WWW.IJRPR.COM

International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Postharvest Management and Chemical Treatments for Apricot Preservation in Pakistan

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ABSTRACT

This comprehensive study explores the urgent need to mitigate postharvest losses and maintain quality in apricots, which hold significant economic and nutritional value in Pakistan's agricultural landscape. The research leverages the Sarbaghal apricot cultivar, harvested at their commercially ripe stage, as the primary subject. A meticulous grading process was employed to select the highest quality fruits, which were then subjected to an array of chemical treatments. These treatments included the application of various fungicides and preservatives aimed at extending shelf life and preserving nutritional quality. The outcomes were encouraging. Detailed analysis revealed a marked improvement in the shelf life of the chemically treated apricots in comparison to a control group of untreated fruits. Moreover, the nutritional integrity of the treated apricots was notably preserved, indicating the treatments' dual benefit of prolonging shelf life while maintaining nutritional value. These groundbreaking findings hold significant implications for the broader agricultural sector, particularly for farmers engaged in apricot cultivation. The research strongly recommends the incorporation of these chemical treatments into standard postharvest management practices. Implementing these scientifically-backed measures can play a pivotal role in reducing postharvest losses, thereby increasing profitability for farmers and contributing to overall food security in the region. In conclusion, this study serves as a cornerstone for future research focused on the scalability and environmental sustainability of these chemical treatments, addressing both the economic and ethical dimensions of food production and conservation.

Keywords "Apricot Preservation", "Chemical Treatments", "Nutritional Integrity", "Postharvest Management", "Shelf Life"

1. INTRODUCTION

Pakistan boasts a diverse range of agro-climatic zones, enabling the large-scale cultivation of various fruits and vegetables. Key export products such as citrus fruits, potatoes, mangoes, apricots, onions, cabbages, and cherries enjoy global recognition. Despite being one of the leading nations in agricultural production, Pakistan faces challenges in maximizing its export potential. These challenges include inadequate processing facilities, an inefficient cold storage chain, and a limited range of processed food items. As a result, the country's exports of fruits and vegetables lag behind those of other developing nations. Postharvest losses are a significant concern, with estimates indicating a loss of 20-40% in developing countries compared to 10-15% in developed nations. According to the Food and Agriculture Organization (FAO) in 2020, postharvest losses can account for up to 30% in dairy and cereals, and 20% in fish. In a comparative study on food waste, it's been observed that India and China experience postharvest losses ranging from 15-25% for citrus fruits, 20-25% for cabbage, and 20-35% for tomatoes. Likewise, mango losses in various tropical nations fluctuate significantly depending on the season, with a staggering 70% loss during the rainy season and a more manageable 15% loss during dry periods. During the 2018-2019 agricultural year, apricot production reached 107,986 metric tons. Notably, Pakistan ranks among the leading global producers of this particular stone fruit (Rajapaksha et al., 2021).

Apricot cultivation is predominantly seen in nations like Turkey, Iran, Italy, and notably, Pakistan (Corbett et al., 2015). In Pakistan, the fruit is primarily grown in the northern regions, boasting as many as 60 different types of apricots. Some of the standout varieties include Castle Bright, which has an orange-yellow hue at full maturity, and Sarbaghal, known for its whitish color. Other popular types such as Narai, Gold Cort, Badami, NJA-13, and Habi display varying shades of yellow to light orange and even greenish colors. These varieties are especially prevalent in specific Pakistani regions like Soan Valley, Nowshehra, and Khushab (Citing Abbas et al., 2016). When it comes to commercial production, apricots are abundantly grown in several provinces and territories of Pakistan, such as Gilgit Baltistan, KPK, Baluchistan, Azad Kashmir, and Punjab. Within Punjab, areas around Murree

including Chitta Morgh, New Murree, Ghora Gali, and others are notable for apricot farming. The Soan Valley and the adjacent Potohar hills also provide suitable conditions for apricot cultivation. As for the timing of maturity, varieties like Castle Bright, Gold Cort, NJA-13, and Habi generally reach full maturity in the second week of May. On the other hand, the Sarbaghal, Narai, and Badami varieties are usually ripe by the third week of June (According to Abbas et al., 2020).

In 2021, the international community spotlighted the critical role of fruits and vegetables in fostering overall health, a campaign spearheaded by the United Nations General Assembly. This initiative aimed to raise global consciousness about the essential contributions of fruits and vegetables to a balanced diet and holistic well-being. These plant-based foods are nutritional powerhouses, abundant in vital energy and nutrients. The World Health Organization (WHO) advocates for the daily intake of fruits and vegetables to be at least 400 grams to achieve optimal health outcomes. The lack of sufficient consumption has dire consequences; WHO data from 2019 indicated that approximately 3.9 million deaths worldwide in 2017 were attributed to inadequate fruit and vegetable intake.

Furthermore, a study published in (Lancet et al., 2019) showed that poor consumption levels could be linked to gastrointestinal cancers, accounting for an estimated 14% of global deaths. Fruits come in a plethora of types, shapes, and sizes, each offering unique health benefits and adding a diverse range of flavors to our diet. One such fruit, the apricot (*Prunus armeniaca* L), stands out for its exceptional health-promoting properties. Rich in a wide array of nutrients vitamin A, C, and K, thiamine, minerals, riboflavin, niacin, pantothenic acid, sugars, polyphenols, flavonoids, and carotenoids it is highly recommended for its potential in treating diseases like cancers and cardiovascular conditions (Wang et al., 2015). Texture is often a deciding factor for consumers when choosing fruits, according to (Liu et al., 2019). Moreover, antioxidants like ascorbic acid and phenolic contents in fruits and vegetables serve to inhibit lipid oxidation in the human body, thus contributing to longevity and health (Karabulut et al., 2018). In summary, fruits and vegetables are indispensable for a balanced diet and a healthy lifestyle, as highlighted by numerous international organizations and scientific studies. The apricot serves as a prime example of the incredible health benefits that can be derived from a diet rich in fruits and vegetables.

Consuming a diet rich in non-starchy fruits and vegetables, such as apples, pears, and leafy greens, is commonly associated with weight loss (Suhadi et al., 2020). Moreover, these dietary choices offer additional health benefits, including mitigating age-related eye conditions like cataracts and macular degeneration, prevalent among Americans over 65 years of age. Public health campaigns advocating for increased fiber intake are well-founded, given its recognized nutritional value. To maximize fiber intake, it is recommended to consume whole fruits, including the peel and membranes (Suhadi et al., 2020). Apricots are a versatile fruit available in various forms, including sulfur-dried and organic versions. They are also commonly processed into products like jams, jellies, and juices. Notably, apricots are more susceptible to quality degradation when dehydrated due to their non-waxy skin (Ali, 2013).

Preservation techniques for extending the shelf life of fruits and vegetables are diverse, ranging from canning and freezing to dehydration, pickling, and fermentation. These processes invariably induce physical and chemical transformations that can alter the produce's sensory attributes and nutritional profile. Minimally processed foods, however, tend to retain the inherent characteristics of the fresh produce more effectively compared to fully processed alternatives (Kulshrestha, 2018). Additionally, value-added products like fruit and vegetable powders offer the dual benefits of natural flavoring and nutritional enrichment, serving as viable substitutes for artificial flavoring agents. Preserving the quality attributes such as taste and flavor of fruits is crucial. This can be achieved through a multi-faceted approach involving low-temperature storage, chemical treatments, and the right packaging materials. Various chemicals are applied in the postharvest stage to prolong fruit freshness. For instance, calcium chloride serves multiple roles, including delaying aging processes, regulating ethylene levels, and enhancing sugar while lowering acid content (Ali, 2013). In particular, calcium chloride is often applied as an edible coating. Its primary function is to maintain the structural integrity and firmness of fresh-cut fruit products. This is because the depletion of calcium levels in climacteric fruits leads to softening. Calcium ions interact with pectin in the cell wall, forming calcium pectate, which stabilizes cell wall structure and prevents cellular damage (Liu et al., 2017).

Over extended storage periods, fruits naturally lose their firmness due to alterations in their cell wall makeup. One of the main components affected is pectin, which undergoes degradation. Calcium chloride counteracts this by preserving the pectin content in the cell walls. Furthermore, it extends shelf life by inhibiting lipid breakdown in cellular membranes (Hajilou and Fakhimrezaei, 2013). Immersing fruits in a calcium chloride solution has been shown to elevate calcium levels in the fruit, thereby delaying ripening and color alterations. This is achieved through modifications in both intracellular and extracellular compositions. Additionally, this treatment has been found to significantly mitigate weight loss in fruits (Moradinezhad and Jahani, 2016). The protective action of calcium also extends to maintaining the integrity of membranes and cell walls, guarding them against enzymatic actions that would otherwise lead to softening (Freitas et al., 2013).

Salicylic Acid belongs to the family of phenolic compounds and serves as a key element in enhancing plant disease resistance. This compound augments the market-related quality attributes by elevating the levels of total soluble solids and mitigating fungal spoilage (Moradinezhad and Jahani, 2016). Recognized as a safe exogenous chemical, salicylic acid sustains the qualitative aspects of fresh produce by attenuating ethylene production. Moreover, it helps in retaining the phenolic and antioxidant content during the storage of various fruits and vegetables (Wang et al., 2015).

In addition to its role in disease resistance, salicylic acid functions as a plant hormone that provides stress resilience during the maturation of a wide range of fruits, including kiwi, banana, strawberry, tomato, sweet cherry, asparagus, and peach. This compound enhances cellular wall robustness and minimizes the loss of nutritional constituents. It is commonly employed to optimize both pre-harvest and post-harvest quality, impacting enzymatic functions, biochemical pathways, and texture preservation in fruits like tomatoes, peaches, sweet peppers, and loquat. Various studies have explored multiple treatment protocols and refrigeration conditions to sustain sensory qualities and extend the shelf-life of apricot (Ezzat, 2014).

The quality and shelf-life of harvested crops can be influenced by multiple variables, including the methods used during harvesting, post-harvest handling techniques, and the conditions under which they are stored. Suboptimal storage environments can accelerate the ripening process, leading to undesirable changes like internal discoloration and the release of compounds such as carotenoids and phenolics due to cellular damage. The emission of ethylene gas and increased respiration rates further expedite the aging process by converting stored sugars into energy. Therefore, post-harvest interventions are essential for preserving the quality and longevity of the produce once it reaches consumers (Ali, 2013).

Significant food wastage occurs due to inadequate handling of fresh produce, undermining both the efficiency and environmental sustainability of the agricultural system. To support small-scale producers, it is crucial to offer affordable training programs focusing on best practices for post-harvest care. Additionally, investing in cost-effective cold chain logistics can make a substantial difference. Effective monitoring systems for commercial post-harvest procedures can further ensure that fruits and vegetables are handled, stored, and transported in a manner that maximizes their quality and shelf-life (Rajapaksha et al., 2021).

To mitigate the impact of postharvest losses, it is crucial to adopt effective strategies. While hand-harvesting is generally used to preserve the quality of fruits, mechanical harvesting is often employed for large-scale processing. However, mechanical methods can induce stress on the plants and compromise the quality of the produce, leading to higher losses compared to manual methods (Qiu et al., 2020). These factors collectively diminish the market value of the fruit by adversely affecting its firmness, quality, and susceptibility to microbial decay and other physiological disorders. To extend the shelf-life and improve the sensory characteristics of stored fruits, low-temperature storage is a commonly employed technique (Yahaya and Mardiyya, 2019). However, long-term storage at low temperatures can result in chilling injuries and other physiological disturbances (Cui et al., 2019). Low-temperature storage, when done correctly, avoids the risk of chilling injuries, minimizes the proliferation of disease-causing agents like bacteria and fungi, and helps to maintain the freshness of fruits and vegetables. For example, the combined use of a 5°C storage environment and a calcium solution has proven effective in reducing the breakdown of cell wall polysaccharides in apricot fruits (Liu et al., 2017).

The primary aim of this research is to assess the quality and sensory attributes of apricots stored at low temperatures. Additionally, the study will investigate the effects of postharvest chemical treatments, specifically Calcium chloride and Salicylic acid, on the quality of apricots during storage.

2. MATERIALS AND METHODS

2.1 Acquisition of Primary Ingredients

The apricot cultivar "Sarbaghal" was collected at its commercially ripe stage from Khanozai, Quetta, Baluchistan. The harvested fruits were securely transported to the research facility in specialized cardboard packaging. Upon arrival, the fruits underwent a grading procedure based on uniformity in size, shape, and optimal coloration. The fruits were also inspected for any physical imperfections or signs of fungal contamination. Concurrently, the required chemical solutions were formulated.

2.2 Post-Harvest Processing Techniques

The apricots were sorted and classified according to their physical characteristics and cleanliness, ensuring they were devoid of any foreign particles like dirt or dust. A select batch of fruits was disinfected by submerging them in a 1% sodium hypochlorite solution (comprising 900ml of water and 100ml of NaOCl) for a duration of 3 minutes. A control group was established by simply immersing the fruits in distilled water, without the addition of sodium hypochlorite. Following sanitation, the fruits were air-dried for an hour and subsequently divided into five distinct experimental groups.

2.3 Calcium Chloride Treatment on Apricots

The graded fruits were further divided into five experimental sets and submerged in calcium chloride solutions with varying concentrations (2% and 3%) for a span of 10 minutes at ambient temperature. Afterward, the samples were air-dried for 20 minutes and placed in perforated plastic containers. These containers were then moved to a refrigerated storage room, where they were kept at a constant temperature of 5 ± 1°C and a relative humidity ranging between 90-95% for 21 days. Physical, chemical, proximate, and sensory evaluations were conducted after one week.

2.4 Salicylic Acid Treatment on Apricots

Apricots were subjected to treatment with salicylic acid by immersing them in solutions containing either 1% or 2% concentrations for 10 minutes at room temperature. Post-treatment, the fruits were air-dried and transferred to refrigerated storage in perforated containers. Evaluations for physical and chemical characteristics, as well as proximate and sensory analyses, were carried out after a week's time.

Table 1. Experimental Treatment Regimens

Treatments	Calcium chloride (%)	Salicylic Acid (%)
T_o (control)	-	-
T_1	2	-
T_2	3	-

T_3	**-**	**1**
T_4	**-**	**2**

2.5 Physicochemical Characterization

- Weight Loss Analysis
- PH Level Assessment
- Textural Firmness
- Concentration of Total Soluble Solids
- Colorimetric Evaluation
- Ascorbic Acid Quantification
- Measurement of Titratable Acidity

2.5.1 Weight Loss Analysis

Weight loss percentages were determined in accordance with the procedures outlined by the Association of Official Analytical Chemists (AOAC, 2016). A precision digital scale was utilized to weigh five apricot samples from each treatment group. These samples were stored in a uniform refrigerated environment. Weight measurements were taken both on the day of harvesting and one week thereafter. Subsequently, the weight loss percentage was computed by comparing the initial and terminal weights of the sampled apricots.

2.5.2 Measurement of pH Levels

The pH metrics for each sample were ascertained by utilizing a pre-calibrated pH meter, in accordance with the guidelines stipulated by AOAC (2016). Prior to measurement, the electrodes were standardized using a buffer solution. For each test, 50 mL of either fruit juice or pulp was placed in a 100-mL beaker. The electrodes were then submerged into the liquid sample, and the pH reading displayed on the digital interface was duly noted.

2.5.3 Evaluation of Fruit Firmness

Fruit firmness was gauged using a dedicated firmness tester equipped with an 11 mm plunger, as per fruits from each treatment group. The fruit was positioned beneath the tester's needle and penetrated to measure the force required. The firmness metric for individual fruits was computed as the average force needed across all fruits in each treatment group, and the results were presented in kilogram-force (kgf) units (Muzumdar & Majumder, 2003).

2.5.4 Assessment of Total Soluble Solids

Total soluble solids (TSS) were quantified using a digital refractometer at ambient temperature, in line with AOAC (2016) procedures. Prior to and during each test, the refractometer was standardized with distilled water. The light deviation varied depending on the sugar concentration in the fruit juice. To prepare samples, small pieces of the fruit were extracted and the juice was applied to the refractometer's prism surface. The reading for each sample was then taken and documented in terms of degrees Brix (°Brix).

2.5.5 Colorimetric Analysis

The color attributes of the apricot samples were analyzed using a Chromameter CR-410, as described in the methodology by Vukić et al. (2018). The device employed a C, D65 illuminant to define the L, a*, and b* color components: where L* represents lightness, a* indicates the green-red spectrum, and b* signifies the blue-yellow spectrum. Samples were assessed at regular time intervals, and the findings were interpreted based on the Hunter L* scale, ranging from 0 to 100, and the a* and b* scales, with ranges of ±60.

2.5.6 Quantification of Ascorbic Acid Content

The ascorbic acid concentration was determined in accordance with the guidelines laid out by the Association of Official Analytical Chemists (AOAC, 2016). For this purpose, 2,6-dichlorophenol indophenol dye was employed as a titrating agent. Initially, a standard calibration was performed using a mixture of 1.5 mL of oxalic acid and 1 mL of ascorbic acid. The titration was carried out until a light pink hue was sustained for 30 seconds, at which point the initial reading (R1) was recorded. Subsequently, 5 mL of the juice sample was transferred into a 100 mL volumetric flask and diluted with a 0.4% oxalic acid solution. From this dilution, 10 mL was extracted, combined with 15 mL of oxalic acid, and titrated with the calibrated 2,6-dichlorophenol indophenol dye until a light pink color was maintained for 15 seconds. The final reading (R) was noted, and the ascorbic acid content was calculated using the following formula:

$$\text{Ascorbic acid} = \frac{1 \times R \times V}{R1 \times W \times V1} \times 100$$

2.5.7 Evaluation of Titratable Acidity

Titratable acidity was assessed following the acid-base titration protocol as defined by AOAC (2016). To ensure the reliability of this metric, a meticulous titration method was employed. A 5 mL sample was transferred into a 100 mL volumetric flask and diluted with distilled water. A 10 mL aliquot was taken from this diluted sample and mixed with 2-3 drops of phenolphthalein indicator. Titration was performed against sodium hydroxide (NaOH) until a pink coloration was observed. The terminal reading on the burette was recorded, and titratable acidity was calculated utilizing the subsequent formula: By following these procedures and calculations, both the ascorbic acid content and the titratable acidity were accurately quantified, thus contributing to the overall evaluation of the sample's quality.

$$\text{TA } \% = \frac{\text{ml NaOH used} \times 0.1\text{N NaOH} \times 0.0064}{\text{grams of sample}} \times 100$$

2.6 Evaluation of Moisture Content

- Moisture contents determination
- Total Ash content
- Crude Protein determination
- Crude Fat determination
- Crude fiber determination

2.6.1 Measuring Moisture Levels in Apricots

To assess the moisture content in apricots, we adhered to the protocols outlined in the AOAC (2016). A representative 5-gram sample of apricot was first collected and placed in a crucible, which was then weighed using a precision electronic balance. The crucible and its contents were subsequently placed in a hot air oven set to 105°C and left to dry for a 24-hour period. After drying, the sample was transferred to a desiccator for a short duration, approximately 5 to 10 minutes, to prevent moisture reabsorption from the ambient air. Once the sample reached room temperature, it was weighed again, and the percentage of moisture content was calculated using the appropriate formula.

$$\text{Moisture } (\%) = \frac{\text{weight of sample before drying-weight of sample after drying}}{\text{Weight of original sample}} \times 100$$

2.6.2 Ash content

The Ash content of the sample was evaluated by the method as described in (AOAC, 2016). Approximately 20 gram of fruit sample was taken in the crucible, weighed and charred on the burner so that all volatile fractions disappear and no smoke arises from the sample, put into muffle furnace at 100oC then temperature gradually increased at 50oC after every 1 hour and reached 500-550oC after 5 to 6 hours. All contents completely burn to white ash. After that dish was cooled and weigh to determine ash percent.

$$\text{Ash } (\%) = \frac{W2 - W1}{Ws} \times 100$$

2.6.3 Crude Protein determination

The crude protein content of apricot fruit was measured according to Kjeldahl's method as described (AOAC, 2016). Approximately 3g sample was taken in digestion tube with 30ml of H2SO4 and added 2 tablets of digestion mixture (copper, potassium sulfate) as a catalyst in a tube. Digestion was carried out at 370-400oC for 3-4 hours and then cooled. After digestion, a digested sample was diluted 250ml with distilled water. In the next step of distillation 10ml of 40% NaOH was used to neutralize the mixture that releases NH3 gas and ammonia was trapped with 4% boric acid solution that contains methyl indicator. Titration of the solution was done with 0.1N sulphuric acid solution and factor 6.25 was used for conversion of percent nitrogen into crude protein.

$$N\% = \frac{0.0014 \text{ x ml of 0.1 N } H_2SO_4 \text{ X Total dilution Volume}}{\text{Weigh of sample x volume of diluted sample taken}} \times 100$$

The protein content as determined by multiplying nitrogen contents with conversion factor: N% x 6.25

2.6.4 Crude Fat determination

Crude fat of apricot fruit was determined by using the soxhlet extraction method as described in (AOAC, 2016). Dried 10g fruit sample and ground into powder form. The required content was packed in filter paper thus, packed filter paper through steeper paper and put in the thimble. Then required sample was run in the soxhlet apparatus n-hexane/ether drops started to fall on the sample in the tube. And extraction was carried out for 2-3 hours. Turn off apparatus; residues were kept into the pre-weighed crucible. Crucible was transferred into the oven for 2-3 hours to evaporate the solvent. Cool the sample and weigh again. The fat content was calculated by using the formula.

$$\text{Crude fat \%} = \frac{\text{Initial weight of sample(g)} - \text{Final weight of sample(g)}}{\text{Initial weight of sample (g)}} \times 100$$

The protein content as determined by multiplying nitrogen contents with conversion factor: N% x 6.25

2.6.5 Crude fiber determination

The crude fiber content of apricot fruit was determined by taking a 5g dried and fat-free sample into the beaker. The dried samples were digested first with 1.25% sulphuric acid filtered and washed. Then the sample was again digested with 1.25% NaOH filtered and washed again. In the next step, the sample residues were dried at130OC for 2 hours and weighed. The dried sample was ignited by placing them in a muffle furnace at a temperature of 500 or 550oC for 4-5 hours. After ignition, crude fiber percentage was calculated according to the given formula. The crude fiber content of samples was determined by digesting them in 1.25% sulphuric acid followed by 1.25% sodium hydroxide solution as determined in (AOAC, 2016).

$$\text{Crude fiber \%} = \frac{\text{weight of dried sample after digestion(g)} - \text{weight of ash(g)}}{\text{Initial Weight of sample(g)}} \times 100$$

2.7 Sensory Assessment

The sensory properties of the product were systematically examined with a focus on color, flavor, firmness, and overall likability. This evaluation was conducted using a 9-point hedonic scale, as adapted from the methodology put forth by Meilgaard et al. (2007). The scale is structured as follows: 9 signifies "Extreme Likability," 8 indicates "Very Much Liked," 7 is for "Moderate Likability," 6 stands for "Slightly Liked," 5 represents "Neutral," 4 is "Slightly Disliked," 3 signifies "Moderately Disliked," 2 represents "Very Much Disliked," and 1 stands for "Extremely Disliked." Expert panelists from the National Institute of Food Science and Technology were provided with a structured questionnaire, as included in the appendix, and were asked to record their assessments at designated time intervals.

2.8 Statistical Evaluation

For a comprehensive interpretation of the data generated from each experimental iteration, statistical analyses were performed. These analyses aimed to identify significant differences and to compare means, drawing on the methods described by Montgomery (2008).

3. RESULTS AND DISCUSSION

3.1 Weight loss

The phenomenon of weight loss in fruits during their respiration and ripening processes has been an area of significant interest within the realm of postharvest science. This weight loss is principally attributed to the evaporation of moisture as the ripening process progresses. As fruits ripen, changes occur at the cellular level that contribute to this weight loss; specifically, the cell wall undergoes a loss of structure and increased permeability due to the breakdown of pectin. This biochemical alteration facilitates the shrinkage of cell tissues, which, in turn, results in the evaporation of water. Concurrently, the increased permeability of the cell membrane allows the release of internal cellular contents, which further exacerbates the loss in weight. Various methods have been employed to mitigate this weight loss, including chemical treatments and cold storage. For instance, salicylic acid has been reported to be effective in reducing the weight loss of strawberries during cold storage, corroborated by a study conducted by Valero et al. (2011). Furthermore, statistical analyses of apricots treated at low temperatures and with chemicals like calcium chloride and salicylic acid have demonstrated significant reductions in weight loss, as presented in Table 6.

In terms of quantitative data, the mean weight loss values for various treatments on apricots are presented in Table 6. These mean values for treatments T0, T1, T2, T3, and T4 were found to be 13.45, 7.64, 3.30, 8.23, and 4.58, respectively. Notably, a significant difference was observed between the control and the treated samples. Treatments T2 and T4 exhibited less reduction in weight loss during a 21-day storage period. This could be attributed to the calcium chloride treatment, which appeared to enhance the structural integrity of the fruit tissue by increasing its calcium content, thereby leading to lower alterations in cell wall structure and breakdown. Regarding the dynamics of weight loss over the storage period, mean values were calculated as 0, 2.23, 10.90, and 16.62 at 0, 7, 14, and 21 days, respectively (Table 2,3,4,5). While weight loss generally increased over the storage period, it remained relatively stable for up to 14 days in the treated samples, subsequently increasing with extended storage. These observations align with previous studies

by Antunes et al. (2003) and Diaz-Mula et al. (2011), which suggest that a 3% concentration of calcium chloride is effective in reducing moisture loss. Similarly, Shafiee et al. (2010) found that salicylic acid, when applied as a nutrient solution or dipping treatment postharvest, was effective in mitigating weight loss in strawberries. In summary, both the biochemical changes at the cellular level during ripening and the efficacy of various treatments like calcium chloride and salicylic acid play pivotal roles in the weight loss of fruits during storage. Understanding these dynamics is critical for improving postharvest handling and extending the shelf life of fruits.

3.2 PH

The pH level serves as a critical marker for assessing the acidic composition of fruit, particularly as it relates to enzymatic activities and the conversion of acids into sugars. During the initial phases of storage, a rise in pH values is commonly observed, attributable to the diminishing acid content, which is metabolized for the biosynthesis of aroma and volatile elements. However, as the storage period progresses, a decrease in pH values is noted, which can be ascribed to an elevated acidic concentration within the stored produce. This increase in acidity is precipitated by the loss of moisture and the catabolic conversion of sugars into acids, often through fermentation processes (Abbasi et al., 2011).

Statistical analyses reveal a significant impact of calcium chloride and salicylic acid treatments on the pH levels of apricots stored at low temperatures. As delineated in Table 6, the treatments, when applied in conjunction with low-temperature storage, elicited marked changes in pH. Furthermore, the mean pH values for various treatment groups, as reported in Table 6, were as follows: for To, T1, T2, T3, and T4 treatments, the mean pH levels were 3.40±0.08, 3.42±0.07, 3.43±0.02, 3.42±0.06, and 3.43±0.04, respectively. A significant difference in pH was observed when comparing untreated apricots to those subjected to the various treatments. Specifically, untreated samples displayed higher pH values relative to all treated counterparts. Remarkably, treatments T2 and T4 managed to sustain their pH levels across a 21-day storage span. This observed trend of incrementally increasing pH across all treatments corroborates the efficacy of calcium chloride in pH stabilization, a finding that aligns well with previously published research by Gupta et al. (2011) and Pila et al. (2010). When considering the storage duration, the mean pH values at 0, 7, 14, and 21 days were 3.46±0.01, 3.44±0.07, 3.44±0.05, and 3.40±0.04, respectively (Table 6). While a general rise in pH was evident over the storage timeframe, the rate of this increase was noticeably tempered in the treated samples, suggesting a moderated, gradual escalation in pH levels throughout the storage period.

3.3 Firmness

Fruit firmness serves as a critical quality indicator, signifying both the freshness and the expected storage longevity of fruits and vegetables. This attribute is largely regulated by the cellular structure and its overall integrity. As fruits undergo the natural ripening process post-harvest, several physiological changes take place. Among these are respiration, moisture loss, and the conversion of complex carbohydrates into simpler sugar forms, as well as the disintegration of pectin structures within the cell wall. These changes are concomitant with increased membrane permeability, resulting in additional water loss, surface shrinkage, and the consequent softening of the tissue. Chemical treatments administered post-harvest, such as calcium chloride and salicylic acid, play a pivotal role in attenuating the loss of moisture, thereby maintaining flesh firmness over extended storage periods. Statistical analyses, as presented in Table 4, indicated that the synergistic effect of chemical treatments and low-temperature storage has a significant impact on the firmness of apricot fruits (Akhtar, 2010).

In relation to the mean values of firmness observed in various treatments and storage conditions for apricot fruits, these are detailed in Table 4.6. Specifically, the mean firmness values for the treatments T_o, T1, T2, T3, and T4 were 9.12±2.32, 7.94±1.59, 7.12±0.88, 9.09±1.62, and 7.90±0.87, respectively. It was observed that the control samples experienced more significant losses in firmness compared to the treated samples. Particularly, the treatments T2 and T4 managed to maintain their firmness over a 21-day storage period. The decline in firmness was universally noted across all treatments during cold storage. However, the application of a 3% concentration of calcium chloride and a 2% concentration of salicylic acid was especially effective in retaining the firmness of the apricot fruits. Calcium ions function as firming agents, interacting directly with cell wall pectin, while salicylic acid serves to regulate plant growth and retard metabolic activities. These observations align well with the findings of Gao et al. (2016) and Lecesse et al. (2011), which also noted higher firmness retention in treated samples. Regarding the storage time, mean firmness values were 10.33±0.003, 7.74±1.17, 7.30±1.59, and 7.52±0.72 at 0, 7, 14, and 21 days, respectively. While a general decrease in firmness was noted over the storage period, a particularly significant reduction was observed between the 14th and 21st days in treated samples.

3.4 Total soluble solids

The total soluble solids in fruits and vegetables are crucial indicators of their ripening stage, providing comprehensive insights into their overall quality and maturity. The refractive index, as measured by a refractometer, is intimately linked to the concentration of various soluble components, including sugars, amino acids, organic acids, and minerals. As the ripening process progresses, there is a noted increase in the concentration of these soluble solids, largely attributable to the breakdown of carbohydrates. This biochemical transformation is not an isolated event but is significantly influenced by both the storage conditions and the ripening process itself. Abbasi et al. (2011) have substantiated that a slower rate of respiration, often induced by specific storage environments, results in less efficient conversion of carbohydrates to sugars, thereby affecting the levels of total soluble solids during the storage period. Moreover, a thorough statistical analysis revealed significant effects of chemical treatments, specifically calcium chloride and salicylic acid, on the total soluble solids in apricot fruits. This is corroborated by the data presented in (Table 2,3,4,5). The analysis showed that the combined influence of chemical treatments and low-temperature storage was especially noteworthy with regard to the total soluble solids in apricots. Further, mean values for these solids under varying treatment conditions (To, T1, T2, T3, and T4) were found to be 18.94±0.05, 19.57±0.06, 18.67±0.04, 19.05±0.05, and

19.18±0.07, respectively (Table 6). This data, presented in (Table 2,3,4,5), indicates a significant difference between the control and treated samples. Particularly, the T2 sample displayed the least reduction in total soluble solids during a 21-day storage period. Ahmad (2008) has previously shown that treatment with calcium chloride results in higher levels of calcium in fruit tissues, which subsequently minimizes alterations in cell wall structure and promotes the stable presence of soluble solids.

In terms of storage duration, mean values of total soluble solids were observed to be 18.69±0.04, 18.91±0.05, 19.18±0.03, and 19.39±0.06 at 0, 7, 14, and 21 days, respectively. While there was an overall increase in total soluble solids during storage, this trend was more stable in treated samples up to the 14-day mark, after which a gradual increase was noted (Table 5). These findings are in alignment with the research conducted by Ishaq et al. (2009) and Fan et al. (2018), which posits that higher retention of total soluble solids is a direct consequence of slower degradation in cell wall structure and more efficient conversion into simple sugars.

3.5 L value*

In the realm of horticultural science, the visual appeal of fruits often acts as a primary indicator of their market potential and consumer acceptance. Among various parameters, the L* value serves as a quantitative measure of a fruit's lightness, effectively representing its freshness. Interestingly, fruits that are freshly harvested exhibit higher L* values when compared to those that have been stored for extended periods. This decline in L* value over time can be attributed to the darkening of the fruit skin, a phenomenon facilitated by a series of enzymatic and biochemical activities that occur during postharvest storage. These processes, driven by the fruit's respiratory activity, lead to tissue degradation and consequential discoloration. However, the use of chemical preservatives, such as calcium chloride and salicylic acid, in tandem with low-temperature storage conditions, can mitigate these unfavorable changes by decelerating both the respiration and ripening processes (Moradinezhad et al., 2016).

Statistical analyses have further elucidated the impact of such treatments on the L* value of apricots. Specifically, (Table 2,3,4,5) outlines the significant effects of calcium chloride and salicylic acid treatments at low temperatures on the L* values. Moreover, the mean L* values of treated apricots under varying conditions referred to as T0, T1, T2, T3, and T4 were recorded as 28.45±1.46, 30.88±0.43, 31.27±0.04, 31.02±0.25, and 31.25±0.08, respectively. A noteworthy variation was observed between untreated control samples and chemically treated ones, with the latter showing a lesser decline in L* values (Arendse et al., 2014; Fan et al., 2018). Particularly, treatment regimens T2 and T4 demonstrated remarkable efficacy in maintaining L* values over a 21-day storage period. The mean L* values during this storage period were observed to be 31.13±0.34, 30.68±1.29, 30.35±1.49, and 30.14±1.67 at intervals of 0, 7, 14, and 21 days. Although a gradual decrease in L* values was noted across all treatment regimens during cold storage, the decline was less pronounced in chemically treated samples, especially after the first week of storage.

3.6 a value*

The coloration of apricots is primarily influenced by the pigment compounds carotenoids, specifically beta-carotene and anthocyanin. These pigments reach peak levels during the ripening stage, as indicated by the a* value that measures the redness of the fruit skin. Over time, this a* value tends to decrease, signifying enhanced color intensity (Moradinezhad et al., 2016). Post-harvest, the fruit undergoes various enzymatic and biochemical transformations due to respiration, which can result in tissue degradation and discoloration. The application of chemical compounds like calcium chloride and salicylic acid, especially when combined with cold storage, effectively mitigates these changes by slowing down the respiration and ripening processes.

Statistical analysis reveals a noteworthy impact of these treatments on the a* value of the apricot. For example, during the storage period, the combined effect of chemical treatments and low temperature was significant, as detailed in (Table 2,3,4,5), furthermore, the mean a* values for different treatments (T0, T1, T2, T3, and T4) were recorded as 1.54±0.26, 1.86±0.08, 1.87±0.05, 1.85±0.07, and 1.89±0.06, respectively. A significant contrast was observed between the control and the treated samples, particularly evident in the maintenance of the a* value in treatments T2 and T4 over a 21-day storage period. These findings align with previous research conducted by Arendse et al. (2014) and Fan et al. (2018). Overall, the a* value decreased progressively over the 21-day cold storage period, irrespective of the treatment. However, a 3% concentration of calcium chloride and a 2% concentration of salicylic acid were most effective in preserving the a* value. The mean a* values at different storage intervals were 1.91±0.05, 1.85±0.1, 1.77±0.19, and 1.67±0.25 for 0, 7, 14, and 21 days, respectively.

3.7 b value*

In assessing the color quality of fruits, the b* value serves as an indicator for the level of yellowness. This attribute plays a pivotal role in influencing consumer preferences, market demand, and the overall commercial viability of the fruit. Freshly harvested fruits generally exhibit a higher b* value, which tends to diminish over time due to natural darkening of the fruit's exterior. Such changes occur because of enzymatic and biochemical reactions during postharvest storage, contributing to tissue degradation and discoloration. However, these processes can be mitigated through the use of chemical compounds and low-temperature storage, which slow down the rate of respiration and ripening. For example, fruits treated with chemicals in conjunction with cold storage show lesser reduction in b* value, thereby retaining their original moisture content (Moradinezhad et al., 2016). Statistical data further substantiates these observations. Specifically, table reveals that the b* values of apricots treated with calcium chloride and salicylic acid during storage were significantly impacted in a positive manner. The combined effects of chemical treatments and low-temperature storage were particularly noteworthy in maintaining the b* value.

Table (2,3,4,5), provides mean b* values across different treatment types and storage durations for apricot fruits. The mean values for the treatments T0, T1, T2, T3, and T4 were 4.91±0.73, 5.85±0.19, 5.95±0.07, 5.83±0.14, and 5.96±0.07, respectively. A noteworthy variance was seen between control and treated samples. The control group manifested greater reductions in L* value compared to all treated groups. During the 21-day storage period, treatments T2 and T4 almost maintained their b* values. A concentration of 3% calcium chloride and 2% salicylic acid proved especially effective in preserving the b* value of apricots. These findings align well with prior research conducted by Fan et al. (2018). Mean values for storage durations of 0, 7, 14, and 21 days were 6.00±0.05, 5.75±0.47, 5.59±0.59, and 5.46±0.69, respectively.

3.8 Ascorbic acid contents

In fruits, Vitamin C (ascorbic acid) serves as a crucial nutritional element. Its levels tend to decrease throughout the maturation and preservation phases, largely because it is vulnerable to oxidation. This leads to its transformation into dehydroascorbic acid, particularly when fruits experience high respiration rates. Various factors contribute to this decline, including water evaporation, ambient temperature, light exposure, and conditions both during storage and after harvest (Ghasemnezad et al., 2010). Statistical analysis reveals that the ascorbic acid levels in apricots treated with calcium chloride and salicylic acid at low temperatures during storage were significantly affected. These findings are summarized in Table 4.15. The combined effects of chemical treatments and low-temperature storage had a significant impact on the Vitamin C content in apricot fruits.

Table (2,3,4,5), displays the average ascorbic acid levels under different treatment conditions for apricot fruits. Specifically, the mean values for treatments T0, T1, T2, T3, and T4 were 12.61±0.1, 14.92±0.06, 16.14±0.03, 14.24±0.10, and 16.07±0.08, respectively. The control group showed more significant losses of ascorbic acid than the treated samples, confirming a noticeable difference between the two. The most effective treatments in preserving ascorbic acid levels were T2 and T4 during 21 days of storage. Calcium chloride at a 3% concentration and salicylic acid at a 2% concentration were particularly effective in maintaining ascorbic acid levels. These findings align with previous research by Ishaq et al. (2009), Kazmi et al. (2011), and Valero et al. (2011). In terms of storage duration, the mean ascorbic acid levels were 16.12±0.08, 14.73±0.04, 13.98±0.08, and 13.52±0.05 at 0, 7, 14, and 21 days, respectively. A consistent decline in Vitamin C content was observed across all treatment types during cold storage.

3.9 Titratable acidity

Titratable acidity significantly influences the quality and flavor profile of apricot fruits. During the early stages of fruit development, high levels of titratable acidity are observed, largely due to the peak concentrations of organic acids such as malic and citric acid. As the fruit ripens, the content of sugars and soluble solids increases, leading to a corresponding decrease in acidity levels. This change is primarily attributed to the breakdown of malic acid, followed by citric acid, as the fruit undergoes metabolic changes during ripening (Bhattarai & Gautam, 2006). Statistical data indicate that treatments involving low-temperature storage and chemical applications like calcium chloride and salicylic acid have a considerable impact on the titratable acidity of apricots (Table 2,3,4,5). The combined effect of chemical treatments and low-temperature storage has shown a significant influence on maintaining the titratable acidity levels in apricots. In terms of numerical representation, the mean titratable acidity levels for different treatments To, T1, T2, T3, and T4 were found to be 0.41±0.33, 0.56±0.24, 0.69±0.16, 0.54±0.23, and 0.72±0.14, respectively (Table 10). The treated samples exhibited a significant difference when compared to the untreated controls. A lesser decline in titratable acidity was noted in T2 and T4 treatments over a 21-day storage period. During cold storage, all treatments demonstrated a reduction in titratable acidity, but a 3% concentration of calcium chloride and a 2% concentration of salicylic acid were particularly effective in preserving the fruit's acidity levels. These findings align with previous research conducted by Ghasemnezad et al. (2010) and Raffo et al. (2007).

Moreover, the average titratable acidity levels during storage were recorded as 0.91±0.02, 0.50±0.16, 0.47±0.16, and 0.45±0.16 at 0, 7, 14, and 21 days, respectively. While a general decline in titratable acidity was observed over the storage period, a significant reduction was only noted up to the seventh day in the treated samples, after which the acidity levels were relatively stable between the 14th and 21st days of storage.

3.10 Moisture contents

The water content in fresh fruits and vegetables plays a crucial role in preserving their quality, including their freshness and nutritional profile. Elevated levels of moisture are advantageous for fruits that undergo various stages of value addition such as drying, processing, or even direct consumption. However, the longevity of these products is compromised when stored, as their moisture levels tend to diminish due to increased respiration (Akin et al., 2008). Statistical analyses indicate that the moisture levels in apricots treated with calcium chloride and salicylic acid during storage were significantly impacted. These findings are summarized in (Table 2,3,4,5). Combining chemical treatments with low-temperature storage had a remarkable effect in retaining the apricot's moisture content.

Table (2,3,4,5), outlines the average moisture content based on different treatments and storage conditions for apricot. The mean moisture levels for treatments T0, T1, T2, T3, and T4 were recorded as 79.32±0.94, 78.60±1.35, 80.62±0.07, 81.66±0.22, and 81.11±0.05, respectively. A significant variation was observed between the control and treated samples. In comparison to the control, the treated samples displayed reduced loss in moisture content. Notably, treatments T2, T3, and T4 successfully preserved moisture levels over a 21-day storage period. Calcium chloride at a 3% concentration and salicylic acid at a 2% concentration were particularly effective in maintaining moisture, corroborating findings by Arendse et al. (2014) and Wani et al. (2018). The average moisture content during storage was observed to be 81.50±1.1, 80.86±0.05, 80.33±0.5, and 79.56±0.05 at 0, 7, 14, and 21 days, respectively. While a general decrease in moisture content was observed throughout the storage duration, the treated samples managed to sustain their moisture levels for up to 14 days, after which a slight decline was noted.

3.11 Ash contents

In unripe fruits, the ash content tends to be lower than that in their ripe counterparts. Ash content serves as a marker for the mineral composition within fruits and vegetables. During the maturation phase, fruits accumulate both sugars and minerals to facilitate the ripening process. These minerals play critical roles in various physiological and biochemical functions. Their presence is a key factor in determining the viability of a particular fruit variety for value addition and downstream processing (Hegedüs et al., 2011). Statistical data underscore the influence of calcium chloride and salicylic acid treatments on the ash content of stored apricots, as presented in Table 12. Notably, these treatments, when coupled with low-temperature storage, produced a synergistic effect that significantly impacted the ash content of apricot fruits.

` Table (2,3,4,5), reveals the average ash content values for various treatments and storage conditions. Specifically, the mean ash content for treatments T_o, T1, T2, T3, and T4 were 4.91±0.05, 4.95±0.04, 4.99±0.05, 4.95±0.05, and 5.00±0.04, respectively. A marked difference was observed between the control and treated samples, with the control showing a more considerable loss of ash content compared to the treated ones. Treatments T2 and T4 effectively maintained ash content over a 21-day storage period. Utilizing a 3% concentration of calcium chloride and a 2% concentration of salicylic acid was particularly effective in sustaining ash levels. The ash content was notably higher on day 7 than on day 0, and minor losses were reported after 14 days of storage. These observations align with the findings of Alexa et al. (2018) and O'Grady et al. (2014), who reported a 7% decrease in ash content in 'Ruby' arils after a 14-day storage period at 8°C. Regarding storage durations, the average ash contents were 4.93±0.01, 5.02±0.03, 4.96±0.05, and 4.94±0.06 at 0, 7, 14, and 21 days, respectively. Although a decline in ash content was observed from days 14 to 21 across all treatments, a slight recovery of ash levels was noted in treatments T1, T2, T3, and T4 after the 7-day storage milestone.

3.12 Crude protein contents

Proteins, the building blocks of life, are rich in essential amino acids that are pivotal for nucleic acid synthesis and various enzymatic processes in organisms. Previous studies have demonstrated a general reduction in protein levels during the ripening phase (Jones et al., 2009). However, our research aligns with findings suggesting that protein levels can be maintained during storage (Sochor et al., 2011). In an experimental setting involving apricots treated with calcium chloride and salicylic acid, statistical analysis confirmed a significant impact on crude protein levels, as indicated in Table 13. The combined effect of chemical treatments and low-temperature storage had a remarkable influence on the protein content of the stored apricots.

The average protein content (Table 2,3,4,5), under different treatment conditions, namely T_o, T1, T2, T3, and T4. These values stood at 4.89±0.05, 4.91±0.04, 4.92±0.05, 4.91±0.05, and 4.93±0.04, respectively. A significant discrepancy was evident between the control and treated samples. Specifically, the control samples exhibited a more substantial decline in crude protein levels compared to any of the treated sets. Our findings further corroborate that a 3% calcium chloride solution and a 2% salicylic acid solution are highly effective in maintaining the protein content of apricots during storage. This aligns with research conducted by Alexa et al. (2018) and O'Grady et al. (2014), who reported a 22% reduction in protein levels in 'Bahgwa' arils stored at low temperatures for a week, followed by a recovery on the 14th day. In terms of storage durations, the mean protein levels at 0, 7, 14, and 21 days were 4.93±0.01, 4.92±0.03, 4.91±0.05, and 4.90±0.06, respectively. Although a decline in protein content was observed across all treatments in the initial 14-day period, samples treated under conditions T2 and T4 showed a modest recovery between the 14th and 21st days.

3.13 Crude fat contents

During the preservation phase of fruits, their quality characteristics tend to diminish due to the natural processes of respiration and maturation, ultimately shortening their shelf life. Apricots are particularly low in fat but are rich in essential unsaturated fatty acids that offer significant health advantages. Our study corroborates the findings of Aziz et al. (2020), who reported that apricots have a fat content of approximately 1.31%. Likewise, research by Arshad et al. (2010) indicated varying fat content in three apricot varieties: Marghulam, Halman, and Shakanda, with values of 2.10%, 1.2%, and 3.56%, respectively. The impact of chemical treatment and low-temperature storage on the crude fat levels in apricots is noteworthy, as displayed in Table 14. Specifically, treatments involving calcium chloride and salicylic acid during the storage period had a marked effect on preserving the crude fat content in apricots. The synergy between chemical treatments and low-temperature storage was particularly effective in maintaining the apricot's fat levels.

As detailed in (Table 2,3,4,5), the mean values for crude fat content under various treatments (T0, T1, T2, T3, and T4) were 1.32±0.16, 1.45±0.06, 1.48±0.04, 1.45±0.05, and 1.50±0.04, respectively. A notable divergence was observed between the control and treated samples. The control samples exhibited greater reductions in fat content compared to the treated ones. Specifically, treatments T2 and T4 were especially effective in minimizing fat loss over a 21day storage period. This is in line with the observations of O'Grady et al. (2014), who noted a 15-20% decrease in fat content after 14 days of low-temperature storage for cv. 'Arakata' arils. Furthermore, the mean fat content values during storage periods of 0, 7, 14, and 21 days were 1.52±0.01, 1.45±0.08, 1.42±0.07, and 1.35±0.13, respectively. Although a declining trend in fat content was noted across all treatments, the chemically treated samples displayed a less significant reduction up to the 14-day mark, after which a more pronounced decrease was observed between the 14th and 21st days.

3.14 Crude fiber contents

Dietary fiber, although devoid of caloric value, plays a crucial role in promoting gastrointestinal health by aiding in bowel regularity and mitigating constipation. Moreover, it helps stabilize blood sugar levels, manage body weight, and absorb excess fats, thereby contributing to overall well-being

(Tamura et al., 2011). Experimental data indicate that low-temperature storage and the use of specific post-harvest chemicals like calcium chloride and salicylic acid effectively preserve the dietary fiber content in apricot fruits.

The impact of these treatments on crude fiber content in apricots (Table 2,3,4,5). Notably, both chemical treatments and low-temperature storage synergistically influenced the crude fiber content in a positive manner. The mean values of crude fiber, presented in Table 14, for the different treatments (T0, T1, T2, T3, and T4) were 2.39±0.02, 2.41±0.04, 2.43±0.02, 2.41±0.05, and 2.42±0.01, respectively. A statistically significant divergence was noted between the control and the treated samples. Specifically, untreated samples exhibited more significant losses in dietary fiber content compared to those subjected to treatments. In treatments T2 and T4, the dietary fiber content remained relatively stable over a 21-day storage period (Table 5). An upward trend in dietary fiber levels was observed across all treatments during the final cold storage phase. Notably, a 3% concentration of calcium chloride and a 2% concentration of salicylic acid were particularly effective in conserving the dietary fiber content (O'Grady et al., 2014; Sharif et al., 2015). The mean dietary fiber values during storage were 2.42±0.01, 2.41±0.02, 2.40±0.03, and 2.41±0.02 at 0, 7, 14, and 21 days, respectively. Although there was an overall increase in dietary fiber over the storage duration, a noticeable reduction was observed in the treated samples up to day 12, followed by a subsequent increase between days 14 and 21.

Table 2. Mean Values for Different Parameters After 0 Days of Storage

Parameter	**To**	**T1**	**T2**	**T3**	**T4**
Weight Loss (%)	N/A	N/A	N/A	N/A	N/A
pH	3.45±0.07	3.45±0.06	3.44±0.01	3.47±0.06	3.47±0.03
Firmness (kg)	10.32±2.31	10.32±1.58	10.33±0.87	10.32±1.61	10.32±0.86
Total Soluble Solids (%)	18.02±0.04	18.98±0.06	18.98±0.03	18.82±0.04	18.64±0.05
Color (L*)	30.52±1.45	31.24±0.42	31.32±0.03	31.24±0.25	31.32±0.07
Color (a*)	1.82±0.25	1.93±0.07	1.93±0.04	1.91±0.06	1.95±0.05
Color (b*)	5.92±0.72	6.03±0.18	6.03±0.06	5.99±0.13	6.04±0.06
Ascorbic Acid (mg)	16.01±0.1	16.12±0.05	16.23±0.02	16.09±0.09	16.16±0.07
Titratable Acidity (%)	0.90±0.32	0.91±0.22	0.92±0.15	0.876±0.22	0.93±0.13
Moisture (%)	80.61±0.93	80.48±1.33	81.94±0.06	82.4±0.21	81.07±0.03
Ash (%)	4.92±0.04	4.93±0.03	4.94±0.04	4.92±0.04	4.94±0.03
Crude Protein (%)	4.92±0.04	4.93±0.03	4.94±0.04	4.92±0.04	4.94±0.03
Crude Fat (%)	1.52±15	1.52±0.05	1.52±0.04	1.52±0.06	1.54±0.04
Crude Fiber (%)	2.41±0.01	2.42±0.03	2.45±0.02	2.42±0.04	2.42±0.04

Table 3. Mean Values for Different Parameters After 7 Days of Storage

Parameter	**To**	**T1**	**T2**	**T3**	**T4**
Weight Loss (%)	3.75±14.05	1.89±8.35	0.61±3.91	2.86±8.98	2.02±4.58
pH	3.42±0.06	3.45±0.07	3.41±0.02	3.47±0.04	3.45±0.07
Firmness (kg)	8.86±2.32	7.28±1.57	6.246±0.88	9.08±1.62	7.003±0.87
Total Soluble Solids (%)	18.54±0.05	19.24±0.05	18.12±0.06	19.00±0.05	19.24±0.07
Color (L*)	28.36±1.46	31.22±0.43	31.29±0.04	31.21±0.24	31.30±0.08
Color (a*)	1.66±0.26	1.90±0.08	1.89±0.05	1.89±0.07	1.91±0.06
Color (b*)	4.92±0.73	5.97±0.19	5.99±0.07	5.89±0.14	5.99±0.07
Ascorbic Acid (mg)	12.87.2±0.05	13.87±0.04	16.13±0.03	14.83±0.10	16.15±0.08
Titratable Acidity (%)	0.26±0.33	0.47±0.23	0.63±0.16	0.45±0.23	0.68±0.14
Moisture (%)	79.54±0.94	80.52±1.34	80.58±0.07	81.62±0.22	81.05±0.04
Ash (%)	4.92±0.03	5.02±0.05	5.05±0.03	5.02±0.03	5.04±0.03
Crude Protein (%)	4.91±0.03	4.92±0.05	4.93±0.03	4.92±0.03	4.94±0.03
Crude Fat (%)	1.31±16	1.46±0.06	1.5±0.05	1.46±0.05	1.52±0.05
Crude Fiber (%)	2.39±0.02	2.41±0.02	2.44±0.02	2.41±0.05	2.42±0.03

Table 4. Mean Values for Different Parameters After 14 Days of Storage

Parameter	**To**	**T1**	**T2**	**T3**	**T4**

Weight Loss (%)	20.08±15.04	10.54±9.36	4.06±4.92	13.98±7.97	5.86±5.57
pH	3.38±0.08	3.41±0.05	3.40±0.03	3.42±0.05	3.43±0.05
Firmness (kg)	8.43±2.34	7.15±1.60	8.40±0.87	8.73±1.63	7.03±0.85
Total Soluble Solids (%)	19.30±0.04	19.38±0.06	18.02±0.04	19.11±0.06	19.38±0.06
Color (L*)	27.71±1.47	30.70±0.44	31.26±0.05	30.84±0.26	31.22±0.06
Color (a*)	1.44±0.27	1.85±0.09	1.86±0.06	1.83±0.08	1.87±0.07
Color (b*)	4.56±0.73	5.76±0.20	5.93±0.08	5.78±0.15	5.94±0.08
Ascorbic Acid (mg)	11.22±0.00	12.27±0.05	16.2±0.03	14.14±0.10	16.10±0.07
Titratable Acidity (%)	0.24±0.34	0.44±0.24	0.61±0.17	0.42±0.25	0.65±0.15
Moisture (%)	79.86±0.93	79.16±1.35	80.57±0.04	81.92±0.24	81.12±0.05
Ash (%)	4.88±0.06	4.96±0.04	5.01±0.06	4.95±0.06	5.04±0.04
Crude Protein (%)	4.88±0.06	4.91±0.04	4.92±0.06	4.91±0.06	4.93±0.04
Crude Fat (%)	1.31±17	1.43±0.07	1.48±0.06	1.43±0.04	1.47±0.05
Crude Fiber (%)	2.37±0.03	2.41±0.03	2.41±0.01	2.41±0.03	2.41±0.05

Table 5. Mean Values with Standard Deviations for Each Parameter After 21 Days for Different Treatments:

Parameter	**To**	**T1**	**T2**	**T3**	**T4**
Weight Loss (%)	29.97±13.04	18.11±7.37	8.54±2.93	16.09±6.99	10.41±3.59
pH	3.35±0.09	3.40±0.05	3.39±0.02	3.39±0.05	3.40±0.04
Firmness (kg)	7.07±2.30	7.01±1.59	7.32±0.88	8.91±1.62	6.30±0.87
Total Soluble Solids (%)	20.01±0.06	20.12±0.08	19.58±0.05	19.24±0.05	19.46±0.07
Color (L*)	27.21±1.44	30.35±0.42	31.22±0.03	30.77±0.25	31.14±0.07
Color (a*)	1.22±0.26	1.75±0.08	1.81±0.05	1.77±0.07	1.82±0.06
Color (b*)	4.24±0.73	5.62±0.19	5.87±0.07	5.67±0.14	5.88±0.07
Ascorbic Acid (mg)	10.34±0.1	11.42±0.06	16.2±0.04	13.9±0.11	15.9±0.06
Titratable Acidity (%)	0.23±0.33	0.42±0.24	0.60±0.15	0.40±0.23	0.62±0.14
Moisture (%)	78.94±0.92	78.25±1.34	80.72±0.05	81.68±0.22	81.18±0.05
Ash (%)	4.85±0.07	4.92±0.05	4.97±0.07	4.92±0.07	5.01±0.05
Crude Protein (%)	4.85±0.07	4.90±0.05	4.92±0.07	4.91±0.07	4.92±0.05
Crude Fat (%)	1.13±15	1.37±0.06	1.42±0.04	1.39±0.05	1.45±0.06
Crude Fiber (%)	2.38±0.02	2.42±0.01	2.42±0.01	2.4±0.02	2.44±0.06

These tables show the mean values along with standard deviations (SD) for each parameter at the 0, 7, 14 and 21-day storage interval for different treatments (To, T1, T2, T3, T4)

Table 6. Mean Values for Various Parameters of Apricot Fruit During Storage

Parameters	**To**	**T1**	**T2**	**T3**	**T4**
Weight Loss (%)	13.4 ± 14.04 a	7.64 ± 8.36 c	3.30 ± 3.92 e	8.23 ± 7.99 b	4.58 ± 4.59 d
pH	3.40 ± 0.08c	3.42 ± 0.07b	3.43 ± 0.02a	3.42 ± 0.06b	3.43 ± 0.04a
Firmness (kg)	9.12 ± 2.32c	7.94 ± 1.59b	7.12 ± 0.88a	9.09 ± 1.62b	7.90 ± 0.87a
Total Soluble Solids (%)	18.94±0.05b	19.57±0.06a	18.67±0.04b	19.05±0.05a	19.18±0.07a
Color (L*)	28.45±1.46d	30.88±0.43c	31.27±0.04a	31.02±0.25b	31.25±0.08a
Color (a*)	1.54±0.26c	1.86±0.08bc	1.87±0.05b	1.85±0.07c	1.89±0.06a
Color (b*)	4.91±0.73e	5.85±0.19d	5.95±0.07a	5.83±0.14d	5.96±0.07b
Ascorbic Acid (mg)	12.61±0.1c	14.92±0.06b	16.14±0.03a	14.24±0.10b	16.07±0.08a
Titratable Acidity (%)	0.41±0.33d	0.56±0.24c	0.69±0.16b	0.54±0.23c	0.72±0.14a
Moisture (%)	79.32±0.94a	78.60±1.35c	80.62±0.07e	81.66±0.22b	81.11±0.05d

Ash (%)	4.91±0.05d	4.95±0.04c	4.99±0.05b	4.95±0.05c	5.00±0.04a
Crude Protein (%)	4.89±0.05d	4.91±0.04b	4.92±0.05a	4.91±0.05b	4.93±0.04a
Crude Fat (%)	1.32±0.16d	1.45±0.06c	1.48±0.04b	1.45±0.05c	1.50±0.04a
Crude Fiber (%)	2.39±0.02e	2.41±0.04d	2.43±0.02a	2.41±0.05c	2.42±0.01b

T_o = Storage at 5 ± 1ºC, RH 90-95%.

T_1 = Storage at 5 ± 1ºC, RH 90-95%, 2% $CaCl_2$

T_2 = Storage at 5 ± 1ºC, RH 90-95%, 3% $CaCl_2$

T_3 = Storage at 5 ± 1ºC, RH 90-95%, 1% salicylic acid

T_4 = Storage at 5 ± 1ºC, RH 90-95%, 2% salicylic acid

3.15 Sensory evaluation

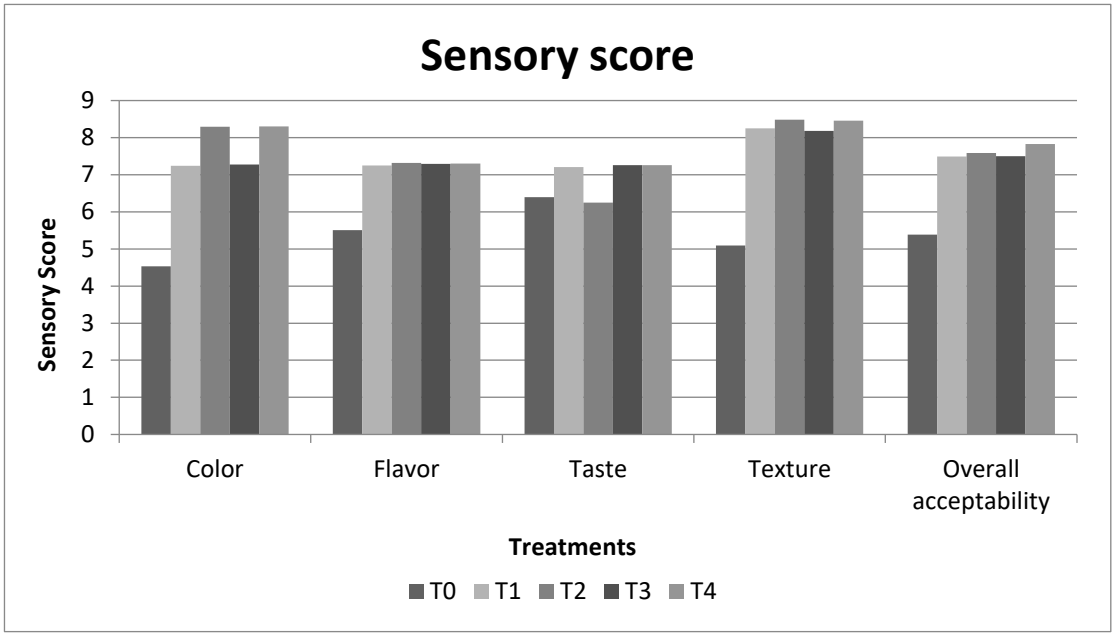
In a study conducted by our team, we utilized a 9-point hedonic scale to assess consumer preferences regarding apricot fruit. This scale ranged from 1 ("Extremely Dislike") to 9 ("Extremely Like"), ensuring a comprehensive evaluation of the fruit's sensory attributes. To maintain consistency, we only used apricots that were at the same stage of maturity. While the texture scores for the control group deteriorated rapidly, the scores for treated samples exhibited a more gradual decline. Texture is a crucial quality factor, serving as an indicator of both the fruit's harvest maturity and its post-harvest shelf life. The decline in textural integrity is primarily attributed to the softening of the fruit, which results from the breakdown of structural carbohydrates during either ripening or storage (Smith & Jones, 2018). Our analysis revealed that treatments T2 and T4, which involved the use of higher chemical concentrations, were most effective in preserving the fruit's color, flavor, and taste. In contrast, the control group exhibited the least desirable scores in these categories. Treatment T3 also performed well, showing scores close to those of treatment T4 in terms of flavor and taste.

In terms of overall acceptability, the control samples scored the lowest, while the treated samples showed the highest and most stable scores throughout the storage period. These observations align with prior research conducted by Moghadam and Eslani (2005), who found similar improvements in apricot sensory quality through chemical treatments. Additionally, Ishaq et al. (2009) reported that a 3% CaCl2 solution, combined with PE packaging and KMnO4, was effective in enhancing the sensory attributes of apricots stored under ambient conditions for up to 10 days. Statistical data further supports these findings, with a significant difference ($p < 0.05$) between the treated and control samples across all sensory attributes evaluated.

Table 7. Hedonic scale table for organoleptic quality testing for apricot fruit

Treatments	**Color**	**Flavor**	**Taste**	**Texture**	**Overall acceptability**
T_o	4.53^{d}	5.51^{e}	6.4^{d}	5.09^{e}	5.38^{d}
T_1	7.24^{c}	7.25^{d}	7.21^{c}	8.25^{d}	7.49^{c}
T_2	8.29^{a}	7.32^{a}	6.25^{a}	8.48^{a}	7.59^{b}
T_3	7.28^{b}	7.29^{c}	7.26^{b}	8.18^{c}	7.50^{c}
T_4	8.3^{a}	7.30^{b}	7.26^{a}	8.46^{b}	7.83^{a}

Fig. 2. Graphical representation Hedonic scale table for organoleptic quality testing for apricot fruit.



CONCLUSION

In summary, apricots are a nutritional and medicinal powerhouse, particularly significant in Pakistan's diverse agricultural landscape. Despite being a leading global producer, the country faces challenges in processing and storage, leading to considerable losses. Our study indicates that the use of 3% calcium chloride and 2% salicylic acid as preservatives effectively maintains the quality of apricots over a 21-day storage period at 5°C. Statistical data revealed minimal fluctuations in essential parameters like weight loss, Total Soluble Solids (TSS), and moisture content. Additionally, sensory tests confirmed that a 2% calcium chloride treatment yielded the most favorable flavor and taste scores. Further research should explore the long-term effects of these chemical treatments on human health. Policy makers should focus on improving the processing and cold storage infrastructure in Pakistan to minimize post-harvest losses. Stakeholders in the agricultural industry could leverage these findings to standardize the use of chemical preservatives, thereby extending the shelf-life of apricots and other fruits. This research holds the potential to significantly improve the shelf life and exportability of Pakistan's apricot crop, thereby enhancing its standing in the global agricultural market.

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