Effect of different Fruitone concentrations on the physical characteristics and postharvest physiological disorder of cold stored pineapple
(Kesan kepekatan Fruitone yang berbeza terhadap ciri-ciri fizikal dan ketidaktentuan fisiologi lepas tuai buah nanas yang disimpan sejuk)

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Key words: Fruitone CPA, pineapple, cold storage, physical characteristics, sensory, internal browning

Abstract
Fruitone CPA (2–(3 Chlorophenoxy) propionic acid) is a plant growth regulator found to exert many beneficial effects on the characteristics of pineapple during development and postharvest storage at low temperature. A study was carried out on the effect of different concentrations of Fruitone CPA (0–44 ppm active ingredient) on the physical characteristics (weight loss, colour, firmness) and sensory evaluation (appearance, colour, texture, odour, flavour, sourness, sweetness, and overall acceptability) of pineapple (cv. Gandul) during storage (10 ± 1 °C) for fresh consumption.

Low concentrations of Fruitone CPA (8.8 ppm) was sufficient in maintaining the quality of pineapple in terms of reduction in weight loss, delayed ripening, and increased skin, pulp and core firmness due to alteration of shape, size, fruitlet air space and internal atmosphere. The effect of Fruitone CPA in improving firmness was more noticeable on the skin than the pulp of the pineapple. Fruitone CPA treatment (44 ppm) has potential in producing pineapple resistant to internal browning disorder and significantly (p <0.05) increased the sensory score in terms of appearance, colour and texture.

Introduction
Gandul is the current canning pineapple cultivar grown in Malaysia. This cultivar is among the most popular choices because of its golden flesh colour, good adaptation to peat soil and better response to flower induction. However, it is smaller in size compared to Sarawak and N36 cultivars.

The presence of many air spaces in the locules of placenta and in the ovules of fruitlet pineapple flesh was the main problem for fresh consumption of Gandul cultivar as these pineapples cannot stand rough handling and transportation turbulence. Internal browning disorder and marbling disease are also common problems in Gandul cultivar and has been known to cause heavy losses in this crop (Lim 1983). Fruitone CPA (cloprop) treatment in the field may reduce the air spaces which can
Fruitone concentration on cold stored pineapple

improve the quality of Gandul pineapples (Mohammed Selamat and Abdul Rahim 1996).

Fruitone CPA (cloprop) or (2–(3 Chlorophenoxy) propionic acid) is a pineapple growth regulator (Nickell 1982). It significantly enhances yield and increases fruit mass, firmness and weight (Vieira et al. 1981; Mohammed Selamat 1999), reduces crown development (Scott 1979), delays shell colouring or ripening process (Py et al. 1987; Mohammed Selamat and Abdul Rahim 1996), and reduces blackheart disorder during cold storage (Kruger et al. 1998). The effectiveness of Fruitone CPA treatment depends on the concentration applied (Anon. 1990) and spraying period before harvest (Kruger et al. 1998).

The increased fruit mass is due to the better filling of the flesh, particularly at the top of the fruit, which are linked to the delay in ripening and consequently the continued accumulation of metabolites. The fruit also appears more compact and could stand rough-handling situation in the field. Fruitone CPA can cause a reduction in acid content and partial alteration of the crown (Py et al. 1987). The positive effects of Fruitone CPA application on fruit development are greater than NAA (naphthaleneacetamide) (Smith 1978) and crowning removal (Mohammed Selamat 1999; Chen and Paull 2001).

Skirmish tests in Australia indicated that the adverse effects of Fruitone CPA application on juice quality and colour are fewer than those caused by NAA (Py et al. 1987). Therefore, in this study, Fruitone CPA treatment in the field is expected to improve the shortcomings of Gandul pineapple during postharvest storage.

The optimum concentration of Fruitone CPA for canning, which gives maximum fruit weight with accepted fruit acidity, soluble solid content and sugar acid ratio, is 85–90 ppm. However, at this concentration, Fruitone CPA will produce fruit without crown. Recommended concentration of Fruitone CPA for fresh consumption (considered based on crown size) is below 50 ppm (Mohammed Selamat and Abdul Rahim 1996; Mohammed Selamat 1999). Therefore, in this study, the concentrations of Fruitone CPA used were 0–44 ppm (active ingredient).

Many studies on the effects of the Fruitone CPA application on the yield and after harvest fruit qualities have been reported in Malaysia (cv. Masmerah, Gandul and Mauritius) (Mohammed Selamat and Abdul Rahim 1996; Mohammed Selamat 1999) and other countries (Nickell 1982; Bredell 1989; Kruger et al. 1998). However, no study has been carried out on the effect of Fruitone CPA treatment on the physico-chemical changes of pineapple during cold storage. Therefore, the objective of this study was to monitor the physical changes of Gandul pineapple during cold storage (10 ± 1 °C, 85–88% relative humidity) when different concentrations of Fruitone CPA (0–44 ppm) were applied.

Materials and methods

Fruitone CPA treatment

Gandul (N19) pineapples were planted at the Integrated Peat Research Station, MARDI Pontian, Johor. Randomized complete block design was used with four replications. Crowns were sprayed with Fruitone CPA (2–(3 Chlorophenoxy) propionic acid) 85 days after flower induction. The Fruitone CPA concentrations used were 0, 8.8, 17.6, 26.4, 35.2 and 44.0 ppm (containing 8% active ingredient of sodium (2–(3-chlorophenoxy) propionate). At 145 days after flower induction, the fruits were harvested when the control fruit was at index 4 (50% yellowing), while Fruitone CPA treated was still at mature green stage (index 1). The fruits were then sent immediately to the laboratory at the Faculty of Food Science and Biotechnology, Universiti Putra Malaysia.

Storage study

The fruits were stored in closed commercial corrugated fibre board boxes
(14 x 32 x 49 cm), each with six fruits laid on their sides in a single layer and kept at 10 ± 1 °C, 85–88% relative humidity for 5 weeks. All the analyses were carried out at weekly intervals. Ten fruits were analysed for each treatment.

**Determination of weight loss**
Samples were picked at random from at least two boxes (containing 6–8 fruits) of each treatment and these samples were separated from each other. Each fruit was labelled clearly and weighed weekly using an electronic top pan balance (model Mettler Goldbalance PJ 3000).

**Internal browning**
Internal browning was measured visually using the score modified by Teisson et al. (1979) and Abdullah et al. (1986). The scores were described as none (0% flesh affected), 1 (10% flesh affected), 2 (25% flesh affected), 3 (50% flesh affected), 4 (75% flesh affected), 5 (100% flesh affected). After removal from cold storage (10 °C), internal browning was determined after 5 days exposure to ambient temperature.

**Determination of colour**
The L, a and b values were measured using Hunterlab Ultrascan (Model D25-2) using 65D lamp. Determination of colour was carried out on skin and pulp of pineapples.

**Determination of texture**
The texture of fresh pineapple was measured using Instron Universal Testing Machine (model 1140) with 5 mm probe attachment. Load cell of full scale ranges from 5–50 kg. A maximum load of 5 kg was used for penetration of the pulp, and 20 kg load was used for penetration through the skin. The drive speed and the chart speed used were 100 mm/min to determine a yield force.

**Sensory evaluation**
Sensory evaluations were carried out weekly by 20 trained panellists on a 1–9 Hedonic scale (1 = dislike extremely to 9 = like extremely) for appearance, colour, texture, and overall acceptability (Price and Butler 1977). Random code numbers were used to differentiate the samples and they were served in both peeled and unpeeled forms.

**Statistical analysis**
Statistical analyses of the treatment responses were conducted using Analysis of Variance (ANOVA) and Duncan Multiple Range Test to determine whether the comparison between different treatments and different storage duration showed significant differences (p <0.05). Experimental data are presented as means ± standard deviation of the determinations for each sample. For comparison of more than two means, the mean separation was done by Duncan Multiple Range Test (SAS Inst. 1985).

**Results and discussion**

**Weight loss**
Fruitone CPA treatment had significantly (p<0.05) reduced weight loss even with a minimum application of 8.8 ppm Fruitone CPA (Figure 1) compared to the control pineapples. The effect of Fruitone CPA on reducing weight loss was significant (p <0.05) after 5 weeks of storage with 8.8 ppm Fruitone CPA treatment. This effect was significant (p <0.05) after 3 weeks of storage with Fruitone CPA treatment of more than 17.6 ppm. The reduced weight loss of treated pineapples may be due to the alteration in fruit characteristics.

Increased fruit size, better filling in the fruit, and the adjustment of the tissues by Fruitone CPA treatment may narrow the locules and reduce the air spaces (Chan 1993). Therefore, Fruitone CPA treatment may reduce the ratio of surface area to volume, hence, modify water deficit stress.
Fruitone concentration on cold stored pineapple (Kays 1991). Compact tissues can limit the movement of gases and moisture (Burton 1982). Crown size reduction may also affect the reduction in weight loss. This is because the crown is the site of most of the fruit’s initial weight loss through their stomata (Paull 1997). Weight loss increased significantly \( p < 0.05 \) with increased storage period \( r > 0.96 \) in Gandul cultivar and other pineapples (Ryall and Pentzer 1974; Kays 1991; Mohamed and Ahmad Khir 1993). The reduction in weight loss by Fruitone CPA treatment may have reduced the texture loss, maintained the freshness and delayed the ripening of pineapples.

**Internal browning (IB)**

Pineapples treated with 35.2 to 44 ppm Fruitone CPA had significantly \( p < 0.05 \) lower internal browning disorder (Figure 2). IB disorder started to develop after 2 weeks of storage, when fruit was ripening. IB symptom was increased with increase of ripening.

IB developed severely in pineapples treated with 0–8.8 ppm Fruitone CPA. IB spoiled the appearance of fresh pineapple even at score 1 (10% flesh affected) (Figure 2). IB developed faster in control pineapples after 1 week of storage at 10 °C, as compared to Fruitone CPA treated pineapples that developed this symptom after 2–3 weeks of storage when the fruits ripened. Fruits treated with 44 ppm Fruitone CPA had significantly \( p < 0.05 \) lower IB disorder. IB symptom was found to increase with increase of ripening.

![Figure 1. Effect of Fruitone CPA treatments on weight loss of Gandul pineapple](image1)

![Figure 2. Effect of Fruitone CPA treatments on internal browning of Gandul pineapple](image2)
IB disorder is a common problem in Gandul cultivar and had been observed to cause heavy losses of this low fruit-acid cultivar (Lim 1983). In Malaysia, the development of IB is due to prolonged refrigeration (Abdullah and Rohaya 1983). In this study, the reduction of IB by Fruitone treatment might be related to the delay of their fruit maturity. IB intensity was very low in immature pineapples as compared to ripen fruits (Smith 1983). The improvement of texture by Fruitone CPA may be related to increment of calcium react with pectic acids to form calcium bridge (Kays 1991). Kew pineapple with higher calcium content was reported to be less significant in IB as compared to Mauritius pineapple with lower calcium content (Wijeratnam et al. 1996).

Increase of IB affected by low ascorbic acid has been reported by many researchers (Van Lelyveld and de Bruyn 1977; Abdullah and Rohaya 1983; Abdullah et al. 1983). This study showed that there was no relationship between IB and ascorbic acid content. This is because Fruitone CPA treatment reduces both ascorbic acid and IB (Zaulia et al. 1999; 2006).

**Skin colour**

Although all the pineapples were harvested at the same age (145 days), skin yellowness (b value) of control pineapples was found to be significantly (p <0.05) higher than the treated pineapples (Figure 3). At this stage, control pineapples were ripe with yellow colour (index 4, b = 7.51) while treated pineapples were still at the mature green stage (index 1, b = 4.5–5.6). At week 2 of storage, treated pineapples were at breaker stage (index 2), showing a slight increase in ‘b’ value compared to control pineapples. At week 3 of storage, significant (p <0.05) differences were observed for ‘b’ values between control and all the treated pineapples where the control pineapples were fully golden yellow (index 6, b = 10.74) while treated pineapples were green with slightly yellow (index 3, b = 4.8–6.1).

The lower ‘b’ value (yellowness) in Fruitone CPA treated pineapple skin compared to control pineapples (Figure 3) and slower changes during storage showed that ripening was delayed with Fruitone CPA treatment. The ‘b’ values were constant during the first 2 weeks of storage and thereafter increased until end of storage which indicated fruit degreening process. The effect of Fruitone CPA was higher (p <0.05) in butt-end and middle sections compared to the crown-end.

The increase in pigment level along with the increase in sugar and volatile flavour content as fruit ripens was found to be quite rapid (unpublished data). The sugar content varies markedly in different parts of the same fruit. In pineapple, from peduncle-end to crown-end the increase of total soluble solids (TSS) is about

![Figure 3. Effect of Fruitone CPA treatments on ‘b’ value (yellowness) of Gandul pineapple skin](image-url)
1 °Brix per inch of fruit length (Tressler and Joslyn 1971). The delayed degreening may be related to alterations in fruitlets air space which may have altered the internal atmosphere (especially ethylene) (Py et al. 1987; Mohammed Selamat and Abdul Rahim 1996), retention of chlorophyll, photosynthesis and respiratory rates (Kays 1991).

As with the skin redness, skin yellowness was significantly ($p < 0.05$) decreased with Fruitone CPA treatment. However, skin yellowness was insignificantly different ($p < 0.05$) with different Fruitone CPA concentrations and for different parts of the fruit. This result indicated that application of Fruitone CPA even at low concentrations was enough to delay the degreening of pineapples.

Pineapples treated with 44 ppm Fruitone CPA showed significantly ($p < 0.05$) higher skin redness beginning the 5th week of storage with golden yellow, while, control pineapples showed senescence symptoms as observed by black spots on the skin. Treatment with 44 ppm Fruitone CPA was able to maintain skin quality up to 5 weeks while degreening was delayed for much longer (about 2 weeks) than other concentrations.

**Pulp colour**
Pulp yellowness ‘b’ was significantly ($p < 0.05$) lower compared to control after 2 weeks of storage (Figure 4). There was no significant difference among the concentrations of Fruitone CPA applied.

**Firmness**
Fruitone CPA treatment significantly ($p < 0.05$) increased the skin, pulp and core firmness of pineapple as shown in Figure 5. The effect of Fruitone CPA concentrations was different in different parts of the fruit. The skin firmness of butt-end and middle section increased with increment of Fruitone CPA concentration of 8.8–17.6 ppm. However, when treated with more than 17.6 ppm Fruitone CPA, it was found to be insignificantly different ($p < 0.05$). For the crown-end section of pineapple, the skin firmness was slightly increased with increasing Fruitone CPA concentration. Pulp firmness was slightly increased ($p < 0.05$) with the increment of Fruitone CPA concentration. Study of firmness on different sections of fruit showed that 26.4 and 44 ppm Fruitone CPA treatments were more effective in improving pulp firmness especially in the middle and crown-end sections.

The increased skin and pulp firmness in Fruitone CPA treated pineapples during development are due to reduced air spaces in the locules of the placenta and in the ovules of the fruitlets (Chan 1993) and the increase in fruit mass (Py et al. 1987). The effect of Fruitone CPA was different in different parts
Figure 5. Effect of Fruitone CPA treatments on (a) skin, (b) pulp and (c) core firmness of Gandul pineapple

do of the fruit where it was more significant at the top of the fruit as reported by Py et al. (1987).

The decrease in firmness \((p < 0.05)\) during the storage duration was rapid in the skin and gradual in the pulp as shown in Figure 5. This is because the skin was exposed to more physical, physiological and pathological stress than the flesh of fruits.

The decrease in firmness may be due to the:
(1) catabolism of cell wall polysaccharides, especially with pectin substances (by pectinesterases and polygalacturonases enzymes), cellulose and hemicellulose
(by cellulase enzyme) during maturation and ripening (Wills et al. 1981); and (2) reduction of cell turgidity caused by increase in weight loss (Kays 1991).

Fruitone CPA treatment significantly \( (p < 0.05) \) increased core firmness of pineapples especially at the concentration of more than 17.6 ppm. The effect of Fruitone CPA concentration on core firmness was similar with skin firmness. Core firmness on the first week was lower than the other storage period due to the adaptation of the fruits to low temperature storage.

Core firmness was insignificantly different when storage was prolonged for all the Gandul pineapples \( \text{(Figure 5)} \). The effect of storage duration on fruit softening was more significant \( (p < 0.05) \) on the skin, followed by the pulp, but did not affect the core significantly. This may be due to the fact that only the skin and pulp are involved in the development of eating quality attributes but the core only plays the role of supportive and vascular tissues. Most of the supportive and vascular cells are always complex, hard, compact, rigid and high in fibre (Ting 1982).

**Sensory evaluation**

The scores for appearance, colour and texture were increased with increasing Fruitone CPA concentrations. Eating quality of control pineapple (odour, flavour, sourness, sweetness, and overall acceptability) was more acceptable than Fruitone treated pineapple \( \text{(Table 1)} \). This is because ripe fruit (control) developed more volatile components (Kays 1991), more soluble sugars (Singleton and Gortner 1965; Maurya 1988; Montana et al. 1996) and lower acidity (Kader 1997) than mature fruit (Fruitone treated pineapples).

With regard to comparing titratable acidity (TA) and sourness, panellists only accepted pineapple acidity below 1.0 mg/100 g as reported by Kader (1997). Organic acids may impart a significant portion of the characteristic flavour, for both taste and odour (Ashrust 1991; Kays 1991).

<table>
<thead>
<tr>
<th>Fruitone conc. (ppm)</th>
<th>Appearance</th>
<th>Colour</th>
<th>Texture</th>
<th>Odour</th>
<th>Sourness</th>
<th>Sweetness</th>
<th>Flavour</th>
<th>Overall acceptability</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>5.50 ± 1.23bc</td>
<td>6.08 ± 1.01ab</td>
<td>5.97 ± 1.23bc</td>
<td>6.24 ± 1.36ab</td>
<td>5.84 ± 1.73a</td>
<td>5.84 ± 1.73a</td>
<td>6.21 ± 1.88a</td>
<td>6.04 ± 2.07a</td>
</tr>
<tr>
<td>8.8</td>
<td>5.50 ± 1.22bc</td>
<td>5.56 ± 2.00bc</td>
<td>5.59 ± 1.56bc</td>
<td>5.51 ± 1.25bc</td>
<td>4.94 ± 1.98bc</td>
<td>4.94 ± 1.98bc</td>
<td>4.96 ± 1.89bc</td>
<td>5.03 ± 1.95bc</td>
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<tr>
<td>17.6</td>
<td>5.50 ± 1.25bc</td>
<td>5.56 ± 1.48bc</td>
<td>5.59 ± 1.56bc</td>
<td>6.11 ± 1.66bc</td>
<td>4.79 ± 1.80bc</td>
<td>4.79 ± 1.80bc</td>
<td>4.56 ± 1.79bc</td>
<td>5.11 ± 1.74bc</td>
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<tr>
<td>26.4</td>
<td>5.80 ± 1.24bc</td>
<td>5.48 ± 1.44bc</td>
<td>5.60 ± 1.66bc</td>
<td>6.30 ± 1.56ab</td>
<td>5.09 ± 1.68bc</td>
<td>5.09 ± 1.68bc</td>
<td>5.42 ± 1.56bc</td>
<td>5.59 ± 1.64ab</td>
</tr>
<tr>
<td>35.2</td>
<td>5.50 ± 1.23bc</td>
<td>5.17 ± 1.78bc</td>
<td>5.74 ± 1.72bc</td>
<td>5.96 ± 1.99bc</td>
<td>4.98 ± 1.60bc</td>
<td>4.98 ± 1.60bc</td>
<td>5.34 ± 1.75bc</td>
<td>5.57 ± 1.64a</td>
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<tr>
<td>44.0</td>
<td>5.60 ± 1.54bc</td>
<td>4.94 ± 1.44bc</td>
<td>5.94 ± 1.77bc</td>
<td>5.74 ± 1.71bc</td>
<td>4.96 ± 1.46bc</td>
<td>4.96 ± 1.46bc</td>
<td>5.59 ± 1.56bc</td>
<td>5.78 ± 1.53a</td>
</tr>
<tr>
<td>44.0</td>
<td>5.60 ± 1.54bc</td>
<td>4.94 ± 1.44bc</td>
<td>5.94 ± 1.77bc</td>
<td>5.74 ± 1.71bc</td>
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<td>4.96 ± 1.46bc</td>
<td>5.59 ± 1.56bc</td>
<td>5.78 ± 1.53a</td>
</tr>
</tbody>
</table>

Means followed by different letters are significantly different \( (p < 0.05) \) between Fruitone CPA treatments.

**Table 1.** Mean values and standard deviations (±) for sensory attributes of Gandul pineapples treated with Fruitone CPA during storage at 10 °C.
This result indicated the effectiveness of Fruitone CPA treatment in delaying ripening. It delayed not only skin colour development but also maturation inside the fruits. The improvement of sensory characteristics of Gandul pineapples by Fruitone CPA treatment was achieved at 44 ppm as compared to other concentrations.

**Conclusion**

Treatments of pineapples with Fruitone CPA have been shown to have profound morphological and physiological effects. Fruitone CPA treatment beneficially affected Gandul pineapples due to its ability to significantly \( p < 0.05 \) reduce weight loss, internal browning and, significantly \( p < 0.05 \) increase the skin, pulp and core firmness, and the sensory attributes in terms of appearance, colour and texture and delay ripening during storage.

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Abstrak

Fruitone CPA (asid propionik 2–(3 klorofenoksi)) merupakan hormon tumbesaran tumbuhan yang dapat memberikan berbagai-bagai kesan berfaedah terhadap ciri-ciri nanas semasa proses tumbesaran dan dalam penyimpanan sejuk selepas dituai. Kajian ini dilakukan untuk menentukan kesan Fruitone CPA pada kepekatan berbeza (0–44 bsj bahan aktif) terhadap ciri-ciri fizikal (kehilangan berat, warna, kekerasan) dan penilaian sensori (rupa bentuk, warna, tekstur, bau, rasa, kemasaman, kemanisan dan penerimaan keseluruhan) nanas (cv. Gandul) semasa penyimpanan (10 ± 1 °C) untuk kegunaan segar.

Fruitone CPA pada kepekatan rendah (8.8 bsj) adalah mencukupi untuk mengekalkan kualiti nanas seperti kehilangan berat, melambatkan kemasakan, dan meningkatkan kekerasan kulit, isi serta empulur disebabkan pengubahsuaian terhadap bentuk, saiz, ruang udara dalam isi buah dan atmosfera dalam buah. Kesat Fruitone CPA dalam membaiki kekerasan kelihatan lebih ketara pada kulit berbanding dengan isi nanas. Rawatan Fruitone CPA (44 bsj) mempunyai potensi dalam pengeluaran nanas yang rintang terhadap penyakit teras hitam dan meningkatkan dengan ketara skor sensori bagi rupa bentuk, warna dan tekstur.

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