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Influence of forced-air precooling time on the changes in quality attributes and consumer acceptance of *Musa* AAA Berangan

[1]Kuan, C.H., [2*]Ahmad, S. H., [1]Son, R., [2]Yap, E. S. P., [2]Zamri, M. Z., [2]Shukor, N. I. A., [2]Tajidin, N. E. and [2]Bunga Raya, K.

[1]Food Safety Research Center (FOSREC), Faculty of Food Science and Technology, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor Darul Ehsan, Malaysia
[2]Department of Crop Science, Faculty of Agriculture, Universiti Putra Malaysia, 43400 UPM, Serdang, Selangor, Malaysia

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Abstract

A good temperature management, such as precooling and cold storage, can delay deterioration of fresh produce. In this study, different forced-air precooling times were applied on *Musa* AAA Berangan to investigate the influence of forced-air precooling time on the changes of quality attributes and consumer acceptance. The banana was subjected to forced-air precooling treatment (5 ± 1°C) for 0, 14, 50, and 120 min and then stored in a cold room (13 ± 1°C) for 2 weeks. Then, all the fruits were transferred to a ripening room (25 ± 2°C) and initiated to ripen with ethylene gas. Quality attributes analyses and sensory evaluations were conducted when the fruits reached maturity index 5. Quality parameters, such as soluble solids concentration, titratable acidity, pulp firmness, and peel colour, showed no significant differences when fruits were precooled at different times. Blackening of peel as a result of chilling injury occurred in fruits treated with forced-air precooling for 50 and 120 min. This blackening significantly influenced consumer acceptance, although it did not affect the pulp colour and taste.

Introduction

Banana is one of the major international trading commodities and widely distributed around the world (Robinson and Saúco, 2010). In Malaysia, banana is the second largest cultivated fruits and 'Berangan', 'Mas' and 'Rastali' are the favourite type of local bananas among Malaysians (Ding and Darduri, 2009; Liew and Lau, 2012). In commercial practice, bananas are harvested at mature green stage (maturity index 2) and then the ripening will be initiated under certain controlled conditions when reaching the destination market. Bananas can be stored at 13°C for up to about 40 days especially when exporting overseas. In general, appropriate storage temperature, relative humidity, air ventilation and ethylene gas are the main components for ripening of bananas (Liew and Lau, 2012). Bananas are climacteric fruit, once induced to ripen with ethylene or ethylene-generated resources, their shelf life can be shortened to about 3-5 days (Ding and Darduri, 2009). Hence, good and proper postharvest handling practices are critical to ensure the quality and extend the shelf life of fresh produces.

Although there are numerous postharvest technologies such as thermal processing, low temperature preservation, chemical and biological reactions coupled with other preservation techniques are applied on fresh produces to maintain or extend the shelf-life, significant postharvest losses still occur due to mishandling or rough handling by the farmers or untrained workers (Saraswathy *et al*., 2008). To reduce the losses, the biological and environmental factors involved in deterioration of the perishables commodities such as banana must be well understood (Kader, 1993). In general, the perishability of bananas is mainly because of various physical and chemical changes that happened during the ripening process.

Good temperature management is one of the most important factors in delaying fresh produces from deterioration; rapid cooling and maintenance of proper temperatures are both critical. Rapid cooling after harvest which is commonly known as 'precooling' and it is primarily designed for rapid removal of field heat (Brosnan and Sun, 2001). According to Brosnan and Sun (2001), in order to ensure the good market quality, it is not only to cool the product along the distribution chain but have to cool it as quickly as possible after harvest. The faster the temperature is reduce to the desired storage temperature, the longer is the storage life of the fresh produce. Although precooling process

*Corresponding author.
Email: *hajar@upm.edu.my, sitihajarahmad@gmail.com*

or cold storage can slow down metabolism (e.g. respiration), banana fruits are highly susceptible to chilling injury (CI) (Wang *et al.*, 2014). CI symptoms of banana fruit such as peel browning, pitting and abnormal ripening pulp can occur at approximately 12ºC and these symptoms can become worse with decreasing temperature (Jiang *et al*., 2004; Chen *et al*., 2008; Promyou *et al.*, 2008). Hence, precool or storing of banana fruits at improper cooling medium can cause quality deterioration and reduce consumer acceptance. The objective of this study was aimed at investigating the effect of forced-air precooling conditions on the changes in quality attributes and consumer acceptance of Berangan banana.

Materials and Methods

Bunches of unripe green bananas (*Musa* AAA Berangan) were purchased from local wholesale market in Selangor, Malaysia. These unripe green bananas were not gone through any postharvest treatments and sent to the wholesale market immediately after harvested due to our special request. Therefore, it was assumed that the fruit conditions at wholesale market were same with the conditions at collecting centres or packing houses. The bananas were transported to the Postharvest Laboratory at Faculty of Agriculture, Universiti Putra Malaysia and treated with forced-air cooling immediately. High quality bananas which are free from blemishes (e.g. cuts and bruised) were selected as sample in this study.

Forced-air precooling treatments

The forced air precooling treatments in this study were designed to simulate the actual and improper postharvest handling practices that routinely used and might happen in the industry. Berangan banana (maturity index 2) with initial temperature of 27.3°C was subjected to forced-air precooling immediately after purchased from wholesale market. Forced-air precooling in this study was carried out by exposed the packages of banana in a cold room (5 ± 1°C) to higher air pressure on one side than on the other. The differences in pressure forced the cooled air passed through the packages and bananas. In order to ensure the cold air will flows through the bananas and out through the fan, two parallel rows of banana were covered by a plastic strip (Figure 1). Initial temperature of bananas was determined by inserted a thermocouple (K-Type, Hanna Instrument, Romania) into the middle part of banana that was located at approximately the centre of the package. Initial temperature was recorded when the final constant temperature is reached. Temperature of the banana

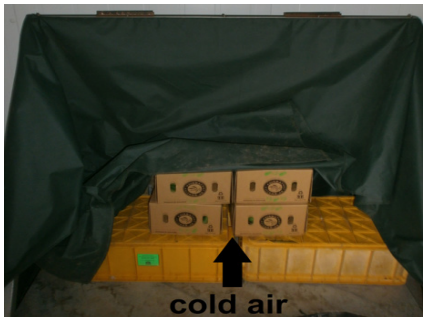

Figure 1. Forced- air cooling setup for precooling the Berangan banana. A mounted fan that located at the back forced the cold air passed through the packages and bananas and out through the fan. Two parallel rows of banana were covered by a plastic strip so that it can force as much cold air pass through the actual product as possible

in each package was checked and recorded at every one minute. All the selected bananas were subjected to different forced-air precooling treatments such as:

Treatment A: Bananas were stored at cold room (13 ± 1°C) for 2 weeks and without any precooling treatment (Control).

Treatment B: Bananas were treated for 14 min until reached first half-cooling period (16.7°C) and then stored at cold room (13 ± 1°C) for 2 weeks.

Treatment C: Bananas were treated for 50 min until reached second half-cooling period (11.3°C) and then stored at cold room (13 ± 1°C) for 2 weeks.

Treatment D: Bananas were treated for 120 min (final temperature was 11°C) and then stored at cold room (13 ± 1°C) for 2 weeks. This treatment was designed to simulate the mishandling practice, which might cause chilling injury in banana fruits.

After that, all the bananas were transferred to a storage room (25 ± 5°C) and initiated to ripen by using 10 µL/L of C_2H_4 for 24 h. After 24 h, the banana fruits were ventilated and allowed to ripen. Analyses were carried out when the bananas reached at the maturity index 5.

Determination of peel colour

Colour analysis was performed by using a chromameter (CR-300, Minolta Corp., Osaka, Japan) and results were expressed as lightness (L^*), chroma (C^*) and hue (h°). Measurements were taken at the stem end, middle part, and floral end of the banana peel (Ding and Darduri, 2009).

Firmness assessment

Banana pulp firmness was evaluated by using a stand mounted penetrometer (Model BS35, Bosch, Germany) with the cylindrical probe area of 0.2828 cm^2. Measurements were taken at the middle part from stem end (1 cm thick) and distal end of the

Table 1. Effect of different forced-air cooling treatments on Berangan banana peel colour (L*, C* and h°)

Treatments	Lightness (L*)	Chroma (C*)	Hue (h°)
A: Control	44.35 ± 0.92[a]	21.94 ± 0.65[a]	89.33 ± 0.75[ab]
B: First half-cooling period (14 min)	45.98 ± 3.87[a]	23.00 ± 2.87[a]	92.07 ± 0.99[b]
C: Second half-cooling period (50 min)	45.92 ± 1.38[a]	24.42 ± 0.40[a]	89.43 ± 2.35[ab]
D: Beyond Second half-cooling period (120 min)	48.60 ± 2.96[a]	24.93 ± 2.37[a]	89.40 ± 0.96[ab]

[#]Mean values in the same column with different superscript lower case letter are significantly different (P≤0.05)

banana (1 cm thick) (Liew and Lau, 2012). The results were expressed in Newtons (N).

Soluble solids concentration (SSC) and pH assessment

Ten grams of banana flesh sample was diluted in 40 mL of distilled water and blended for 1 min until homogenized and turned juicy. The juice was filtered by cotton wool. One drop of the filtrate from each sample were placed onto the refractometer (Model N1, Atago Co., Ltd., Tokyo, Japan) to obtain the SSC in percentage. This value was adjusted based on the dilution factor to give the final SSC measurement. One hundred milliliters of banana juice were also subjected to pH measurement by using a pH meter (Model Crison Micro pH 2000, Crison Instruments, S.A., Barcelona, Spain).

Titratable acidity (TA)

Five milliliters of filtrate from the SSC determination were added with few drops of 1% phenolphthalein as indicator and then titrated with 0.1 mol L^{-1} NaOH until it changed to pink colour. Volume of 0.1 mol L^{-1} NaOH that has been used was recorded and the results were calculated as a percentage of malic acid according to Ding *et al.* (2007).

Consumer preference test

Sensory evaluation was conducted among 20 untrained panellists between the ages of 20 and 30. They were composed of students from Universiti Putra Malaysia. Participants were ask to rate the bananas from each treatment for appearance, flesh colour and taste on a standard 9-point hedonic scale (dislike extremely = 1; dislike very much = 2; dislike moderately = 3; dislike slightly = 4; neither like nor dislike = 5; like slightly = 6; like moderately = 7; like very much 8; like extremely = 9). All the samples were coded using a random three-digit numbers and served together with a glass of water and required all the panellists to rinse and swallow water between samples (Shirani and Ganesharanee, 2009).

Statistical analysis

In this study, each measurement was performed in triplicate independently. All the data were subjected to one-way analysis of variance (ANOVA) and Minitab software (version 14.0) was used to evaluate if there was any significant difference between each treatment by Tukey's test at P≤ 0.05.

Results

The results showed that there was no significant difference (P>0.05) in peel colour of Berangan banana when treated with different forced-air cooling (Table 1). However, it was found that there was a difference in the chilling injury symptom (e.g. blackening of banana peel) and appearance of Berangan banana after treated with different forced air precooling treatments (Figure 2). Berangan banana treated with forced-air precooling for 14 min (Set B) showed less black spots on the peel as compared to the banana from Set A, C, and D. The results indicated that there were no significant differences in pulp firmness, SSC and TA of Berangan banana fruits when treated under different forced-air precooling times (Table 2). However, the pH of Berangan banana was significantly affected by forced air precooling treatment. The pH content of Berangan banana treated with control was significantly higher as compared to the bananas treated with forced-air cooling for 50 min (Table 2). For the sensory assessments, there were no significance difference in flesh colour and taste of Berangan banana fruits after being subjected to different forced-air precooling treatments (Table

Table 2. Effect of different forced-air cooling treatments on pulp firmness, soluble solids concentration (SSC), titratable acidity (TA) and pH of Berangan banana

Type of treatments	A (Control)	B: First half-cooling period (14 min)	C: Second half-cooling period (50 min)	D: Beyond Second half-cooling period (120 min)
Pulp firmness (N)	25.14 ± 1.70[a]	26.13 ± 0.34[a]	25.14 ± 0.90[a]	23.96 ± 0.68[a]
SSC (%)	21.28 ± 1.32[a]	20.95 ± 0.29[a]	21.78 ± 0.50[a]	21.11 ± 1.16[a]
TA (%)	0.67 ± 0.13[a]	0.60 ± 0.07[a]	0.67 ± 0.07[a]	0.58 ± 0.04[a]
pH	5.98 ± 0.06[a]	5.93 ± 0.01[ab]	5.87 ± 0.02[b]	5.94 ± 0.03[ab]

[*] Mean values in the same row with different superscript lowercase letter are significantly different (P≤0.05)
Titratable acidity was expressed in percentage of malic acid

Figure 2. Appearance of Berangan banana after different forced air cooling treatments (5 ± 1°C) (Treatment A: control, Treatment B: first half-cooling period [14 min], Treatment C: second half-cooling period [50 min], Treatment D: Beyond Second half- cooling period [120 min])

3). From the results, it was known that consumers liked the flesh colour and taste of Berangan banana moderately and very much, respectively. However, the appearance of Berangan banana influenced the consumer acceptance significantly. From the sensory scores, there was a significant difference (P≤0.05) in consumer acceptance on appearance between Berangan banana treated with forced-air precooling for 14 min (Set B) and with the other banana fruits (Set A, C and D).

Discussion

In this study, different forced-air precooling conditions were applied on Berangan banana to evaluate the effect of misused of precooling and cold storage methods on the consumer acceptance and quality attributes of Berangan banana. Banana is well known as tropical and subtropical fruit, hence it was not surprising that Berangan banana in this study were susceptible to chilling injury and this manifested itself as dull yellow colour after ripening or slow colour development during ripening. It was found that the degree of lightness (L^*) and chroma (C^*) of Berangan banana peel in this study were lower compared with the previous study that was carried out by Ding and Darduri (2009). In addition, severe chilling injury in this study turned some part of the peel to black. Blackening is mainly due to the oxidation and polymerisation of free phenolics compounds that is caused by polyphenol oxidase (PPO) (Robinson, 1991; Hind *et al*., 1995, Promyou *et al*., 2008). A previous study from Nguyen *et al.* (2003) showed that blackening of the banana peel result of chilling injury was due to the concerted activities of phenylalanine ammonia lyase (PAL) and polyphenol oxidase.

The severity of chilling injury symptoms depend on the exposure time as well as temperature. According to Saraswathy *et al.* (2008), banana fruits stored at temperature above 13ºC can avoid chilling injury. Hall and Scott (1977) also found that bananas stored at 10ºC for 12 hours showed chilling symptoms in Cavendish bananas that were grown in the subtropical regions. However, Cavendish varieties grown in tropical area showed less tolerance

Table 3. Sensory scores# of Berangan banana fruits after different forced air cooling treatments

Treatments	Appearance	Flesh colour	Taste
A: Control	3.55 ± 0.95[a]	7.60 ± 0.75[a]	7.35 ± 0.75[a]
B:First half-cooling period (14 min)	6.25 ± 1.20[b]	7.65 ± 0.67[a]	7.40 ± 0.60[a]
C: Second half-cooling period (50 min)	3.90 ± 0.91[a]	7.55 ± 0.76[a]	7.35 ± 0.59[a]
D: Beyond Second half- cooling period (120 min)	3.65 ± 0.99[a]	7.35 ± 0.75[a]	7.25 ± 0.72[a]

[#]Mean ± standard deviation (n = 20); based on 9-point Hedonic scale (1-Dislike extremely to 9-like extremely)
[*]Mean values in the same column with different superscript lowercase letter are significantly different (P≤0.05)

and chilling damage can occurs when stored at 10ºC (Stover, 1972). Thus, the dull yellow of Berangan banana in this study may be caused by the low temperature (13 ± 1 ºC) during cold storage.

Results from Table 1 and 2 showed that quality attributes of Berangan banana in this study such as colour, SSC, pulp firmness and TA were not affected by forced-air precooling treatment. This could due to the banana fruits not being exposed to low temperatures long enough to experience damage or abnormal ripening. However, it was found that Berangan banana that were precooled to less than 13ºC (e.g. Set C and D) started developing chilling injury symptom such as black spots on banana peel after one week of storage in a cold room (13 ± 1ºC). The mean scores of sensory evaluation from Table 3 showed that Berangan banana were within the acceptable range in terms of flesh colour and taste. It was showed that the appearance of banana, such as blackening of peel, did not affect the flesh colour and taste. Although chilling injury did not affect most of the quality attributes and eating quality of Berangan banana, according to Stuart (2009), high appearance quality standards (e.g. weight, size, shape and appearance) of crops from supermarkets and consumers can lead to food waste. It is because some of the out-graded produces are rejected by supermarket at the farm gate or rejected by the consumer at the wholesale or retail market. Subsequently, these rejected fresh produces will be used as animal feed although their taste is still good and fit for human consumption. The appearance of the commodity is one of the most important criteria in the initial purchase because it acts as first quality determinants made by the buyer whether the wholesaler, retailer or consumer. Therefore, improper postharvest operation such as temperature management as shown in this study can cause quality deterioration and subsequently lead to undesirable postharvest losses.

Conclusion

The exposure time in precooling process depended greatly on the physiological or physical characteristics of the fruits and anticipated storage temperature. Although several studies found that seven-eighth cooling time is acceptably close to the required storage or transport temperature, this concept cannot apply to all types of commodities, especially for chilling sensitive fruit such as the banana. Improper cold storage conditions can also be another factor to cause the quality deterioration of banana. Insufficient knowledge, mishandling, improper postharvest management or misconceptions in the postharvest handling practices can lead to undesirable postharvest losses. Further studies are needed to investigate the influence of cold storage conditions on the changes of quality attributes on Berangan banana and hence, to find out the optimum combination of precooling process and cold storage conditions for Berangan banana.

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