

Effect of different Modified Atmosphere Packaging on Physico-chemical, Microbiological and Sensorial attributes of Fresh-Cut Muskmelon

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Abstract— In minimal processing, pretreated fresh-cut muskmelon fruit with organic treatment 10% Whey protein concentrate recorded changes in physico-chemical parameters, microbial count and sensorial attributes over the initial values. Pretreated fresh-cut muskmelon was packed in different modified atmosphere conditions. Modified atmosphere packagings with 10% carbon dioxide plus 3% oxygen and 100% nitrogen flushing extended shelf life of fresh-cut muskmelon pretreated with organic and inorganic dipping, up to 18-21 days when stored at $5\pm1^{\circ}\text{C}$. Pretreated fresh-cut muskmelon packaged in perforated packaging (M_4) recorded shelf life up to 12 days only. Decrease in firmness, TSS and sensory parameters while increase in acidity, physiological loss in weight, decay and microbial count was recorded in all MAP conditions. The MAP condition, M_2 (10% CO_2 plus 3% O_2) recorded minimum changes in physico-chemical parameters, restricted microbial growth, maintained quality and enhanced acceptability of pretreated fresh-cut muskmelon up to 21 days under refrigerated storage.

Keywords— fresh-cut muskmelon, 10% WPC, microbial count, shelf life, MAP.

I. INTRODUCTION

Modified Atmosphere Packaging (MAP) is one of the most important techniques used to achieve safety in fresh-cut fruits and/or to prolong their shelf life. Modified atmosphere packaging (MAP) of fresh fruits and vegetables refers to the technique of sealing actively respiring produce in polymeric film packages to modify the O_2 and CO_2 levels within the package atmosphere. Fresh fruit continues to respire, consuming oxygen and producing carbon dioxide and water vapour. It is often desirable to generate an atmosphere low in O_2 and/or high in CO_2 to influence the metabolism of the product being packaged, or the activity of decay-causing organisms to increase shelf life. In addition to atmosphere modification, MAP vastly improves moisture retention, which can have a greater influence on preserving quality than O_2 and CO_2 levels. Furthermore, packaging isolates the product from the external environment and helps to ensure conditions that, if not sterile, at least reduce exposure to pathogens and contaminants.

Muskmelon (*Cucumis melo* L.), a predominant edible fruit belonging to Cucurbitaceae family, is fourth important fruit in the world fresh fruit and fresh-cut market with several varieties and serves as major food sources. It is usually characterized by netted surfaces with shallow vein tracts and flesh is salmon-coloured. Muskmelon is native to North Western parts of India and its primary center of origin is hot valley of Iran and adjacent areas; now growing world-wide in both tropical and temperate regions. In India, muskmelon is grown on an area of 45000 ha with production of 9.35 lakh MT (Anon, 2016). It is common component of fresh cut fruit product and popular for their pleasant odour and sweet taste (Villanueva *et al.*, 2004). The preparation is needed for muskmelon before consumption which makes them suitable to be processed as fresh-cut fruit (Amaro *et al.*, 2012). However, due to rapid deterioration rate and enhanced ethylene productivity, muskmelon has lower shelf life so its market is not widespread. Consumers expect fresh-cut products to be without defects, of optimum maturity, fresh appearance, and have high sensory and nutrient quality (Watada and Qi,

1999). Hence, high quality of raw product is necessary to achieve high quality fresh-cut product. Final product can only be as good as the incoming raw product. Effective microbial control is essential to restrict high respiration rate which causes spoilage and give unpleasant flavor and odour. The number of processing techniques currently used by the fresh-cut industry is use of low temperature, antioxidants, surfactants, sanitizers and modified atmosphere packaging (MAP).

II. MATERIALS AND METHODS

Sample preparation

The well matured, sound, healthy and fresh fruits of muskmelon (*Cucumis melo* L.) cv. Kundan were collected from Instructional-cum-research farm of Horticulture section, College of Agriculture, Kolhapur. The cubes of 3.5×3.5 cm size were prepared and used for research. The defect free, good healthy ripe muskmelon fruits were selected. An overripe and unripe fruits were rejected. The fruits were washed with tap water and disinfected by dipping in sodium hypochlorite solution (100 ppm) for 2 minutes. All tools and equipment were sanitized with sodium hypochlorite solution (150 ppm) prior to fresh-cut processing. Both blossom and pedicel ends including the calyx of each fruit were removed with a sharp knife and then cut longitudinally in to slices. The seeds were removed from the cavity. During the cutting process, fruit with internal defects were discarded. The lids of the jars were modified to enable sampling from the sealed jars. A small hole was drilled using a step- drill bit with regular power drill and an airtight seal was created by inserting a half- hole, bilayer silicon septa into this hole. The fresh-cut muskmelon pretreated with 10% WPC was air dried and packed in glass bottles with different atmosphere modifications. The packagings were carried out in a closed glass chamber with desirable modified atmosphere concentrations.

Physico-chemical determinations

The determination of hardness was done by using a fruit pressure tester (Penetrometer) (make Nieuwcoop BV Model FT 327) by measuring the maximum penetration force. Weight loss was estimated based on the fresh produce weight and the significant change in physiological weight loss of fresh-cut muskmelon cubes during storage was determined on percentage basis. In all samplings, the fresh weight was measured by an electronic scale of ± 0.01 g accuracy and reduction in weight over initial weight in

percentage was calculated according to Song *et al.* (2013). The percent decay of fresh-cut muskmelon cubes during storage was calculated based on visual inspection of each fresh-cut cube for infection. Percent decay was calculated according to Gihan (2010) on weight basis. The content of TSS in fresh-cut muskmelon cubes was estimated by using Atago, Tokyo hand refractometer and the values were corrected to 20°C with the help of temperature correction chart (A.O.A.C., 2005) and expressed in percentage. The titratable acidity of fresh-cut muskmelon cubes was determined by anhydrous citric acid by titrating 10milliliter juice against 0.1N NaOH using phenolphthalein as an indicator as per method advocated by A.O.A.C. (2005).

Microbial analysis

Microbiological growth in fresh-cut muskmelon cubes was observed as total plate count (TPC) and yeast and mould (YM). The method suggested by Luna-Guzman and Barrett (2000) and Silveira *et al.* (2011) was used for microbial analysis.

From each replicate, three random fresh-cut muskmelon cubes of 10g were collected using sterile techniques from a polypropylene container and homogenized with 90 ml of sterile Ringer solution in a sterile stomacher bag for 1 minute. Serial dilutions needed for sample plating were prepared in 9 ml of ringer solution. The pour plate method was performed using the following media and culture conditions: Plate Count Agar for TPC and Potato Dextrose Agar for yeast and mould counts with added 10% tartaric acid to attain PH 3.5. Both the media of the TPC and the yeast and mould count were incubated at $35 \pm 1^\circ\text{C}$ for 48 hours and $25 \pm 1^\circ\text{C}$ for 5 days, respectively. The microbial counts were expressed as \log_{10} (cfu g⁻¹). According to microbial legislation, the maximum tolerated counts is 7 \log_{10} (cfu g⁻¹) for aerobic bacteria and 5 \log_{10} (cfu g⁻¹) and 3 \log_{10} (cfu g⁻¹) the yeast and mould respectively.

Sensorial analysis

Subjective overall acceptability measurements were done on the basis of flavour, colour and appearance, taste and microbial limit tests parameters of samples by a panel of testers based on rating with nine point Hedonic scale suggested by Silvina *et al.* (1998) was considered (Appendix I). A score of 6 was considered the limit of acceptability.

Statistical analysis

The data was reported as an average value of replicates with standard deviation. Analysis of variance (ANOVA) was performed using IBM SPSS statistics 22

(Windows 8.1, Statistical analysis). The level of significance for all the tests was $\alpha=0.05$. Followed by Duncan's Multiple Range Test ($P \leq 0.05$) was carried out to evaluate significant statistical difference of data. For the data expressed as proportions arc sine transformation was applied before analysis.

III. RESULTS AND DISCUSSION

Firmness

Among all the modified atmosphere packagings, M₂ (10% Carbon dioxide plus 3% Oxygen) retained significantly maximum firmness (3.109 kg/cm²) after 21 days of the storage, while maximum decrease in the firmness was recorded in M₄ packaged fresh-cut muskmelon (2.860 kg/cm²) after 12 days storage (Fig. 1). This might be due to pretreatment, MAP conditions at low temperatures that maintained cell turgidity, prevented microbiological deterioration, creation of anaerobic condition, restricted availability of free oxygen, slow rate of moisture loss, reduced deterioration rate of bioactive compounds, reduction in respiration rate and ethylene emission as evidenced by Aguayo *et al.* (2007) in fresh cut cantaloupe and Dhumal (2012) in ready to eat fresh arils.

Physiological loss in weight

Minimum physiological loss in weight (2.830%) was recorded in M₂ (10% Carbon dioxide plus 3% Oxygen) followed by M₃ (100% nitrogen flushing) (3.089%) treatment (Fig. 1). Evaporation, transpiration and respiration of fresh-cut muskmelon fruits after harvest and imbalance of vapour pressure in the product tissues and the air inside the package which lead to weight loss over time as reported by Bai *et al.* (2001) in fresh-cut muskmelon.

Per cent decay

At the end of storage period i.e. after 21 day of storage significantly minimum decay (8.993%) was recorded in M₂ (10% Carbon dioxide plus 3% Oxygen) followed by A₃ (100 per cent Nitrogen flushing) (9.252%) with the advancement of time. (Table 1). The established antimicrobial effect of carbon dioxide and less oxygen concentration in package which was responsible for retarding browning and spoilage which delayed of exponential growth phase of microbes and maintained fresh appearance as reported by Bai *et al.* (2001) in fresh cut muskmelon, Oliveria *et al.* (2015) in fresh cut fruits and vegetables,

Zhang *et al.* (2013) in fresh cut honey dew muskmelon, Aguayo *et al.* (2007) in fresh cut cantaloupes.

Total Soluble Solids

At the end of storage period i.e. after 21 days, packaging treatment M₂ (10 per cent Carbon dioxide plus 3 per cent Oxygen) recorded maximum TSS (7.358 °Brix) (Fig. 2). This decrease in TSS is might be due to its correlation with decrease of sugar content and could also be due to decrease of fruit respiration rate contributed by refrigerated storage irrespective of packaging condition and treatment tried as reported by Koh *et al.* (2017) in fresh-cut cantaloupe.

Acidity

During the entire storage period, minimum increase in acidity (0.299%) was recorded in M₂ (10% Carbon dioxide plus 3% Oxygen) (Fig. 2). Numerous studies conducted by Aguayo *et al.* (2007), Koh *et al.* (2017), Aguayo *et al.* (2003) and Lamikanra *et al.* (2000) in fresh cut muskmelon support the findings that low O₂ and/ or high CO₂ atmosphere can retard decomposition of organic acids in plant tissue.

Microbial Limits Test

Initial total aerobic count in fresh-cut muskmelon before dipping in 10% WPC, was 5.249 log cfu per g-1. After dipping, total aerobic count reduced to 4.735 log cfu g-1. At the end of storage period i.e. after 21 days, under MAP conditions, minimum count (4.915 log cfu g⁻¹) was recorded in M₂ (10% Carbon dioxide plus 3% Oxygen) while maximum (6.659 log cfu g⁻¹) was recorded in M₄ (Perforated packaging) after 12th day of storage (Table 2). Before dipping treatment, total yeast and mould count recorded in fresh-cut muskmelon was 4.468 log cfu g⁻¹. After 10% WPC dipping treatment, reduced significantly to 3.980 log cfu g⁻¹. Among all the MAP conditions, M₂ (10% carbon dioxide with 3% oxygen) registered minimum total yeast and mould count (4.010 log cfu g⁻¹) followed by M₃ (4.507 log cfu g⁻¹) at the end of storage period i.e. after 21 days. At the end of 12 days after storage, pretreated fresh-cut muskmelon packaged in perforated packaging (M₄) registered maximum yeast and mould load (5.637 log cfu g⁻¹) (Table 2). Established antimicrobial effect of high CO₂ levels and less oxygen concentration in package which was responsible for retarding browning and spoilage which delayed of exponential growth phase of microbes and maintained fresh appearance as reported by Bai *et al.* (2001) in fresh cut muskmelon, Oliveria *et al.* (2015) in fresh cut fruits and vegetables, Zhang *et al.* (2013) in fresh cut honey dew muskmelon, Aguayo *et al.* (2007) in fresh-cut cantaloupes.

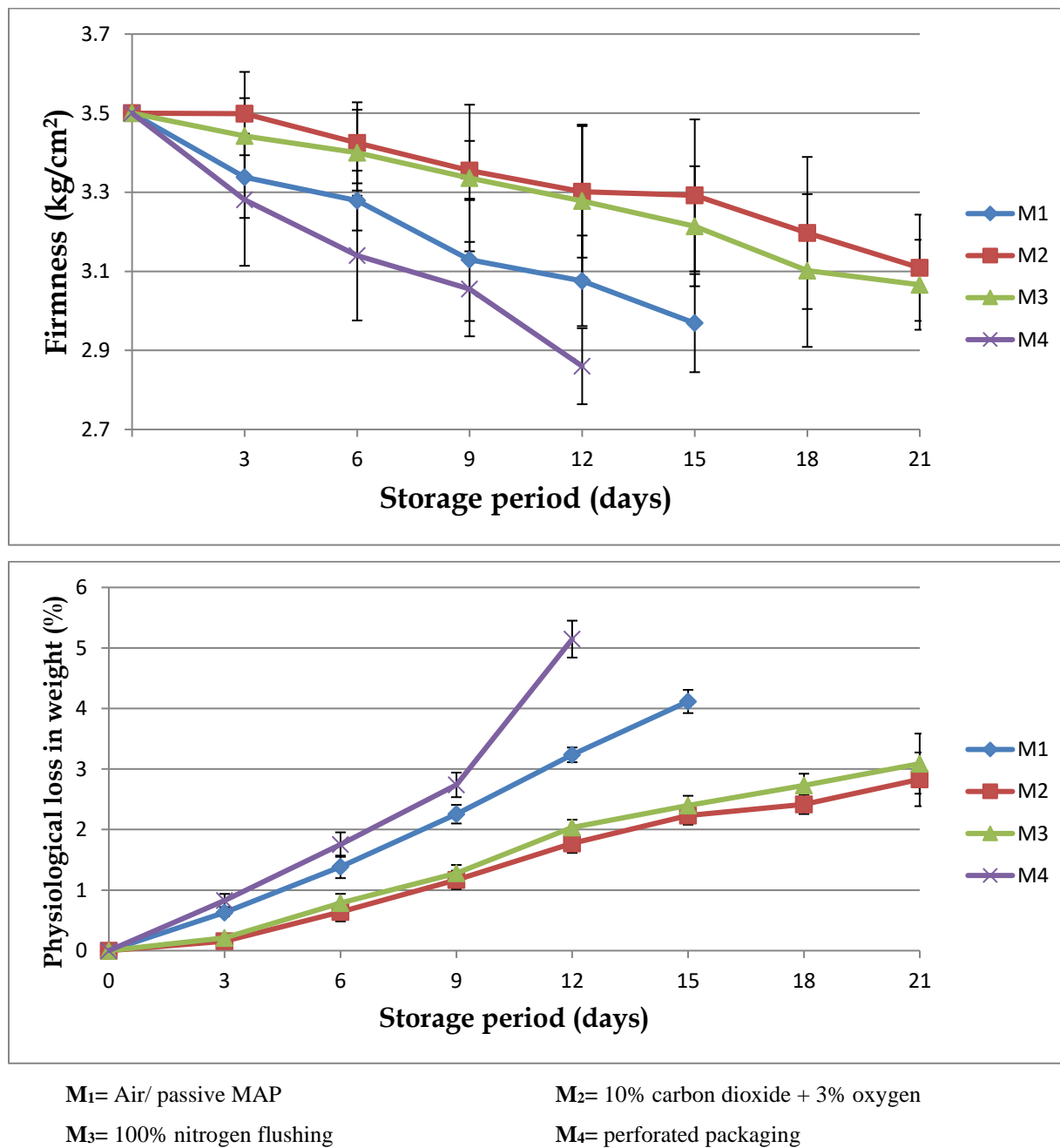
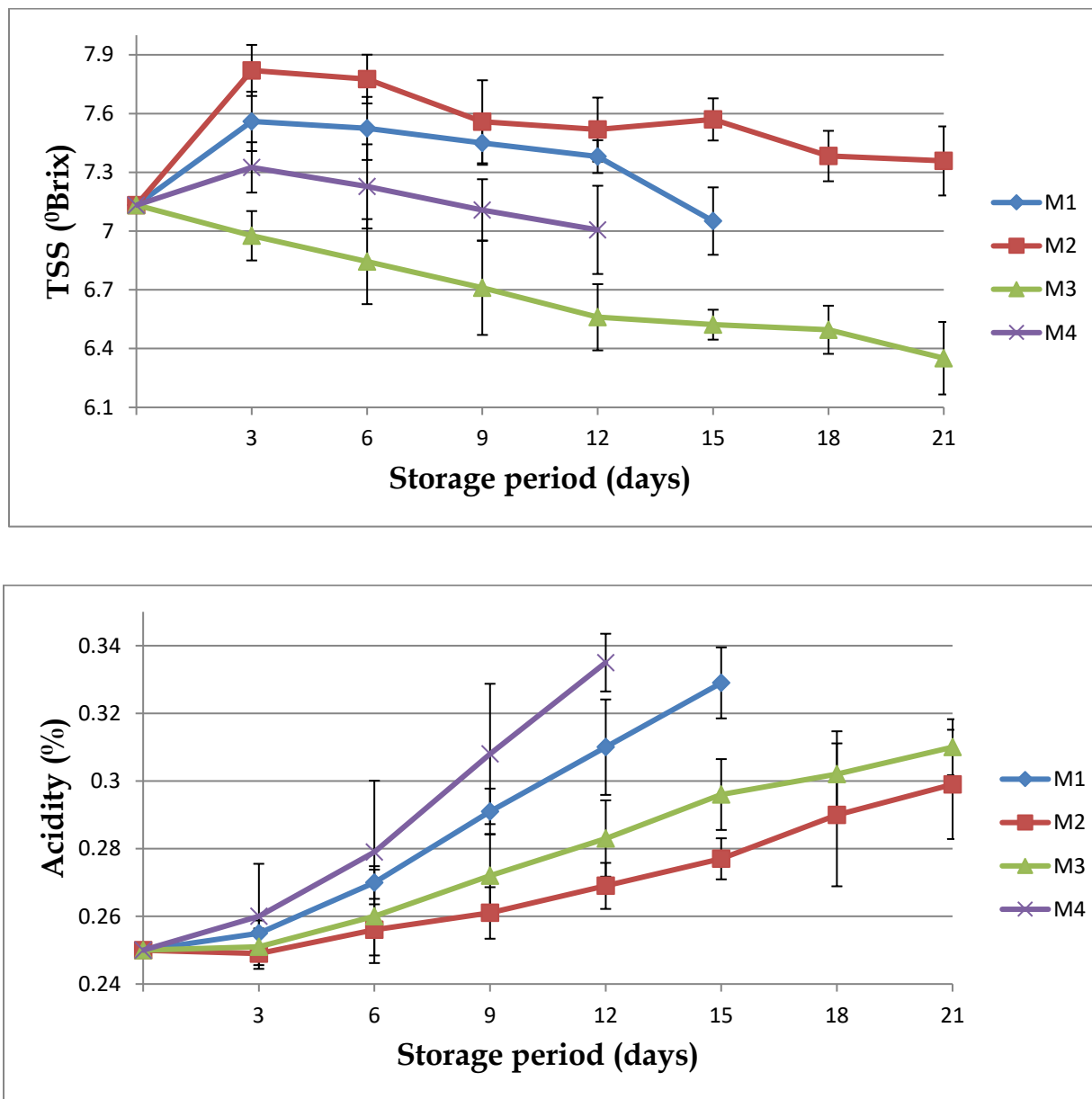


Fig.1: Effect of modified atmosphere packaging on the Firmness and Physiological loss in weight of the fresh-cut muskmelon pretreated with 10 per cent WPC and stored at $5 \pm 1^{\circ}\text{C}$.



M₁= Air/ passive MAP

M₂= 10% carbon dioxide + 3% oxygen

M₃= 100% nitrogen flushing

M₄= perforated packaging

Fig.2: Effect of modified atmosphere packaging on the TSS and Acidity of the fresh-cut muskmelon pretreated with 10 per cent WPC and stored at $5 \pm 1^{\circ}\text{C}$.

Sensorial analysis

Effect of MAP on fresh-cut muskmelon pretreated with organic dipping (Tables 3, 4, 5 and 6) revealed that overall acceptability score in respect of colour and

appearance, taste and flavor was highest in M₂ (10% CO₂ + 3% O₂) condition followed by M₃ (100% nitrogen flushing) packaging. However, M₄ conditions noted lowest acceptability for fresh cut muskmelon pretreated with organic

dipping. The maximum overall acceptability in M₂ (10% CO₂ + 3% O₂) might be due to the effectiveness of carbon dioxide enrichment which led to maintain firmness, acidity and TSS, minimum decay and physiological loss in weight. High nitrogen (100%) and CO₂ (10%) in MAP caused reduced respiration rates of fresh cut muskmelon, gave more firmness and slowed down metabolic activities and microbial growth, creation of anaerobic conditions, accumulation of volatiles,

off flavour development in product as observed by Falah *et al.* (2015), Silveira *et al.* (2011), Silveira *et al.* (2010), Aguayo *et al.* (2003) in fresh cut muskmelon, Ergun and Ergun (2009) in pomegranate arils cv. Hicaznar and Dhumal (2012) in ready to eat fresh pomegranate arils. Low O₂ combined with high CO₂ provided a better sensory quality to melon pieces than air in minimally processed muskmelon at cold storage conditions.

Table 1. Effect of modified atmosphere packaging on the per cent decay of the fresh-cut muskmelon pretreated with 10 per cent WPC and stored at 5±1°C.

Treatments	Decay (%)				
	Storage period in days				
	9	12	15	18	21
M ₁	3.551 ^a (11.910)	6.592 ^b (14.852)	10.129 ^c (18.555)	-	-
M ₂	No decay	0.844 ^a (5.043)	2.715 ^a (9.449)	4.729 ^a (12.539)	8.993 ^a (17.440)
M ₃	No decay	1.007 ^a (5.664)	3.552 ^b (10.835)	5.237 ^a (13.224)	9.252 ^a (17.701)
M ₄	4.290 ^a (10.856)	10.191 ^c (18.613)	-	-	-
SE	0.277	0.524	0.301	0.176	0.209
CD at 1%	1.143	2.166	1.244	0.725	0.863

^-' indicates termination of treatments

Figures in parentheses indicates Arcsine value.

Table 2. Effect of modified atmosphere packaging on the total aerobic count (log cfu g⁻¹) and total yeast and mould count (log cfu g⁻¹) of the fresh-cut muskmelon pretreated with 10 per cent WPC and stored at 5±1°C.

Treatment	Total aerobic count (log cfu g ⁻¹)			Total yeast and mould count (log cfu g ⁻¹)		
	Storage period in days			Storage period in days		
	Initial before dipping	Initial after dipping	Final day of storage	Initial before dipping	Initial after dipping	Final day of storage
M ₁	5.249	4.735	6.186 ^c (15 th day)	4.468	3.980	5.098 ^{bc}
M ₂	5.249	4.735	4.915 ^a (21 st day)	4.468	3.980	4.010 ^a
M ₃	5.249	4.735	5.431 ^b	4.468	3.980	4.507 ^{ab}

			(21 st day)			
M₄	5.249	4.735	6.659 ^d (12 th day)	4.468	3.980	5.637 ^c
SE	-	-	0.130	-	-	0.238
CD at 1%	-	-	0.535	-	-	0.985

‘-’ indicates termination of treatments

M₁= Air/ passive MAP

M₂= 10% Carbon dioxide + 3% Oxygen

M₃= 100% Nitrogen

M₄= Perforated packaging

Table 3. Effect of modified atmosphere packaging on the colour and appearance (score) and taste (score) of the fresh-cut muskmelon pretreated with 10 per cent WPC and stored at $5 \pm 1^{\circ}\text{C}$.

Treatments	Colour and appearance (score)				Taste (score)			
	Storage period in days				Storage period in days			
	3	9	15	21	3	9	15	21
M₁	7.264 ^b	6.000 ^b	4.874 ^c	-	7.873 ^b	6.351 ^b	4.807 ^b	-
M₂	7.957 ^a	7.254 ^a	6.595 ^a	6.143 ^a	8.750 ^a	8.113 ^a	7.303 ^a	6.429 ^a
M₃	7.735 ^a	7.072 ^a	6.350 ^b	6.007 ^a	8.633 ^a	8.002 ^a	7.169 ^a	6.189 ^b
M₄	6.974 ^c	4.839 ^c	-	-	7.487 ^c	5.477 ^c	-	-
SE	0.062	0.066	0.049	0.061	0.077	0.095	0.084	0.054
CD at 1 %	0.258	0.271	0.203	0.254	0.318	0.392	0.346	0.223

‘-’ indicates termination of treatments

Table 4. Effect of modified atmosphere packaging on the flavour (score) and overall acceptability (score) of the fresh-cut muskmelon pretreated with 10 per cent WPC and stored at $5 \pm 1^{\circ}\text{C}$.

Treatments	Flavour (score)				Overall acceptability (score)			
	Storage period in days				Storage period in days			
	3	9	15	21	3	9	15	21
M₁	7.556 ^b	6.116 ^b	4.646 ^b	-	7.564 ^b	6.156 ^b	4.776 ^b	-
M₂	8.670 ^a	7.854 ^a	6.659 ^a	6.112 ^a	8.459 ^a	7.740 ^a	6.852 ^a	6.228 ^a
M₃	8.453 ^a	7.534 ^a	6.563 ^a	6.045 ^a	8.274 ^a	7.536 ^{ab}	6.694 ^a	6.080 ^b
M₄	7.188 ^c	5.668 ^c	-	-	7.216 ^b	6.328 ^b	-	-
SE	0.076	0.079	0.108	0.069	0.126	0.322	0.093	0.032
CD at 1 %	0.316	0.327	0.446	0.286	0.519	1.328	0.385	0.130

‘-’ indicates termination of treatments

M₁= Air/ passive MAP

M₂= 10% Carbon dioxide + 3% Oxygen

M₃= 100% Nitrogen

M₄= Perforated packaging

IV. CONCLUSION

The fresh-cut muskmelon pretreated with organic dipping treatment of 10% WPC and packaged with different modified atmospheres can be stored up to 18-21 days at $5\pm1^{\circ}\text{C}$. Modified atmosphere packagings with 10% CO_2 plus 3% O_2 flushing or with 100 % nitrogen flushing extended the shelf life of pretreated fresh-cut muskmelon up to 21 days at refrigerated storage ($5\pm1^{\circ}\text{C}$) by controlled decay and microbial growth and enhanced sensorial parameters with minimum changes in physico-chemical attributes.

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