levels in this study. Similarly to the study of Ahvenainen *et al*. (1996) found that vitamin C level in potato slices dipped in citric acid also decreased during storage.

Ethylene production and respiration rate

The amount of ethylene production was equal 1.2-1.45 µl C_2H_4/kg/h at the beginning of the storage, and tended to decline throughout the period of storage in all treatments with no significant differences (data not shown). A low temperature storage at 2.5°C could possibly retard the amount of ethylene production in this study. The optimum temperature for fresh-cut fruit was recommended at 5 to 10°C (González-Aguilar *et al*., 2004). Furthermore, pineapple has been known as a non-climacteric fruit, therefore the ethylene production rate was already low (Siripanit, 1998).

The respiration rate as the production of carbon dioxide tended to increase with the longer storage in this study. However, there was no significant difference among treatments (data not shown). This was associated in the study of Marrero and Kader (2006) found that the storage of fresh-cut pineapple more than two days could induce the rate of respiration more and more than those in the fresh fruit. Once cells of fruit were destroyed with cutting process, an increase in the rate of respiration was induced (Watada, 1999).

Sensory evaluation

Color of pineapple slice was light yellow at the beginning of the storage, and then the incidence of a darker color in pineapple slices occurred during storage in all treatments. A 0.5% citric acid solution was the most effective in delaying browning of fruit slices, especially at day 6 of the storage (Table 2), similarly to the study of González-Aguilar *et al*. (2004).

All of the pineapple slices developed an off-odor over the storage period of the 12 days, but the off-odor of the slices in the 0.5% level slices was lowest, but not significantly lower than the control (Table 2).

Fruit quality, as in firmness, was well maintained significantly better in the 0.5% treated fruit for the first 4 days of storage than the other two treatments (Table 2). The results suggest that treating the fresh cut pineapple with a 0.5% solution of citric acid results in better fruit quality, best visual appearance with less browning and delaying senescence of the fresh-cut pineapple.

The acceptable storage life of the fresh-cut pineapple was extended in the 0.5% citric acid treated fruit to 8.5 days at 2.5°C while the storage life of the control and the 1.0% citric acid treated fruit extended to 7.5 and 7 days, respectively (Figure 1C). However, this indicates that there were no significant differences in storage life between the treatments ($p>0.05$). Fresh-cut artichokes treated with citric acid solution alone could be stored up to 5-7 days in the study of Ghidelli *et al*., (2013). However, the efficiency of citric acid was increased by adding ascorbic acid in a ratio of 0.5% CA: 0.5% AA, which reduced the browning incidence in fresh products (Ahvenainen, 1996). Therefore, this mixed solution may be useful for the fresh-cut products, and be necessary for future study.

Conclusions

The solution of citric acid at 0.5% was most effective in delaying the deterioration of Huaimun pineapple slices during storage in this study as shown by better fruit quality, best visual appearance with less browning. The acceptable storage life of the fresh-cut pineapple was extended in the 0.5% citric acid treated fruit to 8.5 days at 2.5°C while the storage life of the control and the 1.0% citric acid treated fruit extended to 7.5 and 7 days, respectively. However, there were no significant differences in storage life between the treatments ($p>0.05$).

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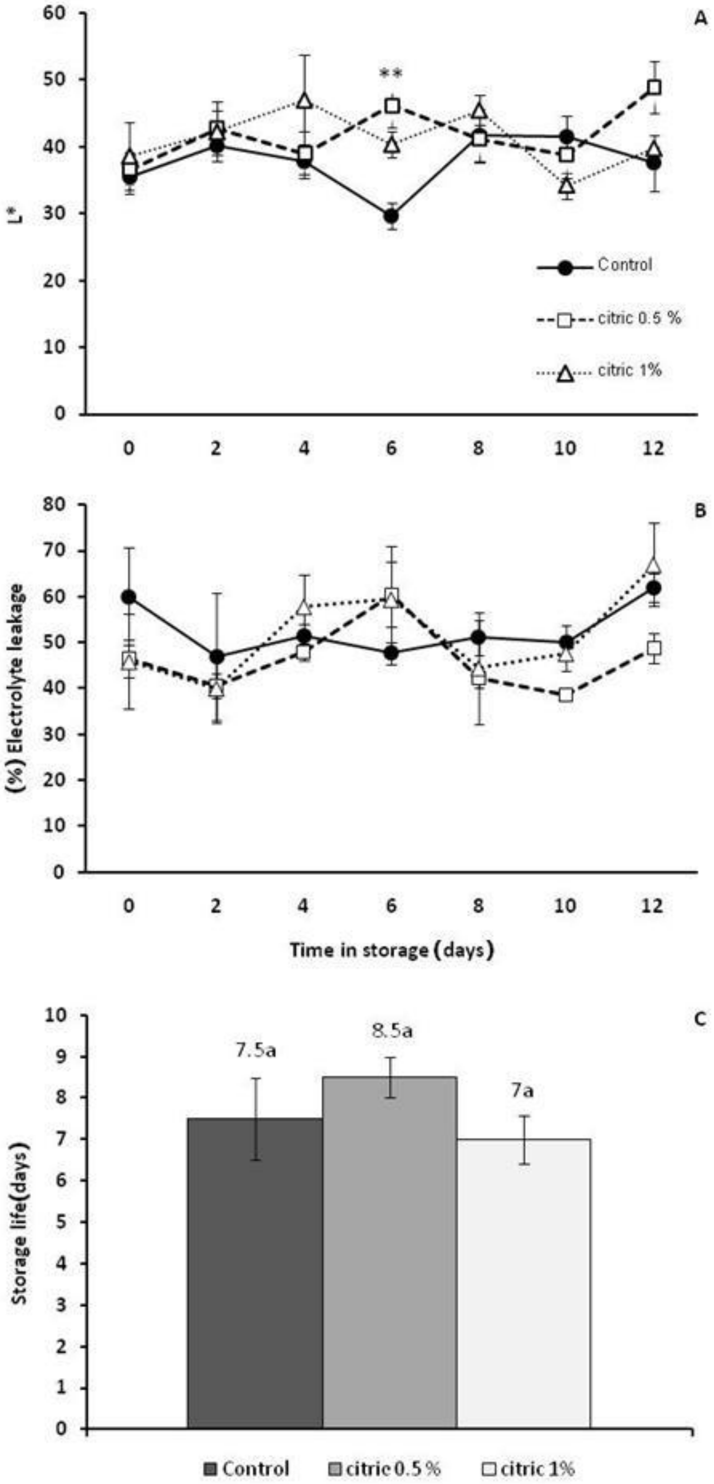

Figure 1 The change of L*(A), electrolyte leakage (B) and storage life (C) of processed pineapple slices with citric acid 0% (a control), 0.5 and 1% w/v, respectively, after storage at 2.5°C for 12 days. Vertical bars represent S.E. with 4 replications.

Table 1 Effect of citric acid on soluble solids content (SSC; °Brix), titratable acidity (TA; %), pH, and vitamin C of the fresh- cut pineapple (mg/100 ml juice) after storage at 2.5°C for 12 days.

		Days of storage						
Parameters	Treatment	0	2	4	6	8	10	12
SSC	Control	13.03[1/]	13.98	13.60	13.95	15.70	16.58	16.00b
	Citric 0.5 %	15.38	13.25	14.75	15.6	15.70	14.68	15.05a
	Citric 1.0 %	13.28	14.90	15.50	14.20	15.70	14.63	14.95a
	F-test	ns	ns	ns	ns	ns	ns	*
TA	Control	3.25[1/]	3.84	4.40	3.25	3.55	3.53	3.75
	Citric 0.5 %	2.83	5.38	3.33	3.90	3.33	3.30	3.83
	Citric 1.0 %	2.96	4.73	3.15	2.53	4.03	3.60	3.38
	F-test	ns	ns	ns	ns	ns	ns	ns
pH	Control	4.15[1/]	4.02	3.99	4.18	4.18	4.03	4.15
	Citric 0.5 %	4.35	3.92	4.18	4.11	4.17	4.18	4.11
	Citric 1.0 %	4.28	4.07	4.24	4.23	4.09	3.92	4.09
	F-test	ns	ns	ns	ns	ns	ns	ns
Vitamin C	Control	13.66[1/]	5.41	3.84	3.42	3.84	2.84	2.72
	Citric 0.5 %	13.66	5.55	3.56	3.56	3.13	3.08	2.96
	Citric 1.0 %	13.66	5.12	3.27	3.13	3.70	3.31	2.13
	F-test	ns	ns	ns	ns	ns	ns	ns

[1/] Means within column followed by different letter are significantly different by using Duncan's new multiple range test at $p<0.05$; (ns) = not significant, (*) = significant at $p<0.05$.

Table 2 Overall quality and sensory of processed pineapple slices treated with 0% (control), 0.5% w/v and 1% w/v citric acid and storage at 2.5°C for 12 days.

		Days of storage						
Parameters	Treatment	0	2	4	6	8	10	12
Color[2/]	Control	2.25[1/]	1.88	2.00	4.50b	3.88	4.38	5.75
	Citric 0.5 %	2.25	2.13	2.50	2.62a	4.13	5.00	5.75
	Citric 1.0 %	2.25	1.88	2.50	4.75b	3.13	3.25	6.13
	F-test	ns	ns	ns	*	ns	ns	ns
Firmness[2/]	Control	4.89b[1/]	5.56	4.56a	4.50	4.88	4.71	4.63
	Citric 0.5 %	4.05a	5.93	5.02a	4.90	5.28	5.63	5.46
	Citric 1.0 %	4.69ab	5.76	6.13b	4.40	5.23	5.79	4.75
	F-test	*	ns	*	ns	ns	ns	ns
Off-odor[2/]	Control	1.00[1/]	1.00	2.00	1.38	2.50	3.13	5.75
	Citric 0.5 %	1.00	1.00	1.25	1.00	2.25	3.50	5.75
	Citric 1.0 %	1.00	1.25	1.00	1.63	1.63	2.50	6.50
	F-test	ns	ns	ns	ns	ns	ns	ns
Sweet[2/]	Control	6.06[1/]	5.08	4.40	4.65	4.15	4.75	3.98
	Citric 0.5 %	5.02	6.17	4.55	4.29	6.48	2.93	2.40
	Citric 1.0 %	5.75	6.85	6.17	4.21	6.38	3.45	3.54
	F-test	ns	ns	ns	ns	ns	ns	ns
Sour[2/]	Control	2.72[1/]	3.76	3.50	4.27	4.96	3.67	4.54
	Citric 0.5 %	3.04	3.13	3.28	3.66	4.27	4.58	6.33
	Citric 1.0 %	2.73	2.44	2.98	1.67	2.81	3.42	5.67
	F-test	ns	ns	ns	ns	ns	ns	ns
Acceptability[2/]	Control	9.00[1/]	5.50	4.46	4.89	4.15	4.29	3.67
	Citric 0.5 %	9.00	5.93	4.50	5.10	5.86	3.96	1.99
	Citric 1.0 %	9.00	7.31	6.26	4.49	6.08	3.64	3.71
	F-test	ns	ns	ns	ns	ns	ns	ns

[1/] Means within column followed by different letter are significantly different by using Duncan's new multiple range test at $p<0.05$; (ns) = not significant, (*) = significant at $p<0.05$.

[2/] A9-hedonic scale was sued for evaluation; for color (1-9) while 1= less color and 9= darkening; for firmness (1-9) while 1= softening and 9= more firmness; for off-odor (1-9) while 1= nor mal aroma and 9= high abnormal aroma; for sweet and sour (1-9) while 1= less sweet or sour and 9= high sweet or sour; for acceptability (1-9) while 1= unlike mostly and 9 = like mostly.