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Original Research

Impact of Blanching and Packaging Materials on Postharvest Quality and Storability of Fresh Spinach

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ABSTRACT

Spinach is a widely consumed leafy green vegetable, but it exhibits short storage life due to quick loss in moisture contents during postharvest period. The present study was aimed to evaluate the effect of blanching treatment and different types of packaging on spinach quality under cold storage conditions. Fresh spinach after treatment [T_0 = control, T_1 = blanching, T_2 = modified atmosphere packaging (MAP-1, Xtend®), T_3 = MAP-2 (Bio-fresh®) and T_4 = perforated polyethylene (PE)] application was stored at 4±1 °C and 90±5 % RH for 20 days. Samples were analyzed at the time of harvest (0 day) and then after 3 days interval during storage. MAP treatments performed well and had a positive effect on spinach by maintaining its freshness and quality. Decay, ion leakage and weight loss were observed lower in spinach packed in MAP-1(Xtend®) followed by MAP-2 (Bio-Fresh®) and perforated PE packaging. MA packaging maintained higher ascorbic acid content, chlorophyll, and total antioxidants of spinach during storage. Nevertheless, spinach packed in perforated PE also displayed better results in maintaining quality as compared to control and blanched samples. The maximum weight loss, poor quality, minimum ascorbic acid content with lower consumer acceptability was recorded in control samples. Overall, MAP-1(Xtend®) could be used as a promising technology to maintain the quality of spinach up to 20 days of cold storage.

Keywords: *Blanching treatment, leafy green, perforated polyethylene, packaging types.*

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INTRODUCTION

Spinach (*Spinacia oleracea* L.) is a leafy green vegetable extensively consumed in both fresh and processed forms all over the world. Spinach leaves contain a significant amount of dietary compounds including a wide array of vitamins, minerals, and possess high antioxidant capacity which results in performing different functions such as lipid-lowering, anti-inflammatory and anti-cancer (Choi et al., 2007; Roberts and Moreaua, 2016). Globally, among leafy greens, spinach is the leading crop growing on an area of 930,791 ha with cumulative production of 30.02 million tonnes (FAOSTAT, 2020). Pakistan is a blessed country with a variety of agro-climatic conditions favorable to produce different fruits and vegetables. In Pakistan, spinach is being cultivated on an area of 8,999 ha with 111.2 thousand tons of production annually (MNFSR, 2020).

Leafy vegetables are usually considered as highly perishable crops showing a quick loss in moisture contents, high rate of respiration, the fast appearance of shriveling symptoms and loosening of crispiness result in high quantitative and qualitative losses in the postharvest supply chains (Wang, 2003; Kader, 1992). Postharvest losses differ significantly among the produce, production zones and seasons. Spinach exhibits lower shelf life at ambient room conditions. However, several technologies have been tested to extend the storage life of fresh spinach including cold storage (Mudau et al., 2015), MAP (Tudela et al., 2013), chemical dipping (Cefola and Pace, 2015) and irradiation treatments (Hussain et al., 2016) which have been proved to maintain freshness and quality during the entire period of storage.

MAP technology is being considered a useful alternative of different pre-storage treatments commercially employed in the fresh horticultural industry for conserving quality attributes and

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maintaining shelf life. Due to its minimal cost and no residual issues, consumers prefer to use it for preserving fresh produce. MAP retained higher relative humidity coupled with low-temperature storage significantly reduce decay incidence and mass loss of perishable commodities. MA packaging established barrier between fresh produce and the external environment which restricted the exchange of respiratory gases from stored commodities and created an internal modified atmosphere which delayed postharvest senescence (Ali et al., 2019a). Bieganska-Marecik et al. (2007) stated that spinach stored in plastic laminate polyethylene showed lower microbial spoilage for 6 days of storage with maintained quality. In a recent study, passive MA packaging was tested for mature spinach leaves stored at non-optimized storage conditions 13 and 21 °C significantly conserved nutritional quality, reduced respiration, yellowing rate, and weight loss during storage for 5 and 9 days, respectively. Minimally processed baby spinach leaves showed off-odour development during storage. Tudela et al. (2013) earlier reported that baby spinach stored in MAP bags exhibited higher consumer acceptability for 7 days and 7 °C while prolonged storage increased off-odour development which limits its marketability.

Hot water dip treatment for longer durations was widely tested as a quarantine technique to disinfect from the infestation of fruit fly which is being imposed by different importing countries for different fresh fruits and vegetables (Hasan et al., 2020). In addition, short hot water dips also known as blanching treatment usually employed as a postharvest treatment to deactivate enzyme activities, retain color, reduce disease incidence, decay, browning and stress-related problems such as alleviating chilling injury in different subtropical fruits and vegetables subjected to low temperature storage (Rehman et al., 2021). As earlier reported by Nasef (2018) that cucumber fruits treated with short hot water dips at 55 °C for 5 min significantly attenuate chilling injury by inducing cold stress tolerance by conserving a higher antioxidant system during storage at 4 °C for 21 days. Considering the existing research gap, the present study was aimed to evaluate the effect of blanching and different packaging materials on fresh spinach under cold storage conditions to extend its marketable green life and maintain quality.

MATERIALS AND METHODS

Plant source and treatments

The proposed study was carried out during 2018 at Postharvest Research and Training Centre, Institute of Horticultural Sciences, University of Agriculture, Faisalabad. The study was aimed to extend the marketable life and maintain the quality by different packaging material under cold storage. Fresh spinach cv. Desi was harvested at commercial maturity after 45 days of sowing from peri-urban farms in Faisalabad. Upon arrival at postharvest lab in 30 min, spinach leaves were sorted and fresh samples free from insect attack, blemish, or mechanical injury were cleaned with simple washing with tap water, followed by soft rinsing with distilled water, air-dried at ambient lab conditions (17 °C) for 30 min and then segregated for treatment application. Treatments were formed as control, blanching, MAP-1 (Xtend ®), MAP-2 (Bio-fresh®) and perforated polyethylene (PE) [9 holes on both sides × 5 kg each] bags replicated thrice. In addition, for blanching treatment, spinach leaves were dipped in water at 95-97 °C for 2-3 min (Monika, 2007), later the samples were cooled in the running water for about 2 min. Each replication consisted of 4 kg weight of fresh spinach. The control and blanched samples were placed in baskets and then transferred to cold storage at 4±1 °C with 90±5 % RH. Data loggers were placed in cold storage to record internal temperature and RH fluctuations. Samples were analyzed at the time of harvest and then at 3 days interval up to 20 days of storage.

Physical parameters

Visual quality was estimated by observing cleanliness, cosmetic look, color retention as per nine-point rating scale such as 9-excellent, 7-good, 5-fair, 3-poor and 1-extremly poor (Medina et al., 2012). Decay incidence in stored spinach was estimated by weighing the decayed leaves and subtracting from the total weight at each removal and expressed their results in percentage. At each removal after 3 days of storage, 15 leaves of each replicate treatment were selected and checked for the marketability index by counting the leaves of each treatment (Malik et al. 2021). Weight loss was calculated as the difference between initial (before storage) and final leaves weight (after storage) and was expressed as a percentage. Chlorophyll contents were estimated by using a digital SPAD meter**.** Ion leakage (%) of spinach leaves was determined by cutting 10 small pieces of leaves in 20 mL water. The initial reading was taken by putting ion leakage meter in the water. After 1 h, the final reading was noted again by putting ion leakage meter in water. Ion leakage (%) was calculated using the following formula as earlier stated by Ali et al. (2016).

$$\text{Ion Leakage (\%)} = \frac{(\text{Final reading} - \text{Initial reading})}{\text{Final reading}} \text{ x } 100$$

Biochemical parameters

Soluble solids content (SSC) of spinach juice was determined using digital refractometer RX 5000 (Atago, Japan). The instrument was calibrated with distilled water before and after use. Furthermore, titratable acidity (TA) was determined by using the titration method as described by Ali et al. (2019b). During this process, 10 mL of extracted juice was taken in 100 mL conical flask and diluted up to 50 mL with distilled water followed by adding 2-3 drops of phenolphthalein dye and finally titrated against 0.1 N NaOH solution. Similarly, ascorbic acid content was estimated from titration protocol during which 10 mL of extracted juice was added in 90 mL of 0.4% oxalic acid solution allowed to stay for 5 min followed by shaking well and filtered for aliquot, 5 mL aliquot in glass beaker was titrated against 2,6 dichlorophenolindophenol dye and stopped titration till the appearance of pink color and expressed as mg 100 g^{-1} FW (Malik et al., 2021). On the other hand, total antioxidants from spinach leaves were estimated by the protocol devised by Brand-Williams et al. (1995) and the value expressed and % inhibition activity.

Statistical analysis

The experiment was carried out under Completely Randomized

Design (CRD) with factorial arrangements and data were analyzed according to standard statistical technique using Statistic 8.1 software package. Means were compared by using the Least Significant Difference (LSD) test (Steel et al., 1997).

RESULTS AND DISCUSSION

Visual quality, decay incidence and marketability index

The visual quality of spinach was affected by packaging material and storage days which showed significant difference among treatments and storage period. The good visual quality was maintained in MAP-1 and MAP-2 packed spinach after 20 days of storage (Fig. 1a). Spinach leaves packed in perforated PE bags also showed a fair appearance which remains acceptable for consumers as compared to blanched and control samples rated poor to extremely poor quality which became unacceptable for consumers (Fig. 1a). Our results support the findings of Allende (2004), who stated that MA packaging has a significant role in maintaining the visual quality of spinach during storage. Likewise, the litchi fruits stored in MAP-1 bags significantly retained their freshness, delayed pericarp browning, maintained eating quality and conserved higher antioxidant compounds during storage (Ali et al., 2019a).

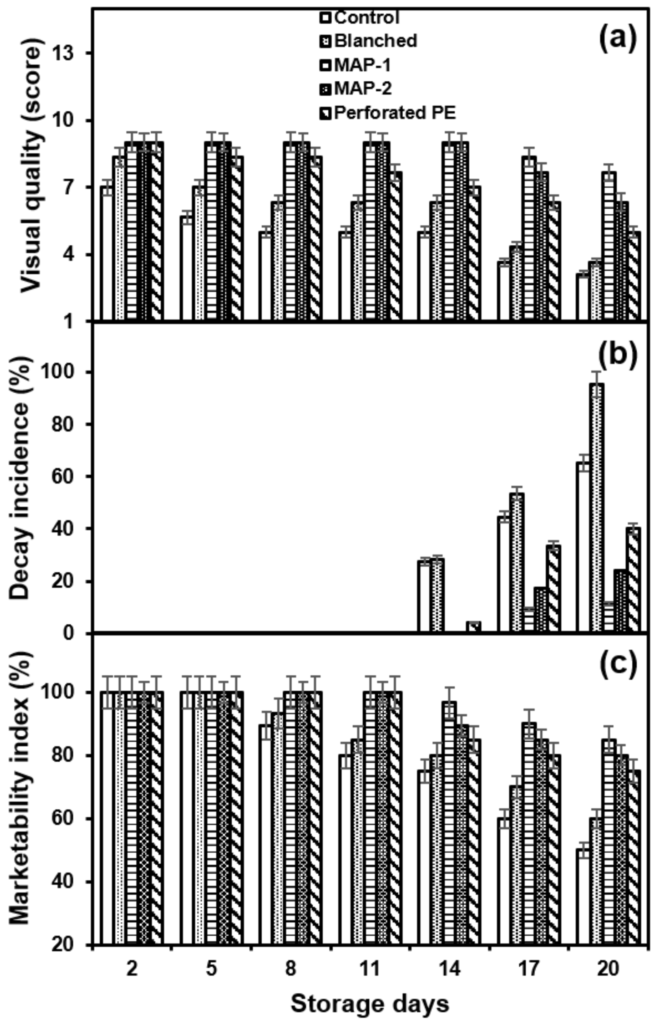

Figure 1: Effect of blanching and packaging materials on visual quality (A), decay incidence (B) and marketability index (C) of fresh spinach during cold storage at 4±1 °C and 90±5 % RH. Vertical bars represent standard error of means (±SE). Invisible bars showed negligible differences.

The results about the decay percentage of spinach as influenced by packaging material and storage days are given in Fig. 1b. No significant decay incidence was observed in stored spinach leaves till 11 days of storage. The mean for decay percentage was lower for MAP-1 and MAP-2 while a higher mean (65.15%) was noted in control samples after 20 days of storage. In addition, the blanching treatment contributed higher decay percentage (>80%) at the end of storage after 20 days. As earlier reported by Piagentini (2002) who stated that plastic film packaging has a significant role in reducing the decay percentage of spinach during storage. On the other hand, the marketability index is prime parameter in the eye of the consumer and gave a perception of market acceptability of produce (Hasan et al., 2020). The results about marketability for spinach treated with blanching and MA packaging are given in Fig. 1c. Interaction between treatments and storage days also showed highly significant differences ($P≤0.01$) regarding the marketable percentage of spinach. Results revealed that spinach leaves packed in MAP-1 packaging showed a higher marketability index than those samples subjected to blanching and control treatment. Grozeff (2010) stated that packaging material has a significant role in maintaining marketable percentage of spinach during storage.

Weight loss, ion leakage and chlorophyll contents (SPAD value)

As far as weight loss is concerned, spinach exhibited gradual moisture loss during the entire period of storage irrespective of treatments. Interaction between treatments and storage period showed a highly significant difference ($P≤0.01$) regarding the weight loss of spinach. At last removal from storage after 20 days, weight loss was 28.6 and 9.5-fold lower for spinach leaves packed in MAP-1 and MAP-2 bags as compared to control, respectively (Fig. 2a). Untreated control spinach leaves showed higher moisture loss (39.53%) after 20 days of storage. Moisture loss in leafy green vegetables is an extremely important factor that decides its marketability and shelf life. Our results for weight loss in spinach confirm the findings of Batziakas et al. (2020) who stated that MA packaging significantly conserved moisture contents and maintained the overall quality of spinach leaves during storage. Regarding relative ion leakage, the analysis of variance for treatments showed non-significant differences and storage days showed a highly significant difference ($P≤0.01$). Nevertheless, the spinach leaves packed inside MAP-1 showed relatively lower electrolyte leakage as compared to other treatments during storage (Fig. 2b). Results revealed that chlorophyll contents were maintained during the entire period of storage. Spinach leaves packed in MAP-1, MAP-2, and perforated PE bags markedly preserved chlorophyll contents throughout the storage period. The presence of chlorophyll contents exhibited green color pigments, which degraded with the passage of time due to oxidative stress (Hasan et al., 2021). MA packaging has been reported for retaining higher chlorophyll contents of spinach leaves during storage as

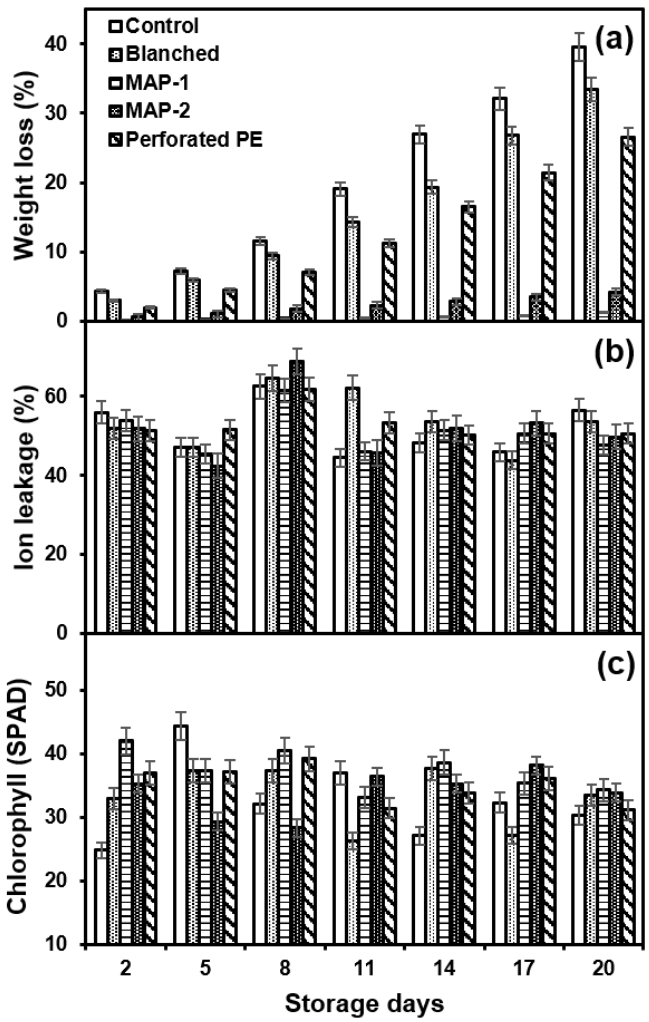

Figure 2: Effect of blanching and packaging materials on weight loss (A), ion leakage (B) and chlorophyll (C) of fresh spinach during cold storage at 4±1 °C and 90±5 % RH. Vertical bars represent standard error of means (±SE). Invisible bars showed negligible differences.

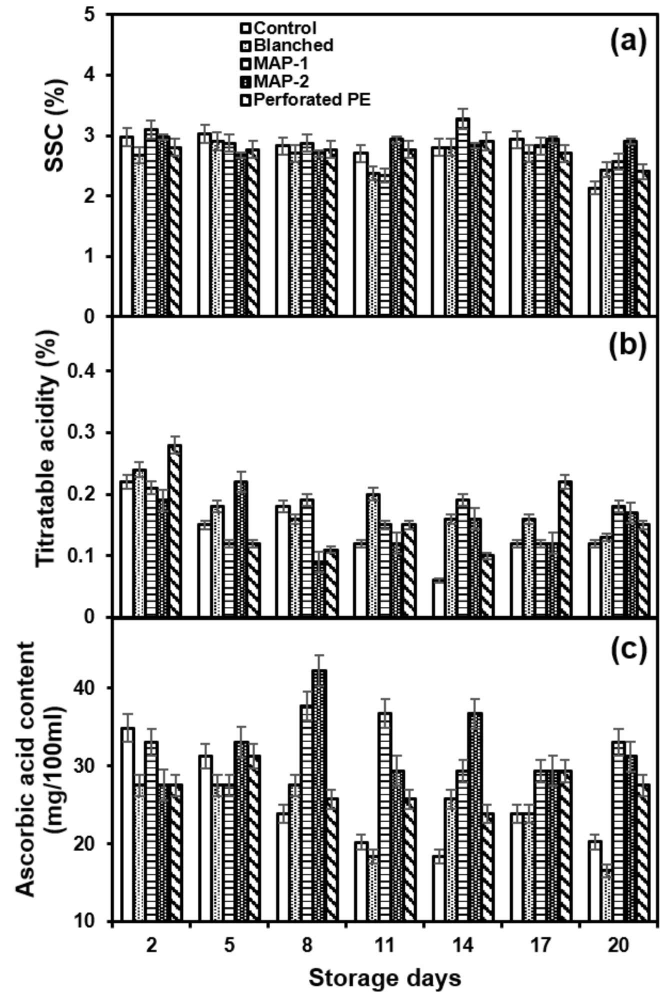

Figure 3: Effect of blanching and packaging materials on soluble solids content (A), titratable acidity (B) and ascorbic acid content (C) of fresh spinach during cold storage at 4±1 °C and 90±5 % RH. Vertical bars represent standard error of means (±SE). Invisible bars showed negligible differences.

compared to non-MAP commercial bags (Batziakas et al., 2020).

Soluble solids content, titratable acidity, and ascorbic acid content

Among biochemical attributes, results for SSC and TA showed non-significant differences. However, SSC was observed slightly higher in spinach packed in MAP-2 bags as compared to MAP-1, polyethylene PE and untreated control at the end of the storage period after 20 days (Fig. 3a). Likewise, after 20 days, TA was slightly increased for spinach samples packed in all the types of packaging materials as compared to control and blanched samples (Fig. 3b). As expected, the ascorbic acid content in spinach leaves was determined higher in packaging during cold storage period. After 20 days of storage, spinach leaves packed in MAP-1, MAP-2 and perforated PE bags significantly retained higher ascorbic acid content as compared to control. However, the blanching treatment markedly reduced the conservation of ascorbic acid content even lower than control group during the entire period of storage (Fig. 3c). Ascorbic acid content is one of the bioactive compounds that possess antioxidant capacity, and its higher amount provides tolerance to plants against oxidative stress. Dewhirst (2017) studied that film packaging was significantly proven in maintaining higher ascorbic acid content of spinach during storage.

2,2-diphenyl-1-picrylhydrazyl- radical scavenging activity

Total antioxidants were estimated in terms of DPPH radical scavenging activity from spinach leaves progressively decreased along the storage period, irrespective of treatments. However, the spinach packed in MAP-1, MAP-2 and perforated PE bags showed higher antioxidant capacity during storage. At 20 days of storage, MAP-1 retained 1.78-fold higher antioxidants as compared to untreated control (Fig. 4). Oxidative damage might be possibly reduced with the conservation of higher antioxidant

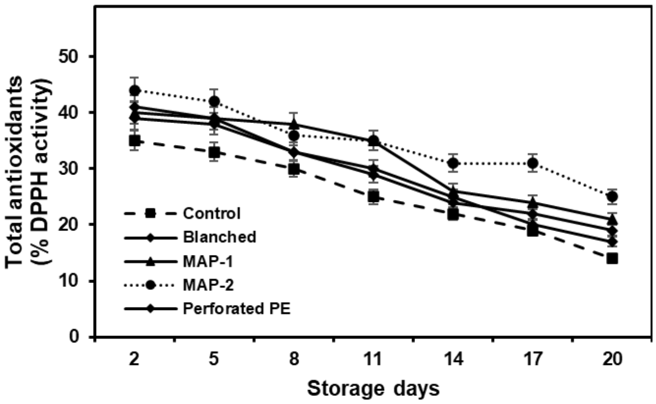

Figure 4: Effect of blanching and packaging materials on total antioxidants (% DPPH radical scavenging activity) of fresh spinach during cold storage at 4±1 °C and 90±5 % RH. Vertical bars represent standard error of means (±SE).

activities during storage (Hasan et al., 2021). Earlier, it has been reported that MAP coupled with low temperature storage significantly displayed higher antioxidants in spinach during storage by altering atmospheric gases inside (Mudau et al., 2018). Similar results for conserving antioxidants have been reported for litchi (Ali et al., 2019a), pomegranate arils (Mphahlele et al., 2016) and sweet cherries (Wang et al., 2015) during storage.

CONCLUSION

In conclusion, MAP-1 (Xtend®) outclassed other packaging types and blanching treatment in maintaining freshness for 20 days cold storage conditions. MAP-1 and MAP-2 significantly showed better external appearance as compared to control and blanching treatment which displayed extremely poor quality. MAP storage of spinach leaves reduced moisture loss, decay, electrolyte leakage, preserved higher chlorophyll, ascorbic acid content and total antioxidants in terms of % DPPH scavenging activity with advanced marketability index for 20 days during cold storage.

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DECLARATION OF COMPETING INTERESTS

All authors declare no conflict of interest for this publication.

AUTHOR CONTRIBUTION STATEMENT

Waseem Siddique: Conceptualized idea, designed and conducted this research work, and collected data. **Mahmood Ul Hasan:** Conceptualized idea, designed and conducted this research work, and collected data. **Muhammad Suliman Shah:** Assisted in methodology, validation, editing, reviewing. **Muhammad Moaaz Ali:** Performed formal analysis, software analysis; **Faisal Hayat:** Editing, reviewing, and improving of the manuscript. **Asaad Mehmood:** Assisted in methodology, validation, editing, reviewing.

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