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MICROBIOLOGICAL QUALITY ASSESSMENT OF WHOLE AND MP PRODUCTS OF FRUITS AND VEGETABLES BY ACTIVE PACKAGING

8.1 INTRODUCTION

Fresh fruits and vegetables are perceived by consumers to be healthful and nutritious foods. Microbial safety is one of the most important factors to be considered for the preservation of minimally processed foods and the microbial evaluation was done to make the present findings a wholesome one in order to know microbiological load in MP fruits and vegetables as they are highly susceptible to microbial contamination during processing operations. The microflora of fruits and vegetables and their processed products differ depending on their pH. Vegetables are usually contaminated by less-acid tolerant organisms, while fruits are contaminated by more acid-tolerant bacteria and fungi. In this chapter total bacterial counts (TBC) and yeast and mould counts are discussed for minimally processed as well as fresh fruits and vegetables at refrigeration (5±1°C) and ambient temperatures (25±5°C).

8.2 RESULTS AND DISCUSSION

8.2.1 Effect of Active Packaging concepts on the microbiological changes in fruits and vegetables

8.2.1.1 Total bacterial count (TBC) and Yeast and mould count

Results regarding TBC and yeast and mould counts for MP and whole fruits and vegetables are presented in Table 8.1 to 8.12 as given in appendices and the observations with respect to TBC and yeast and mould counts for MP produces are presented in Figs. 8.1(a, b,c,d,e,f) and Figs. 8.2(a,b,c,d,e,f), respectively. Whereas, observations regarding TBC values for whole fruits (apple, banana and orange) are presented in Figs.8.3 (a,b,c,d,e,f) at RT and AT. Figs. 8.4(a,b,c,d,e,f) represent the TBC in vegetables (tomato, cauliflower, spinach) at RT and AT. Observations regarding yeast and mould counts for fruits at RT and AT are given in Figs. 8.5(a,b,c,d,e,f) and Figs. 8.6(a,b,c,d,e,f) exhibit the yeast and mould counts for vegetables at RT and AT.

The initial bacterial and yeast and mould counts for MP apple (2.0 and 1.67 cfu/ml), banana (2.0 and 1.0 cfu/ml), orange (1.67 and 1.0 cfu/ml), tomato (2.33 and 1.33 cfu/ml), cauliflower (2.67 and 1.0 cfu/ml) and spinach (2.0 and 1.33 cfu/ml), respectively.
Fig. 8.1(a) and Table 8.1 represent the observations regarding TBC in MP apple and lowest (6.67 cfu/ml) value of TBC was found in chitosan coated samples followed by samples treated with moisture scavenger (8.33 cfu/ml), ethylene scavenger (8.67 cfu/ml), O₂ scavenger (9.33 cfu/ml), CO₂ scavenger (9.67 cfu/ml) and recorded maximum (10.67 cfu/ml) in control samples at 15th day of storage. AP treatments except CO₂ and O₂ scavenger significantly (p<0.05) reduce the increase in TBC count.

Fig. 8.1(a): Effect of active packaging on TBC (cfu/ml) of MP apple

Fig. 8.1(b) and Table 8.1 depict the observations regarding TBC in MP banana and minimum and similar (5.33 cfu/ml) TBC values were observed in chitosan coated and samples treated with moisture scavenger (5.33 cfu/ml) followed by ethylene and O₂ scavenger (7.33 cfu/ml), CO₂ scavenger (8.67 cfu/ml) and recorded maximum (12.0 cfu/ml) in control samples at 15th day of storage. AP treatments significantly (p<0.05) reduce the increase in TBC count.

Fig. 8.1(b): Effect of active packaging on TBC (cfu/ml) of MP banana

Fig. 8.1(c) and Table 8.1 exhibit the observations regarding TBC value in MP orange and minimum (8.0 cfu/ml) was observed in chitosan coated samples followed by samples treated with moisture scavenger (10.67 cfu/ml) whereas ethylene and O₂ scavengers possessed similar (12.0 cfu/ml) value, CO₂ scavenger (13.33 cfu/ml) and control samples recorded maximum (15.33 cfu/ml) at 15th day of storage. AP treatments except CO₂ scavenger significantly (p<0.05) reduce the increase in TBC value.

Fig. 8.1(c): Effect of active packaging on TBC (cfu/ml) of MP orange
Fig. 8.1(d) and Table 8.2 represent the observations regarding TBC value in MP tomato and minimum (7.67 cfu/ml) was observed in chitosan coated samples followed by samples treated with moisture scavenger (9.33 cfu/ml), ethylene scavenger (10.33 cfu/ml) and O₂ scavenger (11.0 cfu/ml), CO₂ scavenger (11.33 cfu/ml) and recorded maximum (18.0 cfu/ml) in control samples at 15ᵗʰ day of storage. AP treatments significantly (p<0.05) reduce the increase in TBC value.

Fig. 8.1(d): Effect of active packaging on TBC (cfu/ml) of MP tomato

Fig. 8.1(e) and Table 8.2 express the observations regarding TBC value in MP cauliflower and minimum (5.67 cfu/ml) was observed in chitosan coated samples followed by samples treated with moisture scavenger (6.67 cfu/ml), samples treated with ethylene and O₂ scavenger exhibited similar (7.0 cfu/ml) values, CO₂ scavenger (8.33 cfu/ml) and maximum counts were recorded (10.33 cfu/ml) in control samples at 15ᵗʰ day of storage. AP treatments significantly (p<0.05) reduce the increase in TBC value.

Fig. 8.1(e): Effect of active packaging on TBC (cfu/ml) of MP cauliflower

Fig. 8.1(f) and Table 8.2 depict the observations regarding TBC value in MP spinach and minimum (5.33 cfu/ml) was observed in chitosan coated samples followed by samples treated with moisture scavenger (6.67 cfu/ml), ethylene scavenger (7.0 cfu/ml) O₂ scavenger (7.67 cfu/ml), CO₂ scavenger (8.33 cfu/ml) and recorded maximum (11.0 cfu/ml) in control samples at 15ᵗʰ day of storage. AP treatments significantly (p<0.05) reduce the increase in TBC value.

Fig. 8.1(f): Effect of active packaging on TBC (cfu/ml) of MP spinach
Fig. 8.2(a) and Table 8.3 exhibit the observations regarding yeast and mould counts in MP apple and minimum (3.33 cfu/ml) counts were observed in chitosan coated samples followed by samples treated with moisture scavenger (4.67 cfu/ml), ethylene scavenger (5.0 cfu/ml) and O₂ scavenger (5.33 cfu/ml), CO₂ scavenger (6.0 cfu/ml) and maximum was recorded (7.33 cfu/ml) in control samples at 15th day of storage. AP treatments except CO₂ scavenger significantly (p<0.05) reduce the increase in yeast and mould counts.

Fig. 8.2(a): Effect of active packaging on Yeast & Mould (cfu/ml) of MP apple

Fig. 8.2 (b) and Table 8.3 represent the observations regarding yeast and mould counts in MP banana. Minimum (3.0 cfu/ml) counts was observed in chitosan coated samples followed by samples treated with ethylene and moisture scavengers recorded similar (3.67 cfu/ml) counts, O₂ scavenger (4.0 cfu/ml), CO₂ scavenger (5.0 cfu/ml) and recorded maximum (5.67 cfu/ml) in control samples at 15th day of storage. AP treatments except CO₂ scavenger significantly (p<0.05) reduce the increase in yeast and mould counts.

Fig. 8.2(b): Effect of active packaging on Yeast & Mould (cfu/ml) of MP banana

Fig. 8.2(c) and Table 8.3 depict the observations regarding yeast and mould counts in MP orange and minimum (3.67 cfu/ml) counts was observed in chitosan coated samples followed by samples treated with moisture and ethylene scavengers recorded identical (6.0 cfu/ml) value, O₂ scavenger (6.33 cfu/ml), CO₂ scavenger (7.0 cfu/ml) and maximum (8.0 cfu/ml) was observed in control samples at 15th day of storage. Chitosan coating treatment significantly (p<0.05) reduce the increase in yeast and mould counts.

Fig. 8.2(c): Effect of active packaging on Yeast & Mould (cfu/ml) of MP orange
Fig. 8.2(d) and Table 8.4 exhibit the observations regarding yeast and mould counts in MP tomato and minimum counts was observed in chitosan coated samples (4.67 cfu/ml) followed by samples treated with moisture scavenger (5.67 cfu/ml), ethylene scavenger (6.33 cfu/ml), O₂ scavenger (7.0 cfu/ml), CO₂ scavenger (8.0 cfu/ml) and recorded maximum (9.0 cfu/ml) in control samples at 15th day of storage. AP treatments except CO₂ scavenger significantly (p<0.05) reduce the increase in yeast and mould counts.

Fig. 8.2(d): Effect of active packaging on Yeast & Mould (cfu/ml) of MP tomato

Fig. 8.2(e) and Table 8.4 depict the observations regarding yeast and mould counts in MP cauliflower and minimum (3.67 cfu/ml) counts was observed in chitosan coated samples followed by samples treated with moisture scavenger (4.67 cfu/ml), ethylene scavenger (5.33 cfu/ml), O₂ scavenger (6.33 cfu/ml), CO₂ scavenger (7.0 cfu/ml) and exhibited maximum (8.67 cfu/ml) in control samples at 15th day of storage. AP treatments significantly (p<0.05) reduce the increase in yeast and mould counts.

Fig. 8.2(e): Effect of active packaging on Yeast & Mould (cfu/ml) of MP cauliflower

Fig. 8.2(f) and Table 8.4 exhibit the observations regarding yeast and mould counts in MP spinach and minimum (4.0 cfu/ml) counts were observed in chitosan coated samples followed by samples treated with moisture scavenger (4.33 cfu/ml), ethylene scavenger (4.67 cfu/ml) and O₂ and CO₂ scavengers registered similar values (6.67 cfu/ml) and control samples recorded maximum (7.33 cfu/ml) value at 15th day of storage. AP treatments except CO₂ and O₂ scavengers significantly (p<0.05) reduce the increase in yeast and mould counts.

Fig. 8.2(f): Effect of active packaging on Yeast & Mold (cfu/ml) of MP spinach
The initial TBC value for whole apple, banana and orange were found to be similar (0.67 cfu/ml) whereas; initial TBC value (1.33 cfu/ml) for tomato, (2.0 cfu/ml) for cauliflower and (1.67 cfu/ml) for spinach.

Figs. 8.3(a,b) represent the TBC values in whole apple at RT (Table 8.5) and AT (Table 8.6) respectively and minimum (3.0 and 2.67 cfu/ml) TBC values were observed in chitosan coated samples followed by samples treated with moisture scavenger (3.67 and 3.67 cfu/ml), ethylene scavenger (3.67 and 4.0 cfu/ml), O₂ scavenger (4.3 and 4.0 cfu/ml), CO₂ scavenger (4.67 and 4.33 cfu/ml) and maximum (5.33 and 7.0 cfu/ml) was observed in control samples at 50th (RT) and 21st (AT) day of storage respectively. AP treatments except CO₂ and O₂ scavengers significantly (p<0.05) reduced the increase in TBC values at RT whereas; AP treatments significantly reduce the increase in TBC values at AT.

Figs. 8.3(c,d) present the TBC values in whole banana at RT (Table 8.5) and AT (Table 8.6) respectively, minimum (3.0 and 5.33 cfu/ml) values were observed in chitosan coated samples followed by samples treated with moisture scavenger (5.0 and 7.33 cfu/ml), ethylene scavenger (5.67 and 7.33 cfu/ml), O₂ scavenger (7.0 and 8.0 cfu/ml), CO₂ scavenger (7.33 and 8.67 cfu/ml) and recorded maximum (8.0 and 9.33 cfu/ml) in control samples at 15th (RT) and 9th (AT) day of storage. AP treatments except CO₂ scavenger significantly (p<0.05) reduce the increase in TBC values at RT and AT.
Fig. 8.3(d): Effect of active packaging on TBC (cfu/ml) of banana at AT

Figs. 8.3(e,f) depict the TBC values in orange at RT (Table 8.5) and AT (Table 8.6) respectively, minimum (2.33 and 2.67 cfu/ml) values were observed in chitosan coated samples followed by samples treated with moisture scavenger (3.33 and 3.33 cfu/ml), ethylene scavenger (3.0 and 3.33 cfu/ml), O$_2$ scavenger (3.33 and 4.0 cfu/ml), CO$_2$ scavenger (4.0 and 4.33 cfu/ml) and recorded maximum (4.67 and 5.0 cfu/ml) in control samples at 25$^{th}$ (RT) and 15$^{th}$ (AT) day of storage. AP treatments except CO$_2$ significantly (p<0.05) reduced the increase in TBC values at RT whereas; AP treatments except CO$_2$ and O$_2$ scavengers significantly reduce the increase in TBC values at AT.

Fig. 8.3(e): Effect of active packaging on TBC (cfu/ml) of orange at RT

Fig. 8.3(f): Effect of active packaging on TBC (cfu/ml) of orange at AT

Figs. 8.4(a,b) depict the TBC values in tomato at RT (Table 8.7) and AT (Table 8.8) respectively In tomato minimum (5.33 and 4.0 cfu/ml) values were observed in chitosan coated samples followed by samples treated with moisture scavenger (6.33 and 6.0 cfu/ml), ethylene scavenger (7.0 and 6.33 cfu/ml), O$_2$ scavenger (7.33 and 7.0 cfu/ml), CO$_2$ scavenger (8.0 and 7.67 cfu/ml) and recorded maximum (11.0 and 9.0 cfu/ml) in control samples at 15$^{th}$ (RT) and 9$^{th}$ (AT) day of storage. AP treatments except CO$_2$ and O$_2$ scavengers significantly (p<0.05) reduce the increase in TBC values at RT and AT.
Figs. 8.4(c,d) express the TBC values in cauliflower at RT (Table 8.7) and AT (Table 8.8) respectively, minimum (10.0 and 16.67 cfu/ml) values were observed in chitosan coated samples followed by samples treated with moisture scavenger (13.0 and 15.33 cfu/ml), ethylene scavenger (13.67 and 17.0 cfu/ml), O₂ scavenger (14.67 and 18.0 cfu/ml), CO₂ scavenger (15.33 and 18.33 cfu/ml) and observed maximum (18.0 and 19.67 cfu/ml) in control samples at 15th (RT) and 6th (AT) day of storage. AP treatments significantly (p<0.05) reduced the increase in TBC values at RT whereas; AP treatments except CO₂ scavenger significantly reduce the increase in TBC values at AT.
Figs. 8.4(e,f) represent the TBC values in spinach at RT (Table 8.7) and AT (Table 8.8) respectively, minimum (8.67 and 11.33 cfu/ml) values were observed in chitosan coated samples followed by samples treated with moisture scavenger (10.67 and 12.67 cfu/ml), ethylene scavenger (11.33 and 13.0 cfu/ml), O₂ scavenger (13.0 and 14.0 cfu/ml), CO₂ scavenger (13.33 and 14.33 cfu/ml) and recorded maximum (13.67 and 16.67 cfu/ml) in control samples at 15ᵗʰ (RT) and 9ᵗʰ (AT) day of storage. AP treatments except CO₂ and O₂ scavengers significantly (p<0.05) reduced the increase in TBC values at RT whereas, AP treatments significantly reduce the increase in TBC values at AT.

**Fig. 8.4(e): Effect of active packaging on TBC (cfu/ml) of spinach at RT**

![Graph showing TBC values of spinach at RT](image)

**Fig. 8.4(f): Effect of active packaging on TBC (cfu/ml) of spinach at AT**

The initial yeast and mould counts (0.33 cfu/ml) for apple and banana, (0) for orange, (0.67 cfu/ml) for tomato, (1.0 cfu/ml) for cauliflower and (0.67 cfu/ml) spinach respectively.

Figs. 8.5(a,b) depict the yeast and mould counts in whole apple at RT (Table 8.9) and AT (Table 8.10) respectively, minimum (1.33 and 1.67 cfu/ml) counts were observed in chitosan coated samples followed by samples treated with moisture scavenger (2.67 and 2.33 cfu/ml), ethylene scavenger (2.67 and 2.67 cfu/ml), O₂ scavenger (3.0 and 2.67 cfu/ml), CO₂ scavenger (4.0 and 3.33 cfu/ml) and exhibited maximum (4.0 and 5.33 cfu/ml) in control samples at 50ᵗʰ (RT) and 21ˢᵗ (AT) day of storage. AP treatments except CO₂ and O₂ scavengers significantly (p<0.05) reduce the increase in yeast and mould counts at RT whereas; AP treatments significantly reduce the increase in yeast and mould counts at AT.

**Fig. 8.5(a): Effect of active packaging on Yeast & Mould (cfu/ml) of apple at RT**

![Graph showing yeast and mould counts of apple at RT](image)
Fig. 8.5(b): Effect of active packaging on Yeast & Mould (cfu/ml) of apple at AT

Figs. 8.5(c,d) present the yeast and mold counts in banana at RT (Table 8.9) and AT (Table 8.10) respectively, minimum (2.33 and 3.67 cfu/ml) counts were observed in chitosan coated samples followed by samples treated with moisture scavenger (3.33 and 4.67 cfu/ml), ethylene scavenger (3.67 and 5.33 cfu/ml), \( \text{O}_2 \) scavenger (5.0 and 5.67 cfu/ml), \( \text{CO}_2 \) scavenger (5.0 and 6.67 cfu/ml) and possessed maximum (5.33 and 7.0 cfu/ml) in control samples at 15\(^{th}\) (RT) and 9\(^{th}\) (AT) day of storage. AP treatments except \( \text{CO}_2 \) and \( \text{O}_2 \) scavengers significantly (\( p<0.05 \)) reduce the increase in yeast and mould counts at RT whereas; AP treatments significantly reduce the increase in yeast and mould counts at AT.

Fig. 8.5(c): Effect of active packaging on Yeast & Mould (cfu/ml) of banana at RT

Fig. 8.5(d): Effect of active packaging on Yeast & Mould (cfu/ml) of banana at AT

Figs. 8.5(e,f) exhibit the yeast and mould counts in orange at RT (Table 8.9) and AT (Table 8.10) respectively, minimum (1.33 and 3.67 cfu/ml) counts were observed in chitosan coated samples followed by samples treated with moisture scavenger (2.67 and 2.67 cfu/ml), ethylene scavenger (2.67 and 2.67 cfu/ml), \( \text{O}_2 \) scavenger (3.0 and 3.0 cfu/ml), \( \text{CO}_2 \) scavenger (3.0 and 3.0 cfu/ml) and recorded maximum (3.0 and 3.67 cfu/ml) in control samples at 25\(^{th}\) (RT) and 15\(^{th}\) (AT) day of storage. Chitosan coating treatment significantly (\( p<0.05 \)) reduce the increase in yeast and mould counts at RT and AT.
Figs. 8.5(e,f): Effect of active packaging on Yeast & Mould (cfu/ml) of orange at RT and AT

Figs. 8.6(a,b) present the yeast and mould counts in tomato at RT (Table 8.11) and AT (Table 8.12) respectively, minimum (4.0 and 3.33 cfu/ml) counts were observed in chitosan coated samples followed by samples treated with moisture scavenger (5.0 and 4.33 cfu/ml), ethylene scavenger (5.33 and 4.67 cfu/ml), O$_2$ scavenger (6.67 and 4.67 cfu/ml), CO$_2$ scavenger (6.67 and 5.33 cfu/ml) and recorded maximum (7.67 and 6.0 cfu/ml) in control samples at 25th (RT) and 12th (AT) day of storage. AP treatments except CO$_2$ and O$_2$ scavengers significantly (p<0.05) reduce the increase in yeast and mould counts at RT whereas, AP treatments except CO$_2$ scavenger significantly reduce the increase in yeast and mould counts at AT.

Fig. 8.6(a): Effect of active packaging on Yeast & Mould (cfu/ml) of tomato at RT

Fig. 8.6(b): Effect of active packaging on Yeast & Mould (cfu/ml) of tomato at AT
Figs. 8.6(c,d) depict the yeast and mould counts in cauliflower at RT (Table 8.11) and AT (Table 8.12) respectively, minimum (4.0 cfu/ml) counts were observed in chitosan coated samples at RT, on the other hand chitosan coated samples exhibited highest (7.33 cfu/ml) values at AT. Samples treated with moisture scavenger registered lower yeast and mold counts (4.33 and 5.33 cfu/ml) followed by ethylene scavenger (5.0 and 5.67 cfu/ml), O2 scavenger (5.67 and 6.0 cfu/ml), CO2 scavenger (5.67 and 6.33 cfu/ml) and recorded maximum (6.0 and 7.67 cfu/ml) in control samples at 20th (RT) and 6th (AT) day of storage. AP treatments except chitosan coating and moisture scavenger significantly (p<0.05) reduce the increase in yeast and mould counts at RT whereas, AP treatments except CO2 scavenger significantly reduce the increase in yeast and mould counts at AT.

Fig. 8.6(c): Effect of active packaging on Yeast & Mould (cfu/ml) of cauliflower at RT

Fig. 8.6(d): Effect of active packaging on Yeast & Mould (cfu/ml) of cauliflower at AT

Figs. 8.6(e,f) express the yeast and mould counts in spinach at RT (Table 8.11) and AT (Table 8.12) respectively, minimum (2.67 and 3.0 cfu/ml) counts were observed in chitosan coated samples followed by samples treated with moisture scavenger (2.67 and 3.67 cfu/ml), ethylene scavenger (3.33 and 4.0 cfu/ml), O2 scavenger (3.67 and 4.0 cfu/ml), CO2 scavenger (4.33 and 5.0 cfu/ml) and registered maximum (4.33 and 6.0 cfu/ml) in control samples at 15th (RT) and 6th (AT) day of storage. Chitosan coating and moisture scavenger significantly (p<0.05) reduce the increase in yeast and mould counts at RT whereas, AP treatments significantly reduce the increase in yeast and mould counts at AT.

Fig. 8.6(e): Effect of active packaging on Yeast & Mould (cfu/ml) of spinach at RT
The data reveals that the storage had significant effect on the microbial count in MP and whole fruits and vegetables. There were significantly higher number of counts in the untreated sample (control) compared to other treatments and on the last day of storage control samples presented the highest microbial count (TBC as well as yeast and mould count), while all other treatments presented a lower count. Among the AP treatments, lowest bacterial and yeast and mold count was observed in all the chitosan treated fruits and vegetables (MP as well as intact commodities) which proves its antimicrobial nature. This is in agreement with Sudharshan et al. (1992) who observed the antibacterial activity of chitosan and stated that the interactions between positively charged chitosan molecules and negatively charged residues on the microbial cell surface play an important role in the inhibitory action of chitosan on microorganisms.

Our results are also in line with El Ghaouth et al. (1992a) who reported the effect of different concentrations of chitosan on tomato fruit and found that chitosan coatings at 0.02 g/ml were more effective in controlling infection by *Botrytis cinerea* than coatings at 0.01g/ml. Further, Gonzales-Aguliar et al. (2008) also studied the fresh-cut papaya cubes coated with chitosan at 5°C and found that chitosan coatings at 0.02 g/ml resulted in higher antimicrobial activity and suppress the growth of mesophilic plate count and yeast and mould as compared to control samples.

Microbial count increased with the advancement of storage period, it probably may be due to the suitable conditions for the growth of microbes such as cell wall degradation of tissues, increased relative humidity, and others during prolonged storage period. Fruits and vegetables, having a high content of water, starch and other vitamins, is an excellent source of nutrients for microorganism growth. Babarinde and Fabunmi (2009) found the increased microbial growth in okra with increasing storage duration at room temperature may be due to high rate of respiration in the packaging material. The humidity-controlling capacity of dry sorbitol, xylitol, NaCl, KCl and CaCl₂ enclosed in polyethylene pouches in modified atmosphere-packed tomatoes has been studied by Shirazi and Cameron (1992), who showed that the storage life of packaged red-ripe tomatoes at 20°C was extended from 5 days with no pouch to 15-17 days with a pouch containing sodium chloride, mainly by retarding surface mold development.
However, TBC and yeasts and moulds counts during the storage were still well below the critical limits: Jacxsens *et al.* (2002) reported that the critical limits for TPC and yeasts and moulds for vegetables are $10^8$ cfu/g and $10^5$ cfu/g, respectively. Further, reducing the respiration rate by controlled atmosphere may not only retard ethylene production but also microbial load. Among the gases involved in CA, only CO$_2$ has a direct antimicrobial effect that results in an increased lag phase and generation time during the logarithmic phase of growth of the organisms involved (Phillips, 1996), with inhibition being dependent on gas concentration and temperature.

Olivas and Barbosa-Canovas (2005) defend that MA created by coating may change the growth rate of spoilage and pathogenic bacteria: MA may inhibit the growth of organisms usually responsible for spoilage, while encouraging the growth of pathogens. In the present study, the application of O$_2$, CO$_2$, ethylene, moisture scavengers and an antimicrobial chitosan coating, compared to the control, exhibited low microbial growth rates on final day of storage.

**8.3 CONCLUSION**

During microbial studies chitosan based edible antimicrobial coating was found best in enhancing the microbiological quality of minimally processed fruits and vegetables by reducing the microbial load. This might be due to the antimicrobial as well as antifungal properties of chitosan, which acts as a barrier between the nutrients contained in the produce and microorganisms. Whereas, in case of scavenging treatments, moisture scavenger application followed by ethylene, O$_2$ and CO$_2$ scavengers showed best results in reducing the total bacterial counts (TBC) as well as yeast and mould counts as scavengers happened to absorb the surface moisture from the commodities, as it provided the favourable growth medium for microbes. Similarly in whole fruits and vegetables, highest reduction in TBC and yeast and mould counts was observed in chitosan coating followed by moisture, ethylene, O$_2$ and CO$_2$ scavengers.