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POSTHARVEST QUALITY AND SHELF LIFE OF FRESH-CUT FENUGREEK (*TRIGONELLA FOENUM-GRAECUM* L.) LEAVES: IMPACT OF PACKAGING AND *ALOE VERA* GEL COATING

Nagarajan Srividya[*1] and Manjula D. Ghoora[1]

[1*]Department of Food and Nutritional Sciences, Sri Sathya Sai Institute of Higher Learning (Deemed to be University), Anantapur, Andhra Pradesh, India.

ABSTRACT

The effects of packaging and edible coating on the postharvest quality and shelf life of fresh-cut fenugreek leaves (FCFL) were investigated. The FCFL packed in macro perforated LDPE bags (single packaging) were used as control (SP C). One set of bagged samples were repacked in polypropylene containers to study the effect of double packaging (DP C). To ascertain the impact of edible coating, 50% *Aloe vera* gel (AG) was used (SP AG and DP AG). All the four samples were stored at 10 ± 1 ºC. Significantly lower weight loss (PLW), higher moisture content and sensory quality were observed in DP C FCFL compared to SP C ($P < 0.001$). However, DP did not help to reduce the respiration rate (RR), colour change and decay percentage. The AG coating showed significantly lower PLW, RR, decay percentage with higher moisture content, better sensory quality and greener colour compared to uncoated samples ($P < 0.001$). Highest postharvest quality and shelf life (18 d) was observed in DP AG, followed by SP AG (14 d), DP C (9 d) and SP C (6 d).

KEYWORDS

Fresh-cut fenugreek leaves, Edible coating, *Aloe vera*, Packaging and Shelf life.

Author for Correspondence:

Nagarajan Srividya,
Department of Food and Nutritional Sciences,
Sri Sathya Sai Institute of Higher Learning
(Deemed to be University),
Anantapur, Andhra Pradesh, India.

Email: nsrividya@sssihl.edu.in

INTRODUCTION

Management of the postharvest quality of fresh-cut vegetables in developing countries like India remains a challenge due to rapid deterioration during handling and inadequate transport and storage facilities. Fresh-cut leaves are very much susceptible to high rates of respiration, transpiration and risks of enzymatic and microbial deterioration[1], all contributing to substantial reduction in the shelf-life. A number of techniques have previously been experimented and some of them did show beneficial

effects on the quality characteristics and shelf-life of fresh-cut greens such as the use of packaging[2-4], light treatments[5-6] and chemical treatments[7-9]. However, the actual need in the developing countries is for low cost, safe and technologically viable method which offers the possibility to scale up in the long run.

In this regard, edible coating shows considerable promise. Edible coating refers to thin layer of material that can be applied on whole or fresh-cut surfaces to enhance their postharvest quality and shelf-life and at the same time it can be safely consumed with the commodity[10-11]. It utilizes a simple and environmental friendly technology to improve appearance, retard colour changes and reduce water loss and decay of fruits and vegetables[12-14]. Recently, there has been interest in *Aloe vera* gel as edible coating and several studies have reported its use on fruits to prevent moisture loss, control respiration, delay oxidative browning and reduce microbial proliferation[15-18]. However, to the best of our knowledge, there is no reported work on the use of *Aloe vera* gel as an edible coating on green leafy vegetables (GLVs). Investigating the effects of this coating on the postharvest quality and shelf life of such a highly perishable commodity would be of great utility.

Alongside with new technologies, earlier methods of preservation, such as the packaging technology, are equally important. The beneficial effects of modified atmospheric packaging have been well documented[19-22]. Permeable polymeric bags have been quite useful in extending the shelf life of fresh-cut greens[8] by modifying the atmosphere due to respiratory oxygen uptake and carbon dioxide output. Packaging technique used at the appropriate storage temperature can substantially help to reduce microbial growth, weight loss, and retard or reduce other physico-chemical changes in fresh-cut commodities.

One of the GLVs popularly consumed and commonly available in India is fenugreek greens (*Trigonella foenum-graecum* L.). Fenugreek is a trifoliate leafy vegetable belonging to the Fabaceae family and is widely cultivated in the semi-arid regions of India, Mediterranean regions, North Africa and Europe.

The present study thus aims at determining the effects of packaging and aloe gel as an edible coating on the postharvest quality and shelf life of fresh-cut fenugreek leaves.

MATERIAL AND METHODS

Sample preparation

Fenugreek greens were grown in the local garden of University Campus at Anantapur, India and harvested manually when fully grown, during the early hours of the day. The bundles were transported to the laboratory quickly, the roots were separated from the plantlets, any damaged tissues were removed and tender stalks and leaves were separated out from the main stem. The fresh-cut fenugreek leaves (FCFL) were cleaned of any contaminating soil particles using a clean dry blotting paper.

Coating treatment and experimental design

The FCFL were dipped in *Aloe vera* gel (AG) solution (50 % v/v) and soaked for 5 minutes. The soak solution was prepared by removing the outer cuticle from medium sized *Aloe vera* leaves, grinding the inner fillets, filtering the extract and diluting it with potable water in a ratio of 1:1. The control (C) was treated in a similar manner in potable water for same length of time. Both the AG coated and C samples were fan-dried for 15 minutes without allowing withering to take place. They were then packaged separately in bundles of 20 g in 5 x 6 inches macro perforated (4 holes 4.5 mm diameter) resealable LDPE bags (Single packaging - SP) and stored at 10 ± 1°C and relative humidity of 55 ± 5 %. Concomitantly, few single packed bags were repacked in polypropylene containers resulting in double packaging (DP) with a relative humidity of 75 ± 5 %. Thus, the resulting four sets of samples were SP C, SP AG, DP C and DP AG.

Physiological loss in weight

Weight loss was determined by weighing the bagged samples at the beginning of the storage period and every two days for a period of 14 days. Three replicates of each treatment were selected for evaluation on every sampling day (day 0, 2, 4, 6, 8, 10, 12 and 14). The results were expressed as percentage of weight loss relative to the initial fresh weight.

Moisture content

The moisture content of the FCFL was determined as per the AOAC official method (925.10)[23] every 7 days of the storage period (day 0, 7 and 14). Leaves were dried in a hot air oven at 100 ± 2 °C until consistent weight and difference in fresh and dry weights were used to calculate the moisture content. Readings were taken in triplicates.

Instrumental colour

The superficial colour of the FCFL samples was measured using a digital colour reader (Konica Minolta CR-10). Leaves were detached from the stems and placed into a 3-inch diameter Petri plate until filled completely. The reflectance spectra as determined by the *a** and *b** colour coordinates were measured at 3 different points on the adaxial surface of the leaves and the respective means were calculated. When positive, *a** stands for red and *b** for yellow while when negative, *a** denotes green and *b** blue.

Respiration rate

The respiration rate of the packaged greens was estimated periodically in a closed jar system. Sampling of the headspace O_2 and CO_2 gases was done on day 0, 4, 8, 12 and 14 using a gas analyzer (PBI Dansensor gas analyzer, Checkmate II, Denmark). Bagged samples (20 g) were placed individually in 470 ml PET jar for 30 min and incubated at storage temperature (10°C). Gas samples were taken by inserting a needle connected to the gas analyzer into a septum fixed on the lid of the jar. Readings taken in triplicates as percentage CO_2 evolved were averaged and expressed as ml $CO_2\ kg^{-1}\ h^{-1}$.

Decay percentage

The decay percentage of the FCFL was monitored every 5 days for a period of 30 days and was estimated macroscopically as the number of leaves decayed to the total number of leaves in the bagged sample.

Sensory evaluation

Fresh-cut fenugreek leaves were assessed on day 0, day 5, day 10 and day 14 for their freshness, colour, wilting, odour and tenderness over the storage period. Leaf samples were evaluated immediately after being withdrawn from the pouches and low temperature was maintained throughout the evaluation session. The samples were labeled with a random 2-digit number and were served to the panel members in a random order. Panelists consisting of 10 members from a semi-trained panel, selected on basis of their interest, time availability and familiarity with the scoring system. The panelists were apprised of the different quality parameters before the evaluation and were asked to rate the attributes using a five-point rating scale. Freshness was defined as having a fresh-cut appearance where a score of 5 = high, 3 = moderate and 1 = low. The colour of the adaxial surface of the leaves was assessed based on the degree of greenness of the leaves, where 5 = dark green, 3 = green and 1 = light green with noticeable yellowing of leaves. Wilting was evaluated as the degree of shrinkage of the leaves where 5 = no wilting, 3= acceptable wilting and 1 = severe wilting. Typical aroma, defined as the characteristic leafy smell of fenugreek was evaluated by smelling the displayed sample at a close proximity where a rating of 5 = maximum aroma, 3 = moderate aroma and 1 = no aroma. Tenderness was examined by the ease of tearing the leaves where 5 = high tenderness, 3 = moderate tenderness and 1 = low tenderness.

Shelf life determination

Shelf life of the FCFL under the various treatments was determined visually as well as on a quantitative basis. Shelf life was defined as the time until the first obvious signs of deterioration make the leaves unmarketable. It was judged by three deterioration factors - wilting, yellowing and decay. The percentage of leaves undergoing these processes over the total number of leaves was recorded and used to estimate the shelf life.

Statistical Analysis

Data were expressed as mean of three replicates along with standard deviation bars. One-way ANOVA was used to analyze the results based on three factors (Packaging, aloe gel coating and storage period) using the statistical software, IBL SPSS Statistics 21. The mean values were compared using the least significant difference test at a significance level of 0.05.

RESULTS AND DISCUSSION

Physiological loss in weight (PLW)

Weight loss in the FCFL of the different treatments ranged from 1.17 to 9.48 % at the end of 14 days (Figure No.1a). Highest PLW (9.48 %) was observed in SP C at the end of the storage period. Similar weight loss was observed in fresh-cut sweet leaf bush during storage by Supapvanich and others[9]. The fresh weight loss resulted primarily from transpiration which is due to the vapour pressure difference between the leaves surface and the surrounding atmosphere. The double packaging system brought a significant decrease ($P < 0.001$) in the weight loss during storage (uncoated - 1.53 % and AG coated - 1.17 % on day 14) probably because of a considerable rise in the relative humidity (RH) of the system thus reducing the water vapour pressure gradient between the leaves and atmosphere. Edible coating is generally known to act as a semipermeable barrier to gases and water vapour aiding in reducing water loss[24]. Coating of the fenugreek leaves with *Aloe vera* gel acted as a barrier to moisture loss and significantly reduced the PLW to 7.44 % ($P < 0.001$) under single packaging condition (SP AG).

Moisture content

The initial moisture content of the FCFL (92.5 %) decreased to various extents in all the treatments over the storage period (Figure No.1b). At the end of 14 days, a maximum reduction of 3.4 % was noted in SP C condition ($P < 0.001$) while in DP C, the reduction was 1.9 %. The double packaging minimized the moisture loss from the leaves. However, the *Aloe vera* gel treatment was as effective as an extra packaging in reducing the moisture content of the FCFL. The SP AG samples recorded a decrease of 1.7 % in the moisture content while DP AG had a reduction of 1.2 %.

Instrumental color

The change in colour of the FCFL expressed by the colour coordinates *a** (greenness) and *b** (yellowness) is represented in Figure No.1c and 1d. The end of the storage period was marked by a significant decrease in the *a** coordinate ($P < 0.001$) and concomitant increase in the *b** coordinate ($P < 0.001$) in SP C. This trend is mostly associated with the senescence process which causes degradation of the dominant chlorophyll pigment[25] thereby unmasking the carotenoids. The greatest reduction in -*a** value (29 %) was noted in SP C from 12.3 to 8.7 ($P < 0.001$). DP C as well recorded a significant decrease ($P < 0.001$) of 12 % (13.5 to 12.7) in the same parameter at the end of 14 days. However, with respect to the AG coated samples, no significant change ($P > 0.05$) was noted in -*a** value at the end of the storage period (SP AG: 12.66 to 12.63; DP AG: 13.36 to 14.06). This reflects the colour retention property of the *Aloe vera* gel coating as reported by previous studies[26-27]. The *b** coordinate (yellowness) increased over the storage period which coincides with a visual change in the superficial colour of the leaves from green to yellow. Maximum *b** value was recorded in the SP C condition representing a 52 % increase from 20.6 to 43.3 ($P < 0.001$). The DP C treatment recorded an increase in the yellowness value (*b**) from 22.3 to 40.6 while for SP AG, the increase was from 19.5 to 37.2. Lowest increase (35 %) in the *b** coordinate was recorded in the DP AG treatment from 19.5 to 30.3 which is probably due to the interactive effects of both techniques of preservation.

Respiration rate (RR)

The initial RR determined by the rate of CO_2 evolved (Figure No.1e) was found to be higher in the uncoated samples under both SP and DP conditions (SP C - 20.1 ml CO_2 kg^{-1} h^{-1}; DP C - 21.1 ml CO_2 kg^{-1} h^{-1}) while the AG coated samples of both packaging types recorded a significantly lower ($P < 0.001$) initial RR of 15.7 ml CO_2 kg^{-1} h^{-1}. This observation is in line with that reported by Martinez-Romero *et al.* (2006) who noted lower respiration rates in aloe treated produce. There was a conspicuous decrease in the RR of all the samples throughout the storage period by 59 %, 66 %, 54 % and 57 % in the SP C, SP AG, DP C and DP AG treatments respectively. The lowest RR was found in the SP AG treated samples with a value of 5.2 ml CO_2 kg^{-1} h^{-1}. A sudden increase in the RR was observed in the DP C condition on day 8. Double packaging maintained higher RR at the end of the storage period in both the coated and uncoated samples with values of 9.5 and 6.7 ml CO_2 kg^{-1} h^{-1}, respectively. This is probably

due to the tissue remaining more active due to the atmosphere prevailing inside the double packaging.

Decay percentage

The decay percentage of the FCFL has been represented graphically in Figure No.1f. With increasing storage period, there was an increase in the percentage decay. The uncoated (SP C & DP C) samples were found to undergo decay (day 10) much before the AG coated samples (day 15). Hundred per cent decay of both uncoated single and double packaging systems was observed after 30 days. Conversely, the coated leaves had only 65 % and 50 % of decay for the SP AG and DP AG treatments, suggesting bio-preservative functions of the *Aloe vera* gel as an edible coating[26].

Sensory quality

The sensory quality of the FCFL was evaluated by the following parameters - freshness, colour, wilting, aroma and tenderness and is represented in the web plot diagrams (Figure No.2). The initial mean sensory scores of the fresh-cut leaves were 4.7, 4.5, 4.7, 4.3 and 4.5 on a five point rating scale for freshness, colour, wilting, aroma and tenderness respectively. A decrease in the quality of the sensory attributes takes place over the storage period as senescence of the leaves begins. After 14 days of storage, SP C had lost maximum of its sensory properties with scores of 1.8 - freshness, 2.0 - colour, 2.4 - wilting, 1.6 - aroma and 1.9 - tenderness. Maximum retention of the sensory quality was observed in the DP AG treatment with final scores of 4.2 - freshness, 4.1 - colour, 4.2 - wilting, 3.9 - aroma and 4.0 - tenderness. The SP AG treatment sensory scores (3.3 - freshness, 3.4 - colour, 3.3 - wilting, 3.1 - aroma and 3.0 - tenderness) and that of DP C (3.0 - freshness, 3.2 - colour, 3.2 - wilting, 3.0 - aroma and 3.5 - tenderness) at the end of 14 days were not significantly different ($P > 0.05$), but both had better sensory quality with respect to SP C.

Shelf life

Based on the postharvest quality changes which occurred in the fresh-cut leaves subjected to different treatments, the shelf life of the FCFL was estimated. The shelf life of SP C samples was found to be 6 days only. Double packaging could only partially help in extending the shelf life of the fresh-cut leaves (9 days). This was mainly due to higher degree of condensation leading to faster decay. However, when *Aloe vera* gel coating was used instead of DP, the shelf life was extended by an additional week under single packaging and thus SP AG was found to have a shelf life of 14 days. In DP AG samples due to positive interactive effects of Aloe gel coating and packaging, the shelf-life of the fresh cut fenugreek leaves was found to be highest (18 days).

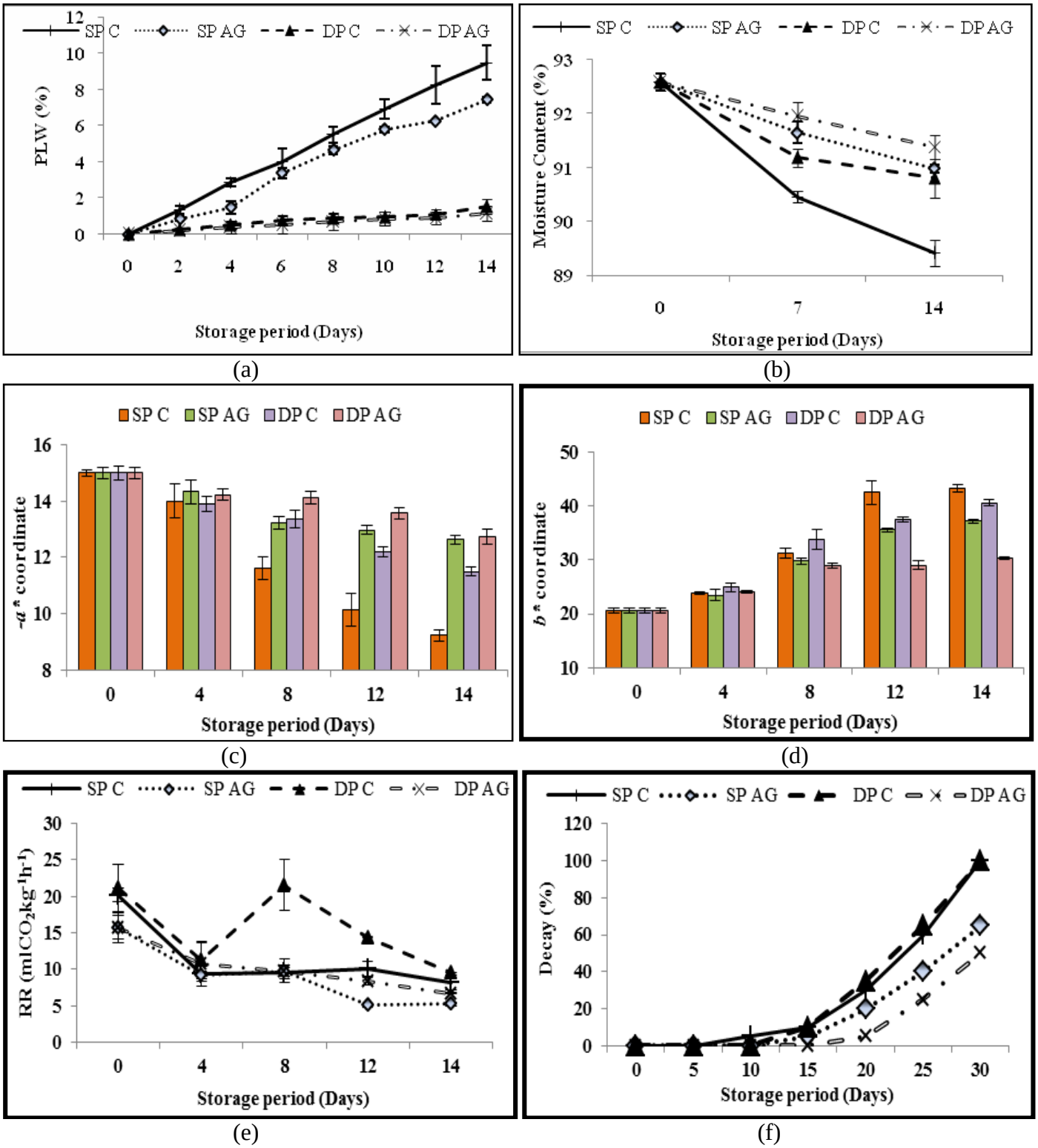

Figure No.1: Effect of packaging and *Aloe vera* gel coating on the (a) physiological loss in weight (PLW) (%), (b) moisture content (%), (c) -*a coordinate, (d) *b** coordinate, (e) respiration rate (RR) (ml CO_2 kg^{-1} h^{-1}), (f) decay (%) of fresh-cut fenugreek leaves [SP C - single packaging control; SP AG - single packaging aloe gel coated; DP C - double packaging control; DP AG - double packaging aloe gel coated] (n=3)**

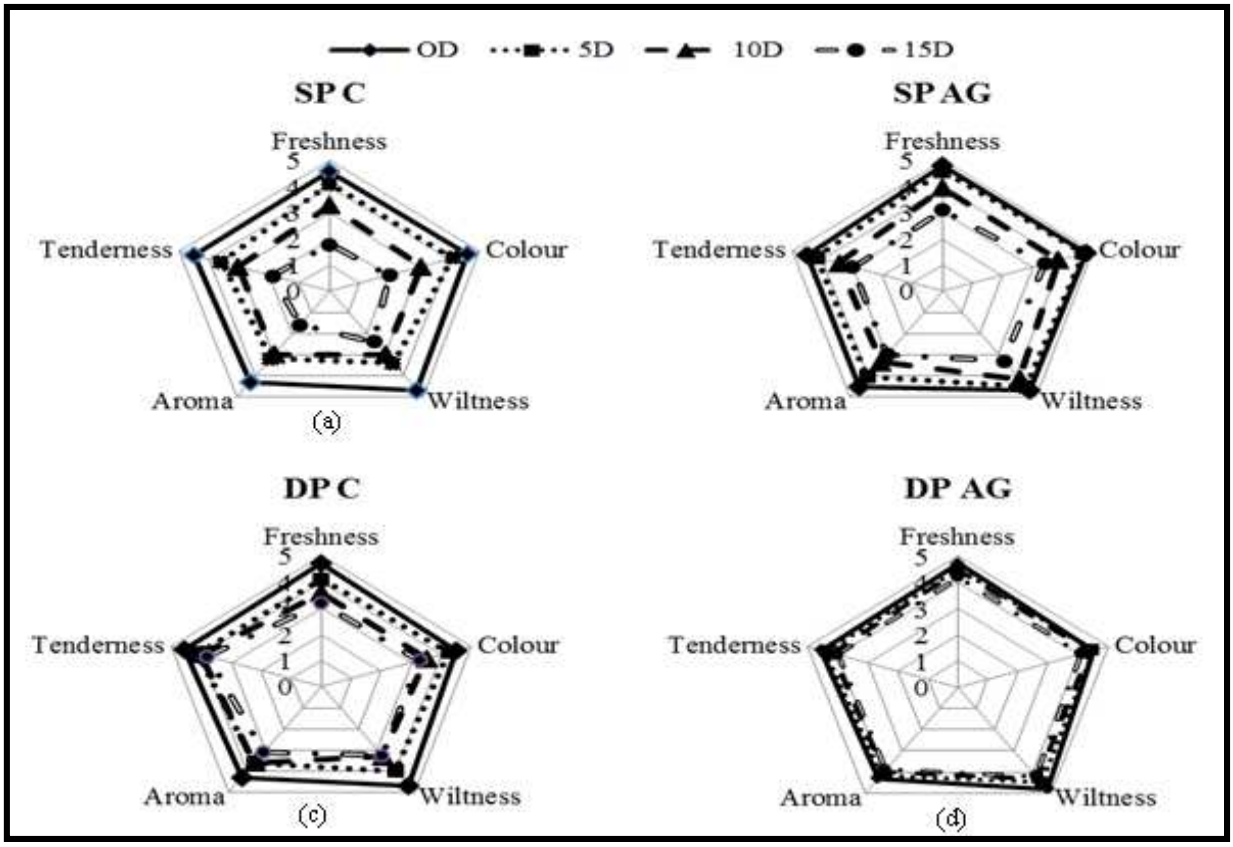

Figure No.2: Effect of packaging and *Aloe vera* gel coating on the sensory quality of fresh-cut fenugreek leaves (a) SP C - single packaging control, (b) SP AG - single packaging aloe gel coated, (c) DP C - double packaging control and (d) DP AG - double packaging aloe gel coated] (n=3)

CONCLUSION

The present study has demonstrated edible coating using *Aloe vera* gel as a novel and safe technique to enhance the postharvest quality and shelf life of fresh-cut green leafy vegetables. The present study was designed to reproduce the market scenario using temperatures (~10°C) generally encountered during transportation and retail distribution to be able to determine the utility of this new technique. Its effects with single packaging were more effective than double packaging system with synergistic effects obtained when both coating and double packaging were used. It can be inferred that *Aloe vera* gel can be an economical alternative to the double packaging system, which involves extra costs and storage space. As an edible coating, *Aloe vera*, with wide accessibility and multifold functions could be utilized as an eco-friendly preservation technique for other green leafy vegetables.

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CONFLICT OF INTEREST

We declare that we have no conflict of interest.

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