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PRETREATMENTS AND COLD STORAGE ON THE QUALITY OF MINIMALLY PROCESSED AMBARELLA (*SPONDIAS DULCIS* L.) AND THE MIXED LOAD OF AMBARELLA AND PINEAPPLE (*ANANAS COMOSUS* (L.) MERR)

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ABSTRACT

Minimally processed ambarella (*Spondias dulcis* L.) and the mixed load of ambarella and pineapple (*Ananas comosus* (L.) Merr) stored at 5-7 ^{0}C for seven days were evaluated for variation in physico-chemical, sensory and microbiological quality. Samples were treated with sodium chloride, calcium chloride, sodium chloride + calcium chloride, ascorbic acid, citric acid, chitosan or distilled water (control) and packed in polystyrene packages before storage. Pretreatments did not have a significant effect on the physico-chemical properties [titratable acidity (TA), total soluble solids (TSS) and pH] when compared to the control. Sensory attributes such as appearance, colour, odour, flavour, taste and overall acceptability generally declined with time but were within acceptable limits by the end of seven-day storage period. The microbial counts (total plate count and yeast and mould count) for all treatments except for the control were within safe-to-consume limits and *Salmonella* was not detected in any of the samples by the end of storage period. As pretreatments tested had no significant effect on physico-chemical or sensory properties and maintained low microbial counts, minimally processed ambarella and mixed load of ambarella and pineapple processed this way could be recommended for sale at supermarket chains with cold storage facility as a value added product.

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Keywords: minimal processing, ambarella+pineapple, pretreatments, cold storage, modified atmosphere packaging

INTRODUCTION

The minimal processing procedures for fruits and vegetables have been designed to maintain freshness and utmost eating quality at the point of consumption (Halim *et al.* 2007). Based on a recent consumer survey conducted in Malaysia, the most important factors that influence consumers to purchase minimally processed fruits is their original taste, cleanliness and the perception that the products are safe to be consumed (Halim *et al.* 2007). At the same time, consumers perceive that minimally processed fruits are healthy and convenient. Thus they are willing to pay a premium price for these products (Halim *et al.* 2007).

Minimally processed foods are similar to the characters and qualities of the fresh commodity, like freshness and aliveness of tissues. Conditions for processing of the raw materials such as peeling, slicing, pre-treatments, packing and storing have to be carefully worked out so that the freshness, texture and flavour of the product is preserved nearer to the raw material which would have a shelf life acceptable to the consumer (Dharmabandu *et al.* 2007).

Cut produce are immersed in pre-treatment solutions at the final stage of the handling operations which will reduce microbial spoilage, excessive tissue softening and tissue browning (Latifah *et al.* 2007). Minimally processed fruits and vegetables can be packaged under various environments, namely, modified atmosphere packaging (MAP), controlled atmosphere packaging (CAP) and vacuum packaging (Hui *et al.* 2006).

Pineapple is eaten fresh worldwide and used in desserts and salads. It is a good source of calcium, iron and significant amounts of vitamins A, B and C (Jayaweera 1981). Ambarella fruits which are used in the preparation of curry, salads and pickles are rich in Vitamin C and the fruit juice is expected to have a considerable effect in lowering blood sugar (Warrier *et al.* 1994).

There, is no record of the two commodities being subjected to minimal processing technology as mixed load. These two commodities are suitable for minimal processing as a mixed load because both commodities are somewhat similar in fragrance and flavour, so they can be packed together without any effect on odour, flavour and taste.

The objectives of the present study were to investigate the physicochemical, sensory and microbiological properties of minimally processed ambarella and minimally processed ambarella and pineapple as a mixed load that has been subjected to selected pretreatments, and stored at 5-7 ^{0}C.

MATERIALS AND METHODS

Investigation of the physicochemical, sensory and microbiological properties of minimally processed ambarella

Preparation of samples**:** *Spondias dulcis* (ambarella – hybrid variety) at 70-80% maturity stage (three quarter ripe stage) harvested from a home garden in Mount Lavinia, Sri Lanka was transported to the laboratory at the Department of Botany, University of Kelaniya, to determine the physicochemical, microbiological and sensory properties. The outer peel of ambarella was removed and the sorted samples were washed with distilled water and dipped in chilled water for 2 minutes. Subsequently, ambarella was cut into slices (each 5 - 8 g) using a sharp stainless steel knife under aseptic conditions. Cut ambarella slices were pretreated by dipping in solutions of either T_1 - 1% (w/v) sodium chloride or T_2 - 1% (w/v) calcium chloride or T_3 - 1% (w/v) sodium chloride + 1% (w/v) calcium chloride or T_4 - 1% (w/v) ascorbic acid or T_5 - 1% (w/v) citric acid or T_6 - 0.1% (w/v) chitosan or T_7 - distilled water /control for 2-3 minutes. Samples were thereafter drained and air dried for 10 minutes and 8-10 slices were packed separately in polystyrene packages of 150 g and sealed by placing the clip-on lids.

Investigation of the physicochemical, sensory and microbiological properties of minimally processed ambarella and pineapple as a mixed load

***Preparation of samples*:** Ambarella (same variety as used in previous experiment) at 70-80% maturity stage (three quarter ripe stage) was harvested from a home garden in Kadawatha area, Sri Lanka. *Ananas comosus* (pineapple cv. Mauritius) at quarter ripe stage (approximately 25% of the eyes are yellowish orange) (Latifah *et al.* 2000), was purchased from Balummahara, Sr Lanka. Both were transported to the laboratory at the Department of Botany, University of Kelaniya to determine physicochemical, microbiological and sensory properties. The outer peel of ambarella and pineapple were removed and the sorted samples were washed with distilled water and dipped in chilled water for 2 minutes. Subsequently, ambarella was cut into slices (each 5 - 8 g) and pineapple was cut into cubes (2 cm^3) using a sharp stainless steel knife under aseptic conditions. Ambarella and pineapple slices together were pretreated by dipping in solutions of either T_1 - 1% (w/v) sodium chloride or T_2 - 1% (w/v) calcium chloride or T_3 - 1% (w/v) sodium chloride + 1% (w/v) calcium chloride or T_4 - 1% (w/v) ascorbic acid or T_5 - 1% (w/v) citric acid or T_6 - 0.1% (w/v) chitosan or T_7 - distilled water /control for 2-3 minutes separately. Samples were drained and air dried for 10 minutes and pre-treated pineapple cubes (8-10) and ambarella slices (12-15) were packed together as a mixed load in 1:1 weight ratio in polystyrene packages of 150 g capacity and sealed by placing the clip-on lids.

All packages of ambarella and mixed load samples were placed on plastic trays of 30×40 cm in size (8 packages per tray) and stored in a cold room at 5-7 ^{0}C and 80-85% relative humidity. Four replicate packages per each treatment were used for analysis.

***Physicochemical properties*:** Samples were removed on day 0, 4 and 7 and subjected to physicochemical analysis.

Total soluble solids (TSS) content: The sample (10 g) was homogenized with distilled water (40 ml) in a blender (Black & Decker, BX 250, Hunt Valley, USA) for 2 minutes. The homogenate was filtered through a muslin cloth. Few drops of the filtrate were used to measure TSS using a hand-held refractometer (ATC-1E, ATAGO Co. Ltd., Japan). The actual TSS content was calculated by multiplying each reading with the dilution factor (Abeywickrama *et al.* 2004). Four replicate samples were used per treatment.

pH of filtrates: pH of the filtrates (samples of pulp prepared for TSS analysis) was measured using a digital pH meter (pHep HI 98107, Hanna Instruments, Portugal) (Anthony *et al.* 2003). Four replicate samples were used per treatment.

Titratable acidity (TA): Ten (10) ml sample from each of the above mentioned filtrates was diluted with distilled water (20 ml) and titrated against 0.1 M NaOH with phenolphthalein as the pH indicator. The end point was taken as the sudden appearance of slight pink colour in the solution. TA was calculated by multiplying the NaOH volume with the dilution factor and the citric acid factor (citric acid factor = 0.0064 g). TA was expressed as % citric acid (Abeywickrama *et al.* 2004).

***Sensory properties*:** Samples were removed on day 0 and 7 and subjected to sensory evaluation. The treated samples were provided to an untrained, 10 member taste panel along with a questionnaire. The evaluation was conducted using a 7 point ranking system (Dharmabandu *et al.* 2007). Twenty replicate samples were used per treatment.

Microbiological properties: Samples were removed on day 0 and 7 and subjected to microbiological assessment.

Total aerobic plate count: Twenty (20.0) g of sample was homogenized with sterile 0.9% NaCl (180.0 ml) in a blender for 2 minutes and a dilution series was prepared up to 10^{-5}. From 10^{-3}, 10^{-4} and 10^{-5} dilutions 1.0 ml was plated to which 12 ml of molten plate count agar (PCA) was poured. Plating was done in duplicate and incubated at 28 ± 2^0C for 72 hours and the number of colony forming units (CFU) was determined. Eight replicate samples were used per treatment (SLS Part 1 1991; Dharmabandu *et al.* 2007).

Yeast and mould count: One (1.0) ml from 10^{-3}, 10^{-4} and 10^{-5} dilutions prepared under total aerobic plate count, were separately plated along with 12 ml molten yeast and mould agar (YMA). Plating was done in duplicate. Plates were incubated at 28 ± 2^0C for 72 hours and CFU were determined (Nur Aida *et al.* 2007). Eight replicate samples were used per treatment.

Salmonella: A 2 g sample from each treatment was separately added to flasks containing 20 ml Selenite broth and incubated at 37 ^{0}C for 24 hours. A loopful from each treatment was sub-cultured onto MacConkey agar medium. Plating was done in duplicate. Plates were incubated at 37 ^{0}C and examined for the presence of colorless colonies after 24 hours (Dharmabandu *et al.* 2007). Four replicate samples were used per treatment.

***Statistical analysis*:** The experimental arrangement was a completely randomized design (CRD). Data obtained for sensory properties were subjected to Kruskal Wallis non-parametric statistical test whereas data with respect to physicochemical properties, gas analysis and microbial content were analyzed by General Linear Model using ANOVA, MINITAB 14. Treatment means were compared using the least significant difference at P=0.05.

RESULTS

Physicochemical, sensory and microbiological properties of minimally processed ambarella

***Physicochemical properties*:** The pH of all treatments and the control were within the range of 4.5 – 5.1 from day 0 to day 7. There was a slight variation in pH for each treatment during day 0, 4 and 7 (Table 1). However, there was no significant difference in pH among the different treatments and the control within the same day. The TSS of the samples from different treatments and control were not significantly ($p>0.05$) different during each analysis days (0, 4 and 7). TSS values were within the range of 4.50-6.25 in all treatments and control during 7 days storage period (Table 1). The TA values of the samples from different treatments and control were within the range of 0.80 – 1.15 % during day 0, 4 and 7 (Table 1). However, there was no significant ($p>0.05$)

difference in the TA values of the samples from different treatments within the same day and also during storage.

***Sensory properties*:** A decrease in all sensory attributes was evident during the storage period of seven days. Statistically significant differences in rank values were also observed with storage with respect to sensory properties. By 7^{th} day of storage, the highest overall acceptability was observed with sodium chloride-alone and Sodium chloride + Calcium chloride - treated ambarella which were significantly different to other pretreatments and control while the lowest acceptability was observed with citric acid treated ambarella (Table 2).

***Microbiological properties*:** The total plate count enumerated from samples on day 0 ranged from 4.48 – 5.18 log_{10} CFU/g and it ranged from 4.60 – 5.08 log_{10} CFU/g on day 7 (Table 1). During 7^{th} day after storage, the highest total plate count of 5.08 log_{10} CFU/g was observed in the ascorbic acid treated samples and the lowest plate count of 4.60 log_{10} CFU/g in calcium chloride treated samples (Table 1). *Salmonella,*

Table 1: Physicochemical and microbiological properties of minimally processed ambarella stored at 5-7 ^{0}C.

Storage time (days)	Treatment						
	T_1	T_2	T_3	T_4	T_5	T_6	T_7
				pH			
0	4.90 ± 0.04	4.93 ± 0.06	4.93 ± 0.09	4.48 ± 0.15	4.53 ± 0.13	4.65 ± 0.12	4.88 ± 0.14
4	4.83 ± 0.15	4.88 ± 0.03	4.93 ± 0.06	4.55 ± 0.12	4.73 ± 0.19	5.00 ± 0.18	4.95 ± 0.13
7	4.63 ± 0.06	4.85 ± 0.10	4.88 ± 0.09	4.73 ± 0.17	4.93 ± 0.16	5.08 ± 0.19	5.03 ± 0.13

				TSS (^{0}Brix)			
0	4.88 ± 0.13	4.50 ± 0.54	5.63 ± 0.47	5.25 ± 0.52	4.88 ± 0.25	5.25 ± 0.52	5.38 ± 0.31
4	5.63 ± 0.24	5.00 ± 0.41	5.63 ± 0.31	5.00 ± 0.46	5.63 ± 0.38	5.63 ± 0.47	5.75 ± 0.43
7	6.25 ± 0.32	5.50 ± 0.35	5.00 ± 0.20	5.38 ± 0.43	5.75 ± 0.32	6.00 ± 0.58	6.00 ± 0.35
				Titratable acidity (% Citric acid)			
0	0.85 ± 0.15	1.08 ± 0.16	1.15 ± 0.20	0.95 ± 0.08	0.89 ± 0.09	0.86 ± 0.09	0.86 ± 0.06
4	0.90 ± 0.06	0.93 ± 0.03	1.02 ± 0.09	0.91 ± 0.05	0.94 ± 0.05	0.83 ± 0.08	0.90 ± 0.06
7	1.03 ± 0.11	0.99 ± 0.08	0.80 ± 0.08	0.99 ± 0.07	1.04 ± 0.04	0.91 ± 0.03	0.92 ± 0.17
				Total plate count (Log_{10} CFU/g)			
0	4.72 ± 0.07	4.48 ± 0.03	4.52 ± 0.06	4.94 ± 0.24	5.17 ± 0.26	4.51 ± 0.04	4.73 ± 0.01
7	4.84 ± 0.26	4.60 ± 0.30	4.64 ± 0.03	5.08 ± 0.11	4.84 ± 0.08	4.80 ± 0.00	4.83 ± 0.03

T_1 - 1% (w/v) Sodium chloride, T_2 - 1% (w/v) Calcium chloride, T_3 - 1% (w/v) Sodium chloride + 1% (w/v) Calcium chloride, T_4 - 1% (w/v) Ascorbic acid, T_5 - 1% (w/v) Citric acid, T_6 - 0.1% (w/v) Chitosan, T_7 - Distilled water (control).

Each data point represents the mean of four replicates; P value for pretreatment: pH-0.308; TSS-0.322; TA-0.639; total plate count-0.533; P value for time: pH-0.212; TSS-0.024; TA-0.756; total plate count-0.337; P value for interaction (pretreatment×time): pH-0.342; TSS-0.663; TA-0.530; total plate count-0.558.

$P<0.05$ indicates a significant difference among variable and control.

Table 2: Sensory properties of minimally processed ambarella stored at 5-7 ^{0}C.

	Day 0						Day 7					
Pre-treatment	Appearance	Colour	Odour	Flavour	Taste	Overall acceptability	Appearance	Colour	Odour	Flavour	Taste	Overall acceptability
T_1	6.50^{a}	6.50^{a}	6.38^{a}	6.38^{a}	6.44^{a}	6.44^{a}	5.31^{a}	5.44^{a}	4.69^{a}	5.25^{a}	5.19^{a}	5.31^{a}
T_2	6.44^{a}	6.31^{a}	6.38^{a}	6.00^{a}	5.94^{a}	6.06^{a}	5.00^{a}	4.88^{a}	4.81^{a}	4.50^{b}	4.50^{b}	4.69^{b}
T_3	6.31^{a}	6.38^{a}	6.44^{a}	6.06^{a}	6.06^{a}	6.13^{a}	5.19^{a}	5.31^{a}	4.75^{a}	5.19^{a}	5.13^{a}	5.06^{a}
T_4	5.56^{b}	5.50^{b}	5.19^{b}	5.56^{b}	5.44^{b}	5.56^{b}	4.00^{b}	4.19^{b}	4.31^{b}	4.88^{a}	4.75^{b}	4.41^{b}
T_5	5.60^{b}	5.44^{b}	5.25^{b}	5.56^{b}	5.56^{b}	5.56^{b}	3.88^{b}	3.94^{b}	3.88^{b}	4.63^{b}	4.75^{b}	4.31^{b}
T_6	5.06^{b}	5.06^{b}	4.94^{b}	5.50^{b}	5.31^{b}	5.31^{b}	4.00^{b}	4.06^{b}	4.25^{b}	4.94^{a}	4.88^{a}	4.66^{b}
T_7	5.94^{b}	5.88^{b}	5.81^{a}	5.69^{b}	5.63^{b}	5.69^{b}	4.13^{b}	4.25^{b}	4.38^{b}	4.56^{b}	4.69^{b}	4.59^{b}

T_1 - 1% (w/v) Sodium chloride, T_2 - 1% (w/v) Calcium chloride, T_3 - 1% (w/v) Sodium chloride + 1% (w/v) Calcium chloride, T_4 - 1% (w/v) Ascorbic acid, T_5 - 1% (w/v) Citric acid, T_6 - 0.1% (w/v) Chitosan, T_7 - Distilled water (control). Each data point represents the mean of six replicates. Means sharing a common letter (s) within the same column are not significantly different by Kruskal Wallis nonparametric test.

Yeasts and moulds were not detected in any of the treatments or control at any stage.

Investigation of the physicochemical, sensory and microbiological properties of minimally processed ambarella and pineapple as a mixed load

Physicochemical properties: The pH of all treatments and the control were within the range of 4.1 –4.95 from day 0 to day 7 (Table 3). There was a slight variation in pH for each treatment between day 0, 4 and 7. The highest value of pH was recorded for calcium chloride treatment on day 0 while the highest value of pH on day 7 was recorded for chitosan treatment. TSS values were within the range of 9.75- 25.00 in all treatments and control within day 0, 4^{th} and 7^{th} (Table 3). The highest TSS value (25.5 ^{0}Brix) among the treatments was recorded for the citric acid treated samples. The TSS values increased with increasing storage period for all treatments and control except for pineapple and ambarella treated with calcium chloride and sodium chloride + calcium chloride. The TA values of the samples from different treatments and control were within the range of 0.10 – 0.30 % during day 0, 4 and 7 (Table 3). The highest acidity level (0.29) was recorded in samples pretreated with calcium chloride on day 4 while lowest acidity level (0.10) was recorded in the same sample, on day 0.

Generally, the titratable acidity decreased with the storage time for all the treatments including the control. However, a slight increment of titratable acidity was observed on day 4 compared to day 0, for calcium chloride, sodium chloride + calcium chloride, ascorbic acid and citric acid treated samples. Also, there was no significant difference ($p>0.05$) in physico-chemical properties among different treatments and the control within the same day and per each treatment with increasing storage time from day 0 to day 7.

Table 3: Physicochemical and microbiological properties of minimally processed ambarella and pineapple as a mixed load and stored at 5-7 ^{0}C.

Storage time (days)	Treatment						
	T_1	T_2	T_3	T_4	T_5	T_6	T_7
				pH			
0	4.55 ± 0.05	4.95 ± 0.06	4.35 ± 0.02	4.25 ± 0.10	4.15± 0.05	4.17 ± 0.03	4.45 ± 0.01
4	4.18 ± 0.10	4.15 ± 0.05	4.35 ± 0.02	4.38 ± 0.08	4.45 ± 0.02	4.25 ± 0.05	4.60 ± 0.03
7	4.10 ± 0.03	4.16 ± 0.05	4.15 ± 0.06	4.55 ± 0.10	4.65 ± 0.02	4.95 ± 0.08	4.70 ± 0.05
				TSS (^{0}Brix)			
0	9.75 ± 0.55	10.37 ± 0.66	10.62 ± 0.77	14.00 ± 0.52	15.00 ± 0.35	15.00 ± 0.29	14.87 ± 0.63
4	9.85 ± 0.95	10.00 ± 0.83	10.00 ± 0.69	21.87 ± 0.69	18.87 ± 0.66	19.87 ± 0.43	22.78 ± 0.24
7	10.00 ± 0.71	10.00 ± 0.65	10.00 ± 0.26	25.12 ± 0.65	25.50 ± 0.65	20.00 ± 0.24	25.54 ± 0.13
				Titratable acidity (% Citric acid)			
0	0.16 ± 0.02	0.10 ± 0.05	0.14 ± 0.04	0.19 ± 0.09	0.14 ± 0.07	0.14 ± 0.08	0.20 ± 0.05
4	0.12 ± 0.05	0.29 ± 0.03	0.19 ± 0.08	0.14 ± 0.03	0.17 ± 0.05	0.19 ± 0.04	0.21 ± 0.07
7	0.12 ± 0.03	0.12 ± 0.04	0.12 ± 0.07	0.13 ± 0.04	0.12 ± 0.03	0.10 ± 0.03	0.12 ± 0.03

	Total plate count (Log_{10} CFU/g)						
0	5.81 ± 0.04	5.29 ± 0.04	5.31 ± 0.00	5.19 ± 0.08	5.75 ± 0.20	5.4 9 ± 0.34	6.61 ± 0.08
7	5.24 ± 0.02	5.19 ± 0.26	4.86 ± 0.09	4.43 ± 0.03	4.93 ± 0.35	5.06 ± 0.29	6.63 ± 0.13
	Yeast and mould count (Log_{10} CFU/g)						
0	5.54 ± 0.42	4.80 ± 0.58	4.37 ± 0.00	0.00 ± 0.00	3.65 ± 1.89	4.13 ± 0.40	5.98 ± 0.12
7	3.95 ± 0.21	0.00 ± 0.00	3.65 ± 0.41	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	6.27 ± 0.31

T_1 - 1% (w/v) Sodium chloride, T_2 - 1% (w/v) Calcium chloride, T_3 - 1% (w/v) Sodium chloride + 1% (w/v) Calcium chloride, T_4 - 1% (w/v) Ascorbic acid, T_5 - 1% (w/v) Citric acid, T_6 - 0.1% (w/v) Chitosan, T_7 - Distilled water (control). Each data point represents the mean of four replicates.

P value for pretreatment: pH-0.684; TSS-0.070; TA-0.489; total plate count-0.000; yeast and mould count-0.000; P value for time: pH-0.077; TSS-0.483; TA-0.251; total plate count-0.000; yeast and mould count-0.000; P value for interaction (pretreatment×time): pH-0.538; TSS-0.672; TA-0.682; total plate count-0.000; yeast and mould count-0.000.

$P<0.05$ indicates a significant difference among variable and control.

Sensory properties: A slight decrease in overall acceptability was observed for all the treatments and control with increase in storage period. However, all values were within the range of 5-7 indicating that the quality of samples was within the scales 'good' and 'very good' (Table 4). A significant difference in rank values was also observed for overall acceptability and taste by 7th day of storage for calcium chloride, sodium chloride + calcium chloride and citric acid treated pineapple and ambarella. The highest overall acceptability of 6.70 on day 0 was recorded for ascorbic acid treated pineapple+ ambarella and on day 7, whereas the highest value (6.91) was recorded for distilled water control (Table 4).

Microbiological properties: Total plate count enumerated from samples on day 0 ranged from 5.19 - 6.61 log10 CFU/g whereas it ranged from 4.43 – 6.63 $\log_{10}$ CFU/g by day 7 (Table 3). During 7th day after storage, the highest total plate count of 5.24 $\log_{10}$ CFU/g was observed in the sodium chloride treated samples apart from control and the lowest plate count of 4.43 $\log_{10}$ CFU/g in sodium chloride + calcium chloride treated samples. The yeast and mould count enumerated for treated /control samples on day 0 ranged from 0.00 – 5.98 $\log_{10}$ CFU/g whereas on day 7 it ranged from 0.00 – 6.27 $\log_{10}$ CFU/g (Table 3).

Table 4: Sensory properties of minimally processed mixed load of pineapple and ambarella stored at 5-7 ^{0}C.

	Day 0						Day 7					
Pre-treatment	Appearance	Colour	Odour	Flavour	Taste	Overall acceptability	Appearance	Colour	Odour	Flavour	Taste	Overall acceptability
T_1	6.52^a	6.29^a	6.21^a	6.29^a	6.41^a	6.52^a	6.41^a	6.52^a	5.82^a	6.05^a	6.29^a	6.41^a
T_2	6.29^a	5.94^a	6.05^a	5.41^a	5.00^a	5.70^a	5.23^a	5.29^b	5.11^a	5.58^b	5.41^b	5.47^b
T_3	6.11^a	6.00^a	6.11^a	5.41^a	5.41^a	5.88^a	6.00^a	5.76^a	5.52^a	5.41^a	5.52^b	5.64^b
T_4	6.76^a	6.64^a	6.58^a	6.76^a	6.70^a	6.76^a	6.52^a	6.64^a	6.29^a	6.17^a	6.58^a	6.47^a
T_5	5.93^a	6.18^a	5.81^a	5.62^a	5.62^a	5.81^a	5.12^a	4.68^b	6.00^a	4.81^b	5.06^b	5.18^b
T_6	5.25^a	5.31^a	5.18^a	4.87^a	5.43^a	5.62^a	5.62^a	5.43^a	4.62^a	6.00^a	5.31^a	5.50^a
T_7	6.55^a	6.25^a	6.41^a	6.25^a	6.08^a	6.81^a	6.50^a	6.20^a	6.38^a	6.30^a	6.20^a	6.91^a

T_1 - 1% (w/v) Sodium chloride, T_2 - 1% (w/v) Calcium chloride, T_3 - 1% (w/v) Sodium chloride + 1% (w/v) Calcium chloride, T_4 - 1% (w/v) Ascorbic acid, T_5 - 1% (w/v) Citric acid, T_6 - 0.1% (w/v) Chitosan, T_7 - Distilled water (control). Each data point represents the mean of twenty replicates. Means sharing a common letter (s) within the same column are not significantly different by Kruskal-Wallis nonparametric test.

The yeast and mould count in ascorbic acid treated samples was zero on both 0 and 7th day. The highest yeast and mould count of 6.27 log_{10} CFU/g was observed for the control on the 7th day after storage. The total plate count and yeast and mould count of mixed load samples decreased by day 7 when compared to the day 0 in all treatments except in control (Table 3). *Salmonella* were not detected in any of the treatments or control during day 0 as well as on day 7.

DISCUSSION

Minimally processed products are more perishable than the intact products because they have been subjected to severe physical stress, such as peeling, cutting, slicing and removal of protective epidermal cells. As a result, physiological and biochemical changes occur more drastically in minimally processed products (Latifah *et al.* 1999).

The total quantity of acids as well as the strength of the acids determines the pH value (Schmidl & Labuza 2000). Gradual variations in pH were observed in all tested commodities. However, there was no significant difference in the variation of pH between minimally processed ambarella, and pineapple + ambarella as a mixed load during the storage time. This was in agreement with the results of Hassan & Atan (1983) where pH values of pineapple stored at 8 ^{0}C increased from 3.9 to 4.0 and decreased from 3.8 to 3.2 when the storage period was extended to 3 and 4 weeks. These results indicate that non-climacteric fruits do not show changes in the biochemical composition at low temperatures.

Titratable acidity (TA) is a measurement that is often associated with pH. Titratable acidity (TA) value is a quantitative measure of the organic acids in a fruit substrate which is a useful measurement to monitor the progress of acid producing fermentations (Schmidl & Labuza 2000). Titratable acidity is often expressed in terms of the predominant acid present, i.e., citric acid in pineapple and ambarella. Therefore use of titratable acidity values to measure acidity is largely dependent on the type of food analyzed

(Downes & Ito 2001). When considering the TA values of the commodities used in this study, relatively low values could be observed for ambarella and the mixed load.

The total soluble solids (TSS) reflect the sugar concentration of a fruit, mainly carbohydrates. Besides that, TSS values also indicate the available energy remaining in the fruit to carry on respiration and other metabolic functions. The absence of significant changes in the total soluble solids in this study indicates that starch is not accumulated in the fruit but converted to sugars (Latifah *et al.* 2000). In all the tested commodities TSS increased during storage period of 7 days. During ripening, the total carbohydrate content is progressively reduced since it is the major fuel source for respiration. Starch is broken down into reducing and non-reducing sugars.

The physicochemical parameters tested (pH, titratable acidity, total soluble solids) were not affected by certain treatments significantly during the present research. The little variations in certain physicochemical parameters are unavoidable as the fruits vary in their postharvest behavior due to maturity (Abeywickrama *et al.* 2004).

Sensory evaluation provided details on the preference of different individuals, vs. effects of pretreatments. However, these results could be more or less subjective. There was a general decrease in all the sensory attributes with increasing storage time, irrespective of the pre-treatment used. Similar results were obtained by Latifah *et al.* (1999) where all the sensory attributes evaluated during a storage period of 3 weeks decreased, for minimally processed pineapple cultivar Josapine, stored at 2^0C, in polypropylene containers. When considering the changes in sensory attributes of ambarella alone and pineapple + ambarella as a mixed load, with storage period, 1% sodium chloride treated samples received a notably higher rank values for all the sensory properties on 7^{th} day.

In minimally processed products, the increase in cut damaged surfaces and availability of cell nutrients provides favourable conditions for rapid growth of different microbial groups. Furthermore, microbial population increases with handling of the products, as it provides greater opportunity for contamination by pathogenic organisms (Dharmasena *et al.* 2002). When considering the microbiological properties the total plate count was a common factor for all tested samples. Total plate count (TPC) gives an idea about the organisms, especially bacteria, growing aerobically at 30^0C, under the specified conditions (SLS Part 1, 1991). When considering the TPC in minimally processed pineapple and ambarella as a mixed load, a notable difference was observed between the treatments and the control. All pretreatments exhibited antimicrobial effects since theyl were capable of reducing the microbial counts on day 7 compared to those on day 0. Shifting pH of the medium/substrate to an acidic range, which most microbial flora cannot tolerate could be the reason for this high antimicrobial effect. Further, samples treated with calcium chloride and sodium chloride + calcium chloride displayed satisfactory reduction in TPC. It could be inferred that calcium chloride displays an antimicrobial effect as well. Calcium (Ca) has also been reported as extending shelf life of minimally processed fruits and vegetables by controlling respiration rate, texture loss, ethylene production apart from microbial decay (Dharmabandu *et al.* 2007).

The total yeast and mould counts (TYM) provide a general guidance for the enumeration of viable yeasts and moulds in products at specified conditions (SLS Part 2, 1991). The total yeast and mould counts were found to be lower than total plate count populations for ambarella and mixed load samples. These results were also in agreement with those of Nur Aida *et al.* (2007) for minimally processed mung bean sprouts where values ranged between 2.05 – 4.15 $\log_{10}$ CFU/g. It was also reported that bacterial populations dominate over yeasts and moulds in vegetables. Yeasts and moulds were not detected in any of the treatments or control during day 0 as well as on day 7 in minimally processed ambarella samples. When considering mixed load samples the yeasts and moulds were completely absent in the ascorbic acid treated samples on day 0 and day 7. Also, calcium chloride, citric acid and chitosan treated samples exhibited no yeast and mould growth on day 7.

The legal regulations on minimally processed fresh vegetables have been established at a maximum total limit for total plate count of 7.7 $\log_{10}$ CFU/g (Francis *et al.* 1999) and the recommended limit for total yeast and mould count of fresh cut produce is 5 $\log_{10}$ CFU/g (Nur Aida *et al.* 2007). The microbial counts reported in this study were well within these limits except for the control in mixed load sample where the yeast and mould count exceeded the recommended limit by day 7.

Sodium chloride and calcium chloride concentrations between 1% - 4% are commonly used as pretreatments. Previous research findings reported that washing with 0.5% - 1% $CaCl_2$ reduced microbial growth on various commodities (Hui *et al.* 2006). When sodium chloride and calcium chloride are incorporated as a pretreatment, high osmotic pressure results in plasmolysis of microbial cells which dehydrate them and inhibit their growth. Moreover, the chloride ion is toxic to microbes (Hui *et al.* 2006). Chitosan is known to form semi permeable films, capable of modifying the internal atmosphere of fruits and decreasing transpiration losses. It also induces defense mechanisms thereby delaying the ripening process, and respiration. It also acts as anti-fungal agent and helps to retain the quality of fruits and vegetables during storage (Hewajulige *et al.* 2005). Ascorbic acid also inhibits the growth of moulds, yeasts and bacteria thereby preventing the microbial growth in food products (Vermeiren *et al.* 2000). Citric acid is one of the most widely used acidulants in the food industry. It is typically applied at levels ranging between 0.5 % - 2 % (w/v). Citric acid is used to inhibit enzymatic and trace metal-catalyzed oxidation reactions which can cause color and flavor deterioration and often combined with ascorbic acid for this purpose. Control of optimum pH reduce the level of microorganisms. Using weak organic acids such as citric acid as a pretreatment is beneficial since the acid lowers the pH and inhibits the growth of certain microorganisms (Hui *et al.* 2006).

Although a comparatively higher value of TYM has been recorded for minimally processed pineapple alone (Ediriweera 2010) processing together with ambarella appears to control TYM effectively. Since yeasts and moulds prefer to grow in acidic environment than bacteria, the acidic nature of pineapple might be facilitating their growth but together with ambarella, the pH range which favours the growth of certain acidophilic fungi may have changed to more basic range. This could possibly be the reason for the reduction in TYM in the minimally processed pineapple+ambarella as a mixed load.

Food-borne diseases are an important public health problem. Salmonellosis is a disease caused by the pathogen *Salmonella* and. their presence in a test sample is regarded as an indication of fecal contamination. *Salmonella* was not detected in any of the samples subjected to different treatments.

Maintaining the quality of minimally processed product at a suitable temperature is considered the primary goal for successful marketing. Minimally processed products demonstrate rapid postharvest quality degradation under tropical ambient storage (Latifah *et al.* 2000). The low temperature storage (5-7 ^{0}C) used in this study is important in reducing the adverse physical and chemical changes that would occur otherwise and also to control the microbial proliferation. In fact, low temperature during transportation, storage and retail display slows ripening, reduces deterioration and minimizes ethylene effect since ethylene accelerates deterioration and senescence in vegetative tissues and promotes ripening of climacteric fruits, thus shortening the storage life (Latifah *et al.* 2000).

CONCLUSIONS

Pineapple cv. Mauritius + ambarella as a mixed load and ambarella alone, could be preserved for a period of 7 days with a minimum effect on physicochemical and sensory properties. As the total plate count, total yeast and mould count were lower than the recommended values and samples were free from *Salmonella*, these minimally processed, products pretreated with sodium chloride, calcium chloride, sodium chloride + calcium chloride, ascorbic acid, citric acid or chitosan and stored for a period of 7 days at 5-7 ^{0}C could be considered as safe to consume. Therefore these products could be recommended to be sold at local supermarket chains in Sri Lanka where cold storage facility is available.

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