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STORAGE STUDY OF PINEAPPLE (*ANANAS COMOSUS* CV. SARAWAK) WITH SPECIAL EMPHASIS ON BLACK HEART DISORDER

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Keywords: Pineapple cv. Sarawak, Storage, Black heart, Ascorbic acid, Total soluble solids, pH value.

RINGKASAN

Satu kajian mengenai masalah (disorder) teras hitam pada nanas kv. Sarawak semasa penyimpanan telah dijalankan. Buah yang disimpan pada suhu 5°C, 10°C, 15°C dan 20°C selama 1, 2 dan 3 minggu diikuti dengan penyimpanan lanjutan selama seminggu pada suhu ambien (28°C) didapati mengalami masalah tersebut. Intensiti keperangan isi meningkat apabila tempoh penyimpanan pada suhu 10°C, 15°C dan 20°C dipanjangkan. Pada suhu 5°C, intensiti teras hitam didapati tidak mempunyai perbezaan yang bererti bagi tempoh penyimpanan selama 1, 2 dan 3 minggu. Buah yang disimpan selama 1, 2 dan 3 minggu pada suhu 10°C mengalami simptom masalah selepas tiga hari didedahkan pada suhu ambien. Bagaimanapun, penyimpanan selama empat minggu pada suhu 10°C didapati boleh menimbulkan simptom masalah teras hitam tanpa pendedahan pada suhu ambien. Buah yang mengalami teras hitam mempunyai kandungan asid askorbik dan jumlah pepejal larut yang lebih rendah berbanding dengan buah yang masih baik keadaannya. Perkaitan di antara intensiti teras hitam *(x)* dan kandungan asid askorbik *(y_1)*, dan jumlah pepejal larut *(y_2)* masing-masingnya dapat digambarkan oleh persamaan log $y_1 = 0.6182 - 0.0104x$ dan $y_2 = 12.2405 - 0.5242x$. Bagaimanapun, nilai pH didapati tidak mempunyai kaitan dengan masalah tersebut.

INTRODUCTION

Besides the common chilling injury, pineapple fruit exposed to low temperature, either during storage or in the field, is also subjected to physiological disorder known as black heart or endogenous brown spot. The initial symptom of the disorder is the formation of yellow or light brown spots at the base of fruitlets close to the core. The spots then enlarge and coalesce to form a dark tissue mass. The symptom of the black heart, however, is undetectable externally as the fruit appears normal.

Earlier studies conducted by MILLER and his associates (MILLER, 1951; MILLER and HEILMAN, 1952 ; MILLER and HALL, 1953 ; MILLER and MARSTELLER, 1953) gave some basic understanding on the nature and causes of the disorder. Other studies were reported by several workers including BOSE, LODH and DE (1962), TISSEAU (1972), AKAMINE, GOOD, STEEPY, GREIDANUS and IWAOKA (1975), AKAMINE (1976), VAN LELYVELD and DE BRUYN (1976; 1977), MIZUNO, TERAI and KOZUKUE (1982), ROHRBACH and PAULL (1982), and SMITH (1983). Among the published reports, the work by TEISSON and his associates (TEISSON, 1979; TEISSON, COMBRESS, MARTIN-PREVEL and MARCHAL, 1979a; TEISSON, LACOEUILHE and COMBRESS, 1979b) can be considered as the most comprehensive. However, the information gathered so far is limited quantitatively.

With regard to Malaysian pineapple, a series of studies on black heart in Mauritius cultivar were reported by ABDULLAH and ROHAYA (1983), ABDULLAH, SUBARI and ROHAYA (1983), ABDULLAH (1984), and ABDULLAH, ROHAYA and ZAIPUN (1985). One of the most interesting results was the inhibition of black heart development when storage at 5°C was extended for a longer period. Earlier study in Australia on Smooth Cayenne cultivar (WILLS, ABDULLAH and SCOTT, 1985) also produced the same result. As pineapple is one of the most important fruit crops in Malaysia, further study on the susceptibility of other

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cultivars, especially for fresh consumption, to black heart is considered vital. The study on Sarawak cultivar is reported in this paper.

MATERIALS AND METHODS

Raw Materials and Sample Preparation

Pineapple cv. Sarawak was obtained from farms in Muar, Johore. The fruit which were less than a quarter ripe, were harvested early in the morning and transported immediately to the laboratory in Serdang, Selangor. On arrival, the fruit were sorted according to size and maturity. The base of the fruit was then dipped in 500 μg/ml benomyl suspension [BENLATE 50% (w/w) a.i.] for five minutes to control Thielaviopsis soft rot caused by *Thielaviopsis paradoxa*. In each treatment, a total of ten replicates each comprised fruit of almost similar physical characteristics were used.

Storage Condition

In the first experiment, the fruit were stored at 5°C, 10°C, 15°C and 20°C for 1, 2 and 3 weeks followed by a holding period of one week at ambient temperature (mean temperature = 28°C). Further inspection and analysis were carried out later. A batch of ten fruits was stored at ambient temperature without any refrigeration for one week (control).

In the second experiment, the fruit were stored at 10°C for 1, 2, 3 and 4 weeks. The fruit were examined daily throughout the exposure period at ambient temperature.

Determination of Black Heart Intensity, Ascorbic Acid, Total Soluble Solids and pH Value

The same procedure as reported by ABDULLAH and ROHAYA (1983) was followed. Determination of black heart (BH) intensity was done by using a scale from 0 to 5 (0 = free from BH, 5 = 100% of the flesh is affected), ascorbic acid by titration with 2, 6 dichloro-phenolindophenol, total soluble solids by refractometer (model HR−1A KYOWA), and pH value by pH meter (BECKMAN digital pH meter model 3500).

RESULTS

Induction of Black Heart

Figure 1 shows the development of BH in the fruit after storage at 5°C, 10°C, 15°C and 20°C for 1, 2, and 3 weeks followed by one week exposure at 28°Celsius. Black heart was shown to develop after induction at all storage temperatures. At 10°C, 15°C and 20°C, the intensity increased as the storage period was extended. However, observation on fruit stored at 20°C was terminated on the second week due to the spoilage of fruit. Induction at 5°C produced BH of the same intensity ($P>0.05$) for refrigeration period between one and three weeks.

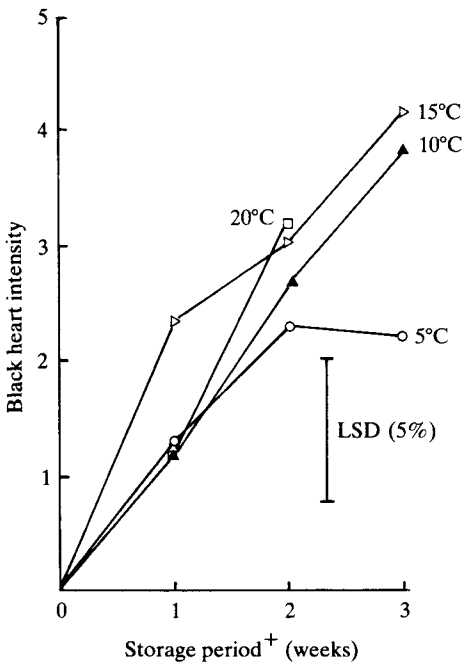

Figure 1. The development of black heart in pineapple cv. Sarawak after storage at various temperatures.

+Each storage period was followed by 1 week holding period at 28°C.

On the first week, the intensity of BH was almost similar at all temperatures. Similar development also took place on the second week. However, on the third week, the fruit subjected to storage at 10°C and 15°C developed BH of significantly higher intensity ($P<0.05$) as compared with that at 5°Celsius. Observation on most of the affected fruit indicated that the final colour of the flesh was dark brown. However, fruit stored at 5°C were light brown or grey. Further examination revealed that the fruit previously stored at 5°C were also affected by chilling injury; the severity increased as the storage period was extended.

In the second experiment, black heart started to develop after three days of exposure at 28°C for fruit previously stored at 10°C for 1, 2 and 3 weeks *(Figure 2)*. Continuous storage for four weeks at 10°C resulted in BH formation on the day the fruit were taken out from the cold room. After the symptom was detected, the intensity increased further as exposure period at 28°C was extended.

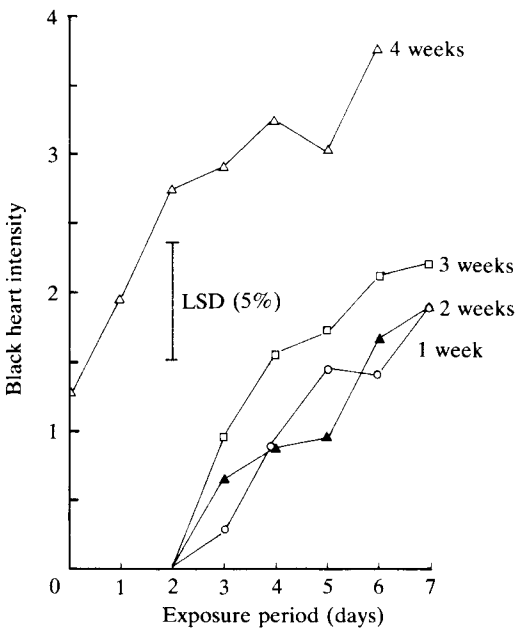

Figure 2. The development of black heart in pineapple cv. Sarawak during exposure at ambient temperature (28°C) after storage at 10°C for various periods.

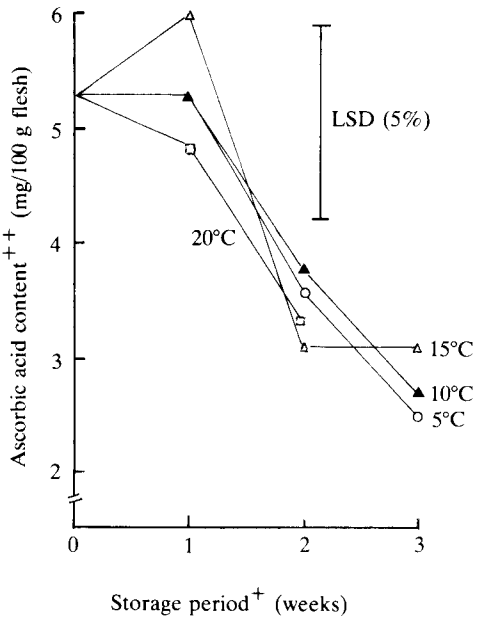

Figure 3. Changes in ascorbic acid content in pineapple cv. Sarawak after storage at various temperatures.

+Each storage period was followed by 1 week exposure at 28°C.

++Mean value of freshly harvested fruit was 16.2 mg/100g flesh.

Changes in Chemical Composition

Ascorbic acid

The changes in ascorbic acid content of fruit previously stored at 5°C, 10°C, 15°C and 20°C followed by one week exposure at 28°C are shown in *Figure 3*. Ascorbic acid composition decreased as the storage period was prolonged. The reduction in ascorbic acid content was also detected in the control treatment which was stored for one week at 28°C without any refrigeration. The reduction was almost the same as the fruit stored for one week at low temperature (followed by one week holding period at 28°C). However, this level was significantly higher than the fruit stored for two and three weeks ($P<0.05$). The relationship between the intensity of BH *(x)* and ascorbic acid content *(y)* can be expressed by the equation, $\log y = 0.6182 - 0.0104x$, or in the exponential form, $y = 4.1515e^{-0.024x}$ *(*$r = 0.6385$, $P<0.05$*)* *(Figure 4)*.

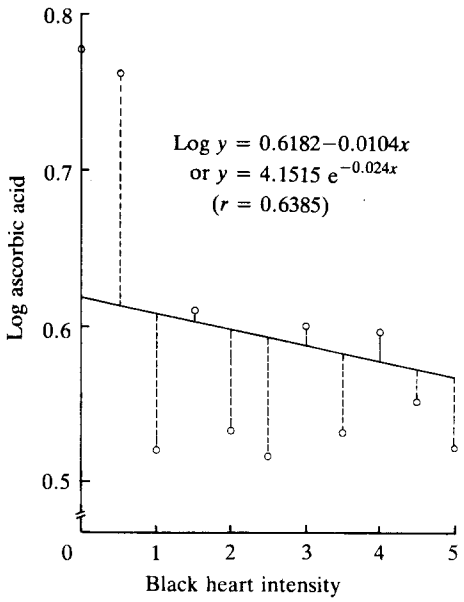

Figure 4. Relationship between black heart intensity and ascorbic acid content in pineapple cv. Sarawak.

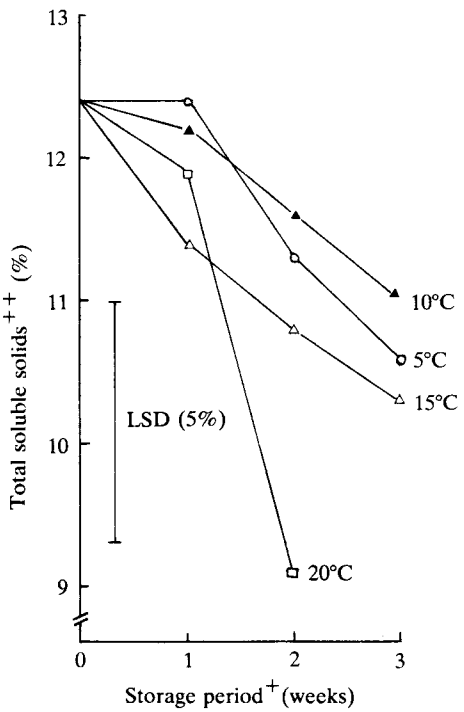

Figure 5. Changes in total soluble solids in pineapple cv. Sarawak after storage at various temperatures.

+Each storage period was followed by 1 week exposure at 28°C.

++Mean value of freshly harvested fruit was 12.1%.

Total soluble solids

Figure 5 shows the changes in total soluble solids (TSS) of the fruit after storage at 5°C, 10°C, 15°C and 20°C followed by one week holding period at 28°Celsius. The TSS of control fruit was slightly higher than that of freshly harvested fruit; however, the difference was insignificant ($P<0.05$). Generally, the changes in TSS showed a reduction trend as the storage period was prolonged. The values were not significantly different for fruit stored at 5°C, 10°C and 15°C for the respective storage periods. In the second week, the TSS value at 20°C was significantly lower ($P<0.05$) as compared with that at other temperatures. The relationship of BH intensity *(x)* and TSS *(y)* can be expressed by the equation $y = 12.24 - 0.52x$ ($r = 0.83$, $P<0.05$) *(Figure 6)*.

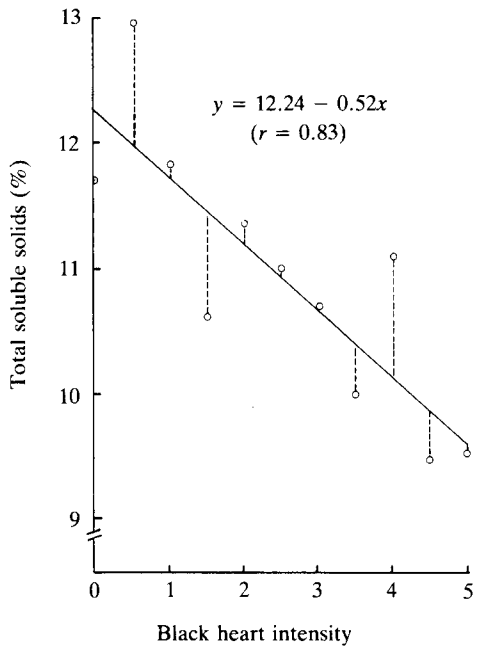

Figure 6. Relationship between black heart intensity and total soluble solids in pineapple cv. Sarawak.

pH value

The pH values for the first two weeks at all temperatures were not significantly different ($P>0.05$) *(Figure 7)*. However, in the third week, these values were at the

lowest level for fruit previously stored at 5°C, 10°C and 15°Celsius. The analysis by regression did not indicate any relationship between pH and the intensity of black heart.

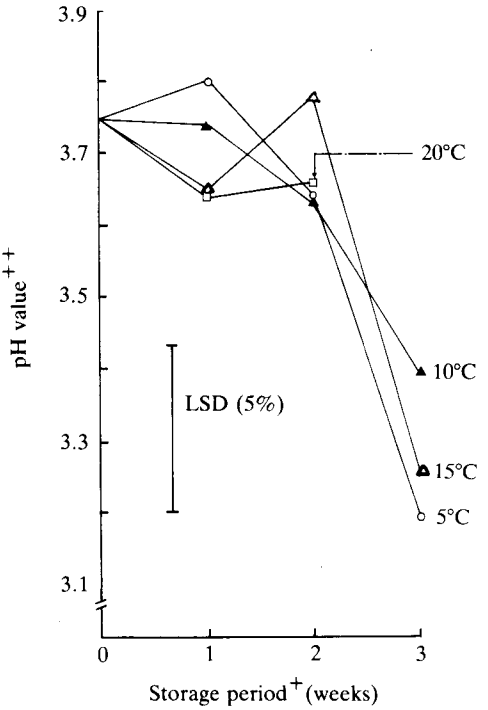

Figure 7. Changes in pH value of pineapple cv. Sarawak after storage at various temperatures.

+Each storage period was followed by 1 week holding period at 28°C.
++Mean value of freshly harvested fruit was 3.7.

DISCUSSION

This study showed that BH in pineapple cv. Sarawak could be induced by storing the fruit at temperatures ranging from 5°C to 20°Celsius. The results obtained are in agreement with SMITH (1983) and TEISSON, MARTIN-PREVEL, COMBRESS and PY (1978) who reported the induction of BH at temperature ranges of 0°C – 21.1°C and 5°C – 20°C respectively. The fruit stored continuously for four weeks at 10°C could develop severe symptom of BH without any exposure to higher temperature. This suggested that a temperature lower than 20°C as reported by TEISSON *et al.* (1978) could also cause the development of the disorder without any exposure to higher temperature if the storage period was extended. The finding by ABDULLAH and ROHAYA (1983) on the development of the disorder in Mauritius cultivar at 8°C is hereby confirmed.

The severity of the disorder was clearly influenced by temperature and duration of storage, and duration of exposure to higher temperature. In Smooth Cayenne (WILLS *et al.*, 1985) and Mauritius (ABDULLAH and ROHAYA, 1983) cultivars, the BH intensity reached a maximum level at a certain temperature followed by a reduction or total inhibition when the period of storage was extended. The reduction in intensity was not observed in Sarawak cultivar.

An initial period of three days was required for the appearance of BH symptom at ambient temperature after storage at 10°C for 1, 2 and 3 weeks. Even though the fruit stored for one week developed symptom after three days at ambient temperature, the BH intensity was lower than 0.5 and the fruit were still consumable. The development of symptom in fruit stored at 10°C continuously for four weeks without any exposure at ambient temperature indicated that the fruit could not be exposed to that temperature for more than three weeks. The results also suggested that BH could only develop after three days of exposure at ambient temperature if stored at low temperature for less than three weeks.

The reduction in ascorbic acid content in pineapples affected by BH was reported by MILLER (1951), MILLER and HEILMAN (1952), MILLER and HALL (1953), MILLER and MARSTELLER (1953), VAN LELYVELD and DE BRUYN (1977), TEISSON *et al.* (1979a), ABDULLAH and ROHAYA (1983), and ABDULLAH *et al.* (1985). The possible role of ascorbic acid in the formation of BH was described by MILLER and HEILMAN (1952). Its relationship with BH intensity in exponential form in Mauritius cultivar was

reported by ABDULLAH and ROHAYA (1983). Similar relationship as reported in Mauritius cultivar was also found in Sarawak cultivar.

Besides association of BH with ascorbic acid, ABDULLAH and ROHAYA (1983) also reported a linear correlation between BH intensity and TSS in Mauritius cultivar. Similar correlation was also observed in Sarawak cultivar. Previously, VAN LELYVELD and DE BRUYN (1977) reported the reduction in total sugar content in pineapple affected by the disorder.

This study indicated that the role of fruit pH in BH development was not clear. Similar results were reported by MILLER (1951), VAN LELYVELD and DE BRUYN (1976), and ABDULLAH and ROHAYA (1983).

As the Sarawak cultivar was found to be highly sensitive to BH induction when exposed to low temperature, further studies on its control method is highly recommended. The application of thermotheraphy (AKAMINE *et al.*, 1975; AKAMINE, 1976; TEISSON *et al.*, 1979b; ABDULLAH *et al.*, 1983), modified atmosphere (ABDULLAH *et al.*, 1985), and waxing (ROHRBACH and PAULL, 1982) were reported to be effective in controlling the development of such disorder at post-harvest stage. It is possible that these methods are also applicable to Sarawak cultivar. However, the most practical approach in overcoming the problem would be through agronomic control. This approach has been practised intensively in Queensland, Australia and produced very encouraging results (SEALE, *pers comm.*, 1980; SCOTT, *pers comm.*, 1983).

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ABSTRACT

The development of black heart disorder in pineapple cv. Sarawak grown in Malaysia was studied. Pineapple fruit previously stored at 5°C, 10°C, 15°C and 20°C for 1, 2 and 3 weeks followed by one week holding period at ambient temperature (28°C) were found to be affected by the disorder. The intensity of flesh browning was found to increase as storage periods at 10°C, 15°C and 20°C were extended. At 5°C, the intensity of black heart was not significantly different among the refrigeration periods of 1, 2 and 3 weeks. The fruit stored for 1, 2 and 3 weeks at 10°C developed the symptoms after three days of exposure at ambient temperature. However, storage for four weeks at 10°C resulted in the development of the disorder without any exposure at ambient temperature. The fruit affected by black heart had significantly lower ascorbic acid content and total soluble solids than the unaffected fruit. The relationship between the black heart intensity (x) and the ascorbic acid content (y_1) and total soluble solids (y_2) can respectively be expressed by equations, $\log y_1 = 0.6182 - 0.0104x$ and $y_2 = 12.2405 - 0.5242x$. However, pH values were found to be unrelated to the disorder.

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