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Modified/Controlled Atmosphere Storage of Minimally Processed Mango Slices (Var. *Arka anmol*)

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Abstract: Stabilization of mango slices (var. *Arka anmol*) in pre-cut form was achieved by using additive based minimal processing and modified atmosphere storage. The pre-treatments included use of firming agents in the form of calcium salt (1%), antimicrobials such as benzoate and sorbate (0.045%), ascorbic acid as anti browning agent (0.02%), mild acidification (0.4% citric acid) and UV conditioning (2.5 kJ m^{-2}). The pre-treated mango slices were subjected to different Modified Atmospheric (MA) conditions i.e., active with gas mixture flushing (4% O_2 + 6% CO_2 + 90% N_2) in polythene pouches; passive MA with air in polythene pouches; passive MA in PET bottles with silicone membrane window (2.25 cm^2) and passive MA in plastic trays, over wrapped with cling film. The pre-treated produce was also subjected to storage under controlled atmosphere (CA) in a continuous gas mixture flushing system (3% O_2 + 8% CO_2 + 89% N_2) at 8±1 °C. The pre-treated samples in combination with MAP or CA showed significant ($p \leq 0.05$) physical, physiological and microbiological stability in terms of respiratory drift without anaerobiosis and retention of ascorbic acid as well as carotenoids. The kinetic model for L, a, b colour coordinates and shear strength followed first order linear model during storage of the product at low temperature (8±1 °C) with high correlation coefficients ranging from 0.824 to 0.987 and 0.942 to 0.993 for tristimulus colour and shear force values, respectively. Microbial safety was also ascertained in terms of SPC, Coliforms, yeast and molds during storage. Shelf life of 14-46 days was obtained for pre-treated mango slices stored in the MA/CA at 8±1 °C. The control samples without pre-treatment kept under similar storage conditions showed restricted shelf life (8-12 days) at 8±1 °C. The study highlights synergistic effect of physical conditioning in combination with additives based minimal processing and MA/CA storage conditions to give longer shelf life and suitability of the mango variety for minimal processing and MA/CA storage in pre-cut form.

Key words: Mango, *Arka anmol*, modified atmosphere, controlled atmosphere, minimal processing, pre-cut

Introduction

Mango is a delicious tropical fruit and Indian mangoes with over 100 exotic varieties find a place of pride in the global market. Newer varieties developed through intensive breeding and biotechnological techniques demand screening for value addition with various process technologies, including preservation of the fruit in sliced form using minimal process technology. Although, post-harvest storage of whole mangoes in CA (Bender *et al*., 2000) and MA (Srinivasa *et al*., 2002) conditions has been reported, the preservation of pre-cut mango has fewer reports describing the interactions of various pre-treatments and types of storage. Gonzalez *et al*. (2000) described that

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anti-browning agents i.e., 4-hexyl resorcinol and iso-ascrobic acid in combination with potassium sorbate extended the shelf-life of mango slices up to 2 weeks at 10°C. As such the slicing of mango induces drift in respiration and ethylene production, resulting in accelerated metabolism under physiological stress (Allong *et al*., 2001). In addition to physiological stress pre-cut mangoes also showed extreme sensitivity towards microbial infections, however, higher CO_2 concentrations were reported to restrict the proliferation of microorganisms and the slices as such showed the ability to withstand higher CO_2 concentrations (Poubol and Izumi, 2005). In addition to the work on mango several reports exist, describing the positive effects of chemical pre-treatments in combination with MA rendering microbiological stability as in the case of spinach (Piagentini *et al*., 2003).

Minimal processing has drawn worldwide attention and considerable process flexibility has been incorporated over the years. The technology such has been framed as a process strategy in which measures could be incorporated sequentially to minimize the physiological stress incurred by the fresh produce due to peeling and pre-cutting. The measures were least dependent on thermal process and largely focused on non-thermal treatments, selective additives and also other physical conditions such as pre-cooling, cold shock, UV conditioning, surface coating etc. Modified Atmosphere Packaging (MAP) and Control Atmosphere (CA) have also drawn pronounced attention in rendering physiological as well as microbiological stability and the later has largely been achieved through surface sanitation and non-thermal measures. The process strategy adopted for mango slices adheres to the basic principles of minimal process and the synergistic effect between minimal process and modified atmosphere storage mediated towards achieving extended shelf life and maintenance of fresh like keeping quality of the produce.

The present study aims at highlighting the role of chemical conditioning in synergy with CA/MA conditions in retarding the senescence of mango slices in terms of quality parameters i.e., texture, colour and retention of ascorbic acid and carotenoids in addition to the microbiological profile. The objectives essentially included the role of pre treatment in maximizing the effect of MA/CA storage and to evaluate the suitability of the cultivar *Arka anmol* for minimal process and storage of slices under MA/CA conditions.

Materials and Methods

Fruits

Mango fruits (var. *Arka anmol*) were procured from the Indian Institute of Horticultural Research, Bangalore, India and brought to Defence Food Research Laboratory, Mysore, India for conducting the experiment in the month of June, 2005. The fruits showed 10% surface yellowing, fully developed shoulders, clearly visible lenticels and had no physical blemishes or malformation. Fruits were graded and surface sanitized by dipping in water containing 0.01% chlorine. After sanitary wash, the fruits were rinsed in boiled and cooled tap water and treated with 2-chloroethyl phosphonic acid (0.02%) for 10 min followed by surface air drying to remove residual moisture. The fruits were kept for ripening in a BOD incubator maintained at 30±1°C and 85-90% relative humidity.

Uniform ripeness was ensured by random testing of fruits with the application of shear force to determine the texture and also the build up of brix: acid ratio within specified limits (Penetration force: 20.50±0.08 N and brix: acid ratio: 29.48±0.12).

Pre-cutting

The semi-ripe fruits were manually peeled using sharp edged stainless steel knives and the cheeks were separated from the seed and cut in to slices (2×0.8×0.6 cm).

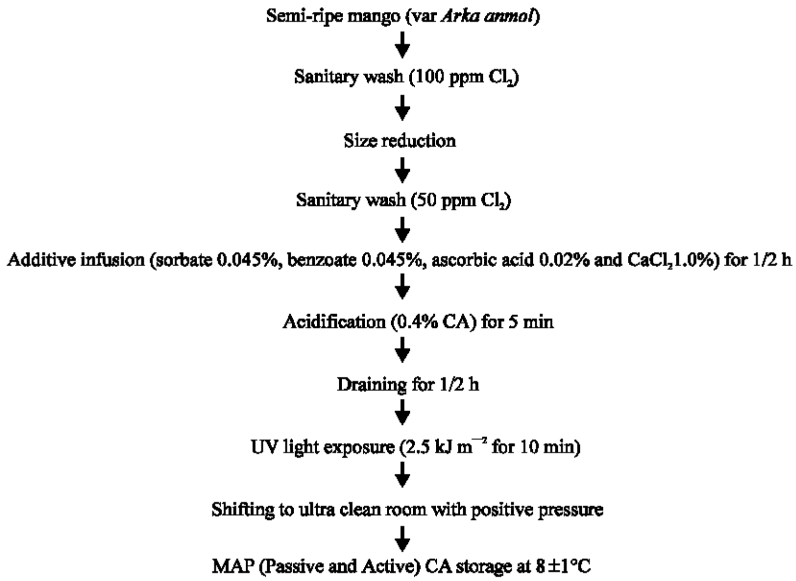

Fig. 1: Flow diagram for MAP/CA storage for minimally-processed mango slices

Pre-treatments

The pre-cut fruit slices were subjected to cold shock immediately after size reduction in chilled water at 5-7°C for 10 min. Fifty kilogram of the pre-cut mangoes were divided into two experimental blocks with each of the block consisting of five segments of 5.0 kg pre-cut fruit and subjected to pre-treatments as shown in Fig. 1.

Modified Atmosphere Packaging

Four types of Modified Atmosphere Packaging (MAP) was carried out including passive (produce generated) as well as active (external modification) type of modified atmosphere using a gas mixer (MAP Mix 9000, PBI Dansensor, Denmark) as well as under controlled atmosphere. In case of gas mixture flushing, a vacuum level of 70% was followed by filling of specific gas mixture using a programmed cycle ending with impulse sealing of pouches.

- Passive MA with air in polyethylene pouches (25 μ thickness, 12×10 cm, fill weight 250 g)
- Active MA with gas mixture flushing (4% O_2 + 6% CO_2 + 90% N_2) in polyethylene pouches (25 μ thickness, 12×10 cm, fill weight 250 g)
- Passive MA in PET bottles (2 kg fill volume) with silicone membrane window (diffusion area of 2.25 cm^{-2}, fill weight 500 g)
- Passive MA in plastic trays over-wrapped with cling film (10 μ thickness, fill weight 250 g)
- Controlled atmosphere (3% O_2 + 8% CO_2 + 89% N_2) in a CA chamber with continuous flushing of gas mixture

The above MAP/CA conditions with specific gas compositions, variables i.e., fill weight, fill volume, type of packaging material inclusive of thickness and also diffusion area for the silicone windows were initially optimized in terms of storage life and sensory attributes based on different permutation combinations. All the samples were kept at 8±1 °C for storage and periodically analyzed for various physico-chemical, microbiological and sensory parameters. The whole experiment was repeated thrice with periodic sampling to analyze physico-chemical, microbiological and sensory parameters using a completely randomized design. Results of each analysis have been reported as mean of six sample replications.

Physico-Chemical Analyses

Ascorbic acid, titratable acidity as well as residual levels of benzoate and sorbate were estimated by the method described in AOAC (1990). pH of the samples was determined using a microprocessor based pH meter (Century, Model CP931, India) and TSS were measured using hand refractometer (ERMA, Japan).

Head Space Gas Analysis

Head space gas analysis for O_2 and CO_2 was carried out using O_2/CO_2 analyzer (PBI Dansensor, Checkmate 9900, Prg. Ver. 1.7, Denmark). Head space gas samples were drawn from the packages as well as the PET bottles with silicon membrane windows using an auto-injector and teflon septa. Drawing of a minimum gas volume of 5 mL was ensured to obtain steady readings. The instrument was calibrated using 100% O_2 and CO_2 gases prior to the analysis. Ethylene synthesis rates were monitored using gas chromatographic method described by Gailard and Grey (1969) using a FID detector (Chemito, 8610 HT, Chemito India Pvt. Ltd. Chennai, India).

Respiration

Respiration rate was monitored following the gas chromatographic method of Hakim *et al.* (2004) using a TCD detector (TCD 866, Chemito, 8610 HT, Chemito India Pvt. Ltd. Chennai, India).

Texture Analysis

The mango slices were subjected to shear force using a texture analyzer (TAHDi, Stable Microsystems, UK) loaded with a software named Texture Expert (Version 1.22, Stable Microsystems, UK). The shear force was measured by cutting the mango slices (2.0×0.8×0.6 cm) in the center using a Warner Bratzler Blade at a test speed of 0.5 mm s^{-1}. The pre and post-test speeds were set at 1 and 5 mm s^{-1}; respectively.

Colour Coordinates

Changes in terms of L, a, b colour coordinates following a hunter scale were measured under D-65 illuminating condition at an angle of 45° and at an observation interval of 2 nm using Chromaflash software (Datalab, Silvasa). The equipment (Model 2810, Datalab, Silvasa) was calibrated using a standard reference tile (L = 77.04, a = -1.4, b = 21.80) as well as blank.

Microbiological Evaluation

The microbiological analysis of mango slices was carried out for standard plate count, yeast and mold count and total coliform count according to APHA (1992) procedures.

Sensory Evaluation

The sensory attributes of the mango slices during storage were evaluated in terms of colour, aroma, taste, texture and overall acceptability by a trained 10 member semi-trained panel using a nine point hedonic scale having a score of 9 for extreme liking and 1 for extreme disliking (Larmond, 1977).

Kinetic Modeling

Experimental data for colour coordinates and texture was fitted to linear (Eq. 1), first-order (Eq. 2) models and a fractional conversion first order (Eq. 3) models, to investigate the effect of test parameters on the kinetics of colour and textural changes (Stoneham *et al*., 2000):

$$TP = TP_0 \pm kt \quad (1)$$

$$TP = TP_0 \exp(\pm kt) \quad (2)$$

$$(TP - TP_\infty) / TP - TP_0 = \exp(\pm kt) \quad (3)$$

Where TP is the parameter property at a given time t, TP_0 is the initial property at time zero, TP_∞ is the non-zero equilibrium property after prolonged storage and k is the kinetic rate constant (day^{-1}).

Statistical Analysis

The data obtained from physico-chemical analysis and sensory evaluation were subjected to Analysis of Variance (ANOVA) using Completely Randomized Design (CRD) and Least Significant Difference (LSD) at $p \leq 0.05$ using Statistica 7 software (StatSoft, Tulsa, OK, USA).

Results and Discussion

Pre-treatment and Conditioning

The minimal process adopted involved unit operations to regulate important aspects i.e. microbial contamination, browning and physiological stress causing textural, colour and flavour losses. The protocol (Fig. 1) shows surface sanitation, use of benzoate and sorbate (0.045%), mild acidification (pH<4.5) and or physical conditioning (UV exposure) towards achieving microbial stability. The anti-browning measures included cold shock and use of ascorbic acid. Application of hypochlorite solution for surface sanitation has also been reported to cause anti-browning function at concentrations higher than 17-18 ppm (Brochet *et al*., 1993). Restriction of physiological stress was achieved through measures such as pre-treatment with calcium salt, cold shock, mild acidification and also by the application of different types of MA for the storage of minimally processed mango slices. Initial physio-chemical, microbiological and sensory data (Table 1) showed significant build up of ascorbic acid due to supplementation as pre-cutting induced rapid losses of the same.

Respiration and Head Space Gases

Slicing of fruit has been reported to significantly result in enhanced respiratory rates (Budu *et al*., 2001) which could be attributed to be an impediment to membrane stability and also to overall physiological stress (Tovar *et al*., 2001). The respiratory pattern of pre-treated mango slices showed an abrupt increase immediately after pre-cutting (62.26±3.74 mg CO_2 kg^{-1} h^{-1}) followed by a fall after the minimal process (45.12±2.08 mg CO_2 kg^{-1} h^{-1}). Later, the respiratory profiles for

Table 1: Initial physico-chemical, microbiological and sensory parameters of pre-treated and untreated mango slices (n = 6)

Parameters	Pre-treated	Untreated (Control)
Respiration rate (mg CO_2 kg^{-1} h^{-1})	45.12 ± 2.08^a	62.26 ± 3.74^b
pH	4.04 ± 0.02^a	4.37 ± 0.03^b
Brix: Acid	24.69 ± 0.11^a	29.48 ± 0.12^b
Ascorbic acid (mg 100 g^{-1})	52.92 ± 1.23^a	30.87 ± 0.98^b
Total carotenoids (mg 100 g^{-1})	9.37 ± 0.40^a	9.40 ± 0.35^a
Shear Force (N)	2.163 ± 0.004^a	2.184 ± 0.006^a
OAA	8.21 ± 0.38^a	8.50 ± 0.10^b
TPC (cfu g^{-1})	$^a4.2\pm0.2\times10^2$	$^b5.5\pm0.2\times10^6$
Yeast and molds count (cfu g^{-1})	$^a2.1\pm0.1\times10^2$	$^b3.5\pm0.1\times10^5$
Total coliforms count (cfu g^{-1})	Nil	$1.9\pm0.1\times10^1$
Spores (cfu g^{-1})	Nil	$7.0\pm0.2\times10^1$

The values in a column followed by different superscripts differed significantly ($p \leq 0.05$)

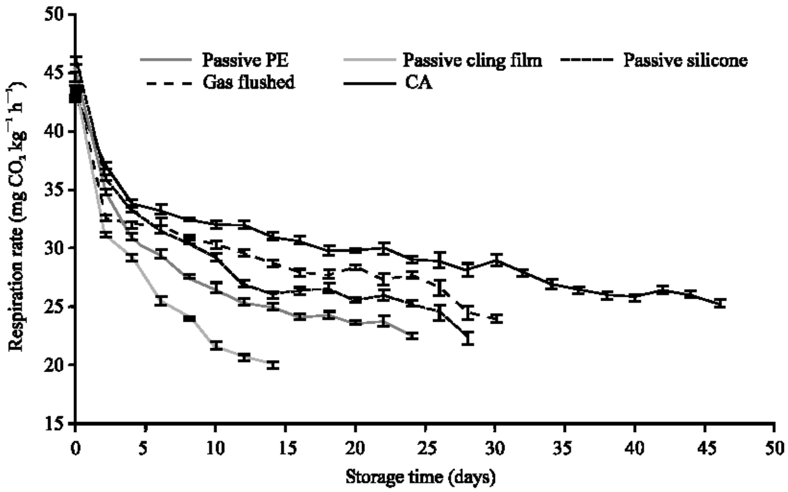

Fig. 2: Changes in respiration rate during MAP/CA storage of pre-treated mango slices at 8±1 °C. Error bars indicate a 95% confidence interval (n = 6)

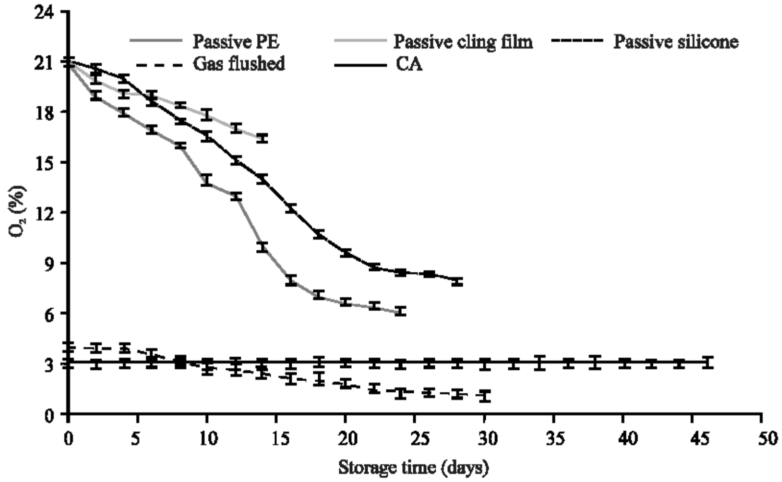

Fig. 3: Changes in head space O_2 concentrations during MAP/CA storage of pre-treated mango slices at 8±1 °C. Error bars indicate a 95% confidence interval (n = 6)

pre-treated mango under different MAP and CA storage showed a steady fall (Fig. 2). The drift in respiration was found to be steady in the CA stored samples followed by different MAP samples. The variation in the respiratory drift was significant ($p \leq 0.05$) for all the MAP conditions besides CA storage. Among the MAP samples, the gas mixture flushed samples showed minimum whereas, the cling film over-wrapped samples showed the maximum drift. The stabilization of respiratory drift can be largely attributed to stress retardants i.e., calcium salt and acidulant while the interactions of pre-treatment and MA/CA conditions maximized the stabilizing factor. A suppressed respiration also resulted in restricted production of ethylene which was found to be 2.25-2.40 μL kg^{-1} h^{-1} as against 2.60-2.75 μL kg^{-1} h^{-1} for untreated mango samples.

The equilibriated O_2 concentrations in different MA/CA storage conditions for the pre-treated samples (Fig. 3) showed significant ($p \leq 0.05$) variation from each other and the gas flushed samples

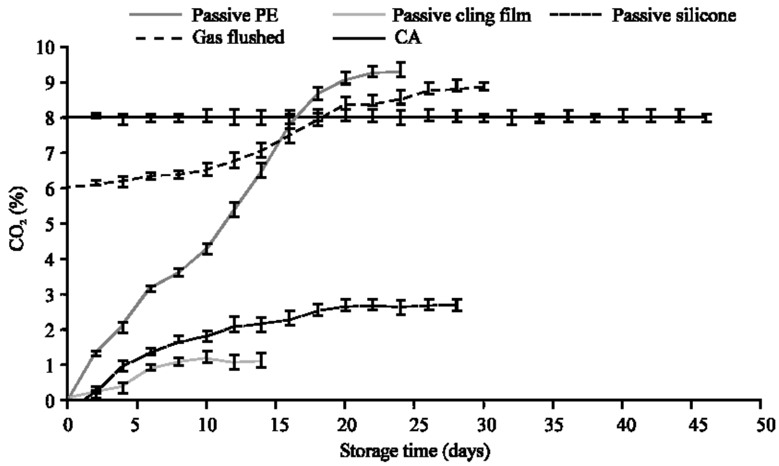

Fig. 4: Changes in head CO_2 concentration during MAP/CA storage of pre-treated mango slices at 8±1°C. Error bars indicate a 95% confidence interval (n = 6)

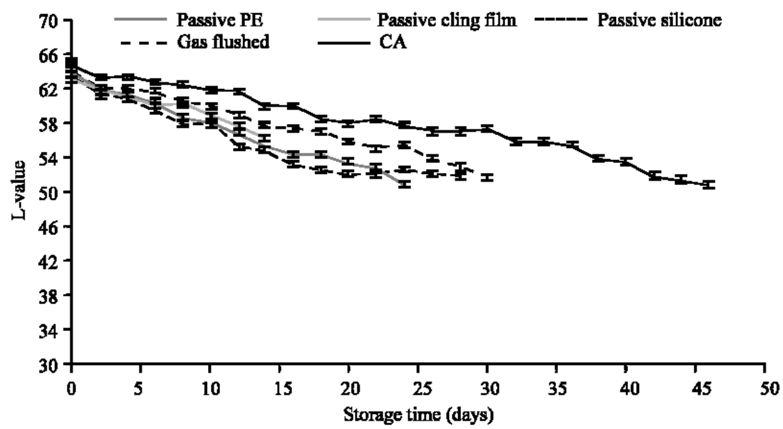

Fig. 5: Changes in colour L-value during MAP/CA storage of pre-treated mango slices at 8±1°C. Errror bars indicate a 95% confidence interval (n = 6)

along with CA stored ones showed an effective residual O_2 concentration of 2-4% to be conducive for achieving optimal shelf life without any symptoms of anaerobiosis. Beaulieu and Lea (2003) reported development of anaerobiosis in pre-cut mango slices stored under MAP without any pre-treatment. Similarly, the ability of mangoes to withstand higher CO_2 concentrations to an extent of 10 kPa has also been reported (Nithiya *et al*., 2001). Bender *et al*. (2000) attributed the susceptibility towards anaerobiosis at concentrations in the range of 2-5 kPaO_2 to cultivar variations. The present study showed that the pre-cut mango slices of cultivar *Arka anmol* could withstand O_2 concentrations as low as 2-4% without any signs of anaerobiosis and the CO_2 concentration during CA at 8% was found to be the threshold value (Fig. 4) beyond which the mango slices showed symptoms of CO_2 injury causing termination of shelf life. As such, the pre-treated mango slices showed an ability to withstand low O_2 and high CO_2 conditions ensuring better results for pre-cut mango stored under MA/CA conditions.

Colour Coordinates

Maintenance of colour stability is an important aspect in minimal processing of fresh produce as the cut surface is highly susceptible to browning as well as the rapid pigment losses, drastically affecting the acceptability of the product in terms of colour. In the present study, pre-treated mango slices under different types of MA and CA showed a steady fall in L-values (Fig. 5) and b-values (Fig. 7). On the contrary a-values showed a steady increase (Fig. 6). The changes in L, a, b colour coordinates as such showed restricted increase in darkness as well as redness and a decrease in yellow shades during MA/CA storage of pretreated mango slices compared with the control samples stored under similar conditions without any pre-treatment. The variations in L, a, b colour coordinates amongst different storage conditions were found to be significant ($p \leq 0.05$) and the least drift in L, a, b coordinates was observed in the case of CA stored samples as compared to MAP ones. Amongst the MAP samples the gas mixture flushed samples showed the least drift followed by those stored in

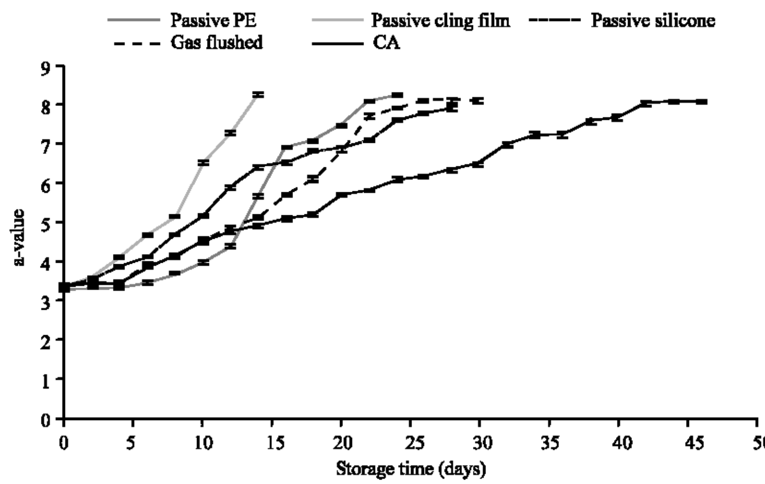

Fig. 6: Changes in Colour a-value during MAP/CA storage of pre-treated mango slices at 8±1 °C. Error bars indicate a 95% confidence interval (n = 6)

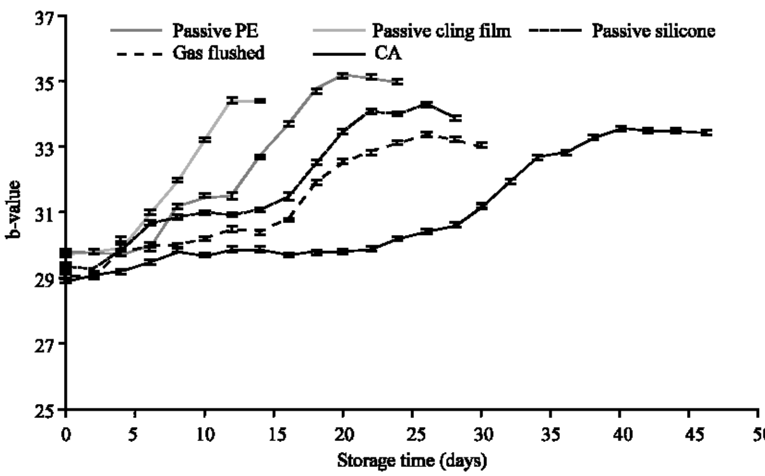

Fig. 7: Changes in Colour b-value during MAP/CA storage of pre-treated mango slices at 81±1 °C. Error bars indicate a 95% confidence interval (n = 6)

Table 2: Kinetic constants for the first order linear model to describe changes in colour coordinates and texture parameters in mango slices during storage at 8±1°C (n = 6)

Parameter	Type of storage	TP_0	TP_t	K_1 (day^{-1})	R^2
L - value	Passive PE	64.01±1.02	51.02±0.03[a]	0.0089±0.0021	0.9868
	Gas flushed		51.71±0.01[b]	0.0067±0.0014	0.9825
	Passive silicone		52.01±0.04[a]	0.0078±0.0021	0.8942
	Passive cling film		56.21±0.03[c]	0.0074±0.0011	0.9537
	CA		50.92±0.02[a]	0.0047±0.0020	0.9686
a - value	Passive PE	3.35±0.02	8.01±0.04[b]	0.0540±0.0007	0.905
	Gas flushed		8.11±0.03[c]	0.0348±0.0009	0.9744
	Passive silicone		7.90±0.04[a]	0.0321±0.0018	0.9414
	Passive cling film		8.23±0.02[d]	0.0675±0.0025	0.9772
	CA		8.09±0.03[c]	0.0198±0.0019	0.9690
b - value	Passive PE	29.82±0.02	35.01±0.07[e]	0.0085±0.0006	0.9414
	Gas flushed		32.84±0.06[a]	0.0047±0.0008	0.8735
	Passive silicone		33.89±0.05[c]	0.0059±0.0009	0.9293
	Passive cling film		34.41±0.04[d]	0.0119±0.0008	0.9170
	CA		33.16±0.05[b]	0.0035±0.0016	0.8238
Shear force (N)	Passive PE	2.16± 0.01	1.38±0.02[a]	0.0214±0.0014	0.9494
	Gas flushed		1.51±0.03[c]	0.0107±0.0011	0.9420
	Passive silicone		1.41±0.05[ab]	0.0160±0.0010	0.9841
	Passive cling film		1.32±0.06[a]	0.0361±0.0013	0.9929
	CA		1.63±0.04[d]	0.0058±0.0007	0.9730

The values in a column followed by different superscripts differed significantly ($p \leq 0.05$)

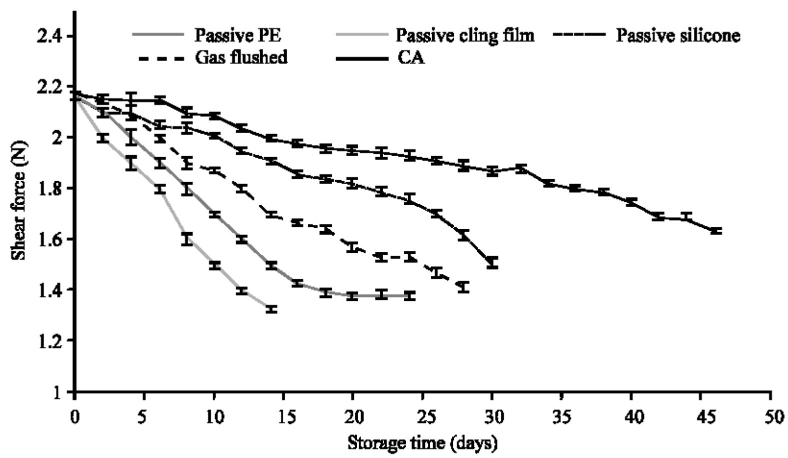

Fig. 8: Changes in shear force during MAP/CA storage of pre-treated mango slices at 8±1°C. Error bars indicate a 95% confidence interval (n = 6)

PET bottles with silicone membrane, polyethylene pouches and cling film over wrapped plastic cups, respectively. As such the synergistic effect of the pre-treatments and MA/CA conditions stabilized the drift in L, a, b colour coordinates, rendering colour stability to the product under low temperature storage.

The colour kinetics showed that the MAP and CA storage followed first order linear model with correlation coefficients ranging from 0.824 to 0.987. The rate constants also showed higher stability for the L, a, b coordinates in the CA stored samples vis-à-vis MAP ones (Table 2). Soliva-Fortuney *et al.* (2001) proposed a fractional conversion first order model for predicting colour changes in minimally processed apples. The present findings are in conflict with the earlier report indicating the colour changes to be dependent on the type of fruit.

Shear Force

The minimally processed mango slices kept under MA/CA conditions showed restricted fall and as such softening and the maximum restriction was found in the CA stored samples (Fig. 8). The changes in texture followed the same pattern as observed in the case of respiratory drift showing a significant ($p \leq 0.05$) variation amongst different types of storage conditions. Restriction in metabolic activity mediated through the synergistic effects of pre-treatments and MA/CA conditions may be attributed to the restriction in textural losses during storage. Soliva-Fortuney ***et al.*** (2002) reported lower rate constants in terms of textural losses in fresh cut pears stored under passive modified atmosphere. The present study also showed lower rate constants for the pre-treated and MA/CA stored samples with the CA stored samples having a higher stability in terms of textural losses and followed first order linear model with correlation coefficients ranging from 0.942 to 0.993.

Microbiological Analysis

The initial counts (Table 1) showed the presence of coliforms in the control samples besides higher counts in SPC as well as yeast and molds compared with pre-treated mango slices. The microbiological analysis carried out after the termination of storage for pre-treated mango slices stored under MA/CA conditions showed a greater influence of pre-treatment over the microbial proliferation compared with the MA/CA conditions (Table 3). The control samples without any pre-treatment under MA/CA conditions showed greater tendency towards microbial proliferation with SPC $>10^6$ and yeast and molds $>10^4$. Several reports exist with regards to the beneficial effect of high CO_2 atmosphere over the growth of microorganisms as in the case of fresh cut apples (Soliva-Fortuney *et al.*, 2004). However, the reports are conflicting with regards to the extent of control over microbial growth and also the target organisms. In the present study the beneficial effect of low O_2 and high CO_2 atmosphere was found to be more pronounced in the case of mesophilic bacteria as compared to yeasts and molds.

Sensory Analysis and Shelf Life

The shelf life of the pre-treated materials as well as the control samples without any pre-treatment, kept under different MA/CA atmospheres was determined, on the basis of overall sensory

Table 3: Microbiological quality of MAP/CA stored mango slices at the end of shelf life (n = 6)

Treatment	Type of MA/CA	TPC (cfu g^{-1})	Y and M (cfu g^{-1})	Coliforms (cfu g^{-1})	Spores (cfu g^{-1})
Pre-treated	Passive PE	$1.0\pm0.1\times10^3$	$3.9\pm0.2\times10^3$	<1	<1
	Gas flushed	$3.0\pm0.2\times10^2$	$2.6\pm0.3\times10^3$	<1	<1
	Passive silicone	$6.2\pm0.1\times10^2$	$3.3\pm0.1\times10^3$	<1	<1
	Passive cling film	$3.0\pm0.2\times10^3$	$4.1\pm0.1\times10^3$	<1	$4\pm0.1\times10^1$
	CA	$4.2\pm0.2\times10^2$	$2.7\pm0.2\times10^3$	<1	<1
Untreated	Passive PE	$3.7\pm0.1\times10^8$	$4.6\pm0.1\times10^7$	$2.2\pm0.2\times10^2$	$2.0\pm0.1\times10^2$
(Control)	Gas flushed	$2.8\pm0.2\times10^7$	$3.7\pm0.2\times10^6$	$3.1\pm0.1\times10^2$	$2.3\pm0.1\times10^2$
	Passive silicone	$5.6\pm0.3\times10^9$	$7.2\pm0.3\times10^8$	$4.2\pm0.1\times10^2$	$2.9\pm0.2\times10^2$
	Passive cling film	$6.7\pm0.2\times10^9$	$8.1\pm0.3\times10^8$	$2.3\pm0.2\times10^2$	$3.4\pm0.2\times10^2$
	CA	$3.2\pm0.2\times10^7$	$6.2\pm0.2\times10^7$	$1.9\pm0.1\times10^2$	$2.8\pm0.1\times10^2$

All the values in a column differed significantly ($p \leq 0.05$) from each other

Table 4: Shelf lives (days) of mango slices stored in different types of MAP/CA at 8±1°C (n = 6)

Type of storage condition	Pre-treated	Untreated (control)
Passive PE	24 ± 2^b	8 ± 1^b
Gas flushed	32 ± 2^d	10 ± 2^c
Passive silicone	28 ± 2^c	8 ± 1^b
Passive cling film	14 ± 1^a	6 ± 1^a
CA	46 ± 2^e	12 ± 1^d

The values in a column followed by different superscripts differed significantly ($p \leq 0.05$)

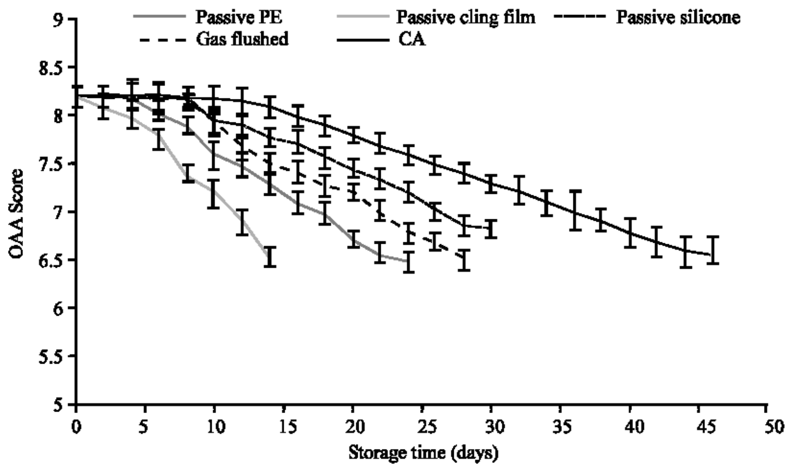

Fig. 9: Changes in overall acceptability during MAP/CA storage of pre-treated mango slices at 8±1 °C. Error bars indicate a 95% confidence interval (n = 10)

scores of 6.0 and above on a 9 point hedonic scale (Fig. 9). The shelf life (Table 4) highlighted the effectiveness of the pre-treatment in improving the efficacy of MA/CA storage. CA stored samples gave the largest shelf life followed by different MAP conditions i.e., gas flushed, PET bottles with silicone membrane, packing in polyethylene and cling film over-wrapped plastic cups. The variation in shelf life of the different samples was found to be significant ($p\leq 0.05$). The unit packages of 250 g each are expected to be conducive for retail marketing of mango slices stored under low temperature (8±1 °C) conditions.

Conclusions

This study highlights the synergistic affect of minimal processing with MA/CA storage conditions to improve the keeping quality of mango slices. The minimal process involving physico-chemical measures restricted microbial proliferation in addition to anti-browning and respiratory drift retardant functions. Acidification of the pre-cut produce with citric acid in addition to the low O_2 and high CO_2 storage atmosphere restricted the respiratory drift causing stabilization of colour and texture during storage. MA/CA storage as such didn't show a pronounced effect on microbial growth retardation and the synergistic affect of the same in combination with pre-treatments gave optimal results in terms of keeping quality and extended shelf life (14-46 days) depending on conditions during storage. CA stored samples gave the maximum shelf life followed by different MAP conditions i.e., active gas mixture flushing, passive in PET bottles with silicone membrane, passive with air in polyethylene pouches and passive in plastic trays over-wrapped with cling film; respectively. The cultivar *Arka anmol* showed ample suitability for minimal processing and subsequent CA/MA storage with requisite texture, colour and sensory attributes besides intrinsic ability to withstand low O_2 and high CO_2 concentrations.

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