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Control of Rotting and Browning of Longan Fruit cv. Biew Kiew after Harvested by Sulphur Dioxide Treatment under Various Storage Temperatures

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Abstract: The experiment of Longan fruit cv. Biew Kiew, untreated (control) and treated with SO_2 treatment were stored under 2±2 and 7±2°C for 0, 2, 4, 6 and 8 weeks were studied. The treatment of fresh longan fruit with SO_2 fumigation combined with the suitable storage condition improved the overall longan fruit quality, especially on inner and outer peel tissue and aril color than no SO_2 treatment. Treatment stabilizes peel color with no subsequent loss of color during storage (fruit color were bright-yellowish color). When the fruit showed during SO_2 treatment, increasing of storage duration and temperatures, the dark color of inner and outer peel of longan fruit was appeared, this was correlated with the increasing of PPO activity. The activity of PPO enzyme in control fruit (no SO_2 treatment) gradually lower than SO_2 treatments. Fruit exposed to cool storage temperature (2°C) exhibited a lower PPO enzymatic activity compared to those kept in high storage temperature (7°C). Moreover, PPO enzymatic activity significantly increased over the storage durations The additional SO_2 treatment no subsequent loss of weight of longan fruit during storage. However, the sulphite residues could detect immediately after SO_2 treatment in all part of longan fruit, especially on aril tissue. The SEM evaluation found that the surface cracking was also impair the physiological function of the cuticle and increasing water permeability, which may cause water soaking at the inner side of the peel. The injured cell would accelerate the oxidation of phenolic substances and the oxidative products resulted in dark color of inner and outer peel.

Key words: Longan, SO_2 treatment, storage, browning, PPO

INTRODUCTION

Longan fruit (*Dimocarpus longan* Lour.) is a non-climacteric subtropical fruit, which was an evergreen tree of the *Sapindaceae* family. Longan fruit was grown commercially in many countries, including China, India, Vietnam and Thailand (Huang, 1995; Campbell and Campbell, 2001). In Thailand, dried and especially fresh fruit of longan is mostly marketed locally and export of the fruit has been increasing rapidly in recent years (Lin *et al*., 2001). Longan fruit contain a relatively large black or brown seed at maturity. The fruit are conical, heart-shaped or spherical with a thin, leathery and indehiscent pericarp. The pericarp can vary in color from yellowish to light brown and the skin is smooth (Wong and Ketsa, 1991). The edible portion of the longan fruit is a fleshy, translucent-white aril. The aril is an extension of the funiculus of seed stalk that arises from the placenta and surrounds to seed. One of the most important problems in marketing longan fruit is rapid pericarp browning a few days after harvest (Wu *et al*., 1999). Color deterioration causes the fruit to fetch a lower price at market and even be unmarketable. Browning can be associated with desiccation and/or heat stress, senescence, chilling injury and pest or pathogen attack (Pan, 1994). Browning has been attributed to enzymatic oxidation of phenolics by polyphenol oxidase (PPO) (Liu, 1999; Tian *et al*., 2002a). PPO is activated by moisture loss from the fruit and treatments to reduce desiccation also reduce browning (Su and Yang, 1996). PPO activity was relatively low at harvest, decreased initially, during low temperature storage and increased reached a peak after long term of storage (Wu *et al*., 1999). Sulfur dioxide (SO_2) is an effective inhibitor of PPO and also effectively reduces fruit browning (Zhang *et al*., 1999). However, evidence for the role of PPO in longan fruit pericarp browning in correlative and the underlaying biochemistry and physiology, which response with storage temperature and

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duration is require further investigation. Thus, the objective of this study was to investigate the effects of sulfur dioxide treatment integrate with storage temperature on the changing of physiology and biochemistry of longan fruit cv. Biew Kiew during storage.

MATERIALS AND METHODS

Longan (*Dimocarpus longan* Lour.) fruit cv. Biew Kiew was harvested from Chiang Mai province, Thailand in the year 2007. The fruits were then separated into bunches with selected homogenous size and grading. The fruit bunches without defects and spoilage were used for the experiments. The experiment design in this study was raid out in 2×2×5 Factorial in CRD with 4 replications. Treatments were including with no SO_2 treatment and SO_2 treating. Then, the treated fruits were stored at 2±2 and 7±2°C. Finally, fruits were stored for 0, 2, 4, 6 and 8 weeks. The fruits were sampling immediately after SO_2 treatment at the rate 4.50 tons per 2.5 kg-SO_2 and then every month after stored under various storage temperatures as discussed above.

Weight loss: The fresh weight of the fruit was determined for all treatments as an index of desiccation rate. Weight loss was calculated as following:

$$\text{Weight loss} = \frac{\text{Weight of fresh fruit-Weight of sample}}{\text{Weight of fresh fruit}} \times 100$$

Polyphenol oxidase activity and determination of pericarp pH: Three fruits per treatment were thawed and peeled. And 2 g of pericarp tissue was homogenized in 0.1 M phosphate buffer, pH 6.6 and 0.5 g of insoluble polyvinyl pyrollidone (Merck) for 30 sec with a polytron homogenizer (Kinematica GmbH, Kreins, Luzern, Switzerland; probe diameter, 20 mm). The homogenate was centrifuged for 10 min at 8000 x g in a Sorvall rotor SS-34 at 4°C. The supernatant was collected and centrifuged repeated in 1.5 mL tubes at 20 000 x g for 10 min at 4°C. The supernatant was collected into a fresh tube and 0.75 mL was used for the PPO assay in duplicate. The PPO assay was conducted by adding 0.12 mL 4-methyl catechol (Sigma, St. Louis, MO, USA) freshly dissolved (0.25 g) in 2 mL of ethanol and 10 mL of distilled water (final concentration, 23 mM). A contron spectrophotometer was used to follow changes in absorbance at 410 nm over 2 min and the linear progress of the reactions was recorded between 30 and 90 sec. Protein content was determined according to Bradford (1976) with bovine serum protein as the standard. Results were calculated as in Δ activity mg^{-1} protein x 1000. The change in the pH of the buffer was determined in duplicate. To determine the pH of pericarp and aril tissue, extraction was carried out as described, but without PVP and with distilled water instead of phosphate buffer.

Peel and aril color: The pericarp (peel) and aril color of longan fruit were analyzed initially and after various storage duration. The color was measured on opposite sides of the fruit using (colourQuest XE, Hunter Associates Laboratory, Inc., New York, USA Date) Minolta chromameter (model CR-200; Minolta, Ramsey, Date NJ) which provided CIE L*, C*, H*, A* and B* values.

Preparation of longan pericarp for Scanning Electron Microscope (SEM): The longan pericarps were cut into 5 mm squares for SEM evaluation. The pericarps were cut in a dish of 0.1 M phosphate buffer pH 7.3. The pieces were transferred immediately after they were cut into a primary fixative. The longan pericarp pieces were fixed in a fixative solution as described by Bozzola and Russell (1999) with slight modification for anatomical study. The pericarp specimens were fixed with a primary fixative containing 2.5% glutaraldehyde in 0.1 M phosphate buffer pH 7.3 at 4°C for 2 h. After that the tissue was usually washed in the same buffer vehicle used in the glutaraldehyde fixation step. Washing is extremely important because it eliminates any free unreacted glutaraldehyde that remains within the tissue. If aldehydes remaining from the primary fixation are oxidized by osmium tetroxide they may generate a peppery spot background and interfere in the specimens. Next, the specimens were post-fixed in 1% osmium tetroxide in the same buffer for 2 h. Then, the specimens were dehydrated stepwise by exposure to ethanol-buffer mixture (30, 50, 70, 80, 90 and 100%) allowing 15 min in each and critical point drying with liquid CO_2. This is a critical drying technique, as it achieves a phase change from liquid to dry gas without the effects of surface tension and is, therefore, suitable for delicate biological specimens for removal of water from the specimens. For SEM, the dried specimen was mounted on specimen studs and sputter coated with gold. Coated samples were stored in desiccator until assessed. Finally, the specimens were viewed with a scanning electron microscope (JEOL, JSM-5910LV, JEOL Ltd., Tokyo, Japan) at 15 kV.

Sulphite residual: A sample of 50 g from the whole fruit, aril and peel was obtained from a minimum of 30 fruits and stored overnight at -70°C. Sample were then examined in duplicate for sulphite residual according to de-Vries *et al*. (1986).

Statistical analysis: The statistical analysis was carried out using a statistical program Statistic version released 8.0 and least significant different test at 95% was used to determine significant difference among the treatments.

RESULTS AND DISCUSSION

The ANOVA results indicated that peel tissue pH and aril pH was affected by SO_2 treatment, storage temperatures, storage durations and interaction between them (Table 2). Initially, peel tissue pH was lower than the aril pH (5.12 and 6.75, respectively) (Table 1). After SO_2 treatment, peel tissue pH significantly decreased. However, aril pH was significantly increased (4.32 and 6.88, respectively). These changes stated similarly with the effects of storage temperatures. Peel tissue pH significantly decreased when storage temperature increasing from 2 to 7°C. On the other hand, pH of aril increased significantly when storage temperature increased. Moreover, both peel tissue pH and aril pH increased gradually over the storage durations (8 weeks) in all treatments, the decrease being greater in SO_2 treatments. In pH measurement of peel tissue was low which was agreed with Underhill and Critchley (1992) measured a pH of 2.5 in the peel of longan after SO_2 treatments. Presumably, the diffusion between peel and aril was responsible for the elevated pH observed for longan fruit. According to Jiang (1999), a pH value lesser than 4.2 in the longan peel may abolish of PPO activity.

The ANOVA results showed that the percentage of weight loss was significantly affected by all treatments. The percentage of weight loss generally low in SO_2 treatments (Table 1). The main factors affected the percentage of weight loss were storage temperatures and storage durations. The percentage of weight loss gradually increased when the storage temperatures and storage duration increase (Table 1). The fruit stored in low temperature (7°C) combined with SO_2 treatment could maintained the lower percentage of weight loss than no SO_2 treatment (Table 2). The high percentage of weight loss of longan fruit may cause wilt and the reduction of freshness, then resulted in browning on the peel and finally fruits were rotten or decay. The browning reaction on the longan peel was caused by oxidation of phenolic compounds by PPO enzyme (Tian *et al*., 2002b; Liu, 1999) and also from the loss of moisture on the fruit hence the enzyme is activated (Su and Yang, 1996; Lu *et al*., 1992). The activity of PPO enzyme in control fruit (no SO_2 treatment) gradually lower than SO_2 treatments. Fruit exposed to cool storage temperature (2°C) exhibited a lower PPO enzymatic activity compared to those kept in high storage temperature (7°C). Moreover, PPO enzymatic activity significantly increased over the storage durations (Table 1). Peel browning and decay are the main factors influencing postharvest quality and storage life of longan fruit. The fact that the browning index of longan peel increased along with PPO activity during storage time and the SO_2 treatment particularly with storage temperatures significantly inhibited PPO activity and effectively prevented peel browning, further indicates that browning of longan peel is related to PPO activity. However, PPO activity is not a unique limiting factor in enzymic browning, since pH, fruit decay and senescence can also influence browning (Larrigaudiere *et al*., 1998; Tian *et al*., 2002b).

The peel color in both site; inner and outer, of no SO_2 treatments were more scarlet than orange-red (hue angle; H*, decreased), became darkened (L* decreased) and less intensely red (chroma; C*, decreased) in comparison to the SO_2 treatments (Table 3 and 4). For SO_2 treatments, inner peel color was more green (A* decreased). On the other hand, outer peel color was blue-yellowish

Table 1: The effects of sulphur dioxide treatments, storage temperatures and storage durations on longan cv. Biew Kiew fruit quality changes

					Color parameters														
					C*			H*			L*			A*			B*		
	pH		Weight loss			Peel			Peel			Peel			Peel			Peel	
Treatment	Peel	Aril	(%)	PPO*	Aril	Outer	Inner	Aril	Outer	Inner	Aril	Outer	Inner	Aril	Outer	Inner	Aril	Outer	Inner
No SO_2	5.12a	6.75b	9.34a	14.37a	5.27a	27.61b	22.91a	62.73b	62.44b	82.14b	38.02b	45.50b	70.92b	1.90a	12.89a	3.31a	4.67b	24.32b	22.61a
SO_2	4.32b	6.88a	7.92b	10.01b	5.55a	37.53a	22.56a	68.56a	70.24a	88.45a	38.88a	53.96a	79.22a	1.87a	12.61a	0.59b	5.09a	35.29a	22.54a
LSD (0.05)	0.04	0.04	0.27	2.48	0.37	0.55	0.41	3.18	1.03	0.98	0.54	0.51	0.79	0.14	0.30	0.17	0.38	0.54	0.41
Temperature (°C)																			
2	4.75a	6.71b	8.34b	9.20b	5.43a	33.63a	22.52b	65.40a	67.15a	84.87a	38.64a	50.13a	75.90a	1.94a	12.93a	2.01a	4.87a	30.87a	22.36b
7	4.70b	6.92a	8.92a	15.30a	5.40a	31.51b	22.95a	65.90a	65.53b	85.72a	38.26a	49.30b	74.30b	1.82a	12.58b	1.89a	4.89a	28.75b	22.80a
LSD (0.05)	0.04	0.04	0.27	2.49	0.37	0.55	0.41	3.18	1.03	0.98	0.54	0.51	0.79	0.14	0.30	0.17	0.39	0.54	0.41
Storage durations (weeks)																			
0	4.68b	6.43c	0e	11.42b	4.44d	32.85b	22.93b	53.14c	68.53a	88.28a	43.40a	50.43a	78.63a	2.33a	11.77c	0.70c	3.57d	30.60b	22.88b
2	4.66bc	6.74b	6.57d	24.83a	4.47d	34.51a	21.33c	62.22b	65.80b	84.72b	37.80b	50.32a	76.90b	2.09b	13.50a	1.94b	3.83d	31.53a	21.20c
4	4.67bc	6.71b	8.97c	6.33c	5.16c	33.60b	22.69b	63.44b	65.90b	83.85b	37.79b	50.30a	73.71d	2.12ab	13.30a	2.35a	7.16a	30.71ab	22.49b
6	4.60c	7.09a	12.50b	7.69bc	5.78b	30.71c	22.50b	65.31b	66.37b	85.12b	36.44c	49.37b	74.40c	2.15ab	12.49b	2.37a	4.61c	27.86c	22.30b
8	5.00a	7.12a	15.13a	10.91b	7.22a	31.20c	24.25a	84.13a	65.16b	84.51b	36.85c	48.21c	71.72d	0.73c	12.80b	2.41a	5.23b	28.36c	24.07a
LSD (0.05)	0.07	0.06	0.43	3.93	0.58	0.87	0.65	5.02	1.64	1.55	0.85	0.81	1.25	0.22	0.47	0.28	0.61	0.86	0.65

The different letters indicate the statistically significant difference by LSD at 5% level. *: Polyphenol enzymatic activity was described in Δactivity mg^{-1} protein×1000

Table 2: Effects of sulphur dioxide treatment, storage temperatures and storage durations on the changes of peel and aril pH and weight loss of longan cv. Biew Kiew

			pH			
SO_2 treatment	Temperature (°C)	Time (weeks)	Peel	Aril	Weight loss (%)	PPO (Δactivity mg^{-1} protein)
No	2	0	5.10cd	6.49i	0.00i	12.54cd
		2	5.17bc	6.63h	7.50g	26.23b
		4	5.14bcd	6.91ef	9.97e	3.10g
		6	5.13bcd	7.00cde	13.50b	3.52fg
		8	5.41a	5.80j	15.89a	5.61defg
	7	0	5.07cd	6.49i	0.00i	12.54cd
		2	5.06cd	6.80fg	7.38g	42.80a
		4	5.00de	7.34a	9.74e	10.05defg
		6	4.92e	7.08bcd	13.20bc	8.81defg
		8	5.25b	7.10cd	16.31a	18.60bc
SO_2	2	0	4.23gh	6.40i	0.00i	10.09defg
		2	4.21gh	6.73gh	5.50h	11.74cde
		4	4.26gh	7.00cde	7.70fg	4.59efg
		6	4.20h	7.21b	10.87d	7.20defg
		8	4.69f	7.00cde	12.62bc	7.40defg
	7	0	4.33g	6.40i	0.00i	10.52defg
		2	4.20gh	6.82fg	5.91h	18.56bc
		4	4.26gh	7.12bc	8.52f	7.61defg
		6	4.22gh	7.20b	12.50c	11.23cdef
		8	4.68f	6.97de	15.69a	12.08cde
LSD (0.05)			0.14	0.13	0.86	7.86
Statistical significant source of variation						
SO_2			*	*	*	*
Temp			*	*	*	*
Time			*	*	*	*
SO_2×Temp			*	*	*	ns
SO_2×Time			*	*	*	ns
Temp×Time			ns	*	*	ns
SO×Temp×Time			*	*	*	ns

The different letters indicate the statistically significant difference by LSD at 5% level. ns: Not significant

Table 3: Effects of sulphur dioxide treatment, storage temperatures and storage durations on the changes of outer part of peel color of longan cv. Biewkaew

			Outer part of peel color parameters				
SO_2 treatment	Temperature (°C)	Time (weeks)	C*	H*	L*	A*	B*
No	2	0	28.42de	65.57de	47.07cd	11.72h	25.86e
		2	29.79d	60.31fg	42.33g	14.72a	25.87e
		4	29.89d	61.76fg	46.04def	14.10ab	26.29e
		6	27.10e	66.57cd	46.52cde	12.94cde	23.57f
		8	29.61d	63.08ef	48.00c	13.38bcd	26.40e
	7	0	28.42de	65.57de	47.07cd	11.72h	25.86e
		2	27.30e	59.76g	42.20g	13.67bcd	23.56f
		4	26.76e	61.37fg	44.84f	12.74defg	23.50f
		6	24.34f	60.15fg	45.00ef	11.97fgh	21.16g
		8	24.43f	60.24fg	45.70def	12.03efgh	21.23g
SO_2	2	0	37.29b	71.49ab	53.80b	11.81gh	35.32b
		2	40.43a	72.87a	54.10b	11.86gh	38.63a
		4	41.09a	71.11ab	53.93b	13.29bcd	38.85a
		6	35.77b	70.08ab	56.15a	12.13efgh	33.61bc
		8	36.87b	68.66bcd	53.43b	13.37bcd	34.32bc
	7	0	37.29b	71.49ab	53.80b	11.81gh	35.32b
		2	40.50a	70.09ab	54.20b	13.73bc	38.05a
		4	36.57b	69.32bc	52.68b	12.91cdef	34.18bc
		6	35.62bc	68.69bcd	53.64b	12.94cde	33.12cd
		8	33.90c	68.66bcd	53.94b	12.29efgh	31.54d
LSD (0.05)			1.73	3.27	1.62	0.96	1.72
Statistical significant source of variation							
SO_2			*	*	*	ns	*
Temp			*	*	*	*	*
Time			*	*	*	*	*
SO_2×Temp.			*	ns	ns	*	ns
SO_2×Time			*	*	*	*	*
Temp×Time			*	ns	ns	*	*
SO×Temp×Time			ns	ns	ns	ns	ns

The different letters indicate the statistically significant difference by LSD at 5% level. ns: Not significant

Table 4: Effects of sulphur dioxide treatment, storage temperatures and storage durations on the changes of aril color of longan cv. Biew Kiew

			Aril colour parameters				
SO_2 treatment	Temperature (°C)	Time (weeks)	C*	H*	L*	A*	B*
No	2	0	3.47g	44.92e	34.38e	1.96bc	2.31g
		2	4.72def	58.42d	38.21b	2.20bc	4.06cdef
		4	7.58a	83.85a	43.76a	0.79d	7.53a
		6	5.13cdef	61.62bcd	37.55bcd	2.28abc	4.52bcdef
		8	6.02bc	61.17bcd	37.28bcd	2.71a	5.29b
	7	0	3.47g	44.92e	34.38e	1.96bc	2.31g
		2	4.24fg	58.57d	37.62bcd	1.95c	3.68ef
		4	7.07ab	84.04a	42.77a	0.76d	7.01a
		6	5.37cdef	63.98bcd	37.95bc	2.19bc	4.85bcde
		8	5.62cde	65.82bcd	36.35cd	2.22bc	5.12bcd
SO_2	2	0	5.41cdef	61.36bcd	38.51b	2.22bc	4.83bcdef
		2	4.35fg	71.14b	37.24bcd	2.18bc	3.63f
		4	7.02ab	84.68a	43.64a	0.65d	6.97a
		6	4.85cdef	62.09bcd	38.30b	2.05bc	4.27bcdef
		8	5.82cd	64.72bcd	37.52bcd	2.40ab	5.24bc
	7	0	5.41cdef	61.36bcd	38.51b	2.226bc	4.827bcdef
		2	4.55efg	60.75cd	38.11b	2.131bc	3.945def
		4	7.19ab	83.95a	43.29a	0.729d	7.137a
		6	5.27cdef	66.07bcd	37.37bcd	2.068bc	4.796bcdef
		8	5.68cde	69.53bc	36.25d	1.985c	5.266bc
LSD (0.05)			1.175	7.101	1.703	0.447	1.222
Statistical significant source of variation							
SO_2			ns	*	*	ns	*
Temp.			ns	ns	ns	ns	ns
Time			*	*	*	*	*
SO_2×Temp.			ns	ns	ns	ns	ns
SO_2×Time			*	*	*	Ns	*
Temp×Time			ns	ns	ns	ns	ns
SO×Temp×Time			ns	ns	ns	ns	ns

The different letters indicate the statistically significant difference by LSD at 5% level. ns: Not significant

(B* decreased) (Table 3). Moreover, the ANOVA results indicated that storage temperature was a main factor that affected the change of outer peel color (Table 4). Under high storage temperature (7°C), the outer peel color was less intensely color (C*, decreased), more purple-red (H*, decreased), became darkened (L* decreased) and showed blue-yellowish (B* decreased) (Table 4). Additionally, the storage temperatures affected on the changing of inner peel color, which appeared less intensely color (C*, decreased), became darkened (L* decreased) and showed blue-yellowish (B* decreased) (Table 3). Extremely changes also were observed by storage durations factor. The peel color in both inner and outer became dark brown color when the storage duration increased (Table 3, 4). For aril color, SO_2 treatments resulted more yellow and bright appearances (significantly increased in H*, L* and B* value) (Table 5). The storage duration also the main factor affected aril color. The aril color was changed to yellowing and cloudy fruit (L*, A* and B* value decreased, but C* and H* increased) (Table 5). Moreover, this factor also affected on the change of peel color (Table 4), inner and outer part of peel was changed to cloudy and dark red or scarlet, which was showed in browning (Table 3, 4). For the pearson correlation coefficients analysis showed that SO_2 treatment and storage temperature factors resulted positive correlation between weight loss and the changing of peel and aril tissue pH (Table 6, 7). Moreover, the effect of storage duration had positive correlation between peel tissue pH, but stated the negative correlation between aril pH and peel tissue pH (Table 8). SO_2 treatment affected both external and internal quality. It changed fruit color from the original dim brown or green-brown to bright yellow-green or light yellow and prevented longan fruit from browning throughout storage duration (Fig. 1a-h). This effect was due to the phenol-quinone browning reaction catalyzed by PPO being inhibited by SO_2 treatment (Wu *et al*., 1999). Meanwhile, anthocyanin was fixed by SO_2 treatment through the bleaching reaction and the formation of colorless sulfo-compounds (Huang and Scott, 1985). It has been proved that sulphur-fumiganted longan fruit were bleached immediately and anthocyanin content decreased markedly to a stable but low level during storage. The small amount of SO_2 treatment could be released from the sulfo-compounds (Huang, 1995). In the later stage of storage, the release of SO_2 from sulfo-compounds might have probably caused a slight increase of anthocyanin in the fumigated fruit peel. The acidity condition affects the ratio between the various forms of the pigments, i.e. red flavylium cation (AH^+), the blue quinonoidal base (A), the colorless carbinol (B) and pale yellow chalcones (C). The pK_a of the reaction between the flavylium ion and the colorless carbinol from of Pg 3-G was found to be 2.98 (Sondheimer, 1953). Therefore,

Table 5: Effects of sulphur dioxide treatment, storage temperatures and storage durations on the changes of inner part of peel color of longan cv. Biew Kiew

			Inner part of peel color parameters				
SO_2 treatment	Temperature (°C)	Time (weeks)	C*	H*	L*	A*	B*
No	2	0	22.63bcde	86.08bc	77.13c	1.58c	22.55bc
		2	21.43ef	80.88d	66.69hi	3.34b	21.13d
		4	21.23f	78.52d	65.72i	4.16a	20.82d
		6	23.55b	80.24d	69.06fgh	4.00a	23.18b
		8	25.15a	81.32d	72.67d	3.79ab	24.85a
	7	0	22.63bcde	86.08bc	77.13c	1.58c	22.55bc
		2	21.06f	80.95d	67.43ghi	3.29b	20.79d
		4	23.48b	81.60d	71.45def	3.38b	23.22b
		6	22.07cdef	85.11c	69.67efg		21.63cd
		8	25.83a	80.65d	72.23d	4.21a	25.47a
SO_2	2	0	23.23bc	90.49a	80.14ab	0.17e	23.22b
		2	19.50g	88.38ab	71.76de	0.54d	19.47e
		4	22.78bcd	87.54abc	78.74bc	0.97d	22.74bc
		6	22.59bcde	87.56abc	79.04bc	0.97d	22.56bc
		8	23.11bc	87.75abc	81.93a	0.93d	23.08b
	7	0	23.23bc	90.49a	80.14ab	0.17e	23.22b
		2	23.34bc	88.67ab	80.99ab	0.54d	23.32b
		4	23.22bc	87.75abc	78.91bc	0.89d	23.20b
		6	21.74def	87.61abc	79.84ab	0.77d	21.71cd
		8	22.91bcd	88.30ab	80.72ab	0.70d	22.88bc
LSD (0.05)			1.31	3.11	2.49	0.56	1.30
Statistical significant source of variation							
SO_2			ns	*	*	*	ns
Temp			*	ns	*	ns	*
Time			*	*	*	*	*
SO_2×Temp			ns	ns	ns	ns	ns
SO_2×Time			*	ns	*	*	*
Temp×Time			*	ns	*	ns	*
SO×Temp×Time			*	ns	*	ns	*

The different letters indicate the statistically significant difference by LSD at 5% level. ns: not significant

Table 6: Pearson correlation coefficients of sulphur dioxide treatments on the changes of polyphenol enzymatic activity, weight loss and pH of peel and aril of longan cv. Biewkaew fruit

Activities	PPO	WL	pH-Peel
WL	ns		
pH-Peel	ns	0.300	
pH-Aril	ns	0.497	ns

Table 7: Pearson correlation coefficients of storage temperatures on the changes of polyphenol enzymatic activity, weight loss and pH of peel and aril of longan cv. Biewkaew fruit

Activities	PPO	WL	pH-Peel
WL	ns		
pH-Peel	ns	0.255	
pH-Aril	ns	0.486	ns

Table 8: Pearson correlation coefficients of storage durations on the changes of polyphenol enzymatic activity, weight loss and pH of peel and aril of longan cv. Biewkaew fruit

Activities	PPO	WL	pH-Peel
WL	ns		
pH-Peel	ns	0.384	
pH-Aril	ns	ns	-0.408

assuming that vacuolar pH is close to fruit pH, much of the anthocyanin pigment will have converted into colorless carbinol and chalcone and some irreversible degradation may have taken place. So, SO_2 treatment reduced the pH value in the peel, causing the redder peel color. Moreover, with regard to the mechanism by which enzymic discoloration is inhibited by SO_2 treatment, Day (1996) hypothesized that SO_2 treatment might cause substrate inhibition of PPO or alternatively, high level of colorless quinones subsequently formed might cause feed back product inhibition of PPO (Han *et al*., 1999). Moreover, the mechanisms of sulphur dioxide, which inhibited enzymatic skin browning during storage were reduction of pH in pericarp cytoplasm, inhibition of PPO activity, increase of free and total phenolic contents and reduction of ascorbic acid content (Wu *et al*., 1999). Meanwhile, the experiment found that a lower pH in the peel kept in SO_2 treatment might be beneficial in preventing browning. The rapid increase in the browning index of the longan fruit stored in SO_2 treatment after long term of storage may be due to the senescence and fruit decay, indicated by increases in pH value, which was agreed with Tian *et al*. (2002b). The result suggests that SO_2 treatment may be suitable for keeping longan fruit over a relatively short period, which skin ultrastructure played a role in longan storability. However, the suitable concentration and fumigation time is also necessary to point out. The normal longan fruit pericarp was thick about 630-700 μm and composed of three layers. The outer layer is exocarp consisted of natural opening and cracking on the surface. It was covered by thin

Fig. 1: The effects of SO_2 treatments, storage temperature and storage duration on the changing of inner and outer peel tissue and aril color of longan cv. Biewkeaw. (a): No SO_2 treatment at the initially of storage, (b): SO_2 treatment at the initially of storage, (c): inner peel tissue and aril color changing by no SO_2 treatment at the initially of storage, (d) inner peel tissue and aril color changing by SO_2 treatments at the initially of storage, (e and f): the changing of inner and outer peel tissue and aril color by no SO_2 treatments stored at 2°C and 7°C for 8 weeks, respectively (g and h): the changing of inner and outer peel tissue and aril color by SO_2 treatments stored at 2°C and 7°C for 8 weeks, respectively

discontinuous layer of cuticle and brown epidermal hair. The mesocarp, main part of the pericarp consisted of about 70% of the pericarp tissue. It contained elliptical in shape with thick cell walls. The vascular bundles were tubular and consisted of one layer cell. When the fruit showed during SO_2 treatment, increasing of storage duration and temperatures, the dark color of inner and outer peel of longan fruit was appeared. SEM observation showed a layer of injured cell in the pericarp was fibrous tissues disappeared. Wax that covered the pericarp and epidermal hair also damaged. The mesocarp cell were also damaged and had collapsed. The destruction of cell membrane was also observed (Fig. 2a-f). Underhill and Critchley (1992) found that the pericarp browning was correlated with moisture loss. Likewise, it is every likely that the natural cracking of longan peel facilitates rapid moisture loss and cause surface browning during harvest and storage. The surface cracking was also impair the physiological function of the cuticle and increasing water permeability, which may cause water soaking at the inner side of the peel (Medeira *et al*., 1999). The injured cell would accelerate the oxidation of phenolic substances and the oxidative products resulted in dark color of inner and outer peel (Abe, 1990).

The whole fruit and peel tissue sulphite residue under cold storage temperature (2°C) was highest (Fig. 3). Moreover, the contamination of sulphite residue was found highest immediately after treatment. On the other hand, the contamination of sulphite significantly decreased along the storage durations. However, sulphite

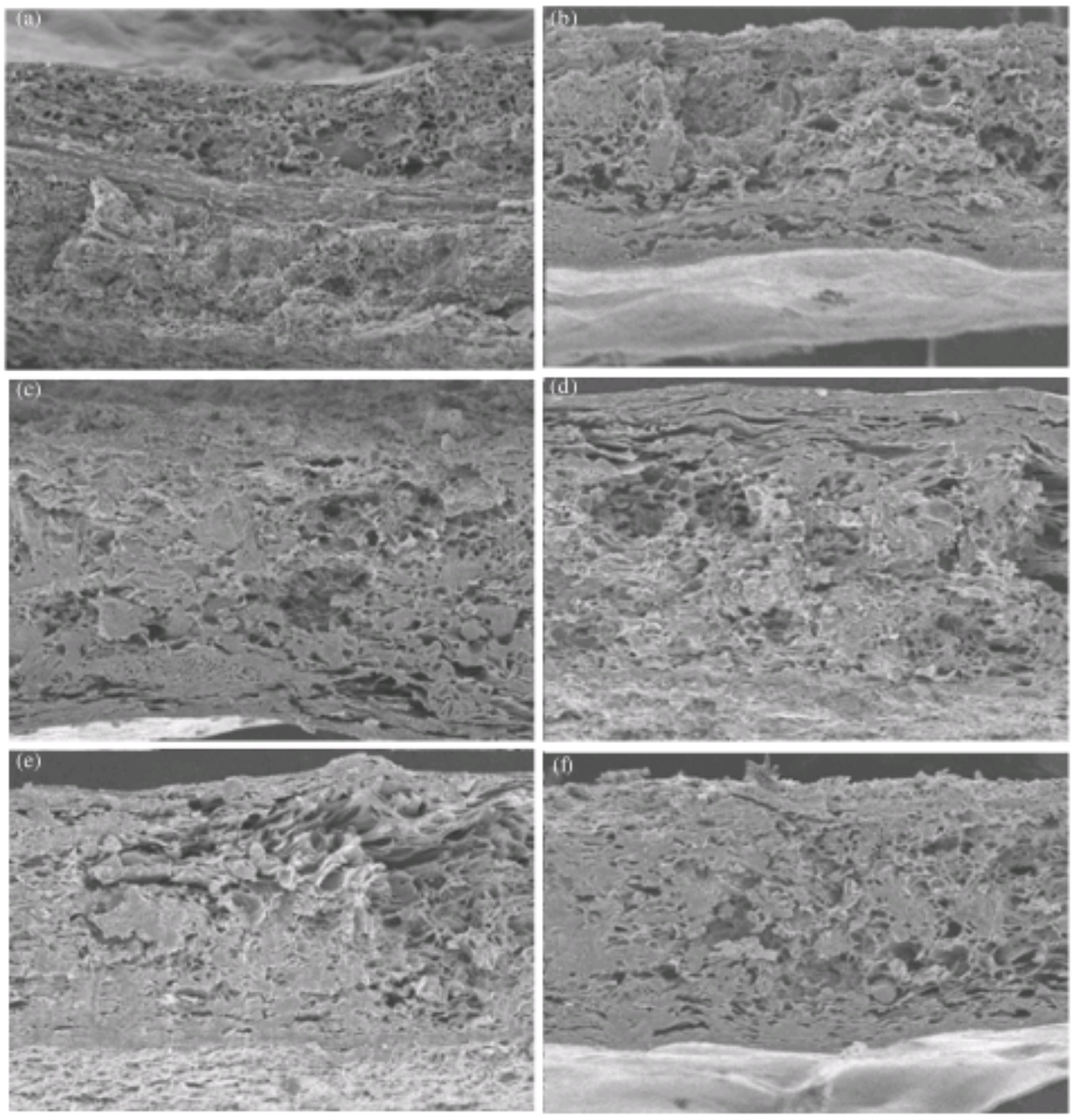

Fig. 2: Transverse sectional micrographs of longan fruit pericarps cv. Biew Kiew affected by SO_2 treatment and various storage condition. (a and b): Longan pericarbs after no SO_2 and SO_2 treatment at the initially of storage, (c and d): Longan pericarbs affected by no SO_2 treatment after stored at 2 and 7°C for 8 weeks, (e and f): Longan pericarbs affected by SO_2 treatment after stored at 2 and 7°C for 8 weeks

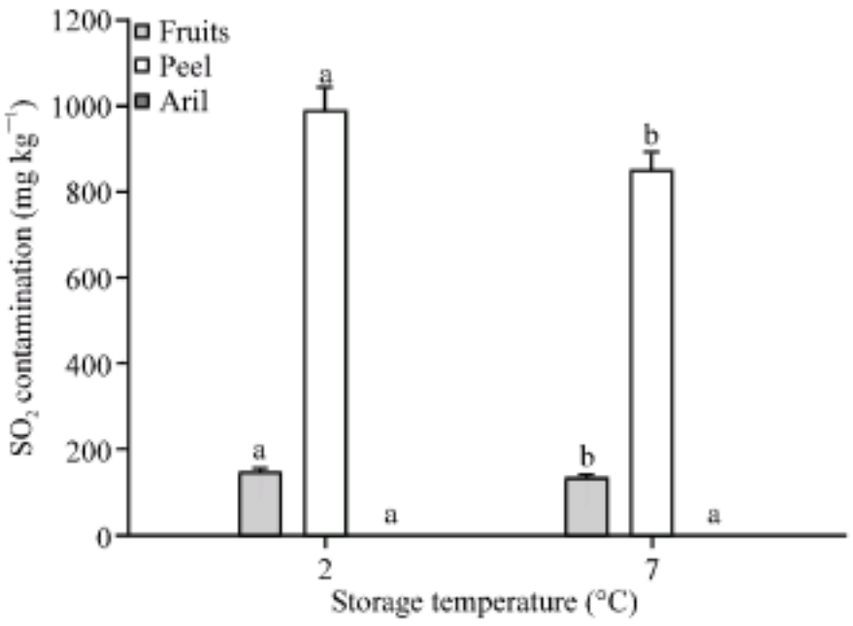

Fig. 3: Effects of storage temperatures on sulphur dioxide contamination in the composition of longan cv. Biewkaew fruit

contamination still high in peel tissue (900.20 mg kg^{-1}) and whole fruit (127.73 mg kg^{-1}), while found in aril only 0.17 mg kg^{-1} (Table 9). The fumigation time and concentration are the most important factors affecting the

Table 9: Effects of storage durations on the changes of sulphur dioxide contamination in the composition of longan cv. Biewkaew fruit

Storage duration (weeks)	SO_2 contamination (mg kg^{-1})		
	Fruit	Peel	Aril
0	198.50a	1096.70a	3.34a
2	125.65b	976.40ab	1.09b
4	123.68b	791.90c	1.10b
6	130.05b	842.70c	0.29b
8	127.73b	900.20bc	0.17b
LSD (0.05)	15.49	125.34	1.1
Statistical significant source of variation			
Temp.	*	*	ns
Time	*	*	*
Temp×Time	ns	ns	ns

ns: Not significant

SO_2 residues. Higher concentration and longer fumigation time resulted in higher SO_2 residue (Ye and Ge, 1996), which was mainly located in the peel and much less in the aril and gradually decreased with prolonged storage. If SO_2 concentration and fumigation time were strictly controlled, lower residue and longer storage life could be achieved.

CONCLUSIONS

The treatment of fresh longan fruit with SO_2 fumigation combined with the suitable storage condition improved the overall longan fruit quality, especially on inner and outer peel tissue and aril color than no SO_2 treatment. Treatment stabilizes peel color with no subsequent loss of color during storage (fruit color were bright-yellowish color). The additional SO_2 treatment no subsequent loss of weight of longan fruit during storage. However, the sulphite residues could detect immediately after SO_2 treatment in all part of longan fruit, especially on aril tissue. Thus, if SO_2 concentration and fumigation time were strictly controlled, lower residue and longer storage life could be achieved.

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