Scholars Academic Journal of Biosciences
Abbreviated Key Title: Sch Acad J Biosci
ISSN 2347-9515 (Print) | ISSN 2321-6883 (Online)
Journal homepage: https://saspublishers.com
NLM ID:101629416

OPEN ACCESS

Nutrition

Shelf-Life Study of Value-Added Freeze-Dried Jujube Cake

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DOI: https://doi.org/10.36347/sajb.2025.v13i12.011 | **Received:** 17.10.2025 | **Accepted:** 26.12.2025 | **Published:** 31.12.2025

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Abstract | **Original Research Article**

Drying is recognized as a crucial and valuable preservation technique today. The current study aimed to compare the antioxidant activity and total phenolic content of fresh, oven-dried, and freeze-dried ber (*Ziziphus mauritiana*) varieties followed by value-added cake development. One batch of fresh fruit was dried in a hot-air oven at 70°C for 8 hours, while another batch was freeze-dried at -50°C for 48 hours. The *cv.* 'Dil Bahar,' which showed the highest Total Phenolic Content (153.65±0.03 mgGAE/100g) and DPPH value (37.14±0.03%) after freeze-drying, was selected for developing a value-added product *i.e.* freeze-dried berry cake. After initial analysis, freeze-dried ber was subjected to product development as per treatment plan @5%, @10% and @15% followed by shelf-life study (0, 7th, 14th day). The findings revealed that the Total Phenolic Content, DPPH, Hardness value of the freeze-dried berry cake increased (p<0.05) with higher treatment percentages and decreased with the passage of storage time. Additionally, the color parameters (L*, a*, and b*) exhibited significant (p<0.01) changes during storage. Sensory evaluation revealed highly significant (p<0.05) results during storage. ***Short Abstract*:** Ber varieties were analyzed using both oven-drying and freeze-drying techniques to create value-added berry cakes. The fresh fruits were evaluated for their DPPH and TPC content. The most suitable drying method, based on TPC and DPPH content, was selected for product development according to a specified treatment plan. The resulting product was then assessed through storage studies, which yielded highly significant results.

Keywords: Ber, Oven, Drying, Freeze, Color, Cake.

INTRODUCTION

Most fruits are seasonal and perishable, and it is estimated that 20-30% of fruits are lost in Pakistan. Ber is a seasonal fruit that can be made available all year with a variety of culinary products that have a longer shelf life. Harvesting of this fruit is done in the autumn season so post-harvest shelf life is less than 10 days under an uncontrolled environment. Therefore, it is responsibility of food processor to find effective preservation techniques for jujubes to prolong their shelf life (Muqaddas *et al*., 2025).

Currently, dried fruits and vegetables are considered as most cherished healthy snacks. Drying phenomena results in changing appearance of fruit and chemical profile but it is effective in proper handling of raw material and its shelf-life enhancement as it reduces enzymatic degradation and controls growth of microbes (Asami *et al*., 2003). Selection of satisfactory drying technique will help in yielding a commodity with high antioxidant potential, more flavored and minute change in appearance. Consumer preference should be considered before selection of drying method as it will help in retaining substantial amounts of bioactive components in end-product (Najjaa *et al.,* 2020).

The post-harvest shelf life of ber is limited due to its perishable nature. Drying is a preservation method of jujubes for keeping desirable characteristics, lessening of storage volume and prolongation of shelf life. Various methods of drying have been introduced that possess considerable attributes. In traditional drying, sun-drying method is useful in ensuring appropriate preservation of jujube fruit (Wojdylo *et al*., 2019; Xiao *et al*., 2015).

In the oven drying method, Wan *et al*., (2025) dried the samples in hot air oven dryer that was designed and built by Oregon Freeze-Dry, Inc. In the freeze-drying phenomenon, food is subjected to freezing first followed

by the removal of water through process of sublimation. This phenomenon helps in inhibiting chances of deterioration and microbial reactions due to the absence of moisture and low-temperature requirements. Eventually, excellent quality product is obtained. Qian *et al.,* 2016 stated that the preservation of valuable food components can be effectively done by freeze-drying as compared to other drying methods (Azeem *et al*., 2025).

Besides the traditional methods of drying, new and other hybrid drying methods are coming into focus as they have better efficiency and quality of products. Oven drying, freeze-drying is some of the techniques that have been shown to improve moisture removal and reduced thermal destruction of bioactive compounds that are sensitive to heat (Maqbool, *et al*., 2025). Such techniques are done under controlled situations, which lead to decrease in oxidation, retention of phenolics, flavonoids, vitamins, and rehydration of dried jujube products. Moreover, factors like temperature, air velocity, pressure and drying period are very important in maintaining color, texture, antioxidant activity and preservation of ber fruit. Such high-level technologies of drying can play a significant role in creating high-value, shelf-stable jujube products with enhanced nutritional and sensory quality that can be processed on a commercial scale and be available all year round (Bao *et al*., 2022).

Objective

The Current Study is planned:

To evaluate effect of oven-drying and freeze-drying on anti-oxidant and total phenolic content of ber (jujube) varieties; to develop and shelf-life study of value-added product (dried berry cake)

METHODOLOGY

The current study was conducted in the research laboratory of the Department of Food Science and Technology, as well as the Post-harvest Lab at MNS-University of Agriculture, Multan, Pakistan. Four ber varieties *i.e.* Karela, Aakash, Pak White, Dil Bahar was procured from farms of Jalalpur Peerwala. All required chemicals and reagents were procured from Sigma Aldrich.

Oven-Drying

Jujubes were oven-dried in a Hot-Air Oven at 70°C for 8 hours until the moisture content reached 18% (Hammi *et al*., (2015). Following the drying process, the dried fruit was analyzed to determine total phenolic content and radical scavenging capacity using the DPPH assay for a comparative evaluation of the ber varieties.

Freeze-Drying

Jujubes were subjected to freeze-drying in a Standard Freeze dryer, model number SFDQ 1000 at a temperature of -50°C for 48 hours until the moisture content reached 0.2% (Wu *et al*., 2022). Jujubes were freeze-dried by sublimation phenomena. After freeze-drying procedure, dried fruit were subjected for determination of total phenolic content and radical scavenging capacity by DPPH assay for comparative evaluation of ber varieties.

TPC and Antioxidant Activity of Fresh, Oven and Freeze-Dried Ber

TPC and Total Anti-oxidant capacity were measured from the pulp of ber fruit (Fresh, oven-dried and freeze-dried) as stated by Gao *et al.,* (2012) and Kassim *et al*., (2013). Samples were collected in replicate and subjected to grinding for fine powder. Fine powder was mixed in 2% ethanol and placed shaking incubator for 24 hours. Later, supernatant was collected and analyzed for anti-oxidant value by using DPPH reagent and TPC content by using ELISA.

Selection of Best Drying Method

After the determination of the total phenolic content and radical scavenging capacity of dried ber, the best freeze-dried ber (Dil Bahar) was chosen for product development.

Product Development

The freeze-dried berry/jujube cake was prepared by the addition of freeze-dried jujube powder as per treatment plan shown in Table 2 according to the method described by Emamifar *et al*., (2020) and Kim *et al*., (2009) with some modifications (Table 1). All ingredients were weighed accurately and subjected to batter development. Dry ingredients including freeze-dried jujube were mixed followed by shortening preparation. Later, dry mixture was added in shortening by dividing flour in three portions. Mixture was poured in cake mold and baked for 25 minutes at 180ºC. After baking, cake was subjected to refrigeration conditions at 4ºC (Figure 1).

Table 1: Ingredients for freeze dried berry (FDB) cake

Ingredients	Amount
All-purpose flour	250 g
Sugar	250 g
Butter	250 g
Egg	150g
Milk	25 ml
Baking powder	7 g
Freeze-dried ber powder	As per treatment plan

Table 2: Treatment plan for freeze-dried berry (FDB) cake

Treatment	FDB powder (%)	All-purpose flour (%)
T_0	0	100
T_1	5	95
T_2	10	90
T_3	15	85

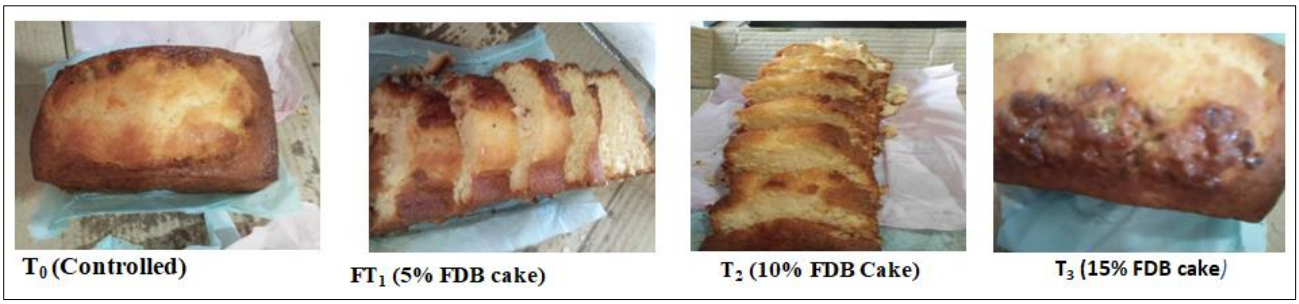

Figure 1: Development of freeze-dried ber cakes at various concentration

Sensory Evaluation of the Product

The prepared cakes were evaluated by 10 judges (trained) at Sensory Evaluation Lab, MNS-University of Agriculture, Multan. The panelists used a hedonic scale, where a score of 9 indicated "extremely like" and 1 indicated "extremely dislike," to assess the cakes. Sensory evaluation was carried out to assess quality characteristics such as texture, color, taste, aroma, and overall acceptability, following the methodology outlined by Gharavi *et al*., (2022) and Wichchukit and O'Mahony (2015).

Chemical and Physical Analysis of Freeze-Dried Berry Cake

The prepared cakes were placed in refrigerator and analyzed for total phenolic content (TPC), DPPH, hardness and color (L*, a*, b*) at 0, 7th and 14th day of storage.

Determination of Color

The prepared cake's color was analyzed using a digital chroma meter, following the protocols outlined by Kara *et al*., (2005).

Determination of Hardness

The textural study of the prepared cake was conducted to measure hardness, following the procedure described by Hosseini *et al*., (2019). The textural properties were assessed using a texture analyzer (Model TA-XT2i, Stable Micro Systems, Haslemere, U.K.)

Statistical Analysis

The resulted data were statistically analyzed by using Two Factor Factorial according to the procedure described by Montgomery (2019).

RESULTS AND DISCUSSION

Effect of Oven-Drying and Freeze-Drying on TPC of Ber

Fresh jujube varieties were subjected to oven-drying and freeze-drying. Results of TPC content for fresh, oven and freeze dried jujubes are shown in shown in Table 3. The present findings were matched with Woo and Ahn (2004) that showed decreased TPC content on oven-drying. Arslan *et al*., (2021) also studied effect of various drying methods on jujubes. Results stated that phenolic compounds show decreasing behavior in dried jujube as compared to fresh jujubes. The reason is that oven drying degrades several phenolic compounds on heating ultimately reducing the phenolic content of jujubes. In the freeze-drying phenomenon, TPC content was significantly increased in jujube varieties. Pu *et al*., (2018) also observed maximum phenolic content in freeze-dried *cv*. Dil Bahar. The reason is that freeze-drying do not destroy nutrients of fruit due to absence of heating.

Effect of Oven-Drying and Freeze-Drying on DPPH

Current findings were in collaboration with Sapkota *et al*., (2023) which showed decreased DPPH value in oven-dried jujubes. In freeze-dried jujubes, the highest DPPH value was observed in the Dil Bahar variety, while the lowest was found in the Pak White variety. The reason is that eat assisted drying caused anti-oxidant compounds to be destroyed that results in lowering of anti-oxidant activity in fruits. Moreover, freeze-drying is considered as safe as it does not cause harm to the nutrients.

Table 3: Effect of oven and freeze-drying on TPC (mgGAE/100g)

Treatment	Karela	Aakash	Pak White	Dil Bahar
Control	87.23±0.02	69.35±0.02	101.24±0.02	144.38±0.02
Oven-drying	72.18±0.03	61.57±0.03	88.36±0.03	122.57±0.03
Freeze-drying	91.55±0.02	74.25±0.04	105.24±0.04	153.65±0.03

Mean±SD
TPC=Total Phenolic Content

Table 4: Effect of oven-drying and freeze-drying on DPPH (%)

Treatment	Karela	Aakash	Pak White	Dil Bahar
Control	28.00±0.02	18.00±0.02	13.00±0.02	39.00±0.02
Oven-drying	22.23±0.03	12.26±0.02	9.09±0.02	33.90±0.03
Freeze-drying	26.44±0.03	17.74±0.02	12.59±0.04	37.14±0.03

Mean±SD ($p<0.05$)

Sensory Evaluation of Freeze-Dried Berry Cake

Freeze-dried Dil Bahar variety was chosen for value-added product development *i.e.* Freeze-dried jujube cake as the highest TPC and DPPH value was observed. Sensory evaluation of four treatments *i.e* Controlled (T_0), T_1(5% freeze-dried jujube powder), T_2 (10% freeze-dried jujube powder), T_3 (15% freeze-dried jujube powder) was done by following a 9-point hedonic scale that involves color, flavor, aroma, texture and overall acceptability as quality parameters as shown in Figure 2. Present results were in corroboration with Krska and Mishra (2008) and Antonio *et al*., (2005) which showed maximum texture score when jujube powder was used @3%. Saadoudi *et al*., (2017) also observed maximum overall acceptability score of freeze-dried jujube-based biscuits. The reason may be due to uniform appearance of biscuits throughout storage period.

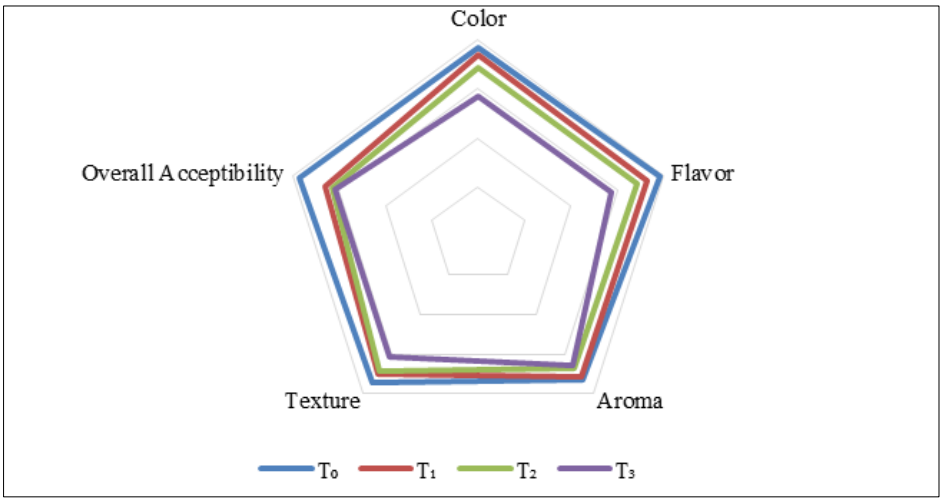

Fig. 2: Sensory evaluation of freeze-dried berry cake ($p<0.05$)

Storage Stability of Freeze-Dried Berry Cake (FDB)
Effect of Storage and Treatment on Total Phenolic Content of FDB

Total phenolic content in freeze-dried jujube cake indicated that on the 0^{th} day, maximum total phenolic content was observed in T_3 (15% freeze-dried jujube powder) whereas lowest total phenolic content was observed in T_0 (Control) followed by T_1(5% freeze-dried jujube powder) as shown in Figure 3. On the 14^{th} day of storage, the maximum total phenolic content was analyzed in T_3 (32.67±0.02) while the lowest was observed in T_0 (7.13±0.02) followed by T_1 (11.26±0.02.)

The current study was matched with findings of Binczak and Samotyia (2018) that showed an increased total phenolic content in walnut cake with the passage of time. The reason is that jujube fruit contains considerable amounts of phenolic that resulted in increased total phenolic content in jujube cake. Moreover, freeze-dried jujube powder retains the maximum amount of total phenolic content as compared to jujube powder dried from other technique including sun drying and oven-drying. The reason for decreased total phenolic content is due to degradation of phenolic compounds at high temperatures. Moreover, phenolic compounds have ability to take part in Maillard reaction that ultimately results in decreased level of total phenolic content (Elaloui *et al*., (2023).

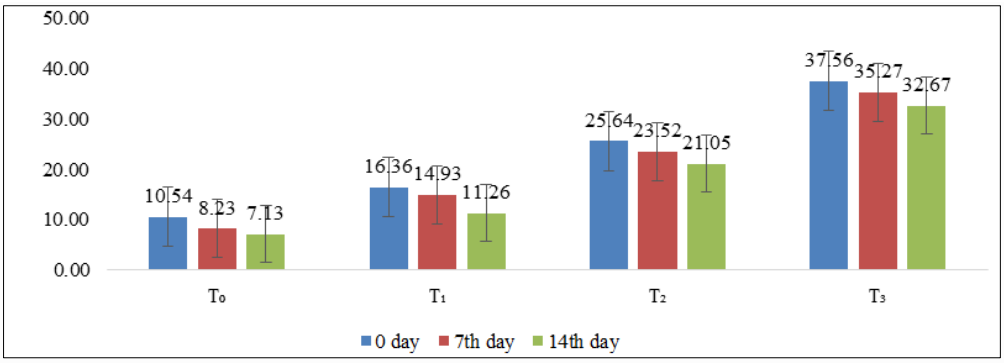

Fig. 3: Combined effect of treatment and storage on TPC of FDB cake (p<0.05)

Effect of Treatment on DPPH of FDB Cake

The results indicated a highly significant value (p<0.01) for T0 on the 0, 7th, and 14th day, as illustrated in Figure 4. Moreover, the effect of treatment on the storage of freeze-dried cake showed highly significant values of T_3 on the 0th day. Current results were in collaboration with Lin *et al*., (2020) which showed decrease in DPPH value in cake. The reason is that phenolics are sensitive to heat. When temperature rises, structure of phenolics changes that ultimately results in decrease in DPPH value. Moreover, various anti-oxidants start evaporating due to onset of high temperature (Zozio *et al*., (2014).

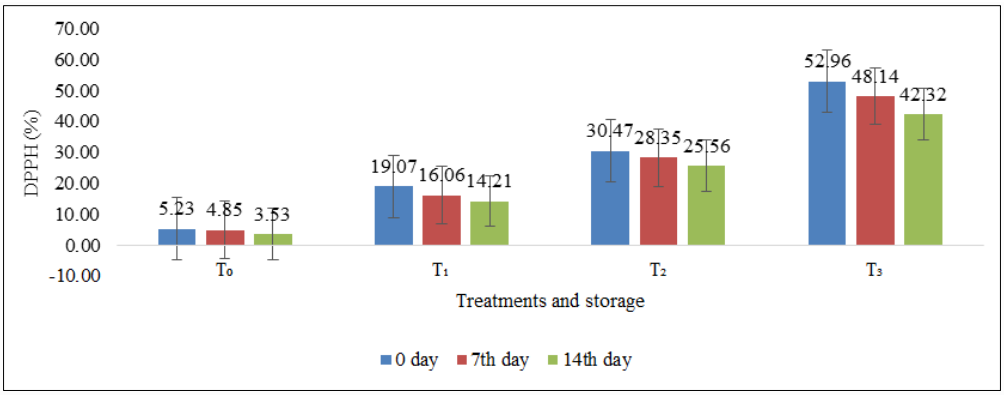

Fig. 4: Combined effect of treatment and storage on DPPH of FDB cake (p<0.01)

Effect of Treatment on the Hardness of FDB Cake

The hardness of freeze-dried jujube cake was analyzed on the 0th, 7th and 14th day of storage. The lowest hardness value was observed on the 0th day while the highest was observed on the 14th day as shown in Figure 5.

Current results were in collaboration with Polak *et al*., (2019) which showed a similar trend of increase in hardness as storage time increased. The increased hardness may be due to the loss of moisture in the cake with the passage of time and the increased percentage of dried jujube powder that results in increased product hardness. The primary reason is due to recrystallization of gelatinized starch granules, majorly amylopectin. It ultimately strengthens the crumb structure. Moreover, crystallization of fat particles results in hardening of cake crumb (Pancharoen *et al.,* (2019).

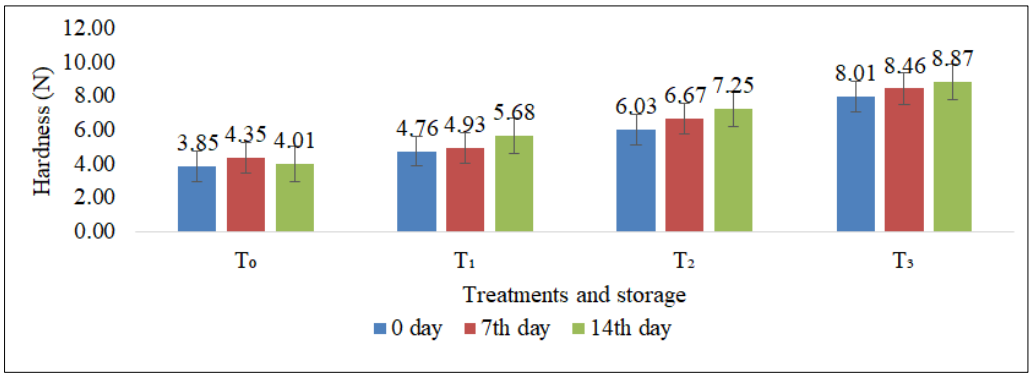

Fig. 5: Combined effect of treatment and storage on hardness (N) of FDB cake (p<0.05)

Effect of Treatment and Storage on the Color of FDB cCake (crumb)

L* Value

Current results showed highly significant values with respect to storage and treatment as shown in Figure 6. Results obtained were in collaboration with Slade *et al*., (2021) which showed similar trend of decrease in L* value when storage time was increased. Moreover, the L* value decreased when the percentage of treatment was increased. Reason for the decreased L* value may be due to addition of dried jujube powder that contain various phenolic compounds that cause reduced lightness in the product. Moreover, various pigments contribute to the lower L* value of the cake. During baking, sugars react with proteins that results in development of melanoidins. These brown colored melanoidins cause reduction in lightness of cake crumb. Moreover, sugar caramelization also leads to browning (Ali *et al*., 2023).

a* Value

At 0day, a* value of treatment T_0, T_1, T_2 and T_3 was measured as 8.85± 0.02, 4.32±0.02, 6.33±0.02 and 7.41±0.02 respectively as shown in Figure 7. In T_0, the Highest a* value was observed on the 0^{th} day while the lowest was observed on the 14^{th} day of storage. On the 7^{th} day of storage, a* value of T_0, T_1, T_2 and T_3 of cake crumb was analyzed as 1.14±0.02, 2.84±0.02, 4.98±0.01 and 6.77±0.02 respectively. The highest a* value was observed on the 0^{th} day in T_1 while the lowest was analyzed on the 14^{th} day of storage. At 14^{th} day of storage, a* value of treatment T_0, T_1, T_2 and T_3 was identified as 0.54±0.02, 1.98±0.03, 3.25±0.02 and 5.95±0.02 respectively. The maximum value was seen on 0^{th} day while lower value was analyzed at the 14^{th} day.

The results demonstrated highly significant values ($P<0.01$) for the effect of treatment on storage. Current finding was matched with Wojdylo *et al*., (2009) that showed similar trend of decreased a value. Furthermore, the value increased when the treatment percentage was increased. Reason for decreased value is due to caramelization of sugars during baking (Amani *et al*., 2022).

b* Value

At 0^{th} day, b* value in treatment T_0, T_1, T_2 and T_3 was measured as 25.14±0.02, 8.91±0.02, 7.23±0.02 and 7.54±0.02 respectively as shown in Figure 8. The highest b* value was noted on the 0^{th} day while the lowest was observed on the 14^{th} day. At 7^{th} day of storage, b* value of T_0, T_1, T_2 and T_3 was observed as 24.67±0.02, 8.70±0.02, 7.05±0.02 and 6.84±0.02. On the 14th day of storage, the highest b* value was noted on the 0^{th} day while the lowest was observed on the 14^{th} day.

Current results showed highly significant values ($P<0.01$) at the combined effect of treatment and storage. Results were in collaboration with Park *et al*., (2008) that showed decreased b* value when storage time was increased. Moreover, when the treatment percentage was increased, the b* value decreased. The reason for decreased b* value may be due to the presence of several pigmented compounds that contribute toward color development. Heat intensifies these pigments that results in brown color development (Ertas, 2021).

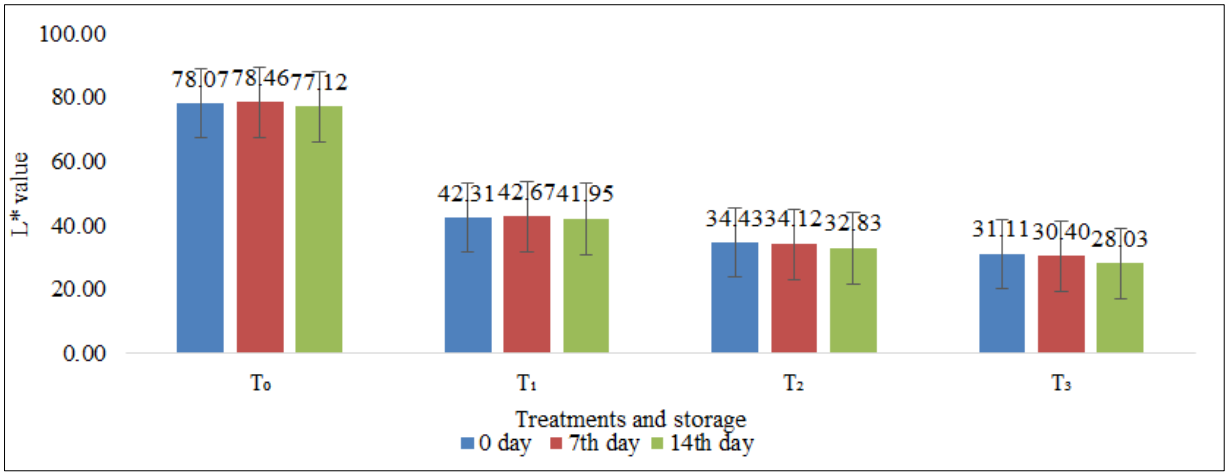

Fig. 6: Combined effect of treatment and storage on L* value of FDB cake crumb ($p<0.01$)

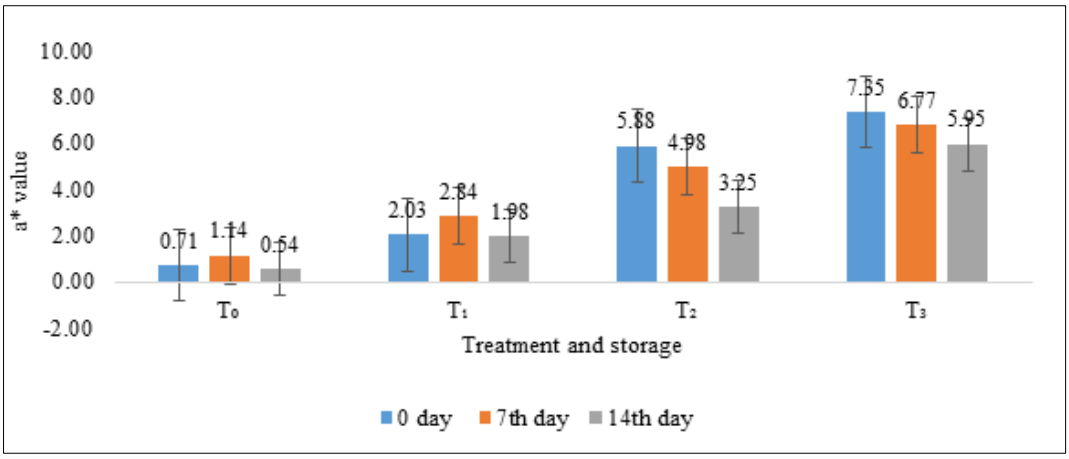

Fig. 7: Combined effect of treatment and storage on a* value of FDB cake crumb (p<0.01)

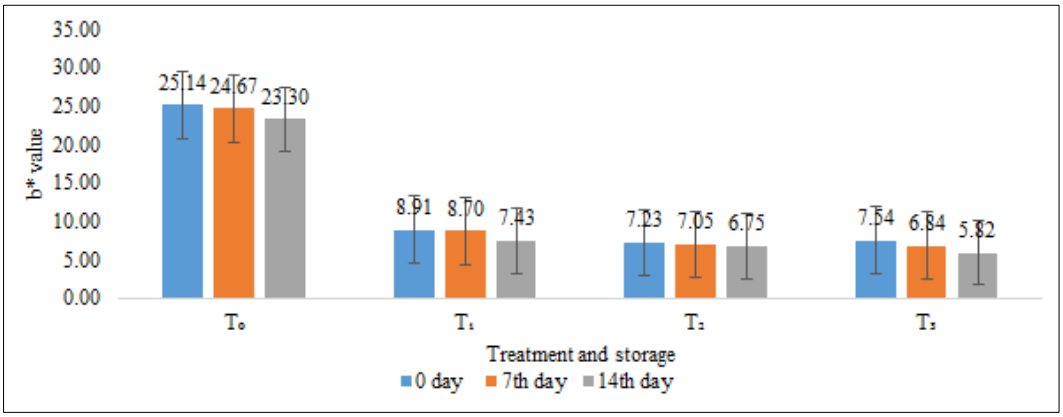

Fig. 8: Combined effect of treatment and storage on b* value of cake crumb (p<0.05)

Effect of Treatment and Storage on Color of FDB Cake (Crust)

L* Value

On the 0th day, the L* value of cake crust in treatments T_0, T_1, T_2 and T_3 were identified as 40.27±0.02, 35.36±0.03, 27.63±0.02 and 24.36±0.03 respectively. On the 7th day of storage, a higher L* value was noticed at T_0 while the lowest was observed at T_3. At 14th day of storage, L* value of T_0, T_1, T_2 and T_3 was identified as 31.24±0.03, 26.06±0.02, 21.26±0.02 and 17.47±0.02.

Results obtained are highly significant (P<0.01) on the interactive effects of treatment and storage as shown in Fig. 9. Current findings were matched with Agrahar *et al*., (2016) which showed a similar trend of decreased L* value when the treatment percentage was increased. The reason for decreased L* value is due to caramelization of sugars.

a* Value

At 0th day, a* value of T_0, T_1, T_2 and T_3 was analyzed as 16.21±0.02, 10.25±0.03, 9.13±0.01 and 8.96±0.02. A higher a* value was determined at T_0 while a lower was noticed at T_3. On the 7th day, a higher a* value was measured at T_0 while a lower one was measured at T_3. At 14th day, a* value of T_0, T_1, T_2 and T_3 was measured as 13.15±0.03, 8.55±0.02, 7.87±0.02 and 6.36±0.03 respectively.

Results demonstrated a highly significant value (p<0.01) on the interactive effect of treatment with storage as shown in Fig. 10. Current findings were in collaboration with Botosoa *et al*., (2013) that showed same trend of decreased a* value when storage time was increased. The primary reason for decreased a* value is due to degradation of carotenoids at higher temperatures.

b* Value

On the 0th day, a higher b* value was observed in T0 while a lower was noted in T_3. At 7th day of storage, value of b* was noted as 18.75±0.02, 10.46±0.02, 9.41±0.02 and 8.67±0.02 in treatment T_0, T_1, T_2 and T_3 as shown in Fig. 11. A higher b* value was identified in T_0 while a lower was noted in T_3. At 14th day of storage, value of b* was measured as 17.64±0.02, 9.83±0.02, 8.07±0.02 and 7.77±0.02 in treatment T_0, T_1, T_2 and T_3. Results indicated a highly significant (P<0.01) effect between the interactive effect of storage and treatment.

The current finding was in collaboration with Mau *et al*., (2017) which showed the same trend of decreasing b* value when the storage time of the cake was increased. Moreover, the same trend of reduced b* value was noticed when the treatment percentage was

increased. The reason may be due to degradation of pigment compounds during storage.

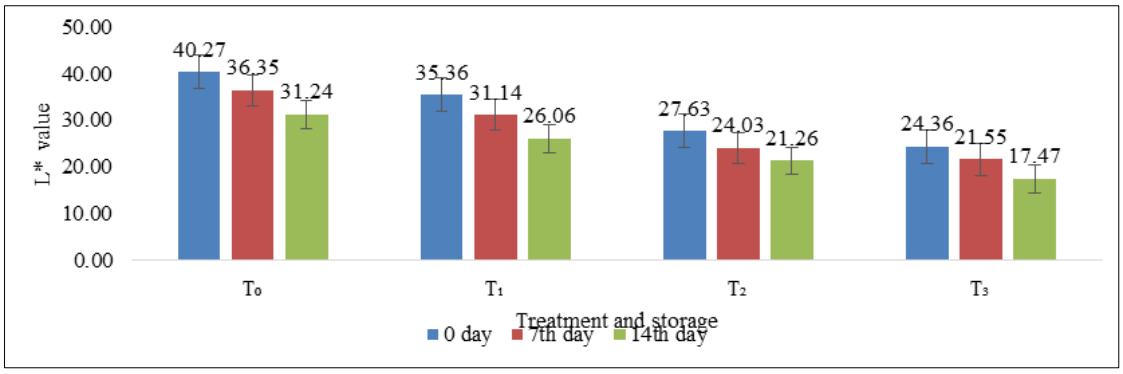

Fig. 9: Combined effect of treatment and storage on L* value of DDB cake crust (p<0.01)

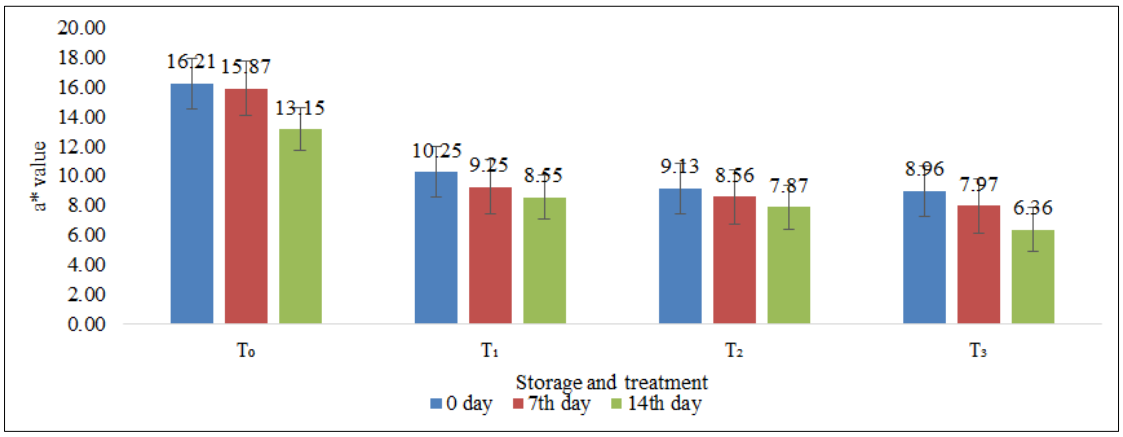

Fig. 10: Combined effect of treatment and storage on a* value of FDB cake crust (p<0.01)

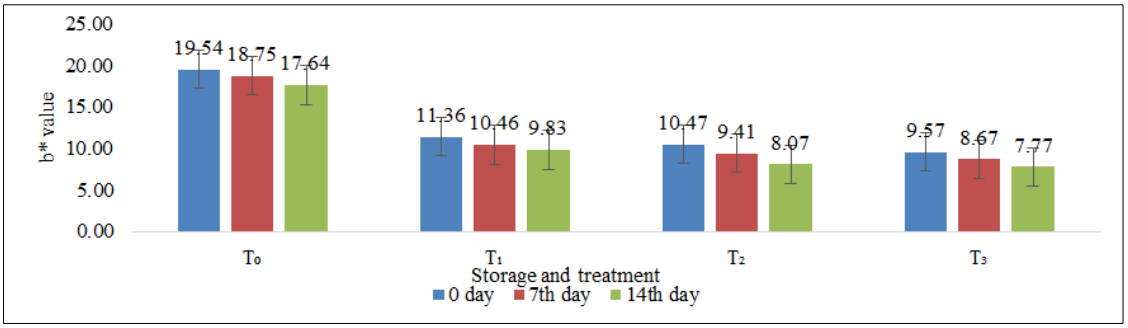

Fig. 11: Combined effect of treatment and storage on b* value of FDB cake crust (p<0.01)

CONCLUSION

The research study has been carried out to give empirical data in favor of freeze drying as a better preservation method with regard to enhancing the functional properties of ber (jujube) and incorporating the same product into baked products. Among the varieties analyzed, the most pronounced retention of total phenolic content (153.65 ± 0.03 mg GAE/100g) and antioxidant activity (37.14 ± 0.03% DPPH inhibition).

The subsequent value-added freeze-dried jujube cake products were found to be statistically significant ($p < 0.05$) with regard to the functional characteristics wherein the incorporations of jujube powder (5%, 10%, 15%) statistically increased the total phenolic content, antioxidative capacity, and hardness of the texture. However, fourteen days of refrigerated shelf-life evaluation showed a steady decline of these beneficial properties along with chromatic values (L*, a*, b*) with time. The simultaneous increase in the hardness and color darkening of crumb and crust may be attributed to the movement of moisture, starch retrogradation and continuous Maillard reaction during storage.

The overall acceptability of the fortified cakes was supported by sensory analysis, hence a good direction of consumer acceptance. To conclude, freeze-dried jujube powder can be used as an effective functional ingredient in the development of nutritionally-

enriched baked products with better antioxidant properties. Despite the fact that storage results into measurable changes to the quality attributes, the product remains stable and acceptable in a period of two weeks. The current research provides a realistic model of valuing seasonable and perishable food products like jujube, reduction of post-harvest losses, and the provision of the food industry with a practical path, towards shelf-stable, health-conscious snack products. The future research must focus on the optimization of packaging mechanisms and incorporation of natural preservatives to extend the shelf life and further protect bioactive compounds in the end product.

Declaration of Competing Interest: The authors declare that they have no conflicts of interest

Acknowledgment

This work is supported by the post-harvest lab of Horticulture, Sensory Evaluation Lab and Food Analysis and Value-Addition Lab of MNS- University of Agriculture, Multan.

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