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Comparative evaluation of postharvest preservation strategies for Brussels sprouts (*Brassica oleracea* var. *gemmifera*)

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Abstract

The study on Brussel sprouts is a comparison of different pre-treatments, i.e. blanching, ascorbic acid, hydrogen peroxide, and chlorine, followed by refrigerated storage in low-density polyethene packets at 6–7°C. As a new variety, basic parameters were studied, and a mean diameter of this variety was 3.2 ± 0.4 cm, sphericity of 0.75 ± 0.12 , bulk density of 0.35 ± 0.05 g/mL, true density of 0.78 ± 0.09 g/mL, and moisture content of $69.4 \pm 1.04\%$, were reported. During the 8-day storage period, pretreatment by ascorbic acid showed the most desirable results, i.e. preserved visual quality, where initial L, a & b is 56.5 ± 0.3 , -13.1 ± 0.2 , and 25.2 ± 0.3 before treatment and 46.5 ± 0.4 , -11.1 ± 0.3 , and 33.2 ± 0.5 , after treatment. Lowest change in TSS $8.0 \pm 0.11^\circ\text{Brix}$ to $6.0 \pm 0.10^\circ\text{Brix}$, significantly less pH increases 8.0 ± 0.04 to 8.4 ± 0.02 , also maintained relatively higher O_2 levels ($15.7 \pm 0.27\%$) and moderate CO_2 levels ($6.5 \pm 0.29\%$). Hydrogen peroxide and chlorine showed an intermediate protective nature, mainly due to their sanitation-related effects. Blanching showed the greatest negative effect on the suitability. Overall, the results support ascorbic acid as the best practical preservation for short-term refrigerated handling of Brussels.

Keywords: Brussels sprouts, preservation, quality, shelf life, ascorbic acid

1. Introduction

Brussels sprouts (*Brassica oleracea* var. *gemmifera*) are a highly nutritious vegetable generally recognised for high dietary fibre, vitamin K and C content, essential minerals, and glucosinolate-rich phytochemical profile, which collectively contribute to antioxidant, anti-inflammatory, and potential chemoprotective effects (Doniec *et al.*, 2022; Bhat *et al.*, 2023) [7, 2]. The Present attribute leads to an increase in demand of Brussels sprouts in both the area, whether fresh consumption, as minimally processed, as salad, or sauteed form. The functional foods continue to rise (Sagar *et al.*, 2021; Cartea *et al.*, 2020) [22, 4]. Though demand and nutrition both are high, the Brussels sprouts are highly perishable commodities, which limits the marketability, distance transportation, storage problems, etc. (Sood *et al.*, 2017) [26]. The losses which occur are due to high continued respiration, transpiration, and metabolic activity, which lead to moisture depletion, post-harvest quality loss, structure degradation (Caleb *et al.*, 2013) [3]. These physiological processes are accompanied by chlorophyll breakdown, enzymatic browning, organic acid metabolism, and accumulation of off-flavor compounds, loss of firmness, ultimately resulting in yellowing, butt-end discolouration, and reduced sensory acceptability (Kader, 2002) [11]. Also, high moisture content led to microbial spoilage; rapid bacterial growth caused physiological loss, discolouration, odour, and poor appearance (Shomodder *et al.*, 2022) [25]. With all other inherent attributes of Brussels sprouts, if one can talk about one more parameter of degradation or post-harvest quality losses is the temperature, which again plays a very critical role in determining the post-harvest behaviour. Brussels sprouts can be stored for 3-5 weeks at 0°C, highlighting the strong temperature dependence of metabolic activity and senescence (Bhat *et al.*, 2023) [2]. Though optimised cold store handling and storage protocols are available in the literature, the challenge of minimal losses and preservation with minimal processing is still in the system, and one has to explore the effectiveness of the same on the shelf life and microbial activity of Brussels Sprouts. (Lurie, 1998; Rico *et al.*, 2007) [16, 21]. The vegetables are usually subjected to a numbers of

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processing steps, making a processing chain for the same. These steps include pretreatment, preservation and storage of the vegetable (Vancoillie *et al.*, 2024) ^[28]. It is generally recognized that each step in this processing chain can have a different impact on the vegetable’s health-related compounds profile. Blanching foods helps reduce quality loss over time, done before freezing, drying or canning (Lin and Brewer, 2005.) ^[15]. Heating vegetables or fruits to inactivate enzymes, modify texture, remove the peel, and wilt tissue (Temiz *et al.*, 2017) ^[27]. The process has three stages: preheating, blanching, and cooling. Drawbacks to the blanching process can include leaching of water-soluble and heat sensitive nutrients and the production of effluent (Sharma *et al.*, 2025) ^[24]. Alternatively, antioxidant-based treatments, particularly ascorbic acid dips, have shown promise in preserving quality by reducing oxidative stress, stabilizing pigments, and maintaining cellular integrity (Eze *et al.*, 2025) ^[8]. Ascorbic acid acts as an antimicrobial agent. Ascorbic acid acts as a reducing agent that limits enzymatic browning and delays senescence-related biochemical changes (Davey *et al.*, 2000; Lee and Kader, 2000) ^[6, 14]. In parallel, oxidative sanitizers such as hydrogen peroxide and chlorine are widely used in fresh produce systems to reduce microbial load and enhance safety (Chinchkar *et al.*, 2022) ^[5]. These chlorine solutions are useful as a disinfection tool for food surface (Gómez-López *et al.*, 2009) ^[10]. Chlorination has been routinely used to treat postharvest cooling water, in postharvest treatments (i.e. calcium for firmness enhancement) and during rehydration at shipping destinations (Sargent *et al.*, 2000). These treatments function through oxidative mechanisms that disrupt microbial cell membranes; however, their application must be carefully controlled to avoid tissue damage, oxidative stress, and regulatory concerns regarding residues and environmental impact (Gil *et al.*, 2009; Parish *et al.*, 2003) ^[9, 18]. Therefore, the present study aims to evaluate the effects of blanching, ascorbic acid, hydrogen peroxide, and chlorine treatments on the postharvest quality of Brussels sprouts stored under refrigerated conditions (6-7 °C) in low-density polyethene packaging. The study focuses on key quality parameters, including pH, moisture loss, total soluble solids, and gas composition, to provide a comprehensive understanding of treatment-induced changes and to identify the most effective strategy for short-term storage and handling

2. Materials and Methods

Fresh Brussels sprouts were sourced from the regional research station, Punjab Agricultural University, Gurdaspur. The mature and healthy sprouts were selected. Selected sprouts were cleaned, and any damaged ones were removed. The final cleaned uniform-sized Brussels sprouts were subjected to pre-treatments and packed in low-density polyethene (LDPE) bags. Storage was done at 6-7 °C. The tested treatments as per the table no. 1 were: (i) 1% ascorbic acid dip for 5 min; (ii) 10% hydrogen peroxide dip for 5 min; (iii) 200 ppm chlorine dip for 5 min; and (iv) blanching in boiling water for 3 min followed by immediate cooling. Samples were withdrawn on days 0, 4, and 8 for quality assessment. Measured quality indicators included total soluble solids (TSS), pH, colour attributes (Hunter L*, a*, b*), moisture content, bulk and true density.

Table 1: Core experimental settings and baseline measurements extracted from the uploaded draft.

Parameter	Reported value/condition
Packaging	LDPE bags
Storage temperature	6–7 °C
Sampling schedule	Day 0, Day 4, Day 8
Ascorbic acid treatment	1% dip, 5 min
Hydrogen peroxide treatment	10% dip, 5 min
Chlorine treatment	200 ppm dip, 5 min
Blanching	Boiling water 3 min + ice cooling

Total soluble solids (TSS) were measured using a hand-held refractometer after calibrating the instrument with distilled water, while pH was determined by extracting juice from crushed samples and recording the readings using a calibrated pH meter. Colour characteristics were analysed using a Konica Minolta colour reader based on Hunter Lab coordinates (L*, a*, and b* values). Gas composition analysis was performed using a GS6600 gas analyser to determine oxygen and carbon dioxide concentrations within sealed LDPE packages during storage. Moisture content changes were estimated through oven drying at 92 °C until constant weight was achieved.

Statistical analysis

The experimental data obtained during the present research work were subjected to statistical analysis. All the experimental data for the analysis of pretreated Brussels sprouts were expressed as mean ± standard deviation calculated from three independent replication experiments. One-way and two-way analysis of variance (ANOVA) was applied and the Duncan multiple range test was performed to measure the test of significance by post hoc test using the software SPSS v16.0 (SPSS Italia, Bologna, Italy).

3. Results and Discussion

3.1 Physical profile of the raw material

The reported physical profile confirms that Brussels sprouts in this study were compact, nearly spherical in the shape units with relatively good moisture content. Baseline properties were estimated like diameter, sphericity, moisture content, bulk density and true density. The results indicated that the crop is high in moisture content and has sensitivity to microbial growth. These baseline properties are consistent with the need for low-temperature management and gentle handling (Table 2).

Table 2: Baseline properties of Brussels Sprouts

Physical Attribute	Value
Diameter	3.2±0.02cm
Sphericity	0.75±0.03
Bulk Density	0.35±0.019g/mL
True Density	0.78±0.014g/mL
Moisture Content	69.4±0.032%

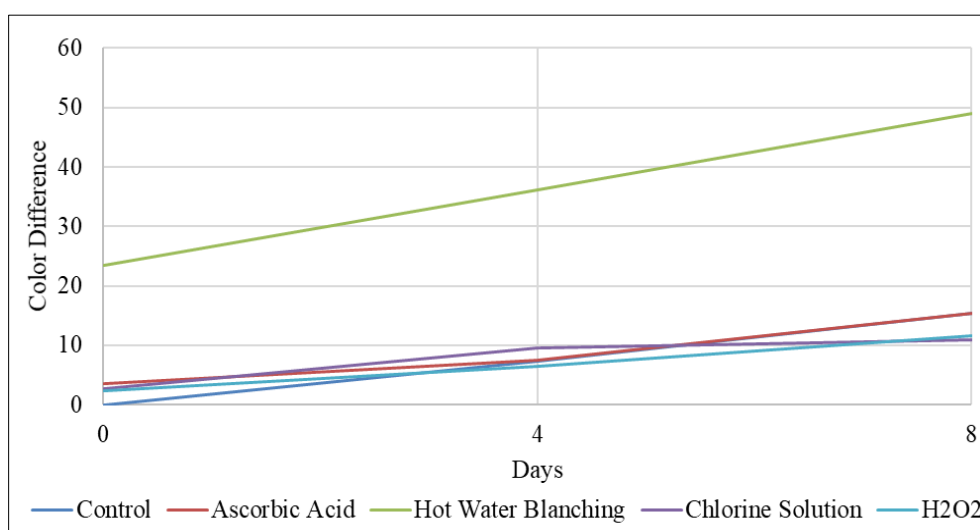
3.2 Effect of pre-treatments on color and visual quality

Color retention indicated a key discriminator among treatments. The study showed that ascorbic acid was the best in preserving the greenness and lightness of the Brussels Sprout, whereas in comparison to other treatments, blanching caused the maximum loss of green character. Statistical analysis revealed significant

differences ($p < 0.05$) among treatment-day combinations as shown in fig 1. The reason is that ascorbic acid limits oxidative browning and can protect chlorophyll-containing tissues, while thermal blanching accelerates pigment disruption and can intensify visual dulling (Patras *et al.* 2011) [20]. Hydrogen peroxide and chlorine showed intermediate results. Changes in these parameters were monitored over storage period of 8 days, and the results are expressed as mean $\pm$ standard deviation ($n = 3$). Initially, the control samples exhibited L, a, b values of 55.6 ± 0.3 , -13.8 ± 0.2 , and 23.0 ± 0.4 , respectively, which gradually changed to 45.5 ± 0.5 , -9.8 ± 0.3 , and 34.0 ± 0.6 by day 8, indicating a progressive loss of greenness and an increase in yellowness during storage. Samples treated with ascorbic acid showed relatively better retention of colour, with values changing from 56.5 ± 0.3 , -13.1 ± 0.3 , and 25.2 ± 0.2 before treatment to 46.4 ± 0.3 , -11.1 ± 0.2 , and 33.2 ± 0.4 on day 8, suggesting its effectiveness in preserving chlorophyll and delaying oxidative

degradation. Results are shown in figure 1.

In contrast, hot water blanching resulted in the most significant colour degradation. The L, a, b values decreased sharply from 53.1 ± 0.5 , -13.3 ± 0.3 , and 24.6 ± 0.4 before treatment to 18.1 ± 0.6 , -46.3 ± 0.4 , and 19.6 ± 0.4 by day 8. This substantial change indicates pigment breakdown and tissue softening due to thermal treatment. Chlorine-treated samples showed comparatively minimal colour variation, with values shifting from 54.2 ± 0.3 , -14.0 ± 0.4 , and 24.9 ± 0.3 initially to 48.2 ± 0.4 , -14.0 ± 0.4 , and 34.0 ± 0.4 by day 8, indicating better retention of visual quality. Similarly, hydrogen peroxide (H_2O_2)-treated samples exhibited moderate changes, with values decreasing from 59.7 ± 0.2 , -13.5 ± 0.4 , and 27.1 ± 0.4 to 49.7 ± 0.5 , -9.5 ± 0.3 , and 31.5 ± 0.5 over the storage period. Overall, colour change increased progressively in all samples during storage. Ascorbic acid treatment was effective in maintaining colour stability due to its antioxidant properties.



*Values are expressed as mean $\pm$ SD ($n = 3$). Different lowercase letters indicate significant differences among treatment-day combinations according to Duncan's Multiple Range Test ($p < 0.05$)

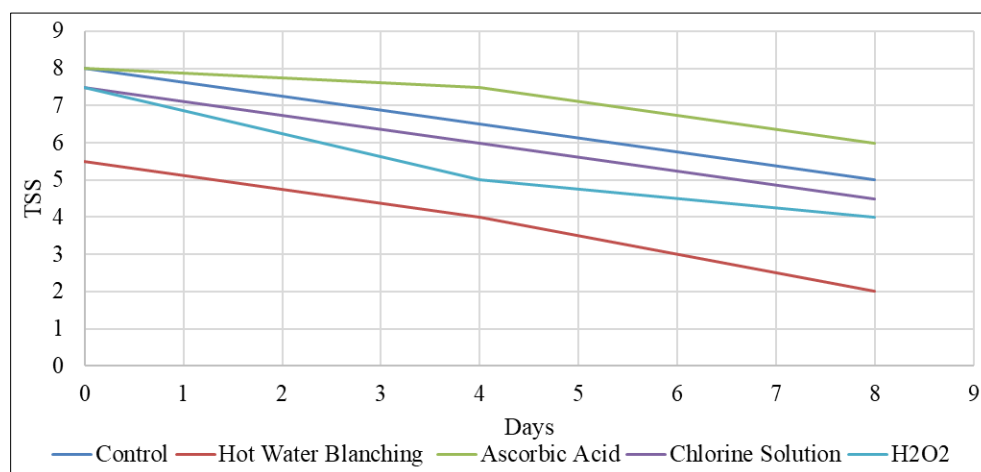
Fig 1: Effect of treatment on the colour of the sample

These findings are consistent with recent studies, which report that thermal treatments such as blanching accelerate pigment degradation, while antioxidant treatments like ascorbic acid help preserve colour by reducing oxidative stress (Kumar *et al.*, 2021; Pathare *et al.*, 2020; Saini *et al.*, 2022) [12, 19, 23].

3.3 Effect of Pre-treatment on Total Soluble Solids

The determination of total soluble solids (TSS, °Brix) was carried out for all treatments at regular storage intervals, and the results are presented in Fig. 2. Statistical analysis revealed significant differences ($p < 0.05$) among treatment-day combinations. A consistent declining trend in TSS was observed across all treatments throughout the storage period, indicating progressive metabolic utilization of soluble sugars. At day 0, TSS values ranged from $5.5 \pm 0.11^\circ\text{Brix}$ in hot water blanched samples to $8.0 \pm 0.12^\circ\text{Brix}$ in ascorbic acid treated samples. During storage, a gradual decrease was recorded in all treatments; however, the rate

of decline varied significantly among treatments. By day 8, the lowest TSS values were observed in hot water-treated samples ($2.0 \pm 0.07^\circ\text{Brix}$) followed by H_2O_2 -treated samples ($4.0 \pm 0.08^\circ\text{Brix}$), whereas relatively higher TSS retention was recorded in control ($5.0 \pm 0.11^\circ\text{Brix}$), ascorbic acid-treated ($6.0 \pm 0.10^\circ\text{Brix}$), and chlorine-treated samples ($4.5 \pm 0.08^\circ\text{Brix}$). The maximum reduction ($\approx 64.6\%$) was observed in hot water-treated samples, while ascorbic acid treatment exhibited the least reduction ($\approx 25\%$), indicating its protective role in maintaining soluble solids. Results are shown in fig 2. The better retention of TSS in ascorbic acid-treated samples can be attributed to its antioxidant properties and ability to scavenge reactive oxygen species, thereby slowing respiration and enzymatic degradation of sugars. Similar findings have been reported where ascorbic acid treatments improved postharvest quality and delayed biochemical degradation in fruits (Ali *et al.*, 2022; Kumar *et al.*, 2023) [1, 13].



*Values are expressed as mean $\pm$ SD (n = 3). Different lowercase letters indicate significant differences among treatment-day combinations according to Duncan's Multiple Range Test ($p < 0.05$)

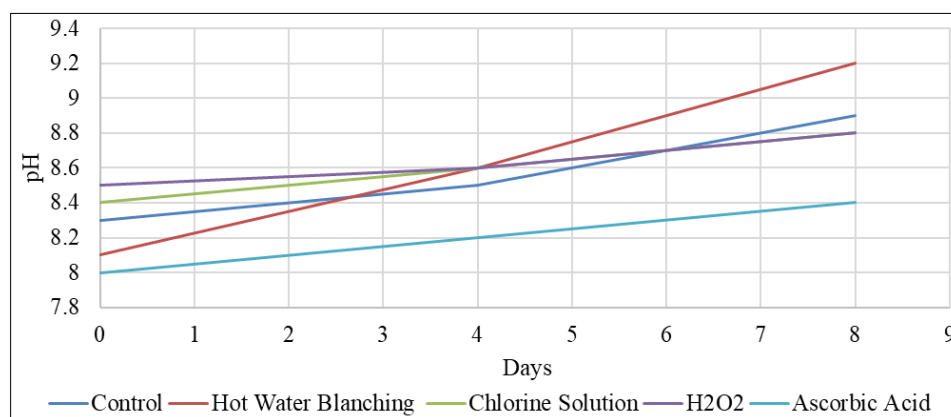
Fig 2: Effect of treatments on the TSS of the sample

3.4 Effect on pH of the Brussels sprout

The pH of all treated samples was monitored at regular intervals during storage, and the results are presented in Fig. 3. Statistical analysis revealed significant differences ($p < 0.05$) among treatment-day combinations. A gradual and consistent increase in pH was observed across all treatments, indicating a progressive shift toward a more alkaline nature over time. At day 0, pH values ranged from 8.0 ± 0.04 (Ascorbic acid-treated samples) to 8.5 ± 0.07 (H₂O₂-treated samples). As storage progressed, all samples exhibited a steady rise in pH. By day 8, the highest pH was

recorded in hot water-blanching samples (9.2 ± 0.09), followed by control (8.9 ± 0.08), chlorine solution (8.8 ± 0.07), H₂O₂ (8.8 ± 0.06), and the lowest in ascorbic acid-treated samples (8.4 ± 0.03). Results are shown in Fig. 3.

The initial lower pH observed in ascorbic acid-treated samples can be attributed to the acidic nature of ascorbic acid, which reduces the overall pH of the system. However, during storage, degradation of organic acids and biochemical transformations resulted in a gradual increase in pH.



*Values are expressed as mean $\pm$ SD (n = 3). Different lowercase letters indicate significant differences among treatment-day combinations according to Duncan's Multiple Range Test ($p < 0.05$)

Fig 3: Effect of treatment on the pH of the sample

3.5 Moisture behavior, tissue integrity, and respiratory implications

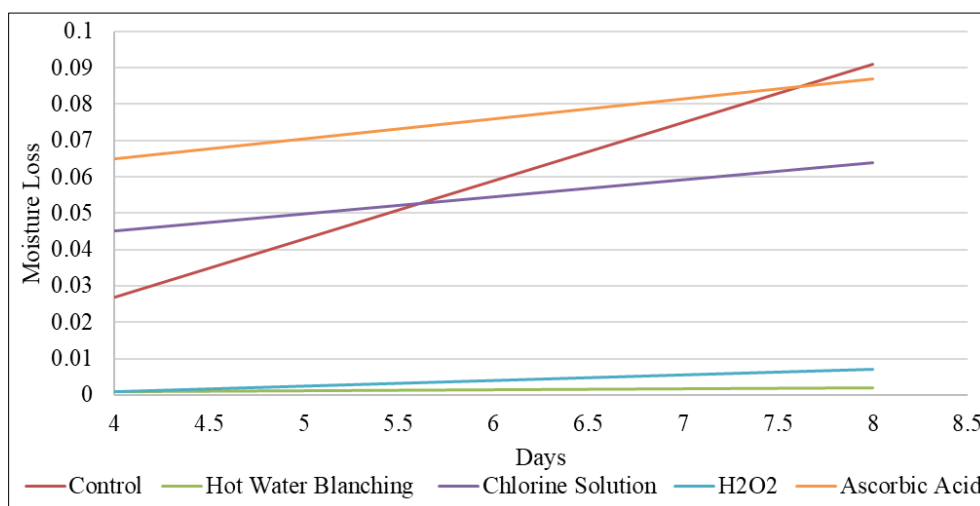
The determination of moisture loss was carried out for all treatments during storage, and the results are presented in Fig. 4. A progressive increase in moisture loss was observed across all treatments with increasing storage duration, indicating continuous water loss due to transpiration and respiration processes. Statistical analysis revealed significant differences ($p < 0.05$) among treatment-day combinations.

At day 4, moisture loss ranged from 0.001 ± 0.0003 (hot water-blanching samples) to 0.065 ± 0.005 (ascorbic acid-treated samples). As storage progressed, moisture loss increased steadily in all treatments. By day 8, the highest moisture loss was recorded in control samples (0.090 ± 0.005), closely followed by ascorbic acid-treated samples (0.087 ± 0.006), while the lowest moisture loss was observed in hot water-blanching samples ($0.002 \pm$

0.0002). Chlorine-treated (0.064 ± 0.003) and H₂O₂-treated samples (0.007 ± 0.002) exhibited moderate moisture loss. The data is shown in fig 4.

The increase in moisture loss during storage can be attributed to physiological weight loss caused by transpiration and respiration, which leads to depletion of cellular water content. Similar findings have been reported by Wills *et al.* (2016) [29] and Kader (2002) [11], who stated that water loss is a major factor affecting postharvest quality due to continuous metabolic activity and environmental influences.

Hot water blanching showed minimal moisture loss, possibly due to inactivation of enzymes and reduction in respiration rate, thereby slowing down water loss. This observation is in agreement with findings by Lurie (1998) [16] and Rico *et al.* (2007) [21], who reported that heat treatments can delay senescence and reduce moisture loss in fresh produce.



*Values are expressed as mean $\pm$ SD (n = 3). Different lowercase letters indicate significant differences among treatment-day combinations according to Duncan's Multiple Range Test ($p < 0.05$)

Fig 4: Effect of treatment on the weight loss of the sample

3.6 Gas Composition During Storage

The composition of gases within the packaging was determined to assess the respiration behavior and metabolic activity of the samples during storage. Gas composition analysis was carried out using a gas analyzer, and the results are presented in Table 3. Changes in oxygen (O_2) and carbon dioxide (CO_2) concentrations provide a direct indication of respiration rate, where decreasing O_2 and increasing CO_2 reflect active metabolic processes.

At day 0, all treatments exhibited nearly similar atmospheric conditions, with O_2 levels ranging from $20.1 \pm 0.11\%$ to $20.4 \pm 0.13\%$ and CO_2 levels around $1.0 \pm 0.04\%$ to $1.2 \pm 0.05\%$, indicating uniform initial packaging conditions.

During storage, a gradual decline in O_2 concentration and a corresponding increase in CO_2 concentration were observed across all treatments. By day 4, O_2 levels decreased notably in hot water-blanching samples ($11.4 \pm 0.20\%$) compared to control ($18.3 \pm 0.24\%$), accompanied by variations in CO_2 accumulation.

By day 8, the lowest O_2 level was recorded in hot water-blanching samples ($6.85 \pm 0.28\%$), while the highest CO_2 accumulation was also observed in this treatment ($9.0 \pm 0.35\%$), indicating a higher respiration rate or altered gas permeability.

In contrast, ascorbic acid-treated samples maintained relatively higher O_2 levels ($15.7 \pm 0.21\%$) and moderate CO_2 levels ($6.5 \pm 0.24\%$) by day 8, suggesting a more balanced gaseous environment and potentially reduced metabolic activity compared to other treatments. Control samples showed intermediate behavior, with O_2 decreasing to $15.8 \pm 0.21\%$ and CO_2 increasing to $4.4 \pm 0.27\%$.

The observed trend of decreasing O_2 and increasing CO_2 is consistent with respiration processes, where oxygen is consumed and carbon dioxide is produced. Similar findings have been reported by Kader (2002) [11] and Caleb *et al.* (2013) [3], who demonstrated that gas composition changes in packaged produce are directly linked to respiration rate and storage conditions.

Table 3: Gas composition during the storage period

Treatments	Day 0 (% O_2 / CO_2)	Day 4 (% O_2 / CO_2)	Day 8 (% O_2 / CO_2)
Control	20.4 ± 0.13^{aA} / 1.0 ± 0.05^{aA}	18.3 ± 0.24^{aB} / 2.5 ± 0.20^{bB}	15.8 ± 0.21^{ac} / 4.4 ± 0.27^{cc}
Hot Water Blanching	20.1 ± 0.10^{aA} / 1.0 ± 0.05^{aA}	11.4 ± 0.20^{cB} / 0.9 ± 0.06^{cA}	6.85 ± 0.24^{cc} / 9.0 ± 0.35^{ac}
Chlorine Solution	20.2 ± 0.11^{aA} / 1.2 ± 0.05^{aA}	17.0 ± 0.24^{bB} / 2.4 ± 0.18^{bB}	14.3 ± 0.23^{bc} / 5.7 ± 0.27^{bc}
H ₂ O ₂ Treatment	20.4 ± 0.12^{aA} / 1.0 ± 0.05^{aA}	15.9 ± 0.28^{bB} / 4.7 ± 0.25^{aB}	11.8 ± 0.22^{cc} / 7.3 ± 0.30^{bc}
Ascorbic Acid	20.1 ± 0.11^{aA} / 1.0 ± 0.04^{aA}	17.3 ± 0.26^{bB} / 3.8 ± 0.22^{aB}	15.7 ± 0.21^{ac} / 6.5 ± 0.24^{bc}

(a–c) within a column indicate significant differences among treatments.

(A–C) within a row indicate significant differences among storage days ($p \leq 0.05$).

Discussion

When the observed quality domains are interpreted together, the treatments can be ranked qualitatively for fresh refrigerated storage as follows: ascorbic acid is the best, followed by chlorine, which was equivalent to hydrogen peroxide, and the worst was blanching. Blanching may still have value in processing chains designed for freezing or cooking, but the dataset does not support it as the preferred option for retaining fresh-like quality during short refrigerated storage.

Among the different preservation treatments evaluated for Brussels sprouts, ascorbic acid treatment showed the highest

overall suitability for refrigerated storage due to its antioxidant and anti-browning properties. It demonstrated superior colour retention, better stability of total soluble solids (TSS) and pH, and comparatively lower respiration activity, although optimization of concentration and treatment duration is still required. Hydrogen peroxide treatment functioned primarily as an oxidative sanitizer and offered effective microbial control with the added advantage of decomposing into water and oxygen without harmful residues; however, excessive concentrations may induce tissue stress and its efficiency depends largely on concentration stability. A comparative table 4 is showing all the data.

Table 4: Quantitative summary of treatment × storage day × quality parameters of Brussels sprouts

Treatment	Storage Day	TSS (°Brix)	pH	O ₂ (%)	CO ₂ (%)
Control	Day 0	7.0 ± 0.10	8.2 ± 0.05	20.4 ± 0.13	1.0 ± 0.05
Control	Day 4	6.0 ± 0.09	8.5 ± 0.06	18.3 ± 0.24	2.5 ± 0.20
Control	Day 8	5.0 ± 0.11	8.9 ± 0.08	15.8 ± 0.21	4.4 ± 0.27
Ascorbic Acid	Day 0	8.0 ± 0.12	8.0 ± 0.04	20.1 ± 0.11	1.0 ± 0.04
Ascorbic Acid	Day 4	7.0 ± 0.11	8.2 ± 0.03	17.3 ± 0.26	3.8 ± 0.22
Ascorbic Acid	Day 8	6.0 ± 0.10	8.4 ± 0.03	15.7 ± 0.21	6.5 ± 0.24
Hydrogen Peroxide	Day 0	6.5 ± 0.09	8.5 ± 0.07	20.4 ± 0.12	1.0 ± 0.05
Hydrogen Peroxide	Day 4	5.0 ± 0.08	8.6 ± 0.05	15.9 ± 0.28	4.7 ± 0.25
Hydrogen Peroxide	Day 8	4.0 ± 0.08	8.8 ± 0.06	11.8 ± 0.22	7.3 ± 0.30
Chlorine Solution	Day 0	6.8 ± 0.10	8.3 ± 0.05	20.2 ± 0.11	1.2 ± 0.05
Chlorine Solution	Day 4	5.5 ± 0.09	8.5 ± 0.06	17.0 ± 0.24	2.4 ± 0.18
Chlorine Solution	Day 8	4.5 ± 0.08	8.8 ± 0.07	14.3 ± 0.23	5.7 ± 0.27
Hot Water Blanching	Day 0	5.5 ± 0.11	8.3 ± 0.06	20.1 ± 0.10	1.0 ± 0.05
Hot Water Blanching	Day 4	3.5 ± 0.09	8.8 ± 0.08	11.4 ± 0.20	0.9 ± 0.06
Hot Water Blanching	Day 8	2.0 ± 0.07	9.2 ± 0.09	6.85 ± 0.24	9.0 ± 0.35

Values are expressed as mean ± standard deviation (n = 3)

Chlorine treatment was also effective as an antimicrobial wash and is widely adopted in industrial applications because of its simplicity and cost-effectiveness, but concerns related to pigment degradation, chemical residues, and changing regulatory preferences limit its desirability. Blanching, which relies on thermal enzyme inactivation, is generally more suitable for products intended for freezing or further processing rather than fresh refrigerated storage, as it may cause nutrient leaching, texture softening, and pigment degradation, resulting in comparatively poor fresh-storage performance.

Conclusion

The evidence base converges on a clear conclusion: among the tested pre-treatments, ascorbic acid is the best candidate for maintaining short-term refrigerated quality of Brussels sprouts intended for fresh consumption. Its benefits include color preservation, pH moderation, TSS retention, and reduced apparent respiratory stress, whereas blanching is comparatively unsuitable for fresh-storage objectives. The study further indicates that next-generation Brussels sprout preservation should combine optimized low-temperature storage with safer sanitation systems, acid-based anti-browning strategies.

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Authors' contributions: PR experimented, collected data, performed statistical analysis and drafted the manuscript. VK contributed to the planning, along with designing the study, provided suggestions to plant protection and reviewed the article.

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Compliance with ethical standards: I confirm that all the research meets ethical guidelines and adheres to the legal requirements of the study country.

Conflict of Interest: Authors do not have any conflict of interest to declare.

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