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Effect of osmotic agents and freeze drying on bioactive compounds and sensory quality of dried strawberries

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ABSTRACT

The rationale of this study was to find out the possibility of using sugar and honey as osmotic agents and use of freeze-drying method to obtain pro-health-promoting dried strawberries. Strawberry fruits of cv.Chandler were dehydrated using sugar and honey syrups in a concentration of 50, 60 and 70°Brix followed by freeze drying. Analysis was conducted to determine the influence of the osmotic agents and freeze drying process on colour values (Hedonic scale), total phenols, antioxidant activity, total flavonoid content and sensory properties of the final dried product. Osmotic drying enhanced the total phenol and total flavonoid content of freshly dried whole strawberries from 64.55 to 138.64 mg/100g and 250.30 to 406.74 mg CE/100g in T1 (control) and T4 (70°Brix sugar), respectively. Better retention of antioxidant activity (87.68 %) in T7 (70°Brix honey) and L* values of 36.64 in T4 (70°Brix sugar) were observed. The sensory scores were higher for osmotically freeze-dried strawberries when compared to the control (strawberries dried without any osmotic agent). The shelf life was enhanced markedly up to three months after packing them in laminated pouches. Hence, osmotic drying can prove to be a promising technology for extending the shelf life of strawberries for three months with better retention of nutritional and sensory characteristics.

Keywords*:* Strawberry, Osmotic agents*,* Freeze drying, Honey, Flavonoids

INTRODUCTION

Strawberry is acknowledged of having a unique chemical composition that features their sweet taste, fruity aroma and nutraceutical properties. They are good source of essential vitamins and minerals with diverse phytochemical compositions that contributes to consumer satisfaction and health (Da Silva *et al*., 1). Strawberries are popular due to their balanced taste as well as low calorific value, easily digestible sugars, organic acids having antioxidant properties (De souza *et al.,* 2. The health benefits of strawberries are dueto presence of biologically active compounds that not only boost the immune system but also the natural resistance of the consumer, viz. ellagic acid, polyphenolics, mainly flavonoids, which help to neutralize damage due to free radical and thus reduced risk of developing cardiovascular disease (Giampieri *et al.,* 3). Several studies have demonstrated that strawberry possess higher antioxidant capacity than apples, peaches, grapes Owing to their antioxidant activity, they play a vital role in the prevention of certain types of cancers, anti-inflammatory functions, cardiovascular, obesity and other chronic diseases Crecente-Campo *et al*., 4).

The popularity and increasing demand for fresh and processed strawberries have made them one of the most extensively researched berries in the world. The quality of fresh strawberries as a function of their chemical composition and organoleptic attributes is an important area of study. Several studies have shown that consumer acceptance is greatly influenced by the quality of strawberry. Throughout world, strawberry is either consumed in fresh form or in processed form such as jams, juices and jellies. Unfortunately, the postharvest life of strawberry is relatively short due to their highly fragile structure and high rates of respiration. At the same time, it is highly susceptible to bruises and fungal attacks, thereby affecting the bioactive compounds and antioxidant activity Seasonality is one of the key reasonswhich invokes the need for processing of strawberry primarily into value based products like juices, beverages, concentrates, solids and frozen or dried products. Hence, to extendthe shelf-life of strawberry and to preserve its bioactive activity, large range of unit operations have been proposed and used to preserve it. One of the most important techniquesis drying, which enhances the possibility of extending the shelf life of strawberries and certain innovations in the manufacturing new products. Regardless of the drying methods applied, use of high temperature during drying process can have detrimental effect on bioactive compounds resulting inloss in sensory properties of fruit. Hence, it

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*Corresponding author: jdbandralpht@gmail.com is essential to develop a drying method in such a way that the resultant product is of highest quality in terms of nutritional quality and consumer acceptability. Also, pre-treatment processes such as osmotic dehydration can befurther used to ensure the desired nutritional and sensory properties of dried products. The current increase in osmotic treatments is not only the water removal with minimum thermal stress but also retention of structural, nutritional, sensory and other functional properties of the raw material and their modification (Kowalska *et al.*, 5). The most commonly used osmotic substances are carbohydrates. The aim of this study was to freeze dry whole strawberries using sugar and honey as osmotic agents so as to retain the bioactive as well as sensory properties of dried strawberries and to enhance their shelf life.

MATERIALS AND METHODS

The study was conducted with Chandler variety of strawberries at the stage of trade maturity and was purchased directly from the farmer. The physical state of the fruit showed that it was completely formed, tasty, brilliantly red coloured and firm. Fully ripe, bright red coloured strawberries were selected and the bruised or diseased fruits were sorted out. The stalks were removed with the help of knife. The selected whole fruits were washed by treating with chlorine solution (200 ppm) for 10 minutes and air dried for further use. The air dried whole strawberry fruits were divided into seven lots (400g each). Out of these, six lots were immersed in three different concentrations of sugar solution viz. 50 (T_2), 60 (T_3) and 70°Brix (T_4) and honey 50 (T_5), 60 (T_6) and 70°Brix (T_7) with Sodium benzoate as chemical preservative. After three days, the strawberries were removed from the solution and excess of sugar and honey syrup was removed followed by freeze drying. One lot (T_1control) was directly freeze dried. Freeze dried whole strawberries were packed in laminated bags and kept at ambient room temperature for chemical analysis and shelf life studies at an interval of 30 days.

Hunter colour anaysis of the osmotically dried strawberries was done by using Hunter Lab colorimeter(S.No. CX2013) using method of Vargas *et al.* (6). Total flavonoid content was determined using the aluminiumchloride colorimetric method (Zhishen *et al.,* 7) with catechin as a standard. The total flavonoid content was expressed as milligrams of catechin equivalent (CE) per 100 grams.Free radical scavenging activity was determined by DPPH (diphenylpicryl hydrazyl) method. Five hundred micro litres of 0.5 Mm DPPH solution and 2ml of 80 per cent methanol aqueous solution were mixed with 25 µL of methanolic extract of sample, and absorbance was determined under 517 nm blank as 80 per cent methanol and tris buffer) after maintaining at 20° C for 30 minutes. The free radical scavenging activity was evaluated as per the method discussed Abe *et al.* (8) by comparing the absorbance of the sample solution with control solution to which distilled water was added instead of sample.

$$\text{Radical scavenging activity (\%)} = \frac{\text{Control OD (0 min)} - \text{Sample OD (30 min)}}{\text{Control OD (0 min)}} \times 100$$

For estimation of total phenols**,** 0.5 ml of freshly prepared sample was taken and diluted with 8 ml of distilled water. 0.5 ml of Folin Ciocalteu Reagent (1 N) was added and kept at 40˚C for 10 min. 1 ml of Sodium Carbonate (20%) was added and kept in dark for one hour. The color was read at 650 nm using Shimadzu UV-1650 Spectrophotmeter (Malick and Singh, 9) The same procedure was repeated for all standard gallic acid solutions and standard curve obtained. The sample concentration was calculated as Gallic acid equivalent (GE).

Sensory evaluationwas carried out on a 9-point Hedonic scale where 1 denoted undesirable, while 9 denoted the desirable product havingthe most desired sensory quality. The analyzed qualitative attributes were as follows: color, taste and texture (Amerine *et al.,* 10).The statistical analysis of results was doneusing a multi-way analysis of variance (ANOVA). Two factors investigatedwere the type of osmotic solution used for fruit pre-treatment and storage intervals (0, 30, 60 and 90 days) at a significance level of p = 0.05 (Gomez and Gomez, 11).

RESULTS AND DISCUSSION

The data on L* value of osmotically dried whole strawberries during storage (Table 1) indicated that there was a decreasing trend in L* valueduring 3 months of storage period. Significant differences were also observed due to different treatments as well as storage period. Among the treatments, the highest (33.91,) mean L* value was observed in the treatment T_4(70°Brix sugar) and the lowest (14.60) mean L* value was found in the treatment T_1(control). With respect to storage condition (3 months), decreasing trend of mean L*, a* and b* values was observed and the values decreased significantly from 28.80 to 21.47, 12.85 to 11.51 and 8.19 to 7.06, respectively after 90 days of storage. The interaction between treatments and storage period was found to be significant at 5 per cent level of significance. The decreasing trend in L* value for colour was indicative of the darkening of osmotically dried whole strawberries during storage

Table 1. Effect of osmotic agents on lightness (L* values) and redness (b* values) of freeze dried whole strawberries

Treatment	Lightness (L* values)					Redness (a* values)				
	Storage (days)					Storage (days)				
	0	30	60	90	Mean	0	30	60	90	Mean
T_1 (Control)	20.55	17.05	12.62	8.17	14.60	8.47	7.68	7.29	6.99	7.61
T_2 (50 °Brix sugar)	28.59	26.53	23.21	19.94	24.57	14.70	14.35	14.06	13.68	14.20
T_3 (60 °Brix sugar)	31.74	30.68	27.53	25.20	28.79	15.15	14.82	14.39	14.00	14.59
T_4 (70 °Brix sugar)	36.64	34.60	33.33	31.08	33.91	13.91	13.47	13.01	12.71	13.28
T_5 (50 °Brix honey)	24.62	22.51	20.17	17.87	21.29	12. 81	12.20	11.69	11.02	11.64
T_6 (60 °Brix honey)	28.77	26.65	25.28	22.05	25.69	13.31	12.75	12.23	11.90	12.55
T_7 (70 °Brix honey)	30.69	28.57	27.25	25.97	28.12	11.58	11.00	10.61	10.28	10.87
Mean	28.80	26.66	24.20	21.47		12.85	12.32	11.90	11.51	
	CD $_{(P = 0.05)}$ Treatments (A) = 0.12 Storage (B) = 0.20 A×B = 0.08					CD $_{(P = 0.05)}$ Treatments (A) = 0.08 Storage (B) = 0.09 A×B = 0.10				

at ambient condition. Similar results of decreasing L* value have been reported by Petriccione *et al.* (12) in uncoated strawberry fruits than in chitosan coated fruits at the end of storage period. Lowering of L values during storage could be attributed to formation of dark coloured compounds from non-enzymatic browning reactions like Maillard reaction and oxidation of organic acids or precipitation of pigments (Kaikadi, 13).

The high antioxidative potentialof strawberries is closely related to their polyphenolics. Both processingmethod as well as storage conditions can cause changes in their content, i.e. some of them may reduce it while others may increase polyphenolic content(Kowalska *et al.* 5). The data on effect of various treatments and storage period antioxidant activity of osmo-freeze dried whole strawberries under ambient conditions is shown in Table 2. The data showed that all the treatments exerted significant effect on antioxidant activity. Minimumantioxidant activity of 54.30per cent was recorded in control (T_1) followed by treatment T_2 (50°Brix sugar) with a value of 76.58 per cent whereas highest antioxidant activity of 87.68 per cent was observed in T_7 (70°Brix honey). Storage period significantly affected antioxidant activity which decreased gradually as the storage

Table 2. Effect of osmotic agents on b* (yellowness) and antioxidant activity (%) of freeze dried whole strawberries

Treatment	Yellowness (b* values)					Antioxidant activity (%)				
	Storage (days)					Storage (days)				
	0	30	60	90	Mean	0	30	60	90	Mean
T_1 (Control)	6.47	6.18	5.89	5.64	6.05	54.30	50.18	55.09	68.97	57.14
T_2 (50 °Brix sugar)	8.15	7.75	7.26	7.01	7.54	76.58	73.48	70.42	65.33	71.45
T_3 (60 °Brix sugar)	9.70	9.32	9.03	8.79	9.21	79.86	77.81	73.73	69.62	75.26
T_4 (70 °Brix sugar)	8.91	8.47	8.16	7.85	8.35	84.75	82.67	80.58	75.46	80.87
T_5 (50 °Brix honey)	7. 81	7.30	7.00	6.72	7.01	78.53	75.40	72.31	68.24	73.62
T_6 (60 °Brix honey)	8.31	8.05	7.63	7.10	7.77	82.83	80.68	79.56	75.49	79.64
T_7 (70 °Brix honey)	7.58	7.13	6.86	6.31	6.97	87.68	85.56	82.48	78.40	83.53
Mean	8.19	7.74	7.40	7.06		77.79	75.11	73.45	71.64	
	CD $_{(P = 0.05)}$ Treatments (A) = 0.12 Storage (B) = 0.07 A×B = 0.05					CD $_{(P = 0.05)}$ Treatments (A) = 0.21 Storage (B) = 0.13 A×B = 0.10				

period progressed irrespective of the treatment. The results further revealed that the rate of decrease in antioxidant activity was significantly lower in coated samples as compared with control samples which might be due reason that high temperatures can cause losses of polyphenolics, but the presence of proteins and carbohydrates in the nutritional matrix have a protective action against the effects of peroxidase and polyphenol oxidase, thereby protecting losses ofantioxidative compounds from the product. Kowalska *et al.* (14) in their study reported that dried strawberry samples comprised of high antioxidative activity, exhibiting the ability to absorb and neutralize free radicals present in the human body. They further stated that osmotic coating had significant role in the maintenance of antioxidant activity in a dose-dependent manner.

The strawberries pre-treated with osmotic agents followed by freeze drying were characterized by the slightly higher total polyphenolic content, which indicated that low temperatures have beneficial effect in preserving total phenolic content. A trend was observed for the highest loss of polyphenolics in dehydrated strawberries without any osmotic agent. The analysis of freshly freeze dried strawberries (without any osmotic agent) was characterized by a mean polyphenols content of 64.55 g GA/100 g(T_1) (Table 3). Osmotic pre-treatment and freeze drying significantly retained the polyphenolic content in strawberries i.e. 138.64 g GA/100g in treatment T_4 (70°Brix sugar) and 128.68 g GA/100g in treatment T_7 (70°Brix honey). This might be due to inactivation of polyphenol oxidase and peroxidase enzymes during osmotic treatment, which significantly reduced the oxidation of polyphenolics. Kowalska *et al.* (14) also found higher total polyphenol content in strawberries dehydrated with sucroseas compared to the untreated samples. Further the pre-osmotic treatment of strawberries in combination with drying proved to be effective in preserving the oxygen and heatsensitive polyphenolics and ascorbic acid. According to Maftoonazad(15) during the osmotic step furanones and pyranones and to lesser extent esters remain in the fruit tissue and osmotic drying improves the volatile retention during drying of strawberry slices. After 90 days of storage, the polyphenol content increased significantly and the highest content of 169.43 g gallic acid/100 g was determined in the dried strawberries osmotically pre-treated in sugar solution (70°Brix) followed by 154.20 g GA/100 g in strawberries pre treated with 60 °Brix sugar. Petriccione *et al.*(12) also reported continuously increase in total phenolics content of chitosan-coated strawberry fruits during storage.

Studies have shown that coatings and pre-treatments can improve the nutraceutical properties of fruits, maintaining high levels of flavonoids during postharvest handling thereby delaying fruit senescence and enhancing the phytochemical content during storage. All the treatments of osmotically pre-treated freeze dried whole strawberries observed significant increase in the total flavonoid content during 0 to 90 days of storage (Table 3). Treatment T_4 (70°Brix sugar) showed the highest total flavonoid content at both 0 days (406.74 mg CE/100g) and 90 days

Table 3. Effect of osmotic agents total phenol (mg/100g) GE and flavonoid content (mg CE/100g) of freeze dried whole strawberries

Treatment	Total phenols					Total flavonoids				
	Storage (days)					Storage (days)				
	0	30	60	90	Mean	0	30	60	90	Mean
T_1 (Control)	64.55	67.05	72.62	71.10	89.85	250.30	306.18	314.09	283.97	288.64
T_2 (50 °Brix sugar)	119.59	124.53	131.21	143.94	129.82	376.59	388.48	400.41	419.33	396.20
T_3 (60 °Brix sugar)	126.73	133.69	140.52	154.20	138.79	389.86	395.80	408.73	434.62	407.25
T_4 (70 °Brix sugar)	138.64	145.60	156.33	169.43	152.50	406.74	416.67	433.58	447.47	426.12
T_5 (50 °Brix honey)	112.61	119.51	128.16	137.87	124.54	361.53	380.40	393.31	404.24	384.87
T_6 (60 °Brix honey)	120.77	126.66	132.28	142.05	130.44	373.81	387.69	399.55	413.48	393.63
T_7 (60 °Brix honey)	128.68	136.57	144.25	152.96	140.62	388.68	403.56	421.48	435.40	412.28
Mean	115.94	121.94	129.43	140.09		363.93	403.56	421.48	405.50	
	CD $_{(P = 0.05)}$ Treatments (A) = 0.27 Storage (B) = 0.16 A×B = 0.14					CD $_{(P = 0.05)}$ Treatments (A) = 1.02 Storage (B) = 0.19 A×B = 0.17				

(447.47 mg CE/100g) of storage, while T_1(control) showed the lowest total flavonoid contentof 250.30 and 283.97 mg CE/100g, respectively. These results are consistent with the findings of Petriccione *et al.* (12) in chitosan coated strawberries. The increase may be attributed to activated level of key enzyme in the phenol synthesis pathway, such as phenylalanine ammonia lyase (PAL) thereby increasing the total polyphenolic content (Romanazzi *et al.,* 16).

Sensory evaluationwas carried out considering sensory acceptability in terms of color, taste and texture.Strawberries dried using sugar as osmotic agent were highly desirable (Figure 1) and the scores for all the sensory attributes differed significantly for all thetreatments. A perusal of data in Figure 1 indicates that maximum taste (8.51), colour (8.31) and texture (8.19) were recorded in freeze dried whole strawberries pre-treated with 60°Brix sugar

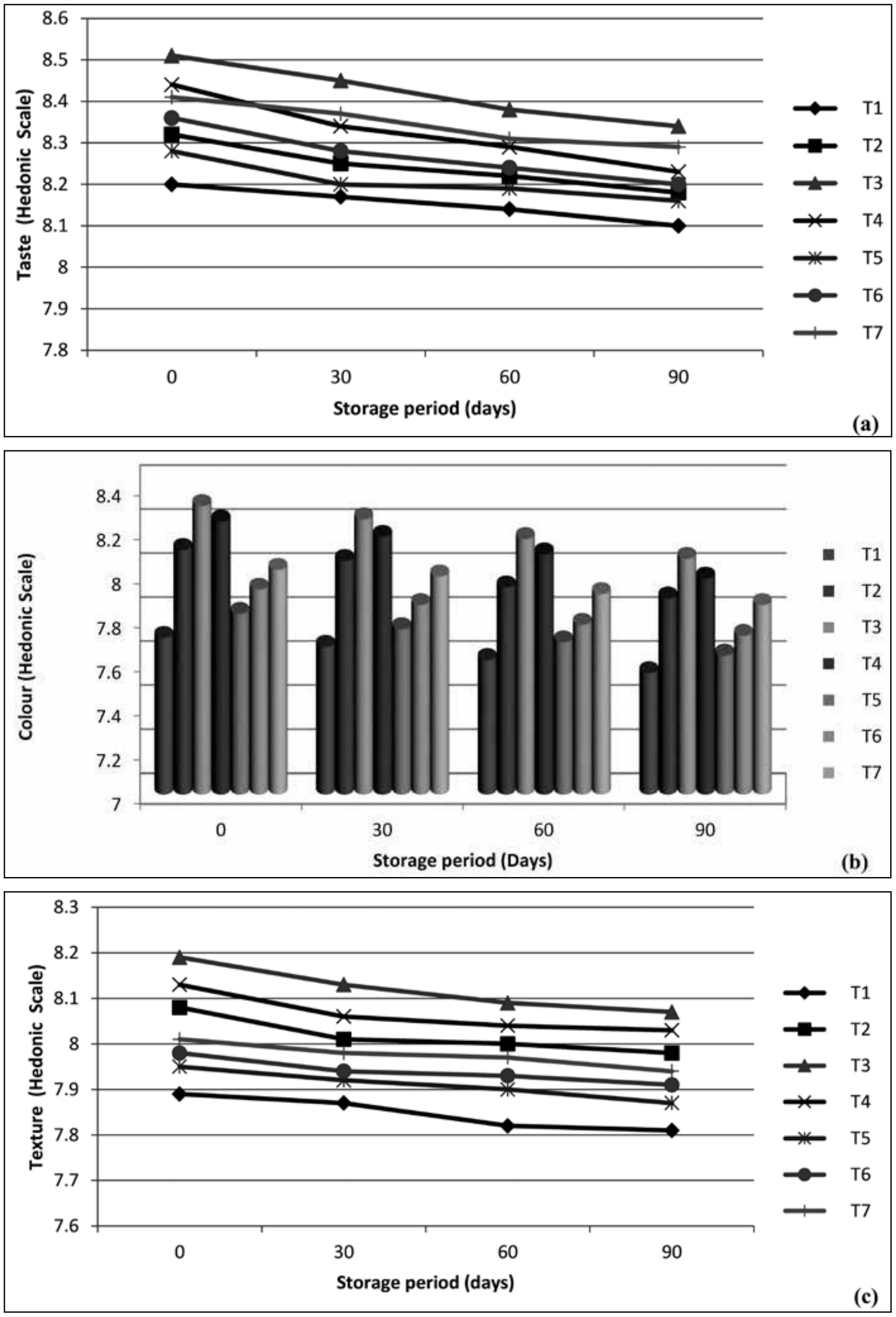

Figure 1. Effect of osmotic agents on (a) taste (b) colour and (c) texture scores of freeze dried whole strawberries

(T3) followed by T4 (70°Brix sugar) having taste, colour and texture scores of 8.44, 8.24 and 8.13, respectively.Alasalvar and Shahidi (17) reported that the freeze-dried fruits are very crispy and light and they retain original flavour (e.g., aroma and taste) and bioactive molecules. During storage, the sensory scores decreased significantly irrespective of the treatments. Higher retention of red colour, taste and texture was noticed in strawberries pre-treated with sugar as osmotic agent which means osmotic treatment in combination with freeze drying delayed discolouration and development of off flavour as the storage progressed. However, control fruits showed rapid fall in the sensory scores during storage. Similar decrease in sensory parameters with storage was reported by Yadav *et al.* (18) in jamun bael blended fruit cheese. Similarly,Gamboa-Santos *et al.* (19)also reported higher flavor and texture values for freezedried fruitscompared to the convection-microwave-vacuum dried strawberry samples. They explained these observations by higher porosity and a more compact structure of sucrose dipped freeze-dried strawberries.

From the overall observations of the experiment it can be concluded that osmo drying is a very effective post-harvest treatment in combination with freeze drying to enhance the shelf life of perishable strawberry fruits upto a period of three months. The osmo-dried whole strawberries retained their bio active components, splendidsensory quality without any appreciable spoilage during storage. Hence, this technology could be used to increase the shelf life and reduce the post-harvest losses of delicate strawberry fruits.

AUTHORS' CONTRIBUTION

Conceptualization of research (JDB), Designing of the experiments (JDB, MS), Contribution of experimental materials (JDB, MS, AB, NG), Execution of field/lab experiments and data collection (JDB, MS, NG), Preparation of the manuscript (JDB, MS).

DECLARATION

The author declare that there is no conflict of interest.

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