Effects of Storage Temperature on Postharvest Quality of Malaysian Grown Fig (*Ficus carica* L.) cv. Ipoh Blue Giant

Phebe Ding* and Choon Sea Yeat
Department of Crop Science
Universiti Putra Malaysia
43400 UPM, Serdang, Selangor, Malaysia
*phebe@upm.edu.my

Date received: January 1, 2021
Revision accepted: August 18, 2021

Abstract

Fresh fig (Ficus carica L.) is delicate and perishable with short postharvest life. Generally, refrigeration is often used to prolong fruits' shelf life. However, fruits from the tropical region are temperature-sensitive with an adverse impact on quality if stored below their critical temperature. Thus, this study was carried out to determine optimal storage temperature for Malaysian grown figs cv. Ipoh Blue Giant. Varying temperatures (5, 10 and 15 °C) were used to observe the responses of the fruit quality during zero, three, six, nine, 12 and 15 storage days. Results showed that respiration and ethylene production rates, weight loss, pH, titratable acidity and antioxidant activities (as assayed using 1,1-diphenyl-2-picryl-hydrazyl and 2,2'-azino-bis[3-ethyl-benzothiazoline-6-sulfonic acid]) of fresh figs were affected significantly by the interaction between storage temperatures and days. Fresh figs stored at 5 °C showed the lowest respiration rate among three storage temperatures during nine and 12 days of storage. Fresh figs kept at 5 °C experienced the least firmness and water loss compared with the ones stored at 10 and 15 °C indicating that 5 °C was beneficial in retaining the eating quality and prolonging the postharvest life of the fruit.

***Keywords**:* antioxidant, firmness, soluble solids concentration, total phenolic content, water loss

1. Introduction

Countries with a Mediterranean climate such as Turkey, Greece and Spain are the major fig (*Ficus carica* L.) fruit production areas. It has never been known that figs can thrive in a hot and humid climate with fruit-bearing until it was successfully proven by Malaysian hobbyists a few years ago. Fig trees in Malaysia can bear fruit all year round with a sweeter taste than those planted

in Mediterranean climate regions (T. S. Tiong, personal communication, December 13, 2019), which could only bear fruit twice a year (Stover *et al*., 2007). Currently, the fresh figs from the local farm could fetch 20-50 US dollars per kilogram depending on its cultivars. The promising value of the fruit has urged investors and growers to venture into the fig fruit industry.

Fig is a nutritious fruit pack with fiber, potassium, calcium and iron which are higher than any major fruits such as bananas, oranges, apples, grapes and strawberries (Chessa, 1997). It is also rich in antioxidants such as carotenoids, vitamin C, tocopherols and phenolics that are beneficial to human health. As such, it is claimed as one of the most powerful superfruits. Albeit fig fruit is high in nutrients and antioxidants, it is delicate and perishable with short shelf life (Freiman *et al*., 2015). Refrigeration is commonly used in postharvest handling to prolong the shelf life of fresh horticultural produces and retain their quality (Wade, 1979). However, the optimal storage temperature for fresh horticultural produces is regional and cultivar-dependent.

In the United States, fresh figs are recommended to be stored at -1 to 0 °C (Crisosto *et al*., 1998). Similarly, Chinese researchers from the northern region claimed that -1 °C significantly ($p < 0.01$) decreased fresh figs decay rate, slowed down figs respiration rate, reduced figs cell membrane permeability and retained the activities of figs antioxidant enzymes compared with fruit stored at 0 and 2 °C (Tang *et al*., 2015). In Spain, white "Cuello de dama" fig fruit stored at 6 °C gave best sensory score than the ones stored at 0 and 3 °C (Garcia *et al*., 2003). In Turkey, 3 °C was used in the supply chain for retaining fresh figs' quality (Ertan *et al*., 2019). These studies indicate that the optimal storage temperature for fresh figs grown in temperate countries ranges between -1 and 6 °C. However, most fruits originating in tropical regions are sensitive to cold temperatures. The temperature-sensitive produces are injured when stored below their critical temperature, which generally ranges between 10 and 13 °C for most varieties. Malaysian grown Rockmelon (*Cucumis melo* L. reticulatus cv. Glamour) encountered cell wall rupture and tissue leakage after 14 days of storage at 13 °C (Zainal *et al*., 2019). 'Tommy Atkins' mangoes fruit from Brazil showed severe chilling injury symptoms when stored at 5 °C for 14 days (Miguel *et al*., 2016). The said studies on rockmelon and mango from the mentioned countries indicate that both tropical fruits are sensitive to low temperature and the quality deteriorates under prolonged cold storage. An appropriate storage temperature should be able to slow down metabolic processes without affecting cellular integrity and causing metabolic stresses that lead to chilling injury (Benkeblia and Beaudry, 2018).

Fig (*F. carica*) cv. Ipoh Blue Giant (IBG) is one of the famous fig cultivars widely cultivated and consumed in Malaysia (Mat Jusoh *et al*., 2020). The fruit of IBG fig is large with purplish-brown skin while pinkish flesh is sweet in taste and rich in flavor. Although figs are gaining great attention from Malaysian investors and growers, the knowledge on postharvest handling of this new and emerging fruit is almost nil. Malaysian fig industries cannot adopt practices and experiences of temperate countries to store tropically grown figs. Furthermore, its agroecology and agronomic practices also differ from other fresh fig-producing countries. Therefore, this study was carried out to elucidate the effects of storage temperatures on the postharvest quality of Malaysian grown fig cv. IBG. As such, storage temperatures of 5, 10 and 15 ℃ were used to determine the responses of physiological and physicochemical characteristics and antioxidant capacity and activities of the fruit.

2. Methodology

The fruit materials used in this study were collected from 2-year-old trees of *F. carica* cv. IBG that were planted in a rain shelter located at Selangor Fruit Valley (3° 23’ 23.2” N, 101° 26’ 51.9” E), Rawang, Selangor, Malaysia. On-tree ripened fruits with 20-25% purplish-brown skin were harvested around 9 AM. Immediately, the harvested fruits were sent to the Laboratory of Postharvest, Faculty of Agriculture, Universiti Putra Malaysia using an air-conditioned vehicle. Defect-free fruits with uniform sizes (30-40 g) were selected.

Upon arrival at the laboratory, the fruits were divided randomly into three lots with each lot containing 20 fruits. A total of four fruits were kept in a clamshell (15 x 15 x 8.0 cm) to imitate the marketing condition in Malaysian supermarkets. The clamshells were then stored at three different temperatures (5, 10 and 15 °C) with 80-90% relative humidity. The relative humidity in clamshells was about 95%. Respiration and ethylene production rates, physicochemical characteristics, total phenolic content (TPC) and antioxidant activities of the fruit during storage were analyzed at days 0, 3, 6, 9, 12 and 15 by using three fruits at every observation day. The visual appearance of fresh figs was also recorded using a digital camera (COOLPIX W300s, Nikon, Japan).

2.1 Determination of Respiration and Ethylene Production Rates

A gas chromatography (Clarus 500, Perkin Elmer, United States) with a flow rate of 25 mL/min was used to measure the respiration and ethylene production rates of the fruits. The system was equipped with a flame ionization detector (150 °C) and thermal conductivity detector (150 °C) fitted with a stainless steel Porapak Q Column (3 m x 3.125 mm; 50/80) (Supelco, Sigma-Aldrich, United States) where nitrogen and hydrogen (flow rate: 45 mL/min) were used as the carrier gas.

A static system as described by Mohamad and Ding (2019) was used to incubate and measure the fruit respiration and ethylene production rates. The rates were measured by the amount of CO_2 and C_2H_4 evolved by the fruits. Fruit respiration (CO_2) and ethylene production (C_2H_4) were calculated based on the peak area of CO_2 (Equation 1) or C_2H_4 (Equation 2) standard gas.

$$mLCO_2/kg/h = \frac{\left[\frac{area\ fr}{area\ std}\right] \times \left[\frac{CO_2}{100}\right] \times [incubator\ vol - fruit\ vol]}{fruit\ weight \times incubation\ time} \quad (1)$$

where *area fr* is the concentration of CO_2 produced by fruit expressed as peak area; *area std* is the concentration of standard CO_2 expressed as peak area; CO_2 is the concentration of standard CO_2 used in percentage; *incubator vol* is the volume of incubator used to incubate fruit; *fruit vol* is the volume of fruit measured.

$$\mu LC_2H_4/kg/h = \frac{\left[\frac{area\ fr}{area\ std}\right] \times [C_2H_4] \times [incubator\ vol - fruit\ vol\ ]}{fruit\ weight \times incubation\ time \times 1000} \quad (2)$$

where *area fr* is the concentration of C_2H_4 produced by fruit expressed as peak area, *area std* is the concentration of standard C_2H_4 expressed as peak area, C_2H_4 is the concentration of standard C_2H_4 used in mg/L, *incubator vol* is the volume of incubator used to incubate fruit and *fruit vol* is the volume of fruit measured.

2.2 Determination of Physicochemical Quality Characteristics

The weight loss and flesh firmness of fig fruits in each storage temperature and duration were determined according to the method of Ding and Ong (2010). The weight loss was calculated by the difference between the initial

and final weights of fruits (Equation 3). The flesh firmness was evaluated using a bishop penetrometer (FT 327, Alfonsine, Italy). The force required for an 11-mm flat surface probe to penetrate the 1-cm cut surface in two opposite locations to a depth of 5 mm was recorded. The penetration force was expressed in newton (N).

$$Weight\ loss\ (\%) = \frac{Initial\ weight - final\ weight}{Final\ weight} \times 100\% \quad (3)$$

Juice of stored fig fruits was extracted from fruit samples and a digital refractometer (PAL-1, Atago Co., Ltd., Japan) was used to determine its soluble solids concentration (SSC) which was then expressed in %SSC. The pH of juice was measured by using the remainder from the SSC determination with a glass electrode pH meter (Micro pH 2000, Crison Instruments, Spain). Titratable acidity (TA) of fresh figs was determined by using a 10-g aliquot of puree in 40 mL of distilled water and titrating against 0.1 N NaOH to a pink solution. The titer was used to calculate TA which was expressed as %citric acid according to the method of Mariani *et al*. (2018).

2.3 Sample Preparation and Extraction for Phenolic Content and Antioxidant Analyses

Fresh figs were cut into small pieces. In total, 5 g of tissue was homogenized in 50 mL of 80% methanol using a hand blender (Philips HR1607 ProMix 550W, Malaysia). The ground sample was extracted for 2 h at 26 °C on an orbital shaker (Solaris 2000, Thermo Fisher Scientific, United States) set at 180 rpm. After filtration, the supernatant was used for TPC quantification and antioxidant activities.

2.3.1 Determination of TPC

The TPC of figs fruit was determined by using Folin-Ciocalteau (FC) reagent according to Nuratika *et al*. (2017). The mixture containing 300 µL extract solution, 1.8 mL 10% FC and 1.2 mL 7.5% Na_2CO_3 was incubated in dark. After 1 h, it was then homogenized and its absorbance was measured at 765 nm using an ultraviolet-visible (UV-VIS) spectrophotometer (GS-UV12, General Scientific Ltd., United Kingdom). The measurement was repeated twice before expressing the concentration of TPC in the extracts as mg gallic acid equivalent (GAE)/g fresh weight.

2.3.2 Determination of Ferric Reducing Antioxidant Power

The ferric reducing antioxidant power (FRAP) assay was determined according to Ding and Syazwani (2016) with some modifications. The 3 mL FRAP working solution was added with 40 µL extracts and incubated in the dark at 37 °C. After 1 h, the absorbance of the mixture was measured at 593 nm using a UV-VIS spectrophotometer. Trolox was used as the standard curve and antioxidant activity of the extracts was expressed as µmol Trolox equivalent (TE)/g fresh weight.

2.3.3 Determination of 1,1-diphenyl-2-picryl-hydrazyl Radical Scavenging Activity

The reduction of free radical-scavenging on the 1,1-diphenyl-2-picryl-hydrazyl (DPPH) assay of figs fruit was evaluated based on the method of Lem *et al*. (2019). The mixture comprising 100 µL extract, 250 µL methanolic DPPH and 2 mL 80% methanol was shaken briskly and allowed to stand at 26 °C in the dark. After 15 min, the decrease in absorbance was measured at 517 nm against a blank using a spectrawave spectrophotometer (WPA S1200, Biochrom Ltd., England). For control, the mixture was prepared by repeating the same procedure as for the sample by using the extraction solvent to replace the sample. The result was presented as a percentage of inhibition (Equation 4).

$$Inhibition\ (\%) = \frac{A_0 - A_1}{A_0} \times 100\% \quad (4)$$

where A_0 is the absorbance of the control and A_1 is the absorbance of the sample or extract.

2.3.4 Determination of 2,2'-azino-bis(3-ethyl-benzothiazoline-6-sulfonic acid) Radical Scavenging Assay

The 2,2'-azino-bis(3-ethyl-benzothiazoline-6-sulfonic acid) (ABTS) radical scavenging was assayed according to the method as described by Mohamad and Ding (2019) with slight modifications. The ABTS radical cation ($ABTS^{\bullet+}$) solution was freshly prepared by reacting 7 mM ABTS and 2.45 mM potassium persulphate in equal volume. After incubation at 26 °C in the dark for 16 h, the $ABTS^{\bullet+}$ solution was then diluted with 80% methanol to obtain an absorbance of 0.700±0.005 at 734 nm. During the determination, 3.9 mL $ABTS^{\bullet+}$ solution was added to 0.1 mL fruit extract and mixed thoroughly. The reaction was allowed to stand at 26 °C for 6 min, and the absorbance was

immediately taken at 734 nm using a spectrawave spectrophotometer. Control preparation and results calculation for ABTS were the same as DPPH.

2.4 Experimental Design and Statistical Analysis

The experiment followed a completely randomized design with a factorial arrangement of treatments (3 storage temperatures x 6 storage days) and replicate for three batches of fruit. Data were analyzed using analysis of variance (ANOVA) while Duncan's multiple range test was used to separate the means when F-values showed significance at 5%.

3. Results and Discussion

3.1 Effects of Storage Temperatures and Days on Fig Physiological Characteristics

Respiration and ethylene production rates of fresh figs were affected by the interaction between storage temperatures and days (Table 1). The respiration rate of fresh figs was not affected by storage temperature during the first three storage days. By day six, the respiration rate of fresh figs stored at 15 °C was higher than those stored at 5 and 10 °C. As storage duration advanced, fruits stored at 15 °C were infected with diseases (Figure 1) and, thus, were discarded from the analysis. During this stage, fruit stored at 5 °C retained a lower respiration rate. A similar trend of ethylene production rate was found in fresh figs wherein fruit stored at 5 °C produced much lower ethylene than others.

The result of this study revealed that the impact of storage temperature was obvious after six days of storage where the respiration rate of fresh figs stored at 15 °C was always faster than those stored at lower storage temperature. This finding is in line with the studies on Californian fresh fig (Crisosto *et al.*, 1998), Indian mangoes (Nithya *et al*., 2011) and ackee (*Blighia sapida* Köenig) fruit arils (Benkeblia and Beaudry, 2018) wherein higher storage temperature causes faster respiration rates in fruit.

Respiration plays a central role in the overall metabolism of a harvested fruit where stored sugars or starch are oxidized to energy, carbon dioxide and water which shorten fruit's shelf life. In other words, a fruit's postharvest life is inversely proportional to its respiration rate.

Table 1. Effects of storage temperature and storage duration on respiration and ethylene production rates of fresh figs var. IBG

	Respiration rate ($mL\ CO_2/kg/h$)	Ethylene production ($\mu L\ C_2H_4/kg/h$)
Main effect of storage temperature (°C)		
5	55.26±3.51[cz]	0.70±0.09[b]
10	83.66±4.01[b]	0.91±0.11[a]
15	100.68±5.62[a]	1.00±0.15[a]
Levels of significance	***	***
Main effect of storage day (day)		
0	92.60±3.47[a]	1.34±0.46[a]
3	90.33±2.79[a]	1.11±0.29[b]
6	81.50±3.04[ab]	0.70±0.31[c]
9	76.58±2.87[bc]	0.69±0.22[c]
12	67.13±1.97[c]	0.64±0.27[c]
15	67.13±2.01[c]	0.59±0.17[c]
Levels of significance	***	***
Interaction effect of storage temperature and storage day		
Storage day 0		
5 °C	92.27±4.01[a]	1.16±0.27[a]
10 °C	95.78±3.89[a]	1.39±0.33[a]
15 °C	89.75±3.96[a]	1.48±0.24[a]
Storage day 3		
5 °C	89.97±3.84[a]	0.83±0.20[b]
10 °C	90.78±4.00[a]	1.08±0.18[b]
15 °C	90.25±3.50[a]	1.43±0.11[a]
Storage day 6		
5 °C	76.62±4.15[b]	0.57±0.14[a]
10 °C	78.69±3.87[b]	0.67±0.23[a]
15 °C	89.19±5.14[a]	0.85±0.21[a]
Storage day 9		
5 °C	47.32±4.10[c]	0.51±0.11[b]
10 °C	59.66±3.21[b]	0.70±0.15[a]
15 °C	122.76±5.21[a]	0.85±0.16[a]
Storage day 12		
5 °C	48.47±2.41[c]	0.45±0.09[b]
10 °C	56.81±3.78[b]	0.57±0.08[b]
15 °C	96.12±4.58[a]	0.89±0.28[a]
Storage day 15		
5 °C	48.00±5.41[b]	0.40±0.15[b]
10 °C	86.25±4.28[a]	0.77±0.12[a]
15 °C	-	-
Levels of significance	***	**

[z]Means followed by the same letter in the same column within factors are not significantly different at $p < 0.05$ according to DMRT. **, ***Significant at $p \leq 0.01$ or ≤ 0.001, respectively.

For every 10 °C reduction in temperature, the postharvest life of fruit doubles (Nair and Singh, 2003). Thus, storage temperature is an important factor that has a profound effect on the biological reactions of fruits.

3.2 Effects of Storage Temperatures and Days on Fig Physicochemical Quality Characteristics

Weight loss of fresh figs was affected by the interaction between storage temperature and day (Table 2). Fresh figs lost about 2% of their weight during the first three days of storage. As storage duration progressed, weight loss increased gradually with fruits stored at 15 °C lost more weight than the ones stored at 10 and 5 °C. The weight loss of fruits stored at 15 °C achieved 10% after nine days of storage and eventually infected by diseases by day 15. Both fresh figs stored at 5 and 10 °C lost about 5.70% of their weight by day 15. Israel-grown fig, which was stored at 1-2 °C for 19 days followed by two days at 20 °C, lost almost 23% of its initial weight (Freiman *et al.*, 2012). This indicates that fresh figs were vulnerable to water loss regardless of the storage temperature used. Water may lose from fruit through stomata, lenticel and micro-crack on the surface of fruit peel (Shahidah and Ding, 2020) and causes fruit weight loss. Water loss is a form of the stress response by fruit towards detachment from the mother plants.

Water loss has a negative impact on cell turgor which influences cell wall rigidity and eventually causes firmness losses in fruit (Shahidah and Ding, 2020). The impact of water loss on fresh figs' firmness was clearly seen in this study where both storage temperature and day affected firmness significantly even though no significant interaction was found (Table 2). The firmness of fresh figs stored at 5 °C was higher than those stored at 10 and 15 °C suggesting 5 °C was superior to 10 and 15 °C with respect to the reduced weight loss and firmness.

Neither storage temperature nor storage day affected the SSC of fresh figs (Table 2). Throughout this study, fruit retained its SSC in the range of 12 to 13%. The SSC is a key parameter in the quality assessment of a fruit that directly influences the taste and willingness of consumers to purchase the fruit. It is also an important indicator for fruit's physicochemical quality changes during storage. However, there was no upsurge or downturn in SSC of fresh figs in the course of this study.

Table 2. Effects of storage temperature and storage duration on weight loss, firmness, soluble solids concentration, pH and titratable acidity of fresh figs var. IBG

	Weight loss (%)	Firmness (N)	Soluble solids concentration (%SSC)	pH	Titratable acidity (%)
Main effect of storage temperature (°C)					
5	3.21±0.51^{bz}	3.42±0.51^{a}	12.31±0.41	5.05±0.21^{b}	0.17±0.04^{a}
10	3.34±0.52^{b}	2.43±0.22^{b}	12.54±0.34	5.14±0.43^{a}	0.12±0.02^{b}
15	6.05±0.71^{a}	1.96±0.47^{b}	12.62±0.40	5.17±0.45^{a}	0.12±0.01^{b}
Levels of significance	***	**	ns	**	***
Main effect of storage day (day)					
0	0^{d}	5.19±0.28^{a}	13.30±0.34	4.95±0.34^{c}	0.17±0.03^{a}
3	2.19±0.17^{c}	3.03±0.27^{b}	13.06±0.42	4.97±0.32^{c}	0.16±0.04^{ab}
6	4.88±0.18^{b}	2.51±0.40^{bc}	12.93±0.29	5.15±0.28^{b}	0.15±0.03^{ab}
9	5.72±0.21^{a}	1.89±0.34^{bcd}	12.80±0.38	5.17±0.24^{b}	0.13±0.02^{c}
12	5.98±0.25^{a}	1.62±0.27^{cd}	13.18±0.47	5.23±0.26^{ab}	0.11±0.04^{cd}
15	6.15±0.18^{a}	0.86±0.21^{d}	13.19±0.54	5.30±0.33^{a}	0.10±0.03^{d}
Levels of significance	***	***	ns	***	***
Interaction effect of storage temperature and storage day					
Storage day 0					
5 °C	0^{a}	4.88±0.51	14.25±0.28	4.94±0.26^{a}	0.18±0.04^{a}
10 °C	0^{a}	5.03±0.29	12.29±0.38	4.98±0.31^{a}	0.17±0.02^{a}
15 °C	0^{a}	5.61±0.34	13.36±0.44	4.93±0.25^{a}	0.17±0.03^{a}
Storage day 3					
5 °C	1.61±0.05^{b}	3.87±0.51	14.19±0.41	4.93±0.16^{b}	0.19±0.01^{a}
10 °C	2.01±0.09^{b}	2.75±0.50	12.79±0.45	5.19±0.33^{a}	0.18±0.04^{a}
15 °C	2.95±0.19^{a}	2.48±0.47	12.20±0.45	4.78±0.24^{c}	0.11±0.01^{b}
Storage day 6					
5 °C	2.86±0.14^{b}	3.31±0.41	14.53±0.51	4.90±0.44^{c}	0.18±0.02^{a}
10 °C	3.27±0.08^{b}	2.50±0.70	12.29±0.42	5.13±0.32^{b}	0.13±0.04^{b}
15 °C	8.51±0.18^{a}	1.72±0.33	11.96±0.54	5.43±0.24^{a}	0.13±0.01^{b}
Storage day 9					
5 °C	3.94±0.17^{b}	3.06±0.28	14.90±0.34	5.11±0.27^{b}	0.15±0.02^{a}
10 °C	3.98±0.19^{b}	1.76±0.52	11.61±0.48	5.14±0.09^{b}	0.13±0.04^{b}
15 °C	10.03±0.25^{a}	0.85±0.34	11.90±0.44	5.43±0.11^{a}	0.12±0.01^{b}
Storage day 12					
5 °C	4.76±0.21^{b}	2.91±0.24	13.00±0.25	5.11±0.21^{a}	0.14±0.01^{a}
10 °C	4.92±0.18^{b}	1.07±0.51	13.17±0.41	5.14±0.13^{a}	0.11±0.02^{b}
15 °C	10.10±0.31^{a}	0.52±0.34	13.37±0.36	5.26±0.14^{a}	0.09±0.02^{b}
Storage day 15					
5 °C	5.56±0.18^{a}	1.28±0.34	13.88±0.11	5.32±0.12^{a}	0.13±0.03^{a}
10 °C	5.89±0.20^{a}	0.44±0.45	12.50±0.08	5.27±0.23^{a}	0.07±0.02^{b}
15 °C	-	-	-	-	-
Levels of significance	***	ns	ns	***	**

[z]Means followed by the same letter in the same column within factors are not significantly different at $p < 0.05$ according to DMRT. NS, **, ***Non-significant or significant at $p \leq 0.01$ or ≤ 0.001, respectively.

A similar finding was also reported by Antunes *et al*. (2008) where SSC of fig fruit cv. Lampa Preta retained the same throughout the 20-day storage at 2 °C. This suggests that the SSC of fig fruit does not change during storage regardless of production regions.

Interaction between storage temperature and day affected pH and TA of stored fresh figs (Table 2). The pH of fresh figs ranged from 4.94 to 5.43. There were significant changes in pH among storage temperatures during days three, six and nine. When the storage day approached the end of shelf life at days 12 and 15, no significant changes in pH were found. Unlike pH, TA of fresh figs stored at 5, 10 and 15 °C showed significant changes after storage day three. Generally, the pH of fresh figs increased while TA decreased with storage temperature and duration (Table 2). Most likely, respiratory activity affected the fruit's metabolic rates albeit refrigeration was used. This implied that storage temperature as low as 5 °C had no adverse effect on Malaysian grown fig cv. IBG. It is important in postharvest where storage temperature used should not induce a negative impact on the commodity.

3.3 Effects of Storage Temperatures and Days on Fig Fruit's TPC and Antioxidant Activity Characteristics

The TPC and antioxidant activity as assayed using FRAP were not affected by the interaction effect between storage temperature and storage day (Table 3). Both TPC and FRAP showed a similar trend of results where storage temperature of 15 °C induced fresh figs to exhibit the highest TPC and FRAP followed by 5 °C and lastly 10 °C. Storage days did not have any effect on the TPC and FRAP of fresh figs. Antioxidant activities assayed using DPPH and ABTS were affected significantly by the interaction effect. Throughout the storage, DPPH of fresh figs stored at 10 °C was lower than fruit stored at 0 and 15 °C. The ABTS of fresh figs showed an almost similar trend as DPPH where fruit stored at 15 °C was always significantly higher than those stored at 10 °C.

Phenolic compounds of fruit have redox properties that act as an antioxidant against stresses and are essential to quantify it. In addition, different assays are required to quantify the antioxidant activity of fruit as each assay has different mechanisms. The most common methods to determine antioxidant activity is based on the free radical scavenging and the redox mechanisms. In the present study, keeping fresh figs at 15 °C caused the fruits' attainment of the highest TPC while fruit stored at 10 °C obtained the lowest TPC. A similar finding was found in FRAP.

Table 3. Effects of storage temperature and storage duration on TPC and antioxidant activities of fresh figs var. IBG

	TPC (mg GAE/g fresh weight)	FRAP (μmol TE/g fresh weight)	DPPH (% inhibition)	ABTS (% inhibition)
Main effect of storage temperature (°C)				
5	0.20±0.04^{bz}	2.94±0.15^{b}	70.54±2.45^{a}	21.13±1.27^{b}
10	0.17±0.04^{c}	2.72±0.18^{c}	64.65±3.01^{b}	16.71±2.47^{c}
15	0.24±0.03^{a}	3.19±0.20^{a}	71.39±2.14^{a}	28.07±2.12^{a}
Levels of significance	***	***	***	***
Main effect of storage day (day)				
0	0.19±0.01	3.02±0.11	69.50±2.15	24.04±2.04
3	0.20±0.02	2.93±0.15	68.91±3.04	22.30±1.98
6	0.19±0.01	2.88±0.20	69.68±3.14	20.55±1.26
9	0.21±0.02	2.90±0.15	68.26±2.79	19.40±2.11
12	0.23±0.02	2.96±0.16	67.86±2.17	23.95±2.49
15	0.20±0.01	2.90±0.19	67.74±2.48	18.35±2.09
Levels of significance	ns	ns	ns	ns
Interaction effect of storage temperature and storage day				
Storage day 0				
5 °C	0.19±0.01	2.96±0.02	68.91±2.87^{a}	24.46±2.11^{a}
10 °C	0.15±0.01	2.89±0.10	70.35±3.01^{a}	24.12±1.89^{a}
15 °C	0.23±0.02	3.21±0.11	69.24±3.17^{a}	23.54±1.57^{a}
Storage day 3				
5 °C	0.21±0.02	2.96±0.10	72.92±2.51^{a}	21.68±2.07^{ab}
10 °C	0.17±0.01	2.66±0.12	63.46±3.01^{b}	18.30±2.12^{b}
15 °C	0.21±0.01	3.19±0.13	70.35±3.19^{a}	26.92±1.97^{a}
Storage day 6				
5 °C	0.19±0.02	2.87±0.05	74.44±2.48^{a}	20.06±1.89^{b}
10 °C	0.15±0.02	2.62±0.08	63.04±2.47^{b}	15.11±2.07^{b}
15 °C	0.24±0.03	3.16±0.10	71.56±3.14^{a}	26.49±1.91^{a}
Storage day 9				
5 °C	0.21±0.01	2.86±0.11	72.75±2.78^{a}	19.73±1.97^{ab}
10 °C	0.16±0.02	2.72±0.08	64.27±3.01^{b}	16.11±2.10^{b}
15 °C	0.25±0.02	3.12±0.11	71.07±3.55^{a}	22.360±2.21^{a}
Storage day 12				
5 °C	0.23±0.01	2.96±0.12	68.60±2.67^{ab}	17.33±1.28^{b}
10 °C	0.17±0.02	2.63±0.09	60.96±2.05^{b}	18.46±1.98^{b}
15 °C	0.29±0.01	3.27±0.13	70.72±2.12^{a}	36.06±2.87^{a}
Storage day 15				
5 °C	0.18±0.01	2.99±0.08	69.52±2.23^{a}	22.37±2.48^{a}
10 °C	0.22±0.02	2.81±0.04	65.52±1.27^{b}	14.32±2.01^{b}
15 °C	-	-	-	-
Levels of significance	ns	ns	***	*

[z]Means followed by the same letter in the same column within factors are not significantly different at $p < 0.05$ according to DMRT. NS, *, ***Nonsignificant or significant at $p \leq 0.05$ or ≤ 0.001, respectively; TPC = total phenolic content; GAE = gallic acid equivalent; TE = Trolox equivalent; FRAP = ferric reducing antioxidant power; DPPH = 1,1-diphenyl-2-picryl-hydrazyl; ABTS = 2-2'-azino-bis(3-ethylbenzothiozoline-6-sulfonic acid).

Although both DPPH and ABTS were affected significantly by the interaction between storage temperature and duration, the results revealed that fig fruits stored at 10 °C contained lower DPPH and ABTS than those stored at 5 and 15 °C. The findings of the present study are in agreement with the report of Ayala-Zavala *et al*. (2004) where strawberries stored at high temperatures resulted in a significant increase in TPC and antioxidant activity.

The high TPC and antioxidants activities in fresh figs stored at 15 °C could be due to its responses towards high-temperature stress which induced a high respiratory rate. As a result, the scavenging activity of the fruits increased. However, the high respiratory rate of the fruits stemmed from faster metabolic processes and caused the oxidation of stored food in fresh figs. Once stored food has been used up, the fruit senesces and this could explain why fresh figs stored at 15 °C deteriorated faster than fruit stored at 10 and 0 °C. Furthermore, a storage temperature of 15 °C was not able to suppress fungal growth in the fruits (Figure 1). A similar observation was also reported by Mat Jusoh *et al*. (2019) where fig fruits stored at 15 °C were infected by fungus and incurred serious water loss by the second week of storage.

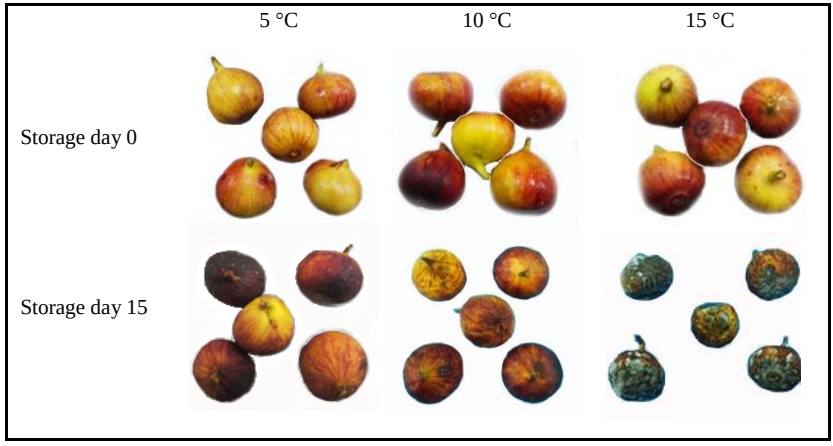

Figure 1. The visual appearance of fresh fig fruits cv. IBG at storage day 0 and 15 when storage temperature of 5, 10 and 15 °C were used. Fruits stored at 15 °C had rotten by storage day 15.

The TPC and antioxidants activities in fresh figs stored at 5 °C were higher than those stored at 10 °C (Table 3). This indicates storage temperature had altered the metabolism of figs. Although visible chilling injury-symptom of figs was not found in this study (Figure 1), it is undeniable that the symptom may appear after transferring the cold-stored fruit to a higher temperature. The

visible chilling injury-symptom of tomato fruit that was stored at 10-12 °C only appeared once the fruit was transferred to 20-22 °C (Cárdenas-Torres *et al.*, 2020). In this study, cold-stored fruit was not further observed at elevated temperatures. Thus, it was not clear whether or not chilling injury-symptom would develop after transferring the cold stored fresh figs to 20 °C.

4. Conclusion and Recommendation

The purpose of refrigeration is to retain fruit physicochemical characteristics and extend the postharvest life of fruit without adverse effects. Among the storage temperatures used in this study, 5 °C retarded respiration rate of Malaysian grown fig cv. IBG to the lowest level while retaining higher firmness compared with 10 and 15 °C. However, further study needs to be carried out to determine the effects of elevated temperature towards cold-stored fresh figs, especially chilling injury.

5. Acknowledgement

The authors would like to acknowledge Putra Geran (GPB) given by Universiti Putra Malaysia (UPM/800-3/3/1/9629600) for funding this project.

6. References

Antunes, M.D.C., Costa, P., Miguel, M.G., Martins, M.A., & Gomes, C. (2008). The effect of postharvest treatments with sodium bicarbonate or acetic acid on storage ability and quality of fig fruit. Acta Horticulturae, 798, 279-284.

Ayala-Zavala, J.F., Wang, S.Y., Wang, C.Y., & Gonzalez-Aguilar, G.A. (2004). Effect of storage temperatures on antioxidant capacity and aroma compounds in strawberry fruit. LWT – Food Science and Technology, 37, 687-695. https://doi.org/10.1016/j.lwt.2004.03.002

Benkeblia, N., & Beaudry, R.M. (2018). Effects of temperature on postharvest respiratory parameters and quality attributes of ackee (*Blighia sapida* Köenig) fruit arils during storage. International Food Research Journal, 25(1), 119-126.

Cárdenas-Torres, F.I., Cruz-Mendivil, A., Lopz-Valenzuela, J.A., Ayon-Reyna, L.E., Lopez-Lopez, M.E., Tamayo-Limon, R., Martinez-Tellez, M.A., & Vega-Garcia, M.O.

(2020). Tolerance to chilling injury induced by hot water treatment increases activities of antioxidant enzymes in tomato fruits. International Fruit Research Journal, 27(6), 1111-1120.

Chessa, I. (1997). Fig. In S. Mitra (Ed.), Postharvest physiology and storage of tropical and subtropical fruits (pp. 245-264). Wallingford, United Kingdom: CAB International.

Crisosto, H.C., Mitcham, E.J., & Kader, A.A. (1998). Fig: Recommendations for maintaining postharvest quality. Retrieved from http://postharvest.ucdavis.edu/files/259420.pdf

Ding, P., & Ong, P.T. (2010). Extending 'Kampuchea' guava shelf-life at 27 °C using 1-methylcyclopropene. International Food Research Journal, 17(1), 63-69.

Ding, P., & Syazwani, S. (2016). Physicochemical quality, antioxidant compounds and activity of MD-2 pineapple fruit at five ripening stages. International Food Research Journal, 23(2), 549-555.

Ertan, B., Senkayas, H., & Tuncay, O. (2019). Postharvest logistics performance of fresh fig varieties in Turkey. Scientia Horticulturae, 257, 108769. https://doi.org/10.1016/j.scienta.2019.108769

Freiman, Z.E., Rodov, V., Yablovitz, Z., Horev, B., & Flaishman, M.A. (2012). Preharvest application of 1-methylcyclopropene inhibits ripening and improves keeping quality of 'Brown Turkey' figs (*Ficus carica* L.). Scientia Horticulturae, 138, 266-272. https://doi:10.1016/j.scienta.2012.01.007

Freiman, Z.E., Rosianskey, Y., Dasmohapatra, R., Kamara, I., & Flaishman, M.A. (2015). The ambiguous ripening nature of the fig (*Ficus carica* L.) fruit: A gene-expression study of potential ripening regulators and ethylene-related genes. Journal of Experimental Botany, 66(11), 3309-3324. https://doi.org/10.1093/jxb/erv140

Garcia, B.M.J., Hernández, M.M.T., & Lozano, R.M. (2003). Effect of temperature on the shelf-life of fig fruit during refrigerated storage. Acta Horticulturae, 605, 229-232. https://doi.org/10.17660/ActaHortic.2003.605.34

Lem, M.S., Ding, P., & Mahmud, T.M.M. (2019). Response of 1-methycyclopropene on postharvest quality of local soursop (*Annona muricata* L.). Sains Malaysiana, 48(3), 571-579. https://doi.org/10.17576/jsm-2019-4803-09

Mariani, M., Cahaya, N.M., & Ding, P. (2018). Physicochemical characteristics of *Carissa congesta* fruit during maturation. Acta Horticulturae, 1213, 461-464. https://doi.org/10.17660/ActaHortic.2018.1213.68

Mat Jusoh, N.A., Ding, P., & Choon, S.Y. (2019). Performance of fig (*Ficus carica* L. cv. Ipoh Blue Giant) fruit stored at various storage temperatures. International Journal of Agriculture, Forestry and Plantation, 8, 9-11.

Mat Jusoh, N.A., Ding, P., & Choon, S.Y. (2020). Extending post-harvest quality of fresh fig (*Ficus carica* L.) fruit through manipulation of pre- and post-harvest practices: A review. Sains Malaysiana, 49(3), 553-560.

Miguel, A.C.A., Durigan, J.F., Marques, K.M., Morgado, C.M.A., & Ferraudo, A.S. (2016). Prevention of chilling injury in 'Tommy Atkins' mangoes previously stored at 5 °C, using heat treatment and radiation UV (UVC). Revista Brasileira de Fruticultura 38(1), 53-63. https://doi.org/10.1590/0100-2945-123/14

Mohamad, M., & Ding, P. (2019). Physico-textural and cellular structure changes of *Carissa congesta* fruit during growth and development. Scientia Horticulturae, 246, 380-389. https://doi.org/10.1016/j.scienta.2018.09.024

Nair, S., & Singh, Z. (2003). Pre-storage ethrel dip reduces chilling injury, enhances respiration rate, ethylene production and improves fruit quality of 'Kensington' mango. Journal of Food, Agriculture and Environment, 1, 93-97.

Nithya, J.D., Karuppiah, A., & Abirami, K.C.V. (2011). Effect of storage temperatures, O2 concentrations and variety on respiration of mangoes. Journal of Agrobiology, 28(2), 119-128. https://doi.org/10.2478/v10146-011-0013-8

Nuratika, T.S.M., Ding, P., Jugah, K., & Hasanah, M.G. (2017). Potential of UVC germicidal irradiation in suppressing crown rot disease, improving postharvest quality and antioxidant capacity of *Musa* AAA 'Berangan' during fruit ripening. Food Science & Nutrition, 5(5), 967-980. https://doi.org/10.1002/fsn3.482

Shahidah, M.D., & Ding, P. (2020). Trends and advances in edible biopolymer coating for tropical fruit: A review. Food Research International, 134, 109208. https://doi.org/10.1016/j.foodres.2020.109208

Stover, E., Aradhya, M., Crisosto, C., & Ferguson, L. (2007). The fig: Overview of an ancient fruit. HortScience, 42, 1083-1087. https://doi.org/10.21273/HORTSCI.42.5.1083

Tang, X., Zhang, M., Ma, J., & Zhang, Z. (2015). Appropriate stored temperature to maintain quality of fresh fig fruits. Transactions of the Chinese Society of Agricultural Engineering, 31(12), 282-287. https://doi.org/10.11975/j.issn.1002-6819.2015.12.038

Wade, N.L. (1979). Physiology of cool-storage disorders of fruits and vegetables. In J.M. Lyons, D. Graham, & J.K. Raison (Eds.), Low temperature stress in plants (pp. 81-96). New York: Academic Press.

Zainal, B., Ding, P., Ismail, I.S., & Saari, N. (2019). Physico-chemical and microstructural characteristics during postharvest storage of hydro-cooled rockmelon (*Cucumis melo* L. reticulatus cv. Glamour). Postharvest Biology and Technology, 152, 89-99. https://doi.org/10.1016/j.postharvbio.2019.03.001