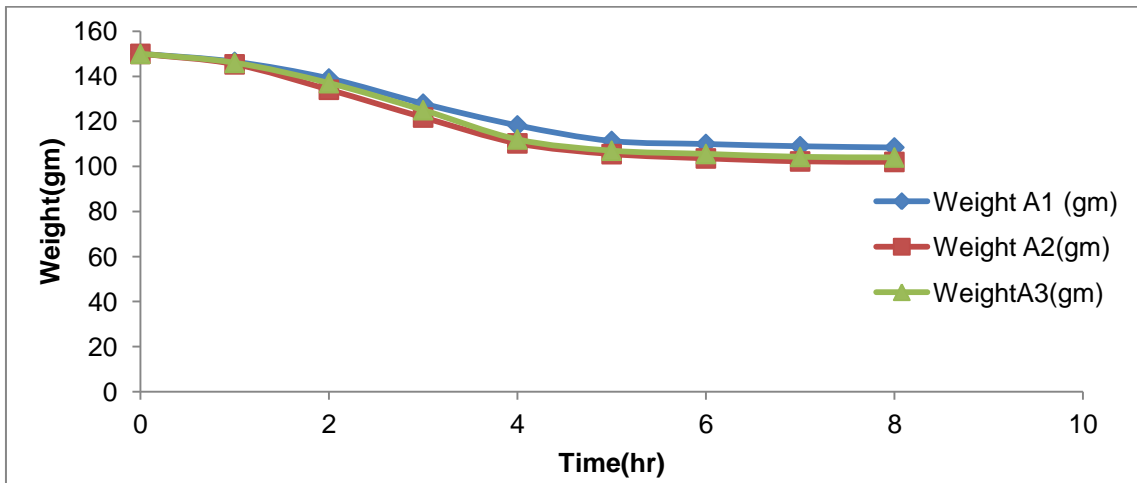


Fig. 2. Effect of sugar syrup concentration 50°C on mass transfer at room temperature

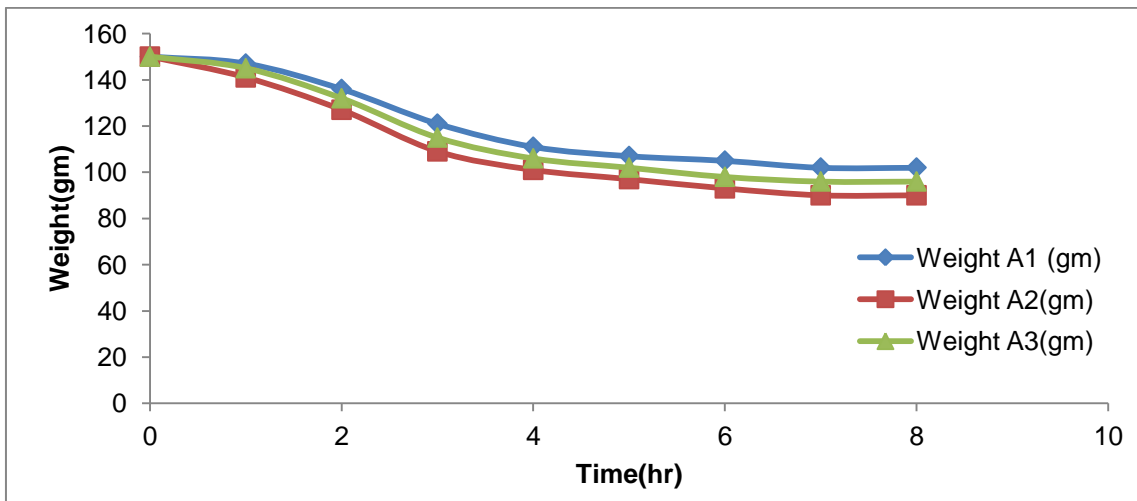


Fig. 3. Effect of sugar syrup concentration 60°C on mass transfer at room temperature

Table 3. Effect of sugar syrup concentration on moisture content on osmotically treated dry pineapple cuboids

| Concentration of sugar solution | Sample | Moisture content (%) |
|---------------------------------|-----------------------|----------------------|
| 30°B | Control(A1) | 80 |
| | Steam blanching(A2) | 76 |
| | Microwave heating(A3) | 75 |
| 50°B | Control(A1) | 75 |
| | Steam blanching(A2) | 66 |
| | Microwave heating(A3) | 79 |
| 60°B | Control(A1) | 69 |
| | Steam blanching(A2) | 60 |
| | Microwave heating(A3) | 65 |

Table 4. Effect of sugar syrup concentration on Vitamin C, total phenol content and antioxidant activity of osmotically treated dry pineapple cuboid

| Sample | Sugar syrup concentration | Vitamin C (mg/g) | Total phenol content (mg GAE/g) | Antioxidant activity |
|-----------------------|---------------------------|------------------|---------------------------------|----------------------|
| Control(A1) | 30°B | 18.5±0.4 | 48.12±0.3 | 57.4±0.2 |
| | 50°B | 12.03±0.08 | 35.5±0.1 | 48.3±0.7 |
| | 60°B | 5±0.04 | 27.6±0.4 | 33.3±0.1 |
| Steam blanching(A2) | 30°B | 15.6±0.05 | 49.5±0.3 | 59.8±0.3 |
| | 50°B | 9.67±0.9 | 38.7±0.5 | 50.43±0.2 |
| | 60°B | 2.7±0.2 | 30.5±0.8 | 38.56±0.6 |
| Microwave heating(A3) | 30°B | 17±0.3 | 49.67±0.3 | 57.1±.3 |
| | 50°B | 10±0.7 | 39.5±0.8 | 49.2±0.46 |
| | 60°B | 3.8±0.4 | 39.9±0.3 | 48.14±0.5 |
| Fresh | | 21.5 | 51.1±0.2 | 62.4±0.2 |

3.3 Sensory Evaluation

Osmotically dehydrated pineapple cuboids were analyzed using 9 point scale for various quality attributes and results are summarized in Table 4. It is found that the sample dipped in 60° B solution and dried is significantly superior to other samples in terms of color and

texture. However the taste was better for samples dipped in 50°B solution and dried. Better retention of total phenol, antioxidant activity and vitamin C was observed in case of microwave heated samples than that of steam-blanching sample. Control samples were considered as unacceptable due to discolouration of cuboids.

3.3.1 Sensory analysis of osmotically treated pineapple cuboids

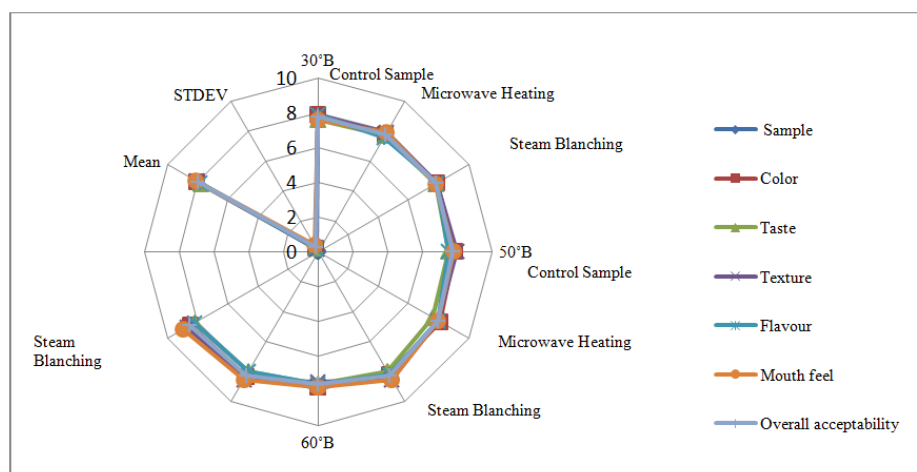


Fig. 4. Sensory analysis of pre-treated osmodehydrated pineapple cuboid storage study of pre-treated pineapple cuboids

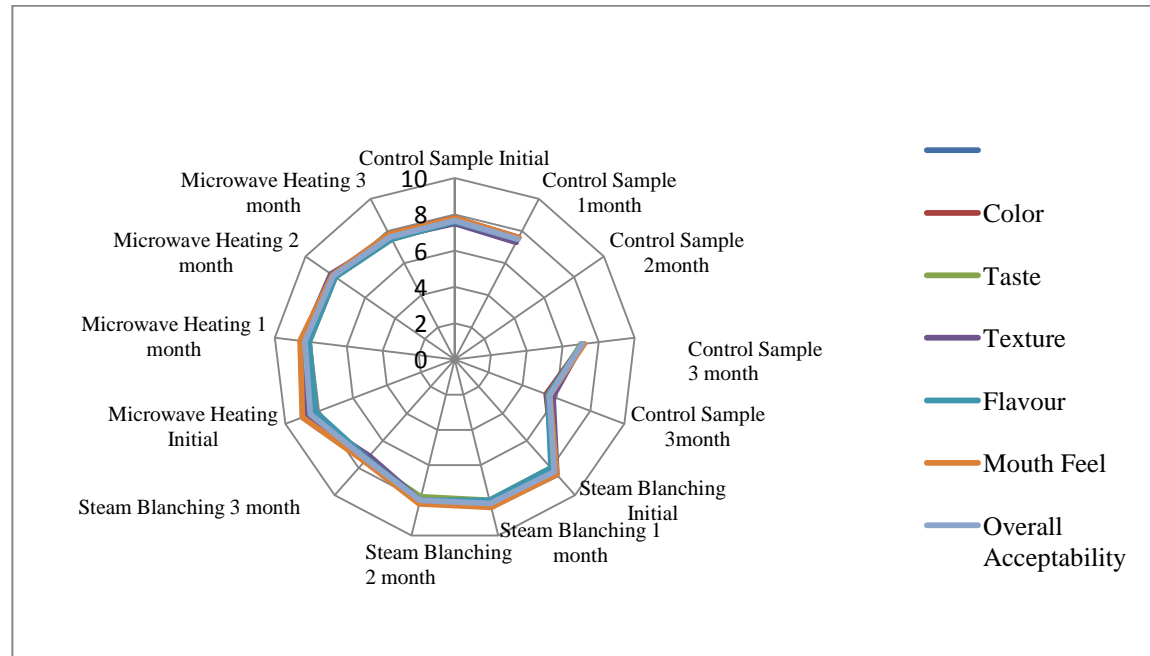


Fig. 5. Sensory score of pre-treated samples dipped in 60°B sugar syrup

Table 5. Effect of sugar syrup concentration on vitamin C, total phenol and antioxidant activity of osmodehydrated pineapple cuboid during storage

| Samples | Vitamin-C | | | | Total phenol Content | | | | Antioxidant Activity | | | |
|-------------------|-----------|-----------|-----------|----------|----------------------|-------------|------------|------------|----------------------|------------|-----------|------------|
| | Initial | 1month | 2month | 3month | Initial | 1month | 2month | 3month | Initial | 1month | 2month | 3month |
| Control | 5±0.02 | 2.67±0.05 | 0.8±0.02 | 0.4±0.06 | 27.6±0.1 | 18.6±0.2 | 11.32±0.3 | 8.7±0.45 | 33.3±0.1 | 17.04±0.02 | 9.07±0.06 | 4.06±0.05 |
| Steam Blanching | 2.7±0.02 | 2.5±0.4 | 1.8±0.05 | 1.5±0.02 | 30.4±0.8 | 29.89±0.034 | 23.04±0.05 | 16.07±0.02 | 38.2±0.5 | 35.02±0.3 | 28.4±0.2 | 21.5±0.4 |
| Microwave Heating | 3.8±0.47 | 3.5±0.05 | 3.1±0.023 | 2.5±0.04 | 39.8±0.3 | 36.5±0.07 | 31.7±0.02 | 27.6±0.03 | 48.1±0.3 | 45.5±0.03 | 39.8±0.04 | 30.06±0.02 |

4. CONCLUSION

Osmotic dehydration kinetics indicated that both water loss and solid gain increased with the increase of sugar syrup concentration. Microwave heated samples showed the better vitamin C retention; total phenol content is high better than that of the other samples. Also osmodried pineapple cuboid dipped in 60°B gives the better antioxidant activity. Color, flavour, texture and the overall acceptability is high and stored for 3months at ambient condition without any adverse effect on the quality.

ACKNOWLEDGEMENT

This study was supported by Maulana Aazad National fellowship under the scheme UGC (Ref-F1-17.1/2017-18/MANF-2017-18-WES-80905/ (SA-III/Website)), Government of India.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Bartholomew DP, Paul RE, Rorbach KG. The pineapple 'Botany, Production and Uses'. Manoa, Honolulu: University of Hawaii; 2003.
Available:<http://bookshop.cabi.org/Uploads/Books/PDF/978085995038/>
2. Joy PP. Benefits and uses of pineapple. Pineapple research station. Kerala, India: Kerala Agricultural University; 2010.
Available:<http://www.kau.edu/prsvkm/Html/BenefitsofPA.htm>
3. Tedjo W, Taiwo KA, Eshtiaghi MN, Knorr D. Comparison of pretreatment methods on water and solid diffusion kinetics of osmotically dehydrated mangos. J Food Eng. 2002;53(2):133-42.
DOI: 10.1016/S0260-8774(01)00149-2
4. Bchir, Besbes B, S, Attia H, Blecker C. Osmotic dehydration of pomegranate seeds (*Punica granatum* L.): effect of freezing pretreatment. 2011.
DOI: 10.1111/j.1745-4530.2010.00591.x
5. Rastogi NK, Raghavarao KSMS, Niranjan K, Knorr D. Recent developments in osmotic dehydration: methods to enhance mass transfer. Trends Food Sci Technol. 2002;13(2):48-59.
DOI: 10.1016/S0924-2244(02)00032-8
6. Lazarides HN. Reasons and possibilities to control solid uptake during osmotic treatment of fruit and vegetables. In: Fito P, Chiralt A, Barat MJ, Spiess EW, Behsnillian D, editors Osmotic dehydration and vacuum impregnation. Technomic Publishing; 2001.
7. Lazarides HN, Mavroudis NE. Freeze/thaw effects on mass transfer during osmotic dehydration. J Food Sci. 1995;60(4):826-8.
DOI: 10.1111/j.1365-2621.1995.tb06239.x
8. Gardner PT, White TAC, McPhail DB, Duthie GG. The relative contributions of vitamin C, carotenoids and phenolics to the antioxidant potential of fruit juices. Food Chem. 2000;68(4):471-4.
DOI: 10.1016/S0308-8146(99)00225-3
9. Charoensiri R, Kongkachuichai R, Suknicom S, Sungpuag P. Betacarotene, lycopene, and alpha-tocopherol contents of selected Thai fruits. Food Chem. 2009; 113(1):202-7.
DOI: 10.1016/j.foodchem.2008.07.074
10. Singleton VL, Orthofer R, Lamuela-Raventós RM. Analysis of total phenols and other oxidation substrates and antioxidants by means of Folin-Ciocalteu reagent. Methods Enzymol. 1999;299: 152-78.
DOI: 10.1016/S0076-6879(99)99017-1
11. Matuska M, Lenart A, Lazarides HN. On the use of edible coatings to monitor osmotic dehydration kinetics for minimal solids uptake. J Food Eng. 2006;72(1): 85-91.
DOI: 10.1016/j.jfoodeng.2004.11.023
12. Advanced in Food and Nutrition Research. 2004;48:174–225.
13. Renaud SC, Guéguen R, Schenker J, d'Houtaud A. Alcohol and mortality in middle-aged men from France. Epidemiology. 1998;9(2):184-8.
DOI: 10.1097/00001648-199803000-00014, PMID 9504288.
14. Shi J, Xue JS. Application and development of osmotic dehydration technology in food processing. In: Ratti C, editor. Advances in food dehydration. CRC Press; 2009.
15. Khin MM, Zhou W, Perera CO. A study of mass transfer in osmotic dehydration of coated potato cubes. J Food Eng. 2006; 77(1):84-95.
DOI: 10.1016/j.jfoodeng.2005.06.050
16. FAOSTAT; 2016.

- [Cited August 2018].
Available:<http://faostat3.fao.org/home/E>
17. Halliwell B. Antioxidants in human health and disease. *Annu Rev Nutr.* 1996;16: 33-50.
DOI:10.1146/annurev.nu.16.070196.000341, PMID 8839918.
 18. Diplock AT. Antioxidants and disease prevention. *Mol Aspects Med.* 1994;15(4):293-376.
DOI: 10.1016/0098-2997(94)90005-1, PMID 7845187.
 19. Geocoppens. Eeckenbrugge; 2001.
Available:http://www.ciat.cgiar.org/ipgri/fruits_from_americas/d
 20. Brahim B. Upgrading agro industries and related technical skills; 2000.
Available:<http://www.Unido.org/doc/39.html>
 21. Torreggiani D, Bertolo G. Present and future in process control and optimization of Osmotic dehydration. *Advances in Food and Nutrition Research.* 2004:173-238.
DOI: 10.1016/S1043-4526(04)48004-8 Ed.)
 22. Rahman S, Lamb J. Air drying behavior of fresh and osmotically dehydrated Pineapple. *J Food Process Engineering.* 1991;14(3):163-71.
DOI: 10.1111/j.1745-4530.1991.tb00088.x
 23. Available:<http://livewell.jillianmichaels.com/acids-pineapple-juice-5081.html>
 24. Ranganna S. Handbook of analysis and quality control for fruit and vegetable products. Tata: McGraw-Hill Education. 1986;1112.
 25. Benzie IFF, Strain JJ. The ferric reducing ability of plasma as a measure of 'antioxidant power.' The FRAP assay. *Anal Biochem.* 1996;239(1):70-6.
DOI: 10.1006/abio.1996.0292, PMID 8660627.
 26. Aktas T, Fujii S, Kawano Y, Yamamoto S. Effects of pretreatments of sliced vegetables with trehalose on drying characteristics and quality of dried products. *TranslChemE, Part C, Food and Bio products processing.* 2007;85(C3): 178-83.

© 2022 Sultana and Ghosh; This is an Open Access article distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/4.0>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Peer-review history:

The peer review history for this paper can be accessed here:
<https://www.sdiarticle5.com/review-history/92624>