CHAPTER 4
RESULTS

4.1 Effect of High Carbon dioxide Pressure Treatments on Postharvest Quality in Longan fruit

4.1.1 The pricarp and aril color

Pericarp browning

It was found that in all treatments pericarp color changed from light yellow-brown to red-brown during the storage. Pericarp browning increased as storage time increased. High Carbon dioxide Pressure (HCP) treatments delayed the browning development of the pericarp and showed higher fruit quality than untreated.

In all treatments pericarp browning index increased during the storage. (Figure 3 and Table 1) HCP treatment decreased browning index and 2.0 kg-cm^{-2} treatment showed the lowest browning index since day 12th.

Howerver, the explosion time had negative affected on browning index. As explosion time increased, the browning index increased. There was an interaction between pressure and explosion time on pericarp browning index at 15 days after storage. The HCP with 2 kg-cm^{-2} for 1 hour had the lowest pericarp browning index, less than 3 or 25 % browning.

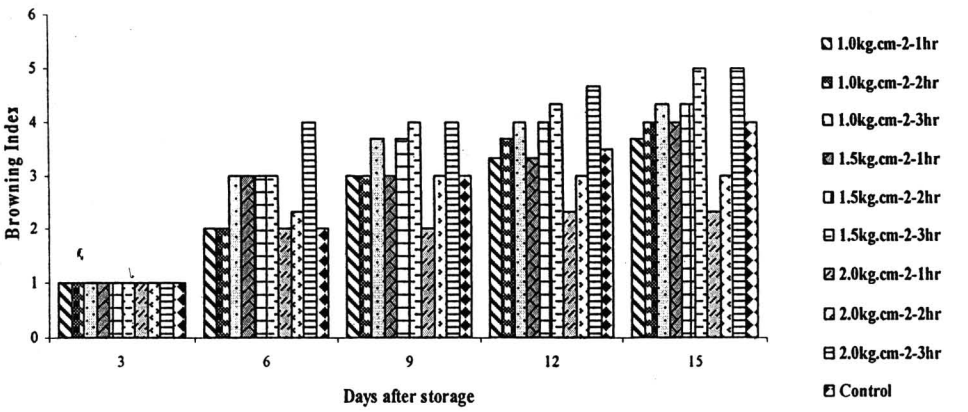

Figure 3 Browning index of longan fruit pericarp cv. Daw stored at 10°C after treating with high carbon dioxide pressures.(Browning index : 1 = no browning (excellent quality; 2 = slight browning; 3 = < ¼ browning; 4 = ¼ - ½ browning; and 5 = > ½ browning (Poor quality))

Table 1 Browning index of longan fruit pericarp cv. Daw stored at 10°C after treating with high carbon dioxide pressures

TREATMENT	DAYS AFTER STORAGE AT 10°C				
	3	6	9	12	15
P = Pressure					
1.0 kg-cm-2	1.00a	2.33a	3.22ab	3.67a	4.00a
1.5 kg-cm-2	1.00a	3.00a	3.56a	3.89a	4.44a
2.0 kg-cm^{-2}	1.00a	2.77a	3.00b	3.11b	3.44b
Untreated	1.00	2.00	3.00	3.50	4.00
T = Treated time					
1 hr	1.00a	2.33b	2.67c	3.00b	3.33b
2 hr	1.00a	2.44b	3.22b	3.33b	3.77b
3 hr	1.00a	3.33a	3.89a	4.33a	4.78a
Pressure x Treated time					
1.0 kg-cm-2 – 1 hr.	1.00a	2.00b	3.00b	3.33bc	3.67bc
2 hr.	1.00a	2.00b	3.00b	3.67ab	4.00b
3 hr.	1.00a	3.00b	3.67a	4.00ab	4.33ab
1.5 kg-cm-2 – 1 hr.	1.00a	3.00b	3.00b	3.33bc	4.00b
2 hr.	1.00a	3.00b	3.67a	4.00ab	4.33ab
3 hr.	1.00a	3.00b	4.00a	4.33ab	5.00a
2.0 kg-cm-2 – 1 hr.	1.00a	2.00b	2.00c	2.33c	2.33d
2 hr.	1.00a	2.33bc	3.00b	3.00c	3.00cd
3 hr.	1.00a	4.00a	4.00a	4.67a	5.00a
Untreated	1.00	2.00	3.00	3.50	4.00

Means within the same column followed by different letters are significant differences at 95 % ($P \leq 0.05$) by DMRT.

Browning index: 1 = no browning (excellent quality) ;

2 = slight browning; 3 = < ¼ browning; 4 = ¼ - ½ browning; and

5 = > ½ browning (Poor quality)

Outer Pericarp color

The L* value (lightness) of outer pericarp tended to reduce with prolonged storage time (Table 2 and Figure 4). However, the carbon dioxide pressure did not affect the L* value. The L* value decreased, as their explosion time increased. The interaction between carbon dioxide pressure and explosion time was found on day 9 and 12. The highest lightness was shown in the carbon dioxide pressure of 2 kg-cm^{-2} for 1 hour at day 12th after storage.

The C* value (Table 3 and Figure 4) of outer pericarp tended to decrease along with storage time. The C* value of carbon dioxide pressure treatment tended to increase as pressure increased but the increased explosion time decreased C* value.

The Hue angle (Table 4 and Figure 4) of outer pericarp tended to decreased along with storage time. The increased pressure and explosion time decreased Hue angle. The interaction between pressure and explosion time was found on day 6 and 9 after st6rage. The longan exposed to carbon dioxide pressure of 2.0 kg-cm^{-2} for 1 hour and 1.5 kg-cm^{-2} for 3 hours provided the highest Hue angle.

Table 2 L* value of outer pericarp of longan fruit cv. Daw stored at 10°C after treating with high carbon dioxide pressures

TREATMENT	DAYS AFTER STORAGE AT 10 °C				
	3	6	9	12	15
P = Pressure					
1.0 kg-cm-2	53.23a	50.76a	54.04a	51.33ab	46.86a
1.5 kg-cm-2	53.30a	51.46a	54.41a	52.54ab	46.95a
2.0 kg-cm^{-2}	53.38a	51.95a	53.92a	50.19b	46.09a
Untreated	53.43	51.51	52.67	53.02	42.89
T = Treated time					
1 hr	53.86a	51.32a	54.91a	52.64ab	46.16a
2 hr	53.20a	51.68a	54.85a	50.38b	46.87a
3 hr	52.86a	51.17a	52.61b	51.04b	46.87a
Pressure x Treated time					
1.0 kg-cm-2 – 1 hr.	54.64a	50.28a	55.68ab	50.06bc	44.80a
2 hr.	52.19c	51.13a	53.06bc	51.71ab	46.47a
3 hr.	52.86abc	50.87a	53.38abc	52.23ab	47.20a
1.5 kg-cm-2 – 1 hr.	52.72bc	50.43a	53.92ab	53.86ab	47.10a
2 hr.	53.91abc	52.21a	55.81a	51.90ab	46.65a
3 hr.	53.28abc	51.73a	53.51abc	51.87ab	46.87a
2.0 kg-cm-2 – 1 hr.	54.22ab	53.25a	55.14ab	54.00da	48.68a
2 hr.	53.50abc	51.71a	55.68ab	47.5cd	47.73a
3 hr.	52.44bc	50.90a	50.94c	49.02bc	44.20a
Untreated	53.43	51.51	52.67	53.02	42.89

Means within the same column followed by different letters are significant differences at 95 % ($P \leq 0.05$) by DMRT.

Table 3 C* value of outer pericarp of longan fruit cv. Daw stored at 10°C after treating with high carbon dioxide pressures

	DAYS AFTER STORAGE AT 10°C				
TREATMENT	3	6	9	12	15
P = Pressure					
1.0 kg-cm-2	31.14a	29.28a	28.16a	27.47a	21.18ab
1.5 kg-cm-2	30.94a	28.48ab	26.78b	28.05a	20.74b
2.0 kg-cm^{-2}	30.85a	27.62b	28.02a	27.11a	21.96a
Untreated	30.64	28.32	28.13	27.57	21.74
T = Treated time					
1 hr	31.00a	29.10a	27.80ab	27.92a	21.54a
2 hr	31.52a	29.39a	26.85b	27.08a	21.47a
3 hr	30.42a	26.89b	28.30ab	27.63a	20.88a
Pressure x Treated time					
1.0 kg-cm-2 – 1 hr.	30.67ab	29.51a	26.68cd	26.72a	22.17ab
2 hr.	31.01ab	29.18a	28.23bc	26.90a	20.28d
3 hr.	31.75a	29.15a	29.58ab	28.78a	21.09bcd
1.5 kg-cm-2 – 1 hr.	30.68ab	28.41ab	28.70bc	30.54a	20.60cd
2 hr.	32.40a	29.48a	26.26cd	26.63a	21.39bcd
3 hr.	29.74b	27.54b	25.37d	26.97a	20.24d
2.0 kg-cm-2 – 1 hr.	31.63a	29.38a	28.02bcd	26.48a	21.84abc
2 hr.	31.14ab	29.51a	26.08cd	27.71a	22.73a
3 hr.	29.78b	28.98a	29.97a	27.15a	21.30bcd
Untreated	30.64	28.32	28.13	27.57	21.74

Means within the same column followed by different letters are significant differences at 95 % ($P \leq 0.05$) by DMRT.

Table 4 Hue angle of outer pericarp of longan fruit cv. Daw stored at 10°C after treating with high carbon dioxide pressures

TREATMENT	DAYS AFTER STORAGE AT 10°C				
	3	6	9	12	15
P = Pressure					
1.0 kg-cm-2	63.50a	67.27a	66.92a	66.31a	65.33a
1.5 kg-cm-2	63.74a	68.11a	67.19a	65.65a	65.18a
2.0 kg-cm^{-2}	64.37a	67.33a	65.80b	65.28a	64.06b
Untreated	65.58	67.63	66.56	67.79	65.61
T = Treated time					
1 hr	63.78	66.77b	67.27a	66.25a	65.43a
2 hr	64.52	68.66a	67.66a	66.30a	64.58a
3 hr	63.30	67.28ab	64.99b	64.69b	64.57a
Pressure x Treated time					
1.0 kg-cm-2 – 1 hr.	63.68a	65.58a	67.62abc	65.19bcd	64.78a
2 hr.	63.20a	68.11a	66.76bc	67.03ab	64.86a
3 hr.	63.62a	68.13a	66.39c	66.72ab	66.36a
1.5 kg-cm-2 – 1 hr.	63.38a	67.86a	66.55bc	67.52a	67.22a
2 hr.	64.94a	69.30a	68.59a	65.36bc	64.52a
3 hr.	62.89a	67.17a	66.43bc	64.07cd	63.81a
2.0 kg-cm-2 – 1 hr.	64.29a	66.87a	67.65ab	66.06abc	64.30a
2 hr.	65.41a	68.58a	67.62abc	66.50ab	64.36a
3 hr.	63.40a	66.54a	66.13c	63.27d	63.53a
Untreated	65.58	67.63	66.56	67.79	65.61

Means within the same column followed by different letters are significant differences at 95 % ($P \leq 0.05$) by DMRT.

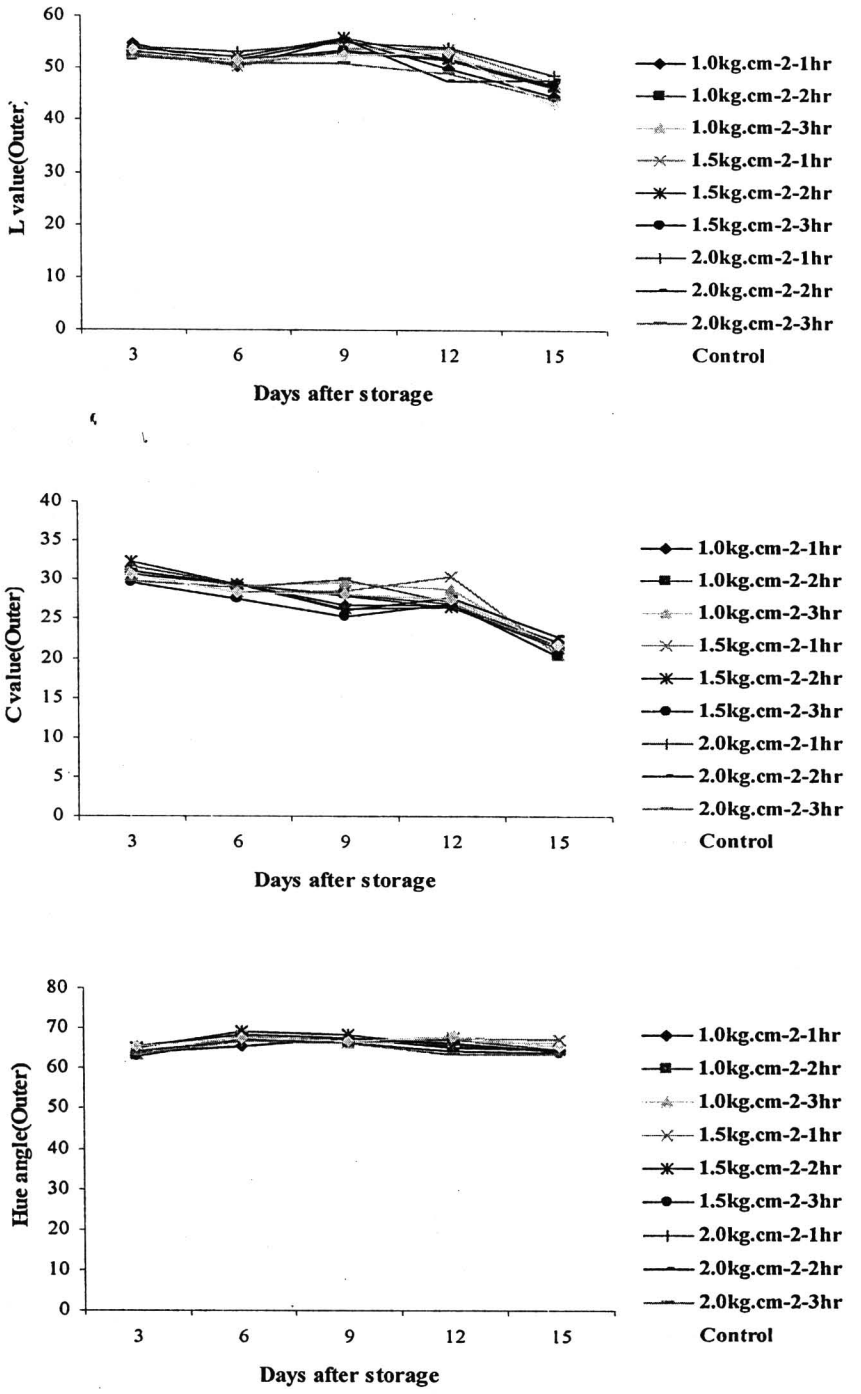

Figure 4 L* value C* value and hue angle of outer pericarp of longan fruit cv. Daw stored at 10°C after treating with high carbon dioxide pressures

Inner Pericarp color

The L* value (lightness) of inner pericarp tended to decrease with prolonged storage time (Table 5 and Figure 5). Similar to L* value of outer pericarp, the HCP had no effect on L* value of inner pericarp but increased explosion time decreased L* value. As explosion time increased, the L* value decreased.

The C* value (Table 6 and Figure 5) of inner pericarp tended to increase along with storage time. The C* value tended to decreased with increased pressure and tended to increase with increased explosion time. The interaction between pressure and explosion time was found on day 9 after storage. The longan exposed to carbon dioxide pressure of 1.5 kg-cm^{-2} for 2 hour and 2 kg-cm^{-2} for 1 hour provided the lowest C* value.

The Hue angle (Table 7 and Figure 5) of inner pericarp tended to decrease along with storage time. That means pericarp color changed from yellow to red. The carbon dioxide pressure did not affect the Hue angle, but the increased explosion time decreased Hue angle. The interaction between pressure and explosion time was found on stored fruit for 3, 6, 9 and 12 days. The longan exposed to carbon dioxide pressure of 2.0 kg-cm^{-2} for 1 hour and 2.0 kg-cm^{-2} for 2 hour provided the highest Hue angle.

Table 5 L* value of inner pericarp of longan fruit cv. Daw stored at 10°C after treating with high carbon dioxide pressures

TREATMENT	DAYS AFTER STORAGE AT 10°C				
	3	6	9	12	15
P = Pressure					
1.0 kg-cm-2	73.15a	71.81a	73.60a	71.81a	66.42a
1.5 kg-cm-2	72.63a	73.52a	75.20a	70.21a	66.66a
2.0 kg-cm^{-2}	72.91a	73.26a	73.47a	72.38a	63.75a
Untreated	73.35	74.29	75.61	72.55	62.81
T = Treated time					
1 hr	72.75a	72.96a	75.18a	71.65a	65.00a
2 hr	73.13a	73.50a	74.99a	72.45a	66.93a
3 hr	72.81a	72.13a	72.08b	70.29a	64.91a
Pressure x Treated time					
1.0 kg-cm-2 – 1 hr.	72.61a	73.96a	73.19a	71.85a	66.32a
2 hr.	73.11a	71.51a	72.81a	72.30a	65.89a
3 hr.	73.73a	69.95a	75.29a	71.28a	67.04a
1.5 kg-cm-2 – 1 hr.	72.35a	71.51a	75.45a	68.29a	65.50a
2 hr.	73.25a	74.35a	76.84a	72.15a	66.72a
3 hr.	73.30a	74.55a	73.80a	70.17a	67.78a
2.0 kg-cm-2 – 1 hr.	73.31a	73.25a	76.92a	74.82a	63.17ab
2 hr.	73.02a	74.63a	76.16a	72.90a	68.19a
3 hr.	72.39a	71.90a	67.84b	69.41a	59.90b
Untreated	73.35	74.29	75.61	72.55	62.81

Means within the same column followed by different letters are significant differences at 95 % ($P \leq 0.05$) by DMRT.

Table 6 C* value of inner pericarp of longan fruit cv. Daw stored at 10°C after treating with high carbon dioxide pressures

TREATMENT	DAYS AFTER STORAGE AT 10°C				
	3	6	9	12	15
P = Pressure					
1.0 kg-cm-2	19.51a	24.73a	24.69a	25.69a	28.14a
1.5 kg-cm-2	19.79a	24.86a	24.08a	23.54b	24.51b
2.0 kg-cm^{-2}	21.05a	24.75a	24.45a	25.56a	24.54b
Untreated	20.78	25.43	24.65	24.43	25.18
T = Treated time					
1 hr	20.14a	24.82a	23.85b	24.49a	25.99a
2 hr	19.97a	24.49a	24.46ab	25.18a	25.70a
3 hr	20.24a	25.04a	24.90a	25.12a	25.50a
Pressure x Treated time					
1.0 kg-cm-2 – 1 hr.	19.57a	24.44a	23.92b	25.06a	28.08a
2 hr.	19.65a	24.93a	25.59a	26.01a	27.80a
3 hr.	19.30a	24.83a	24.52ab	26.00a	28.55a
1.5 kg-cm-2 – 1 hr.	19.86a	25.58a	24.99ab	24.29a	25.58a
2 hr.	19.22a	24.01a	23.14b	23.40a	25.17a
3 hr.	20.31a	24.98a	24.59ab	22.91a	22.78a
2.0 kg-cm-2 – 1 hr.	20.99a	24.44a	23.55b	24.11a	24.32a
2 hr.	21.05a	24.53a	24.26ab	26.14a	24.15a
3 hr.	21.11a	25.29a	25.53a	26.44a	25.18a
Untreated	20.78	25.43	24.65	24.43	25.18

Means within the same column followed by different letters are significant differences at 95 % ($P \leq 0.05$) by DMRT.

Table 7 Hue angle of inner pericarp of longan fruit cv. Daw stored at 10°C after treating with high carbon dioxide pressures

TREATMENT	DAYS AFTER STORAGE AT 10 °C				
	3	6	9	12	15
P = Pressure					
1.0 kg-cm-2	80.80a	79.72a	78.81a	77.53a	75.20a
1.5 kg-cm-2	80.53a	80.20a	80.12a	77.11a	76.26a
2.0 kg-cm^{-2}	80.63a	80.47a	78.69a	78.11a	74.34a
Untreated	80.40	80.89	80.19	80.16	75.04
T = Treated time					
1 hr	80.43ab	79.85a	79.47a	77.72a	74.63a
2 hr	81.31a	80.52a	80.49a	78.45a	75.91a
3 hr	80.24b	80.03a	77.72b	76.57a	75.26a
Pressure x Treated time					
1.0 kg-cm-2 – 1 hr.	80.02bc	79.87ab	77.95bc	77.55ab	75.24a
2 hr.	80.81abc	78.39b	78.76b	77.84ab	75.15a
3 hr.	81.02a	80.92ab	79.89abc	77.19ab	75.20a
1.5 kg-cm-2 – 1 hr.	80.02abc	79.15ab	79.89abc	75.38b	74.30a
2 hr.	82.09a	81.31ab	81.50ab	78.78a	76.49a
3 hr.	79.15c	80.15ab	79.87abc	77.19ab	78.00a
2.0 kg-cm-2 – 1 hr.	80.90abc	80.52ab	81.96ab	80.26a	74.35a
2 hr.	81.02abc	81.85a	80.92abcd	78.74a	76.10a
3 hr.	79.98bc	79.03ab	74.09d	75.34b	72.57a
Untreated	80.40	80.89	80.19	80.16	75.04

Means within the same column followed by different letters are significant differences at 95 % ($P \leq 0.05$) by DMRT.

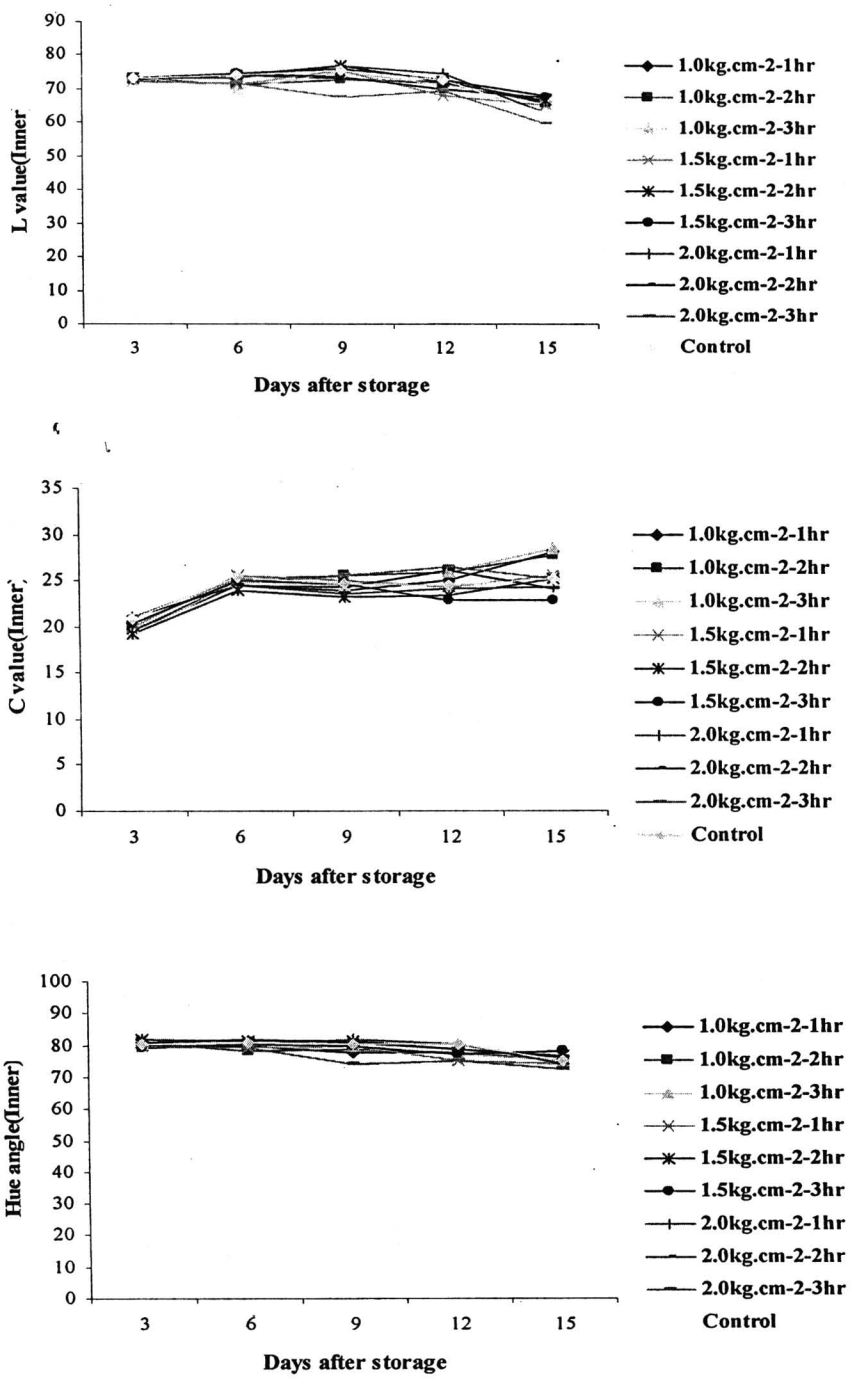

Figure 5 L* value c value and hue angle of inner longan fruit pericarp cv. Daw stored at 10°C after treating with high carbon dioxide pressures

Aril color

The L* value (lightness) of aril tended to reduce with prolonged storage time (Table 8 and Figure 6). The increase of carbon dioxide pressure and explosion time decreased L* value. The interaction between carbon dioxide pressure and explosion time on L* value was found at 9 and 15 days after storage. The lowest L* value was shown in the carbon dioxide pressure of 2 kg-cm^{-2} for 3 hour when fruit were stored for 15 days.

The C* value (Table 9 and Figure 6) of aril tended to increase along with storage time. The increased pressure and explosion time increased C* value. The interaction between pressure and explosion time was found on day 9 after storage. The longan exposed to carbon dioxide pressure of 1.5 kg-cm^{-2} for 2 hour and 2.0 kg-cm^{-2} for 1 hour provided the lowest C* value.

The Hue angle (Table 10 and Figure 6) of aril tended to decrease along with storage time. That means pericarp color changed from yellow to red. The increased pressure decreased Hue angle, however, explosion time did not affect the Hue angle. The interaction between pressure and explosion time were found on stored fruit for 15 days. The highest Hue angle was found on carbon dioxide pressure with 1.0 kg-cm^{-2} for 3 hours and 2.0 kg-cm^{-2} for 2 hours treatments.

Table 8 L* value of aril of longan fruit cv. Daw stored at 10°C after treating with high carbon dioxide pressures

TREATMENT	DAYS AFTER STORAGE AT 10°C				
	3	6	9	12	15
P = Pressure					
1.0 kg-cm-2	37.72a	33.93a	33.26a	29.47a	22.79a
1.5 kg-cm-2	37.31a	27.36b	33.65a	27.28b	21.87a
2.0 kg-cm^{-2}	36.70a	32.21a	33.79a	24.43c	23.38a
Untreated	37.02	33.72	34.58	24.03	22.83
T = Treated time					
1 hr	37.07a	29.88b	32.69b	27.43a	23.21a
2 hr	36.97a	33.35a	32.85b	27.25a	20.58b
3 hr	37.69a	30.28b	35.15a	26.49a	24.25a
Pressure x Treated time					
1.0 kg-cm-2 – 1 hr.	37.17a	36.02a	33.62a	28.56a	23.16ab
2 hr.	37.70a	35.64a	30.96a	28.76a	21.56bc
3 hr.	38.29a	30.13b	35.19a	31.07a	23.65ab
1.5 kg-cm-2 – 1 hr.	37.59a	28.36bc	31.21a	29.85a	20.61bc
2 hr.	36.95a	28.44bc	34.26a	28.42a	18.78c
3 hr.	37.38a	25.29c	35.48a	23.58b	26.21a
2.0 kg-cm-2 – 1 hr.	36.46a	25.26c	33.25a	23.87b	25.87a
2 hr.	36.25a	35.96a	33.33a	24.59b	21.40bc
3 hr.	37.39a	35.40a	34.78a	24.82b	22.88ab
Untreated	37.02	33.72	34.58	24.03	22.83

Means within the same column followed by different letters are significant differences at 95 % ($P \leq 0.05$) by DMRT.

Table 9 C*value of aril of longan fruit cv. Daw stored at 10°C after treating with high carbon dioxide pressures

TREATMENT	DAYS AFTER STORAGE AT 10(C				
	3	6	9	12	15
P = Pressure					
1.0 kg-cm-2	5.65b	8.75a	9.72a	9.93a	12.61a
1.5 kg-cm-2	6.30ab	8.42a	9.15a	9.51b	11.33b
2.0 kg-cm^{-2}	6.79a	8.44a	8.90a	10.26a	11.36b
Untreated	7.30	9.92	9.56	11.85	12.95
T = Treated time					
1 hr	6.00a	8.40b	8.99a	9.35b	11.55a
2 hr	6.06a	8.37b	9.03a	9.90ab	11.43a
3 hr	6.68a	8.84a	9.73a	10.45a	12.32a
Pressure x Treated time					
1.0 kg-cm-2 – 1 hr.	5.19a	8.90a	9.78a	10.66ab	12.86a
2 hr.	5.73a	8.65a	9.78a	10.08ab	12.26a
3 hr.	6.02a	8.70a	9.59a	9.07b	12.71a
1.5 kg-cm-2 – 1 hr.	6.13a	8.42a	8.73a	8.78bc	11.65a
2 hr.	5.76a	8.46a	8.99a	9.43b	10.97a
3 hr.	7.04a	8.40a	9.74a	10.32ab	11.37a
2.0 kg-cm-2 – 1 hr.	6.69a	7.87a	8.49a	8.63bc	10.13a
2 hr.	6.69a	8.02a	8.34a	10.19ab	11.07a
3 hr.	7.01a	9.43a	9.88a	11.98a	12.89a
Untreated	7.30	9.92	9.56	11.85	12.95

Means within the same column followed by different letters are significant differences at 95 % ($P \leq 0.05$) by DMRT.

Table 10 Hue angle of aril of longan fruit cv. Daw stored at 10°C after treating with high carbon dioxide pressures

TREATMENT	DAYS AFTER STORAGE AT 10°C				
	3	6	9	12	15
P = Pressure					
1.0 kg-cm-2	55.34a	63.92a	66.35b	69.81a	65.38a
1.5 kg-cm-2	54.98a	61.33b	68.61a	69.60a	60.63b
2.0 kg-cm^{-2}	57.54a	61.96ab	66.93ab	67.96b	61.98b
Untreated	59.23	58.15	67.76	70.36	59.56
T = Treated time					
1 hr	55.16a	61.75a	66.80a	69.10a	62.27a
2 hr	55.56a	62.96a	67.48a	68.84a	61.98a
3 hr	57.15a	62.51a	66.92a	69.42a	63.73a
Pressure x Treated time					
1.0 kg-cm-2 – 1 hr.	54.55a	62.72a	64.55a	68.99a	65.12a
2 hr.	55.83a	66.08a	67.97a	70.26a	64.32ab
3 hr.	55.66a	62.97a	66.52a	70.20a	66.69a
1.5 kg-cm-2 – 1 hr.	54.84a	61.80a	68.59a	69.19a	61.13bc
2 hr.	53.48a	59.70a	68.68a	69.28a	59.92c
3 hr.	56.62a	62.49a	68.56a	70.34a	60.82bc
2.0 kg-cm-2 – 1 hr.	56.10a	60.72a	67.24a	69.15a	60.55bc
2 hr.	57.37a	63.09a	65.55a	67.00a	61.71bc
3 hr.	59.17a	62.08a	67.74a	67.73a	63.67ab
Untreated	59.23	58.15	67.76	70.36	59.56

Means within the same column followed by different letters are significant differences at 95 % ($P \leq 0.05$) by DMRT.

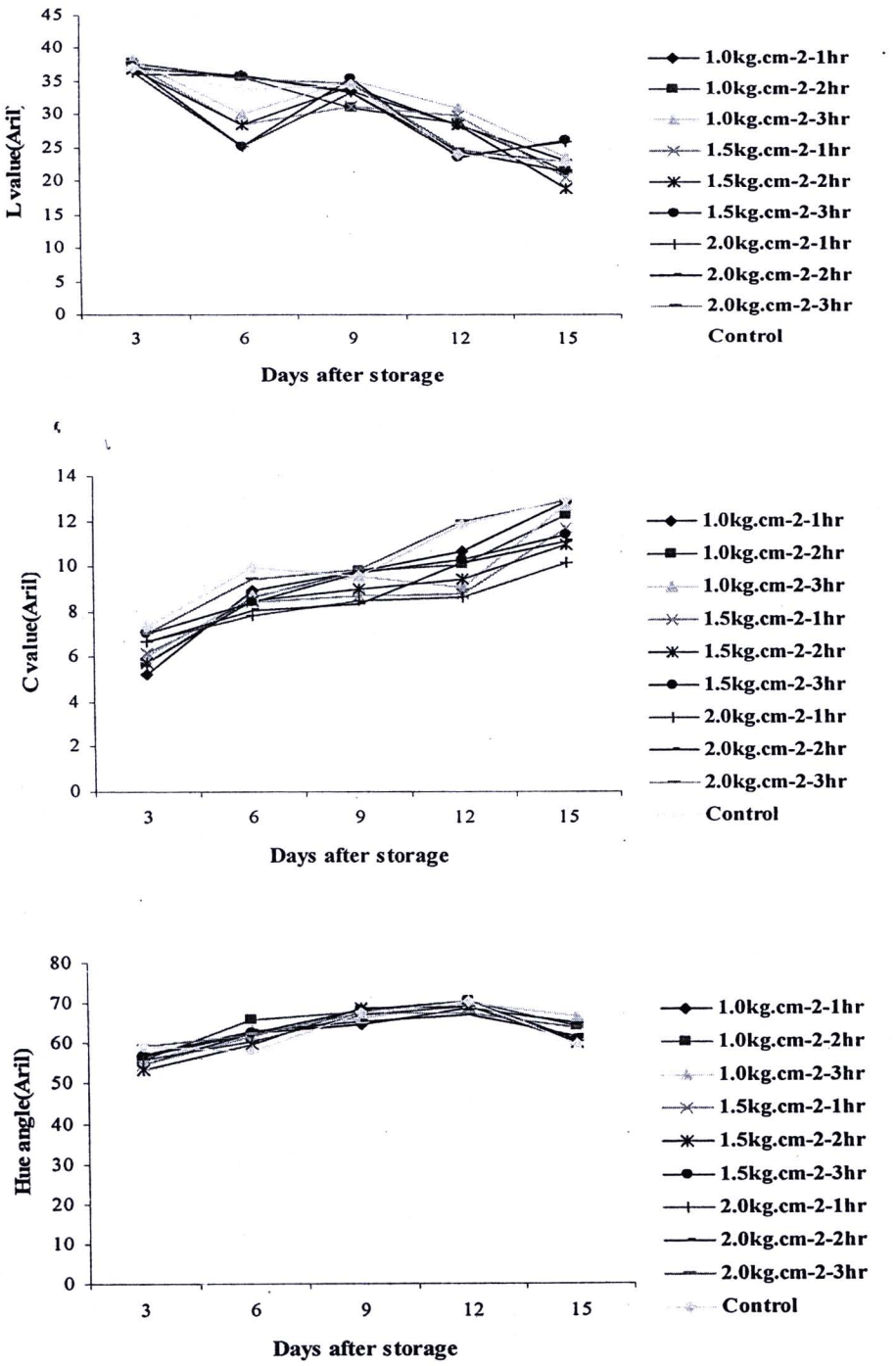

Figure 6 L* value C* value and Heu angle of longan fruit aril cv. Daw stored at 10°C after treating with high carbon dioxide pressures

4.1.2 Fruit weight loss percentage

It was found that in all treatments weight loss percentage increased during the storage. (Figure 7and Table 11). HCP treatments decreased weight loss percentage, on the contrary with explosion time increased weight loss percentage. The interaction between carbon dioxide pressure and explosion time was found on day 15th after storage. The longan exposed to carbon dioxide pressure of 2 kg-cm^{-2} for 1 hour provided the lowest weight loss percentage.

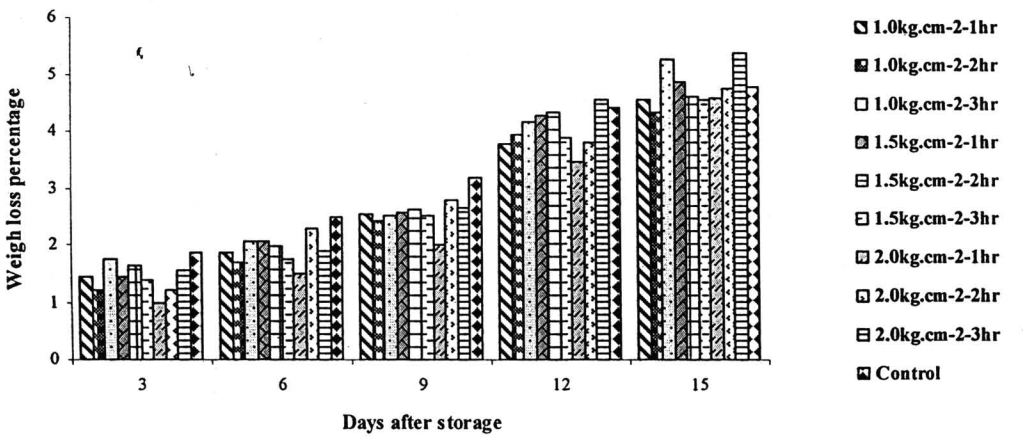

Figure 7 Weight loss percentage of longan fruit cv. Daw stored at 10 °C after treating with high carbon dioxide pressures

A loss in product weight after harvest, resulting from a loss of water and consumption of the accumulated nutrition, leads to a loss in quality (Wills *et al.*, 1981). The weight loss percentage of treated fruit were lower than untreated The treated fruit with HCP for 1 hour had the last weight loss percentage during the storage (Table 1). From the Browning Index, the losses in the longan fruit's weight correlated with the pericarp browning, with a 0.74 of correlation (Table 13). According to La-ongsri (1995), the browning of longan pericarp is the result of a loss of water, which leads to cell and mesocarp plasmolysis, causing a loss of membrane properties and leakage of the PPO enzyme.

Table 11 Weigh loss percentage of longan fruit cv. Daw stored at 10°C after treating with high carbon dioxide pressures

TREATMENT	DAYS AFTER STORAGE AT 10°C				
	3	6	9	12	15
P = Pressure					
1.0 kg-cm-2	1.47a	1.87a	2.48a	3.97a	4.73a
1.5 kg-cm-2	1.49a	1.93a	2.56a	4.17a	4.68a
2.0 kg-cm^{-2}	1.25b	1.89a	2.48a	3.95a	4.90a
Untreated	1.87	2.48	3.17	4.42	4.80
T = Treated time					
1 hr	1.30b	1.81a	2.37b	3.84b	4.67b
2 hr	1.35b	1.98a	2.60a	4.04ab	4.57b
3 hr	1.56a	1.97a	2.54a	4.21a	5.06a
Pressure x Treated time					
1.0 kg-cm-2 – 1 hr.	1.44ab	1.86bc	2.54a	3.80ab	4.56b
2 hr.	1.21bc	1.69bc	2.41ab	3.95ab	4.35b
3 hr.	1.75a	2.07ab	2.50a	4.18ab	5.27a
1.5 kg-cm-2 – 1 hr.	1.45ab	2.07ab	2.57a	4.27a	4.87b
2 hr.	1.64a	1.96ab	2.62a	4.35a	4.61b
3 hr.	1.37abc	1.75bc	2.50a	3.89ab	4.55b
2.0 kg-cm-2 – 1 hr.	1.00c	1.5c	2.01b	3.46b	4.55b
2 hr.	1.21bc	2.29a	2.79a	3.81ab	4.76b
3 hr.	1.55ab	1.88bc	2.64a	4.57a	5.37a
Untreated	1.87	2.48	3.17	4.42	4.80

Means within the same column followed by different letters are significant differences at 95 % ($P \leq 0.05$) by DMRT.

4.1.3 Respiration rate

In all treatments respiration rate slightly increased during the storage (Figure 8 and Table 12). HCP decreased respiration rate whereas high explosion time increased them. The interaction between carbon dioxide pressure and explosion time was found on day 6 and 9 after storage. The longan fruit exposed to carbon dioxide of 2 kg-cm^{-2} for 1 and 2 hour provided the lowest respiration rate.

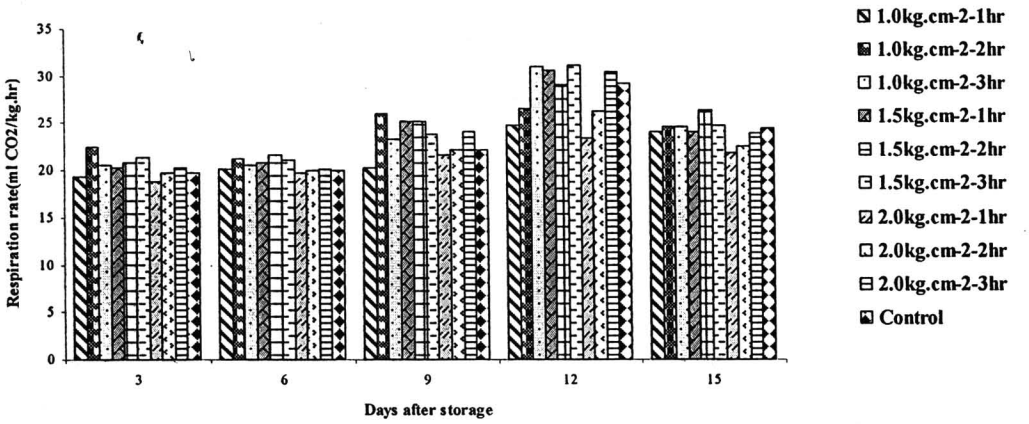

Figure 8 Respiration rate of longan fruit cv. Daw stored at 10°C after treating with high carbon dioxide pressures

Table 12 Respiration rate of longan fruit cv. Daw stored at 10°C after treating with high carbon dioxide pressures

TREATMENT	DAYS AFTER STORAGE AT 10°C				
	3	6	9	12	15
P = Pressure					
1.0 kg-cm-2	20.77a	20.63ab	23.21ab	27.50a	24.47a
1.5 kg-cm-2	20.85a	21.21a	24.69a	30.32a	25.12a
2.0 kg-cm^{-2}	19.62a	19.96b	22.64b	26.72a	22.84a
Untreated	19.78	20.06	22.14	29.32	24.56
T = Treated time					
1 hr	19.48a	20.22a	22.38b	26.27a	23.38a
2 hr	20.99a	20.99a	24.43a	27.37a	24.55a
3 hr	20.76a	20.59a	23.37ab	30.90a	24.49a
Pressure x Treated time					
1.0 kg-cm-2 – 1 hr.	19.37a	20.15a	20.32d	24.79a	24.07a
2 hr.	22.43a	21.22a	26.02a	26.61a	24.66a
3 hr.	20.53a	20.51a	23.30abc	31.10a	24.68a
1.5 kg-cm-2 – 1 hr.	20.33a	20.81a	25.17a	30.68a	24.15a
2 hr.	20.78a	21.68a	25.13a	29.17a	26.42a
3 hr.	21.43a	21.14a	23.78ab	31.12a	24.78a
2.0 kg-cm-2 – 1 hr.	18.76a	19.71a	21.67bc	23.36a	21.93a
2 hr.	19.78a	20.06a	22.14bc	26.32a	22.56a
3 hr.	20.31a	20.12a	24.13ab	30.49a	24.02a
Untreated	19.78	20.06	22.14	29.32	24.56

Means within the same column followed by different letters are significant differences at 95 % ($P \leq 0.05$) by DMRT.

4.1.4 Ethylene production

HCP treatments showed potential to reduce the ethylene production (Figure 9). The increased pressure and explosion time increased ethylene production. The longan exposed to carbon dioxide of 2 kg-cm^{-2} and 1.5 kg-cm^{-2} for 3 hours provided the highest ethylene production and 1.5 kg-cm^{-2} for 1 hour, 2 kg-cm^{-2} for 1 and 2 hours showed the lowest ethylene production, less than 0.02 nmol/mg.hr.

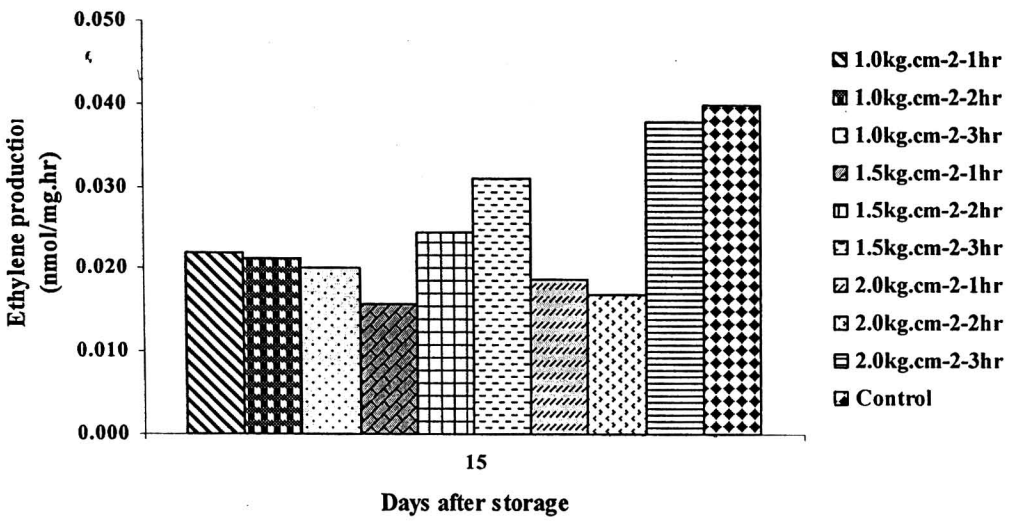

Figure 9 Ethylene production of longan fruit cv. Daw stored at 10°C after treating with high carbon dioxide pressures

4.1.5 Disease incidence percentage and overall acceptance

Disease incidence percentage

HCP treatments reduced the fruit decay (Figure 10), but the increased explosion time increased disease incidence. The fruit decay was found since day a after storage. The lowest disease incidence was found in longan exposed to carbon dioxide pressure of 2 kg-cm^{-2} for 1 and 2 hours (4.4 %) at last day of storage, while the untreated and exposed to carbon dioxide pressure of 2 kg-cm^{-2} for 3 hours showed highest disease incidence (66.67 %).

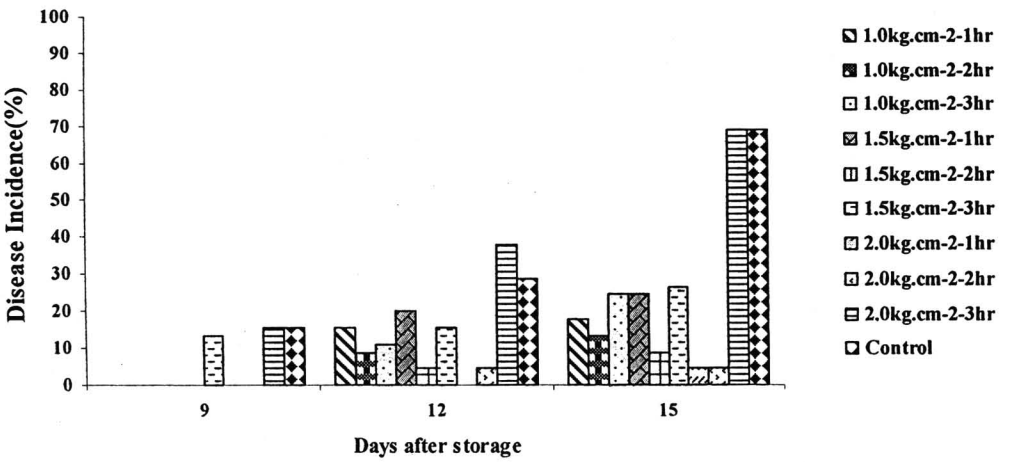

Figure 10 Disease incidence percentage of longan fruit cv. Daw stored at 10°C after treating with high carbon dioxide pressures

Overall acceptance

On day 15 after storage, the carbon dioxide pressure with 2 kg-cm^{-2} for 1 and 2 hours were the most accepted from the consumer whereas the untreated and 2 kg-cm^{-2} for 3 hours were the least accepted. The acceptance score of carbon dioxide pressure with 2 kg-cm^{-2} for 1 and 2 hours treatments were greater than 3 while the untreated and 2 kg-cm^{-2} for 3 hours were 1 (1 = most dislike).

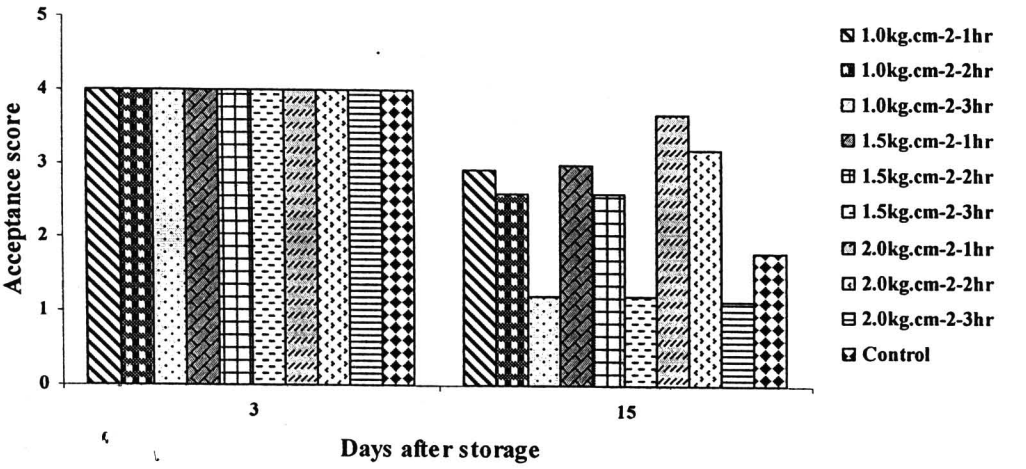

Figure 11 Overall acceptance score of longan fruit cv. Daw after treating with high carbon dioxide pressures then stored at 10°C (1 = most dislike; 2 =moderately dislike; 3 =neither like nor dislike; 4 =moderately like; and 5 =most like)

Pearson's correlation (r) between pericarp color, respiration rate , ethylene production ,fruit decay and their relations

The losses in longan fruit's weigh correlated with the browning index score and C* value of aril (Table 13), with 0.74 and 0.84 of correlation. However, the weigh loss had negative correlation with Hue angle of inner pericarp and L* value of aril (r = -0.76 and -0.81). The production of ethylene had negative correlation with L* value of outer and inner pericarp (r= -0.80 and -0.81). The disease incidence of longan fruit correlated with ethylene production(r = o.66) but had a negative correlation with L* value of pericarp, with -0.76 and -0.81 of correlation.

Table 13 Pearson's correlation(r) between peel discoloration, fruit decay and their relations.

	WL	BI	L* Out	C* Out	H° Out	L* In	C* In	H° In	L* aril	C* aril	H° aril	Resp.	Eth
WL													
BI	0.74**												
L*-out	-0.66**	-0.50**											
C*-out	NS	0.53**	NS										
H°-out	NS	NS	NS	0.78**									
L*-In	-0.66**	-0.48**	0.81**	NS	0.39**								
C*-In	0.62**	0.72**	-0.53**	0.72**	0.38**	-0.38*							
H°-In	-0.76**	-0.62**	0.72**	NS	0.33*	0.88**	-0.56**						
L*-aril	-0.81**	-0.63**	0.69**	-0.39**	NS	0.60*	-0.64**	0.62**					
C*-aril	0.84**	0.85**	-0.74**	NS	NS	-0.64**	0.83**	-0.77**	-0.77**				
H°-aril	0.51**	0.65**	NS	0.56**	-0.38*	NS	0.69**	NS	NS	0.57**			
Res	0.68**	0.65**	NS	NS	NS	NS	0.42**	-.050**	-0.47**	0.52**	0.69**		
Eth	0.65**	0.48**	-0.80**	NS	NS	-0.81**	NS	-0.65**	-0.62**	0.66**	NS	NS	
DI	0.60**	0.64**	-0.64**	NS	NS	-0.73**	NS	-0.74**	-0.50**	0.67**	NS	0.47**	0.66**

** Correlation is significant at the 0.01 level.

*Correlation is significant at the 0.05 level.

WL = weight loss, BI = browning index, L* = lightness, C* = chroma , H° = Hue angle, Res = respiration rate Eth = Ethylene production and DI = disease incidence

4.2. Effect of High Carbon dioxide Pressure Treatments and Storage Temperature on Some Chemical Components and Biochemical Characteristics on Longan Fruit

4.2.1 Effect of High Carbondioxide Pressure Treatments and Storage Temperature on Some Chemical Components on Longan Fruit

4.2.1.1 pH and TA value of aril and pericarp

Aril and pericarp pH tended to decreased during storage, but high carbon dioxide pressure treatments and storage temperature did not affect on pH of aril and pericarp (Figure 12, 13 and Table 14, 15).

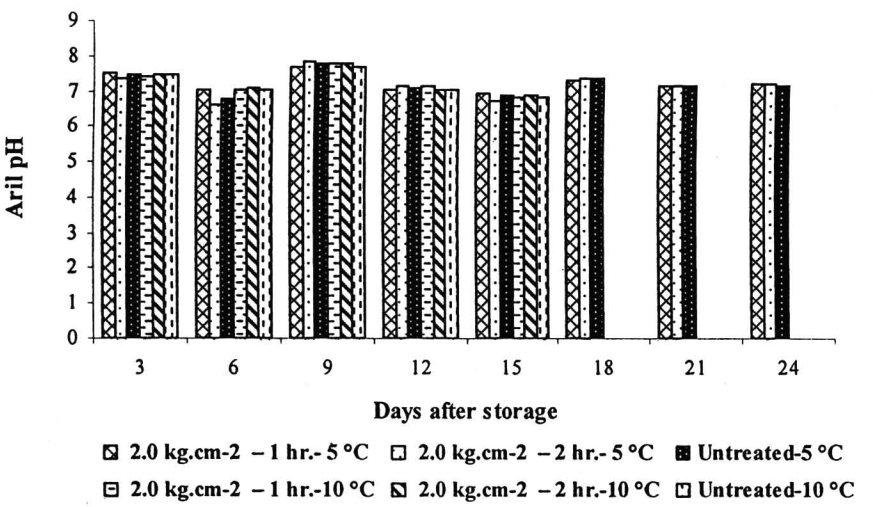

Figure 12 Aril pH of longan fruit cv. Daw stored at 5 and 10°C after treating with high carbon dioxide pressure

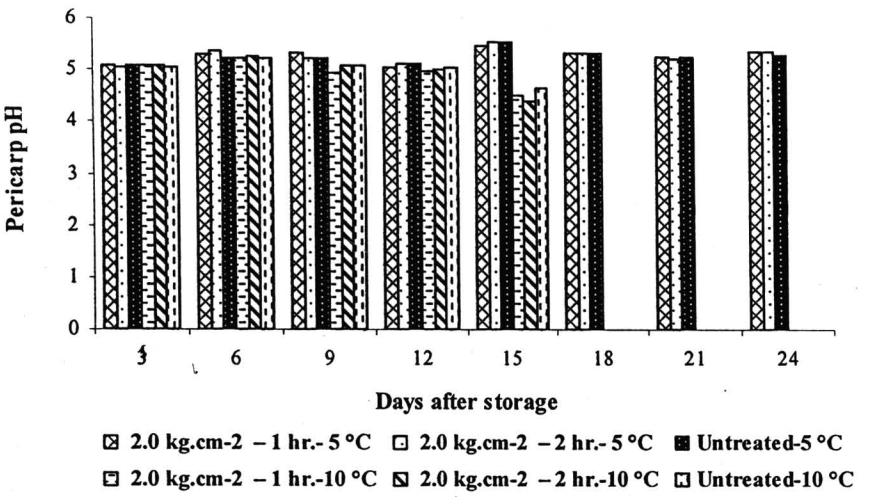

Figure 13 Pericarp pH of longan fruit cv. Daw stored at 5 and 10°C after treating with high carbon dioxide pressure

Table 14 pH of longan fruit aril juice stored at 5 and 10°C after treating with high carbon dioxide pressure

TREATMENT	DAYS AFTER STORAGE				
	3	6	9	12	15
CO_2 pressure treatment					
Untreated	7.47a	6.90ab	7.73a	7.05a	6.86a
2.0 $kg.cm^{-2}$ – 1 hr.	7.47a	7.03a	7.71a	7.08a	6.87a
2.0 $kg.cm^{-2}$ – 2 hr.	7.41a	6.86ab	7.79a	7.08a	6.81a
Storage temperature					
5 °C	7.45a	6.80a	7.76a	7.07a	6.85a
10 °C	7.44a	7.06a	7.72a	7.07a	6.84a
CO_2 pressure treatment x Storage temperature					
Untreated - 5 °C	7.45ab	6.77a	7.79a	7.06a	6.89a
2.0 $kg.cm^{-2}$ – 1 hr. - 5 °C	7.53a	7.01a	7.67a	7.03a	6.93a
2 hr. - 5 °C	7.37b	6.62a	7.82a	7.11a	6.73a
Untreated- 10 °C	7.48ab	7.03a	7.66a	7.03a	6.83a
2.0 $kg.cm^{-2}$ – 1 hr. - 10 °C	7.41b	7.05a	7.75a	7.13a	6.81a
2 hr. - 10 °C	7.44ab	7.10a	7.76a	7.04a	6.89a

Means within the same column followed by different letters are significant differences at 95 % ($P \leq 0.05$) by DMRT.

Table 15 pH of longan pericarp stored at 5 and 10°C after treating with high carbon dioxide pressure

TREATMENT	DAYS AFTER STORAGE				
	3	6	9	12	15
CO_2 pressure treatment					
Untreated	5.06a	5.23a	5.16a	5.08a	5.11a
2.0 $kg.cm^{-2}$ – 1 hr.	5.08a	5.25a	5.13a	5.01a	4.99a
2.0 $kg.cm^{-2}$ – 2 hr.	5.06a	5.30a	5.15a	5.06a	4.98a
Storage temperature					
5 °C	5.07a	5.28a	5.26a	5.09a	5.52a
10 °C	5.07a	5.22a	5.03a	5.00b	4.53b
CO_2 pressure treatment x Storage temperature					
Untreated - 5 °C	5.08a	5.23a	5.23a	5.11a	5.55a
2.0 $kg.cm^{-2}$ – 1 hr. - 5 °C	5.08a	5.28a	5.32a	5.04a	5.46a
2 hr. - 5 °C	5.04a	5.35a	5.23a	5.11a	5.54a
Untreated- 10 °C	5.04a	5.22a	5.09a	5.05a	4.66a
2.0 $kg.cm^{-2}$ – 1 hr. - 10 °C	5.08a	5.22a	4.94a	4.98a	4.52a
2 hr. - 10 °C	5.08a	5.24a	5.07a	5.00a	4.42a

Means within the same column followed by different letters are significantly at 95 % ($P \leq 0.05$) level by DMRT comparison

Titratable acidity (TA)

High carbon dioxide pressure treatments and storage temperature did not affect on of titratable acidity (TA) of aril and pericarp (Figure 14, 15 and Table 16, 17). They tended to have a few decreasing during the storage.

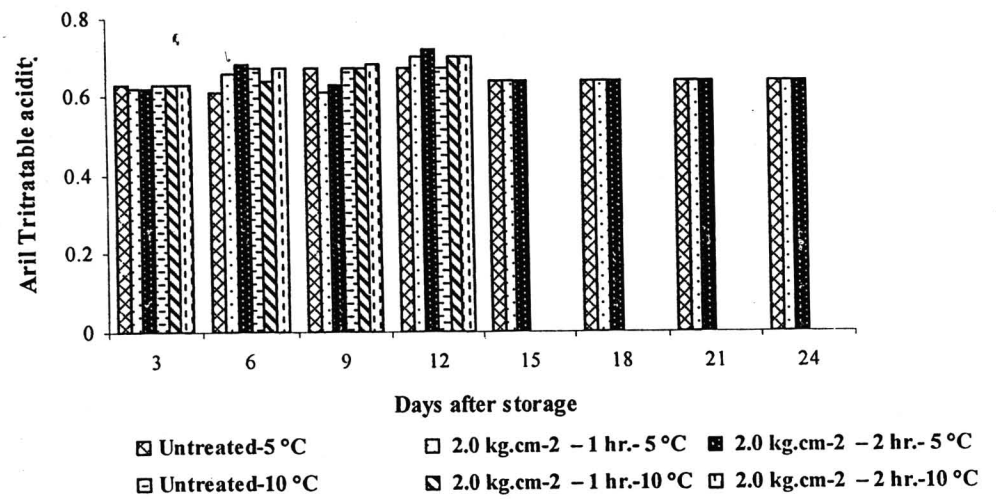

Figure 14 Titratable acidity percentage of aril of longan fruit cv. Daw stored at 5 and 10°C after treating with high carbon dioxide pressure

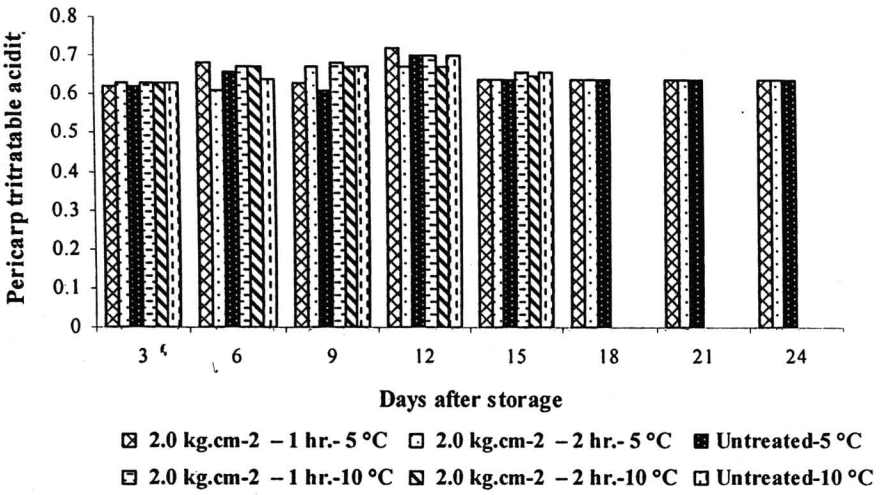

Figure 15 Titratable acidity percentage of pericarp of longan fruit cv. Daw stored at 5 and 10°C after treating with high carbon dioxide pressure

Table 16 Titratable acidity of longan fruit juice stored at 5 and 10°C after treating with high carbon dioxide pressure

TREATMENT	DAYS AFTER STORAGE				
	3	6	9	12	15
CO_2 pressure treatment					
Untreated	0.51a	0.54a	0.49a	0.48a	0.51a
2.0 $kg.cm^{-2}$ – 1 hr.	0.47a	0.50a	0.52a	0.52a	0.52a
2.0 $kg.cm^{-2}$ – 2 hr.	0.49a	0.53a	0.52a	0.51a	0.52a
Storage temperature					
5 °C	0.48a	0.52a	0.51a	0.50a	0.52a
10 °C	0.50a	0.52a	0.51a	0.50a	0.51a
CO_2 pressure treatment x Storage temperature					
Untreated - 5 °C	0.51a	0.52a	0.49a	0.48a	0.52a
2.0 $kg.cm^{-2}$ – 1 hr. - 5 °C	0.46a	0.51a	0.52a	0.51a	0.52a
2 hr. - 5 °C	0.47a	0.52a	0.52a	0.51a	0.52a
Untreated- 10 °C	0.51a	0.55a	0.50a	0.48a	0.50a
2.0 $kg.cm^{-2}$ – 1 hr. - 10 °C	0.48a	0.48a	0.51a	0.52a	0.52a
2 hr. - 10 °C	0.51a	0.54a	0.51a	0.51a	0.51a

Means within the same column followed by the same letters did not significant differences at 95 % ($P \leq 0.05$) by DMRT.

Table 17 Titratable acidity of longan pericarp stored at 5 and 10°C after treating with high carbon dioxide pressure

TREATMENT	DAYS AFTER STORAGE				
	3	6	9	12	15
CO_2 pressure treatment					
Untreated	0.64a	0.68a	0.65a	0.71a	0.65a
2.0 $kg.cm^{-2}$ – 1 hr.	0.63a	0.64a	0.67a	0.67a	0.66a
2.0 $kg.cm^{-2}$ – 2 hr.	0.63a	0.65a	0.64a	0.70a	0.65a
Storage temperature					
5 °C	0.62a	0.65a	0.63b	0.70a	0.64a
10 °C	0.63a	0.66a	0.67a	0.69a	0.66a
CO_2 pressure treatment x Storage temperature					
Untreated - 5 °C	0.62a	0.68a	0.63a	0.72a	0.64a
2.0 $kg.cm^{-2}$ – 1 hr. - 5 °C	0.63a	0.61a	0.67a	0.67a	0.64a
2 hr. - 5 °C	0.62a	0.66a	0.61a	0.70a	0.64a
Untreated- 10 °C	0.63a	0.67a	0.68a	0.70a	0.66a
2.0 $kg.cm^{-2}$ – 1 hr. - 10 °C	0.63a	0.67a	0.67a	0.67a	0.65a
2 hr. - 10 °C	0.63a	0.64a	0.67a	0.70a	0.66a

Means within the same column followed by the same letters did not significant differences at 95 % ($P \leq 0.05$) by DMRT.

4.2.1.2 Reducing sugars

The treated longan with carbon dioxide pressure showed lower sugar content than the untreated (Figure 16 and Table 18). The lowest reducing sugar content was found in longan fruit treated with carbon dioxide pressure for 1 hour at temperature 5 and 10 °C

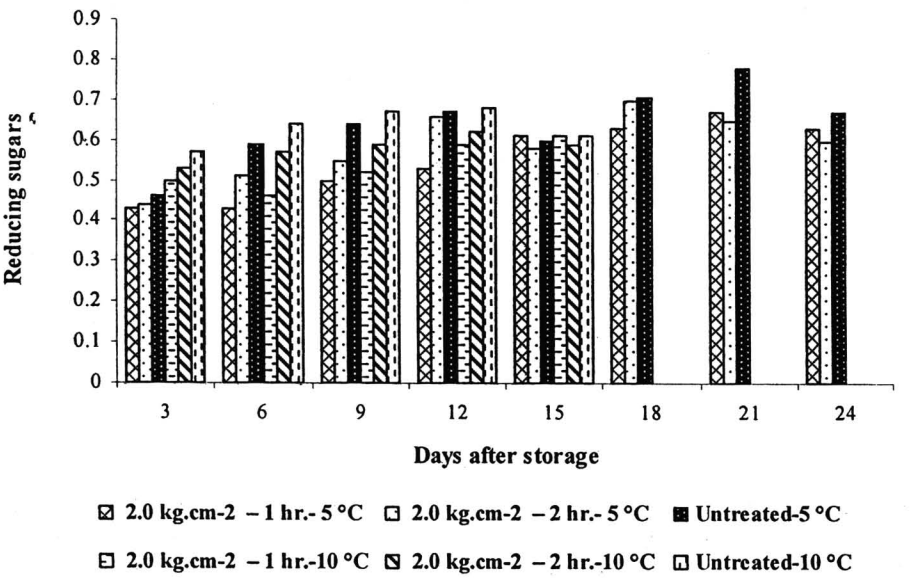

Figure 16 Reducing sugar of longan fruit cv. Daw stored at 5 and 10°C after treating with high carbon dioxide pressure

Table 18 Reducing sugar of longan fruit juice stored at 5 and 10°C after treating with high carbon dioxide pressure

TREATMENT	DAYS AFTER STORAGE				
	3	6	9	12	15
CO_2 pressure treatment					
Untreated	0.47a	0.67a	0.66a	0.68a	0.61a
2.0 $kg.cm^{-2}$ – 1 hr.	0.46a	0.44b	0.51b	0.56b	0.61a
2.0 $kg.cm^{-2}$ – 2 hr.	0.48a	0.54ab	0.57ab	0.64a	0.59a
Storage temperature					
5 °C	0.44a	0.51a	0.56a	0.62a	0.60a
10 °C	0.53a	0.55a	0.59a	0.64a	0.60a
CO_2 pressure treatment x Storage temperature					
Untreated - 5 °C	0.46a	0.59ab	0.64a	0.67a	0.60a
2.0 $kg.cm^{-2}$ – 1 hr. - 5 °C	0.43a	0.43b	0.50b	0.53b	0.61a
2 hr. - 5 °C	0.44a	0.51b	0.55ab	0.66a	0.58a
Untreated- 10 °C	0.57a	0.64a	0.67a	0.68a	0.61a
2.0 $kg.cm^{-2}$ – 1 hr. - 10 °C	0.50a	0.46b	0.52b	0.59b	0.61a
2 hr. - 10 °C	0.53a	0.57ab	0.59ab	0.62ab	0.59a

Means within the same column followed by different letters are significant differences at 95 % ($P \leq 0.05$) by DMRT.

4.2.2 Effect of High Carbondioxide Pressure Treatment and Storage Temperature on Some Biochemical Characteristics on Longan Fruit

4.2.2.1 Respiration rate

High carbon dioxide pressure treatments had effect on of respiration rate of longan pericarp (Figure 17 and Table 19). The treated longan with carbon dioxide pressure showed lower respiration rate than the untreated. The lowest respiration rate was found in longan fruit treated with carbon dioxide pressure for 1 and 2 hours at 5 °C on the end of storage.

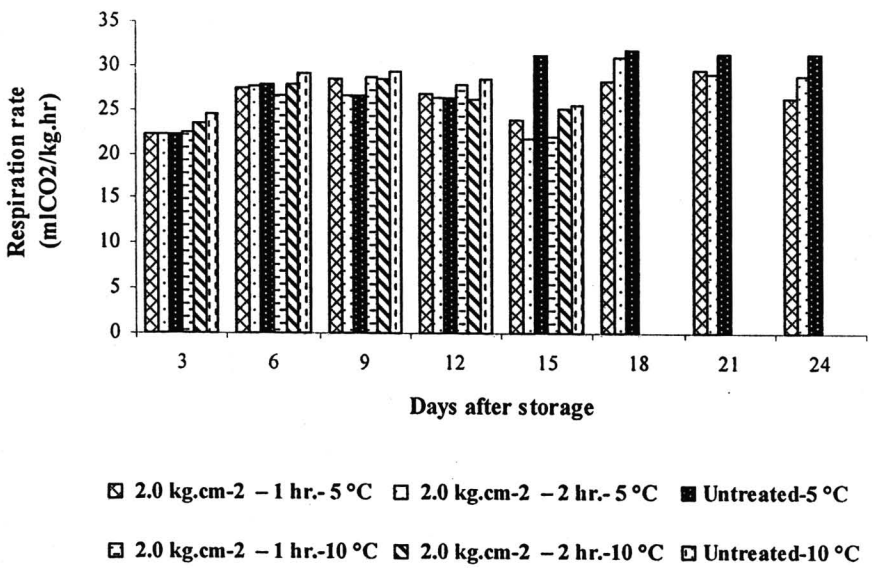

Figure 17 Respiration rate of longan fruit cv. Daw stored at 5 and 10 °C after treating with high carbon dioxide pressure

Table 19 Respiration rates of longan fruit stored at 5°C and 10°C after treating with high carbon dioxide pressure

TREATMENT	DAYS AFTER STORAGE				
	3	6	9	12	15
CO_2 pressure treatment					
Untreated	22.29a	27.65a	27.92a	27.40a	28.97a
2.0 $kg.cm^{-2}$ – 1 hr.	22.41a	27.69a	28.60a	26.57a	23.00b
2.0 $kg.cm^{-2}$ – 2 hr.	23.52a	27.86a	27.63a	27.53a	23.47b
Storage temperature					
5 °C	23.24a	27.18a	27.25a	26.36a	25.67a
10 °C	23.36a	28.49a	28.85a	27.41a	24.62b
CO_2 pressure treatment x Storage temperature					
Untreated - 5 °C	22.16a	27.85a	26.60a	26.32a	31.32a
2.0 $kg.cm^{-2}$ – 1 hr. - 5 °C	22.14a	27.48a	28.48a	26.90a	23.96d
2 hr. - 5 °C	22.19a	27.74a	26.66a	26.50a	21.73d
Untreated- 10 °C	24.56a	29.14a	29.24a	28.50a	25.62b
2.0 $kg.cm^{-2}$ – 1 hr. - 10 °C	22.44a	26.63a	28.71a	27.89a	22.03cd
2 hr. - 10 °C	23.56a	27.81a	28.60a	26.22a	25.21bc

Means within the same column followed by different letters are significant differences at 95 % ($P \leq 0.05$) by DMRT.

4.2.2 .2 Phosphofructokinase activity

Phosphofructokinase (PFK) activity (Figure 18 and Table 20)of high carbon dioxide pressure treatments and untreated tended to increase during storage and reached the maximum activity on day 15th after storage. The PFK activities of carbon dioxide pressure treatments for 1 and 2 hours were significantly lower than untreated on day 15th after storage. Moreover low temperature lowered PFK activity. PFK activities of carbon dioxide pressure treated fruit kept at 5 °C were 0.18 unit/mg protein.min while untreated fruit kept at 10 °C were 1.12 unit/mg protein.min.

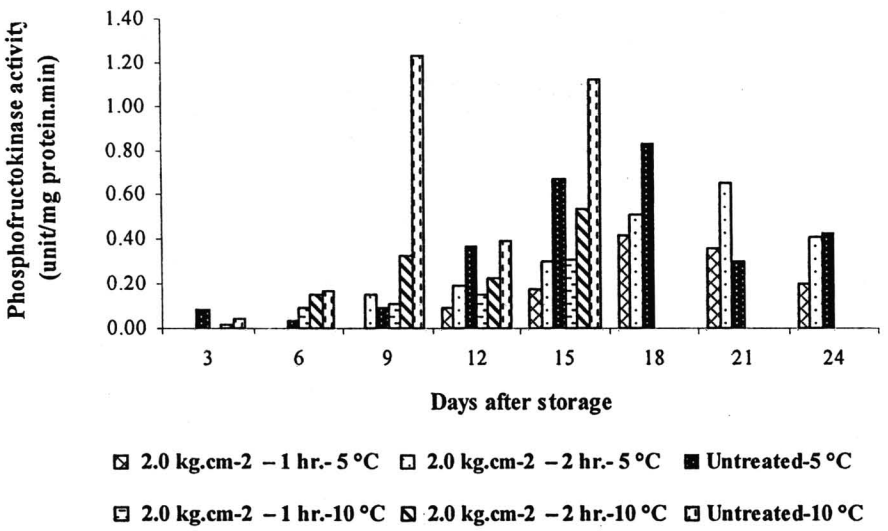

Figure 18 Phosphofructokinase activities of longan fruit cv. Daw stored at 5 and 10°C after treating with high carbon dioxide pressure

Table 20 Phosphofructokinase activities of longan fruit cv. Daw stored at 5 and 10°C after treating with high carbon dioxide pressure

TREATMENT	DAYS AFTER STORAGE				
	3	6	9	12	15
CO_2 pressure treatment					
Untreated	0.05a	0.10a	1.32a	0.53a	1.79a
2.0 $kg.cm^{-2}$ – 1 hr.	0.00b	0.04c	0.06c	0.12c	0.36b
2.0 $kg.cm^{-2}$ – 2 hr.	0.02a	0.08b	0.24b	0.31b	0.30b
Storage temperature					
5 °C	0.006b	0.01b	0.08b	0.18b	0.38b
10 °C	0.04a	0.13a	0.56a	0.28a	0.66a
CO_2 pressure treatment x Storage temperature					
Untreated - 5 °C	0.08a	0.03b	0.09bc	0.37a	0.67b
2.0 $kg.cm^{-2}$ – 1 hr. - 5 °C	0.00b	0.00c	0.00c	0.09d	0.18c
2 hr. - 5 °C	0.00b	0.00c	0.15bc	0.19c	0.30bc
Untreated- 10 °C	0.04a	0.17a	1.23a	0.39a	1.12a
2.0 $kg.cm^{-2}$ – 1 hr. - 10 °C	0.00b	0.09ab	0.11bc	0.15c	0.31bc
2 hr. - 10 °C	0.02a	0.15a	0.33b	0.23b	0.54b

Means within the same column followed by different letters are significant differences at 95 % ($P \leq 0.05$) by DMRT.

4.2.2 .3 Pyrophosphate : fru-6-p phosphotransferase activity

pyrophosphate : fru-6-p phosphotransferase (PFP) activities (Figure 19 and Table 21) of carbon dioxide pressure treated fruit and untreated tended to increase during storage and reached a maximum activity on day 15th after storage. The PFP activities of carbon dioxide pressure treated fruit were lower than untreated. Low temperature also lowered PFP activity. The lowest PFP activity was found in longan fruit treated with carbon dioxide pressure for 1 hr at 5 °C on 15th days after storage.

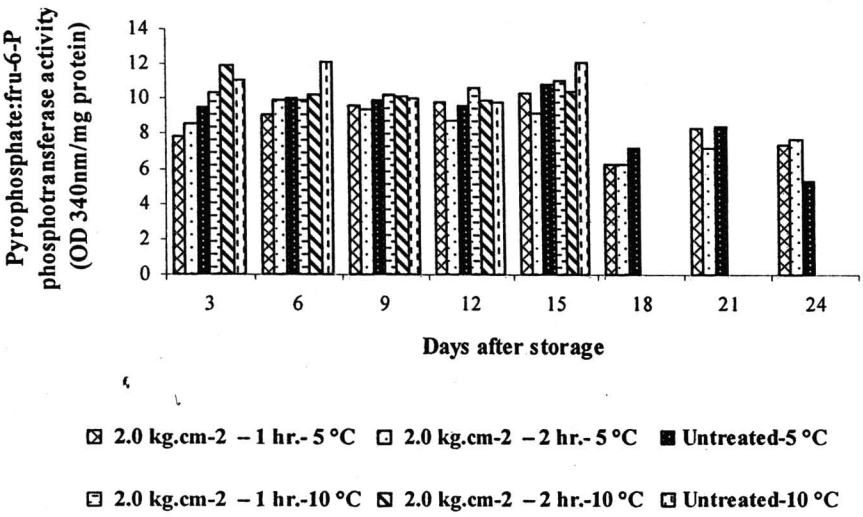

Figure 19 Pyrophosphate: fru-6-P phosphotransferase activities of longan fruit cv. Daw stored at 5 and 10°C after treating with high carbon dioxide pressure

Table 21 Pyrophosphate: fru-6-P phosphotransferase activities of longan fruit cv. Daw stored at 5 and 10°C after treating with high carbon dioxide pressure

TREATMENT	DAYS AFTER STORAGE				
	3	6	9	12	15
CO_2 pressure treatment					
Untreated	10.28a	9.89b	9.99a	9.70a	11.47a
2.0 $kg.cm^{-2}$ – 1 hr.	9.06a	9.48b	9.93a	10.22a	10.74ab
2.0 $kg.cm^{-2}$ – 2 hr.	10.22a	10.11a	9.75a	9.36a	9.83b
Storage temperature					
5 °C	8.62b	10.37a	9.62b	9.40b	10.14b
10 °C	11.09a	9.95a	10.16a	10.11a	11.21a
CO_2 pressure treatment x Storage temperature					
Untreated - 5 °C	9.51a	9.72b	9.91a	9.61ab	10.86ab
2.0 $kg.cm^{-2}$ – 1 hr. - 5 °C	7.79a	9.89b	9.58a	9.77ab	10.36ab
2 hr. - 5 °C	8.57a	10.25ab	9.37a	8.82b	9.21b
Untreated- 10 °C	11.06a	12.07a	10.07a	9.78ab	12.08a
2.0 $kg.cm^{-2}$ – 1 hr. - 10 °C	10.33a	9.08b	10.28a	10.67a	11.11ab
2 hr. - 10 °C	11.87a	9.97b	10.14a	9.90ab	10.45ab

Means within the same column followed by different letters are significant differences at 95 % ($P \leq 0.05$) by DMRT.

4.2.2 .4 Pyruvate kinase activity

The Pyruvate kinase activity (Figure 20 and Table 22) in the peel of the treated and untreated fruit tended to increase over the storage period. The activity of Pyruvate kinase activities was found to be highest in longan fruit stored at 10 °C for 15 days, and decreased over the 5 °C storage period. Moreover, in terms of average of temperature, Pyruvate kinase activity in treated fruit was found to be lower than in the untreated fruit to a statistically significant degree, and was found to be lowest after it had been stored at 5 °C.

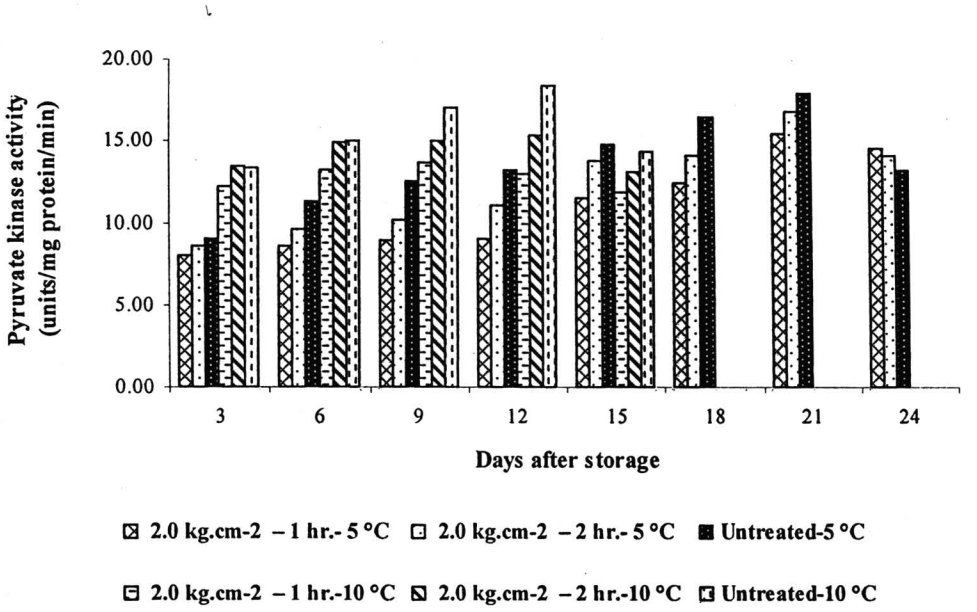

Figure 20 Pyruvate kinase activities of longan fruit cv. Daw stored at 5 and 10°C after treating with high carbon dioxide pressure

Table 22 Pyruvate kinase activities of longan fruit cv. Daw stored at 5 and 10°C after treating with high carbon dioxide pressure

TREATMENT	DAYS AFTER STORAGE				
	3	6	9	12	15
CO_2 pressure treatment					
Untreated	11.20a	13.20a	14.82a	15.81a	14.59a
2.0 $kg.cm^{-2}$ – 1 hr.	10.14a	10.89b	11.31b	11.04c	11.73b
2.0 $kg.cm^{-2}$ – 2 hr.	10.99a	12.25ab	12.63b	13.22b	14.43a
Storage temperature					
5 °C	8.55b	9.84b	10.57b	11.12b	13.38a
10 °C	13.00a	14.39a	15.27a	15.59a	13.21a
CO_2 pressure treatment x Storage temperature					
Untreated - 5 °C	9.02b	11.32bc	12.52b	13.21bc	14.85a
2.0 $kg.cm^{-2}$ – 1 hr. - 5 °C	8.07b	8.56c	8.97c	9.02c	11.54b
2 hr. - 5 °C	8.56b	9.63c	10.21bc	11.12bc	13.74a
Untreated- 10 °C	13.38a	15.08a	17.11a	18.41a	14.32a
2.0 $kg.cm^{-2}$ – 1 hr. - 10 °C	12.21a	13.21b	13.65b	13.05bc	11.92b
2 hr. - 10 °C	13.42a	14.87a	15.04ab	15.32b	13.11a

Means within the same column followed by different letters are significant differences at 95 % ($P \leq 0.05$) by DMRT.

In terms of the changes in respiration rate of longan fruit treated with high carbon dioxide pressure, it was found that longan fruit treated with 2.0 kg cm^{-2} pressure carbon dioxide for 1 hour had the lowest respiration rate (Table 12). The respiration rate of the product depends on elements in the surrounding atmosphere. In the study of Siripanich (1999), an atmosphere containing high carbon dioxide restrained activity of the succinic dehydrogenase enzyme in Kreb's cycle, blocking the respiration process from operating normally; a process associated with starch degradation and sugar consumption, leading to a low-rate of metabolic reaction (Kays, 1997). The respiration of products produces heat which accelerates or stimulates every reaction associated with cell deterioration in fruit, resulting in changes in the chemical compounds present. Jiang and Li (2001) found that an increase in the respiration rate of longan fruit lowered PPO activity and led to browning of the pericarp. This was associated with the results of another experiment which found that longan fruit treated with 2.0 $kg.cm^{-2}$ pressure carbon dioxide for 1 hour had a low respiration rate. Moreover, the respiration rate was even lower when treated further with a low temperature. In addition, the respiration rate of the longan fruit had a positive correlation with weight loss ($r = 0.68$).

Treating products with CO_2 is one of many methods used to restrict the respiration rate and several hypotheses have been proposed for its mode of action (Mathooko, 1996). Chang distinguished three types of CO_2 inhibition with regard to the reaction of enzymes: competitive, uncompetitive and non-competitive inhibition (Chang, 1981). In a study carried out by Karbel *et al.* (1988), Bartlett pears stored using high concentrations of carbon dioxide had a low respiration rate, which might have been the result of an increase in the phosphofructokinase enzyme (PFK) within the glycolytic pathway; a reaction associated with the results of this experiment. phosphofructokinase activity in the longan fruit treated with high pressure carbon dioxide was lower than in the untreated. Moreover, Lin *et al.* (2004) reported that the respiratory climacteric was suppress and pyruvate, 2-oxoglutarate and malate contents were decreased in banana fruit stimulated with ethylene for 24 hours and 60% carbon

dioxide storage. NADP linked isocitrate dehydrohenase (NADP-IDH) activity was also suppressed by exposure to CO_2.

4.2.2 .5 Ethylene production

Ethylene production (Figure 21) of treated fruit and untreated tended to increase during storage but treated fruit had less ethylene production than untreated. Low temperature also showed lower ethylene production than high temperature. At storage temperature 10 °C, we found ethylene production on day 15 and at 5 °C, ethylene production was found on day 21th and 24th.

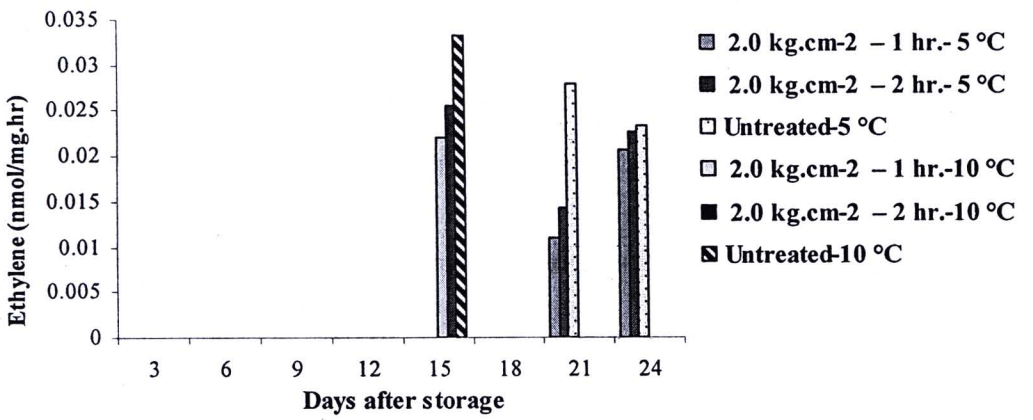

Figure 21 Ethylene production of longan fruit cv. Daw stored at 5 and 10°C after treating with high carbon dioxide pressure

4.2.2 .6 ACC synthase, ACC oxidase activity and ACC concentration.

The ACC synthase, ACC oxidase and ACC content (Figure 22) were found on day 15th and 24th after storage at 10 and 5 °C, respectively. The high carbon dioxide pressure treated fruit showed lower ACC synthase and ACC oxidase activities than untreated. Moreover, low storage temperature delayed ACC synthase and ACC oxidase activities and ACC content. The lowest ACC synthase and ACC oxidase activities and ACC concentration were found in longan fruit treated with carbon dioxide pressure for 1 hour.

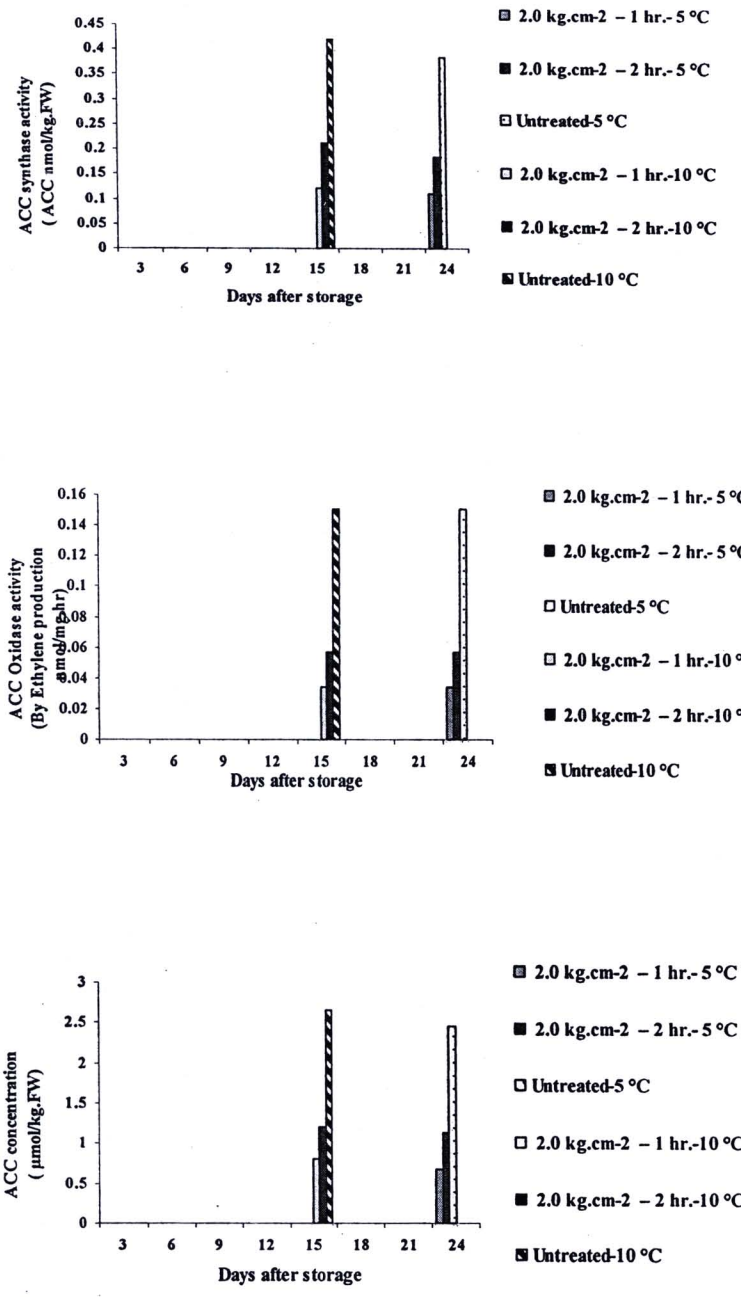

Figure 22 ACC synthase, ACC oxidase activity and ACC concentration of longan fruit cv. Daw stored at 5 and 10°C after treating with high carbon dioxide pressure

In terms of the ethylene synthesis of longan fruit after treated with high carbon dioxide pressure, it was found that fruit treated with 2.0 kg-cm^2 pressure carbon dioxide for 1 hour produced the lowest amount of ethylene. Grony and Kader (1996) and Siriphanich and Kader (1986) reported that high concentrations of carbon dioxide and low oxygen might restrain the synthesizing of ethylene through the following processes:

1. Carbon dioxide and low oxygen levels restrain the activity of enzymes related to the synthesizing of ethylene, such as the ACC synthase enzyme and the ACC oxidase enzyme, as a result of:
   1.1 Changes of pH in the Cytoplasm,
   1.2 Abnormalities within the phoshorylation process, or
   1.3 Feedback inhibition.
2. Carbon dioxide acts as a competitive inhibitor in the binding of ethylene and a receptor.

de Wild *et al.*, (2003) reported that carbon dioxide kinetic parameters derived from models, point to the conversion of ACC to ethylene by ACC oxidase as a possible action site for carbon dioxide inhibition. This corresponds with the results of another experiment which found that the activity of ACC oxidase in longan fruit treated with high-pressure carbon dioxide was lower than in an untreated (Figure 21). It has also been reported that high-concentrations of carbon dioxide can reduce ethylene synthesis and ACC oxidase activity in many kinds of fruit, such as apples, pears, bananas and tomatoes (James and Kader, 1996, Ahmad *et al.*, 2001 and de Wild *et al.*, 2005).

4.2.2 .7 Polygalactoronase activity

PG activities (Figure 23 and Table 23) of treated fruit and untreated increased as storage time increased and reached maximum value on day 15 at 10 °C. The PG activities of 2 kg-cm^{-2} for 1, 2 hours and untreated were 18.88, 29.7 and 35.42 OD 575 nm/mg protein, respectively. The maximum PG activities of fruit stored at 5 °C were found on day 24. These meaned that low temperature delayed PG activities. The maximum PG activity of 2 kg-cm^{-2} for 1, 2 hours and untreated were 23.18, 21.99 and 32.32 OD 575 nm/mg protein, respectively. The PG activities of treated fruit were lower than untreated. The lowest PG activity was found in longan fruit treated with carbon dioxide pressure for 1 hour at 5 °C.

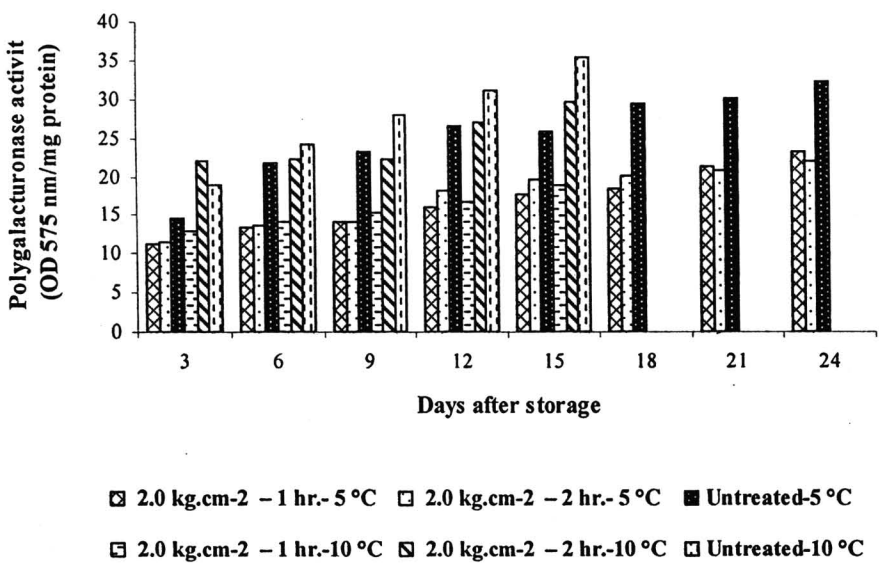

Figure 23 Polygalacturonase activity of longan fruit cv. Daw stored at 5 and 10°C after treating with high carbon dioxide pressure

Table 23 Polygalacturonase activities of longan fruit stored at 5 and 10°C after treating with high carbon dioxide pressure

TREATMENT	DAYS AFTER STORAGE				
	3	6	9	12	15
CO_2 pressure treatment					
Untreated	30.16a	20.99a	28.92a	32.48a	24.75a
2.0 $kg.cm^{-2}$ – 1 hr.	21.51b	17.82b	23.33b	21.94b	18.21b
2.0 $kg.cm^{-2}$ – 2 hr.	18.67b	13.19c	15.71c	17.61c	18.57b
Storage temperature					
5 °C	25.42a	16.78a	20.78b	20.74b	20.87a
10 °C	21.47b	17.89a	24.52a	27.28a	20.15a
CO_2 pressure treatment x Storage temperature					
Untreated - 5 °C	32.32a	23.18a	26.58b	29.55b	30.11a
2.0 $kg.cm^{-2}$ – 1 hr. - 5 °C	20.77b	13.71c	19.71c	14.12c	14.24c
2 hr. - 5 °C	23.18b	13.46c	16.06cd	18.54c	18.27bc
Untreated- 10 °C	28.01a	18.82b	31.25a	35.42a	19.40bc
2.0 $kg.cm^{-2}$ – 1 hr. - 10 °C	22.25b	21.94ab	26.955b	29.75b	22.18b
2 hr. - 10 °C	14.16c	12.92c	15.36d	16.69c	18.88bc

Means within the same column followed by different letters are significant differences at 95 % ($P \leq 0.05$) by DMRT.

4.2.2 .8 Polyphenoloxidase activity

PPO activities (Figure 24 and Table 24) of treated fruit and untreated increased along with storage time and reached maximum values on day 15th of both temperatures. The maximum PPO activities of 2 kg-cm^{-2} for 1 and 2 hours and untreated were 1.53, 2.42 and 2.40 unit x 10^3/mg protein, respectively. PPO activities of fruit stored at 5 °C declined from day 15th to the end of storage. Both high carbon dioxide pressure and cold temperature decreased PPO activities. PPO activity of treated fruit with 2 kg-cm^{-2} for 1 hour was significantly lower than untreated.

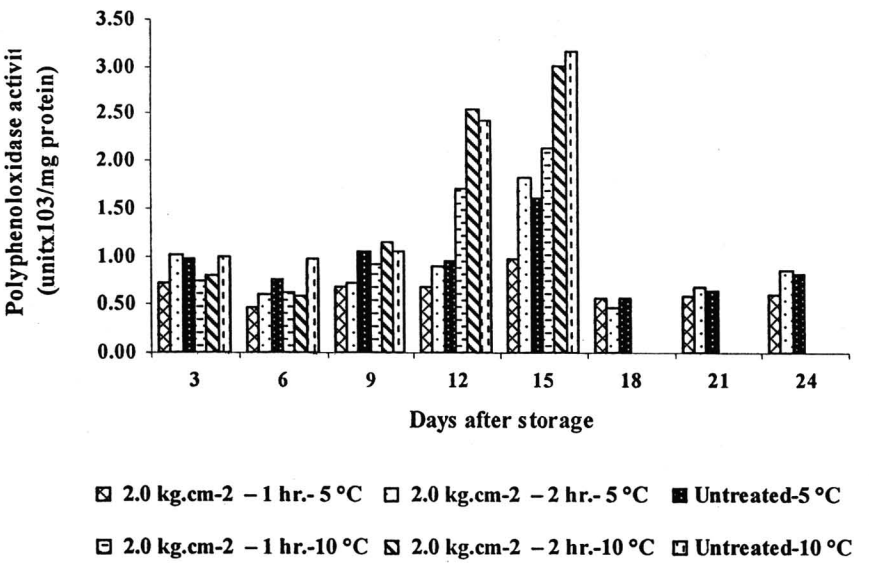

Figure 24 Polyphenoloxidase activity of longan fruit cv. Daw stored at 5 and 10°C after treating with high carbon dioxide pressure

Table 24 Polyphenoloxidase activity of longan fruit stored at 5 and 10°C after treating with high carbon dioxide pressure

TREATMENT	DAYS AFTER STORAGE				
	3	6	9	12	15
CO_2 pressure treatment					
Untreated	0.98a	0.86a	1.05a	1.70a	2.40a
2.0 $kg.cm^{-2}$ – 1 hr.	0.74a	0.55b	0.79b	1.20b	1.53b
2.0 $kg.cm^{-2}$ – 2 hr.	0.98a	0.59b	0.93ab	1.72a	2.42a
Storage temperature					
5 °C	0.90a	0.61a	0.82b	0.84b	1.46b
10 °C	0.85a	0.72a	1.03a	2.23a	2.77a
CO_2 pressure treatment x Storage temperature					
Untreated - 5 °C	0.97a	0.76a	1.06ab	0.96c	1.62c
2.0 $kg.cm^{-2}$ – 1 hr. - 5 °C	0.72b	0.46a	0.68c	0.69d	0.92d
2 hr. - 5 °C	1.01a	0.60a	0.73c	0.89c	1.83c
Untreated- 10 °C	0.99a	0.97a	1.05a	2.44a	3.17a
2.0 $kg.cm^{-2}$ – 1 hr. - 10 °C	0.75b	0.63a	0.91b	1.71b	2.13b
2 hr. - 10 °C	0.81ab	0.58a	1.14a	2.55a	3.01a
2 hr. - 10 °C	0.81ab	0.58a	1.14a	2.55a	3.01a

Means within the same column followed by different letters are significant differences at 95 % ($P \leq 0.05$) by DMRT.

The high carbon dioxide treatments reduced PPO activity but activity would be increased if storage time was increased. This is because polygalacturonase is an enzyme that degrades polygalacturonan by hydrolysis of the glycosidic bond, one that links galactoronic acid residues and that is important in the fruit ripening process and in the level of fungal and bacterial attacks on plants. In addition, Deng *et al.* (2007) reported that grapes stored in a untreatedled atmosphere (low O_2 [4%] and high CO_2 [30%]) had the lowest polygalacturonase activity. Moreover, such a untreatedled atmosphere also suppressed the activity of both cellulase and peroxidase.

4.2.2 .9 Percentage of disease incidence

High carbon dioxide pressure treatments showed potential to reduce the fruit decay (Figure 25, 26 and 27). The decay fruit were found at 15 (10 °C) and 21 (5°C) days after storage. The treated longan with high carbon dioxide pressure showed lower disease incidence than the untreated. The highest disease incidence was found in the untreated treatment, with a 56.67 percentage.

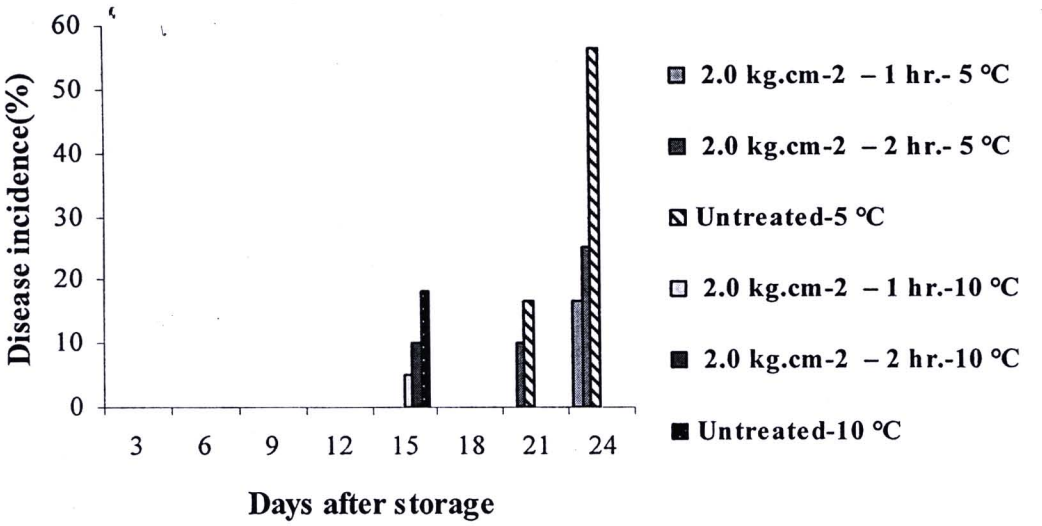

Figure 25 Disease incidence of longan fruit cv. Daw stored at 5 and 10°C after treating with high carbon dioxide pressure

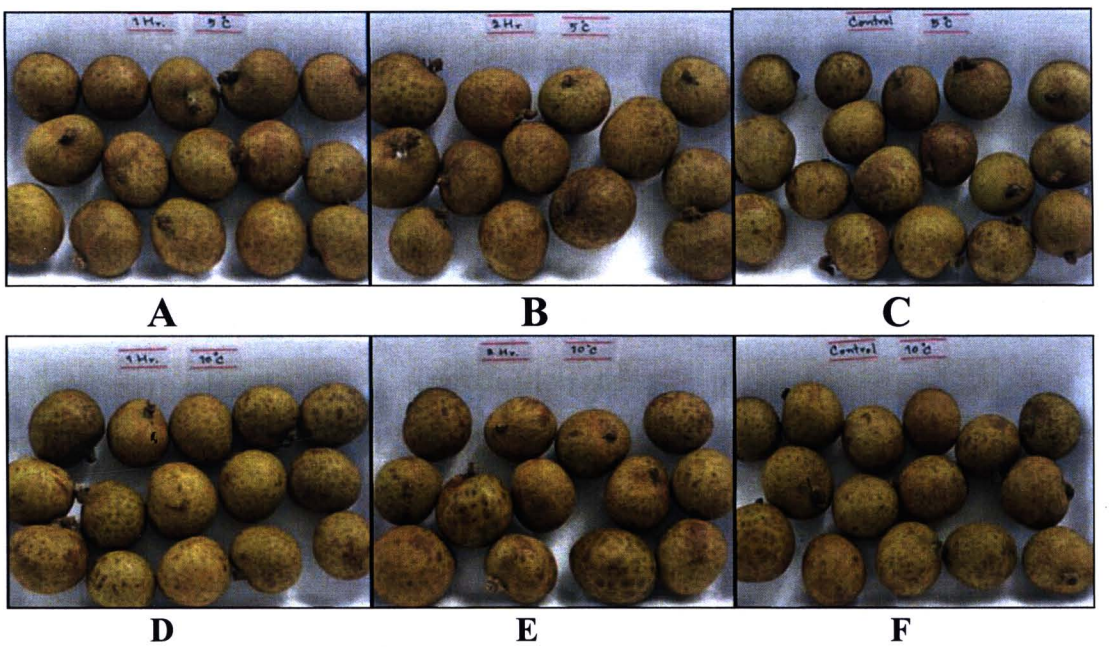

Figure 26 Longan fruit cv. Daw stored 15 days at 5 and10 °C after treating with high carbon dioxide pressure (A= 2.0 kg.cm^{-2} – 1 hr. - 5 °C, B= 2.0 kg.cm^{-2} – 2 hr. - 5 °C, C=Untreated - 5 °C,D= 2.0 kg.cm^{-2} – 1 hr. - 10 °C, E= 2.0 kg.cm^{-2} – 2 hr. - 10 °C, F = Untreated- 10 °C)

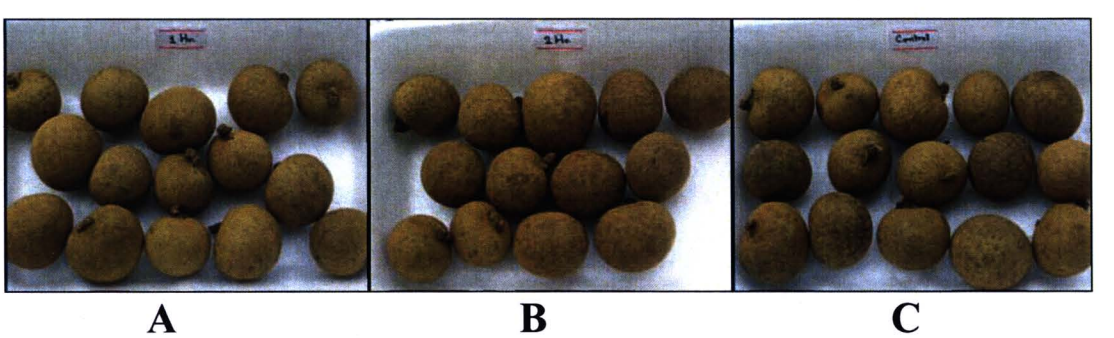

Figure 27 Longan fruit cv. Daw stored 21 days at 5 °C after treating with high carbon dioxide pressure (A= 2.0 kg.cm^{-2} – 1 hr., B= 2.0 kg.cm^{-2} – 2 hr., C=Untreated)

Pearson's correlation (r) between chemical component, biochemical changes and their relations

The correlation between chemical component and biochemical changes of longan fruit treated with high carbon dioxide pressure showed in table 25. The TA of aril showed negatively correlated with polygalacturonase activity and disease incidence, with 0.77 and 0.77 correlation. Phosphofructokinase activity was positively with polygalacturonase activity($r = 0.70$). The disease incidence of longan fruit was correlated with ethylene production and ACC oxidase activity.

Table 25 Pearson's correlation(r) between peel discoloration, fruit decay and their relations.

	pH-aril	pH-per	TA-aril	TA-per	Sugar	Res	PEP	PFK	Eth	ACC	PG	PPO
pH-aril												
pH-per	NS											
TA-aril	NS	NS										
TA-per	NS	NS	NS									
Sugar	NS	NS	NS	NS								
Res	NS	NS	NS	NS	0.58**							
PEP	NS	-0.42**	0.61**	NS	NS	-0.35**						
PFK	NS	NS	NS	NS	0.57**	0.41**	NS					
Eth	NS	-0.36**	-0.55**	NS	NS	NS	NS	0.40**				
ACC	NS	NS	-0.49**	NS	NS	NS	NS	0.41**	0.75**			
PG	NS	NS	-0.77**	NS	NS	NS	-0.43**	0.70**	0.52**	0.52**		
PPO	NS	-0.62**	NS	NS	NS	NS	0.45**	0.37*	NS	NS	0.49**	
DI	NS	NS	-0.77**	NS	NS	NS	-0.43**	NS	0.74**	0.83**	0.47**	NS

** Correlation is significant at the 0.01 level.

*Correlation is significant at the 0.05 level.

PPO = Polyphenoloxidase activity, PG = Polygalactoronase activity, PEP = Pyrophosphate:fru-6-P phosphotransferase activities.PFK = Phosphofructokinase activities, Res = respiration rate, Sugar= reducing sugar, pH-aril = aril pH, pH-pericarp = -pericarp pH, TA-aril= aril TA, TA-pericarp = -pericarp TA and DI = disease incidence

4.3.2 Effect of high CO_2 pressure treatment on mycelium morphology of *Pestalotiopsis* sp. on inoculated fruit

High carbon dioxide pressure treatments did not affect on inoculated longan fruit with *Pestalotiopsis* sp. (Figure 28 and 29). Disease severity increased dramatically over 50 % after 72 hours treated with high carbon dioxide pressure treatments.

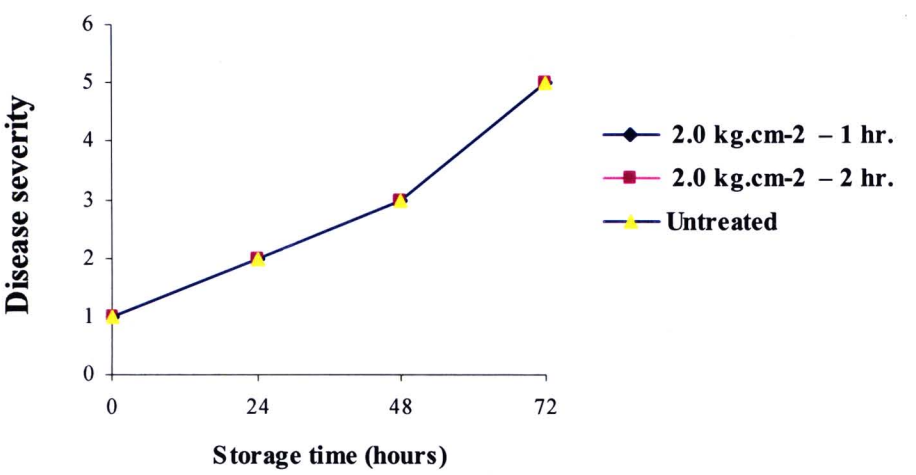

Figure 28 Disease severity of inoculated longan fruit with *Pestalotiopsis sp.* after treating with high carbon dioxide pressure

Figure 29 Disease severity of inoculated fruit cv. Daw stored 72 hours in room temperature after treating with high carbon dioxide pressure

The mycelium growth of treated fruit was significantly slower than untreated (Figure 30). The slowest mycelium growth was found on high carbon dioxide pressure for 2 hours treatment. The treated fruit showed thinner mycelium more condensed spore than untreated. (Figure 31)

In terms of the percentage of disease occurring in longan fruit treated with high carbon dioxide pressure, it was found that the percentage of disease was lower than in the untreated fruit (Figure 10 and 24). Tian *et al.* (2001) longan fruit stored in high carbon dioxide (5-15%) rotted more slowly than untreated. Moreover, carbon dioxide can be used to reduce fruit decay in blueberries, strawberries, sweet cherries and pears (Beaudry, 1993; Wszelaki and Mitcham, 2000; Tian *et al.*, 2000; and Sugar and Bendow, 2002). On the contrary in this experiment, there were not significantly different between high carbon dioxide pressure treatments and control. High carbon dioxide pressure might not have effect on pathogen growing in plant tissure. However, the high carbon dioxide pressure with 2 kg-cm^{-2} for 2 hours reduced the mycelium growth of *Pestalotiopsis* sp. in the culture medium.This corresponds with the research of Tian *et al.* (2000) which found that high-concentrations of carbon dioxide (10-30%) can restrain the growth of *Monilinia fructicola* - the cause of fruit decay in sweet cherries, both *in vitro* and *in viro*. Furthermore, Amanatidon *et al.* (1999) reported that the use of high-concentration carbon dioxide (10-20%) had an effect on the growth of *Pseudomonase fluorescens* and *Salmonella enteritidis*. In addition, to control pathogens in food, high-pressure carbon dioxide treatment (HPCT) at 75 % carbon dioxide; 10 MPa for 120 minutes reduced the activity of vegetable food-borne pathogens such as *Geobacillus stearothermophillus* and *Salmonella tryphimurium,* and this new process has subsequently replaced thermal-pasteurization in the food industry (Garcia Gonzalez *et al.*, 2007; Kincal *et al.*, 2005; Amanatidou *et al.*, 2000; and Watanabe *et al.*, 2003).

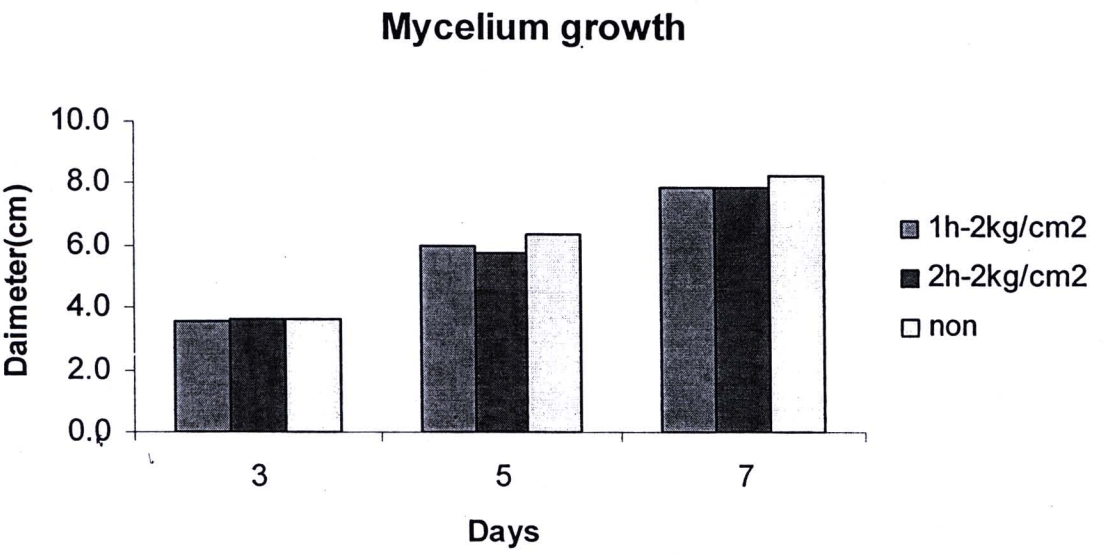

Figure 30 Mycelium growth of *Pestalotiopsis sp.* on PDA after treating with high carbon dioxide pressure

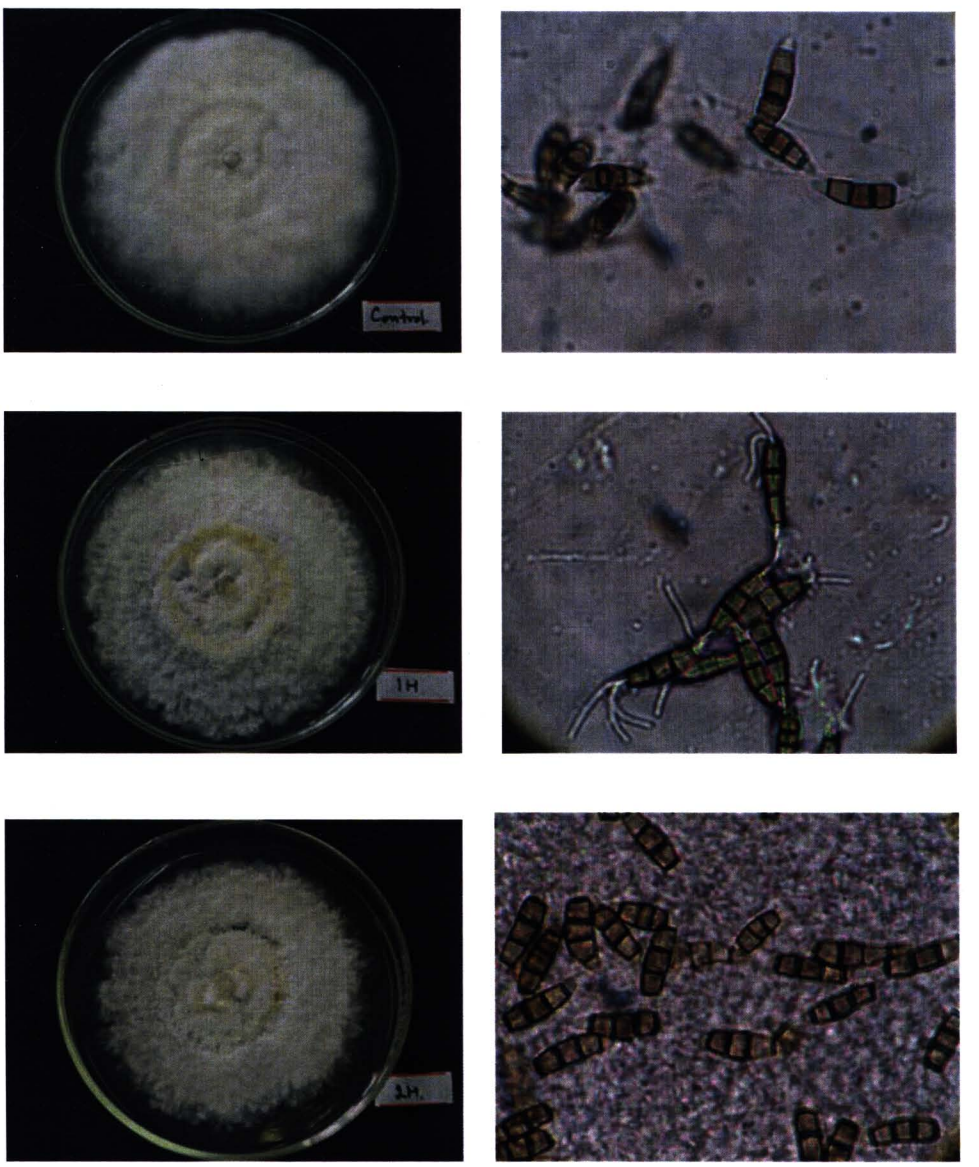

Figure 31 Mycelium and spore morphology of *Pestalotiopsis sp*. after treating with high carbon dioxide pressure