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Mobile precooler for horticultural produces – a preliminary study

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Abstract
Cooling is one of the critical unit operations in the horticultural supply chain. Cooling shortly after harvest is called precooling. A mobile forced-air-cooler has been developed to visualize these precooling techniques. The mobile forced-air-cooler with a dimension of 0.6x0.15x1.3 m was developed using an axial fan with five nylon blade impeller and a fan capacity of 1425 rpm. During experiments, five boxes of fruits were stacked in two columns in a cold room for the precooling experiments. The mobile forced-air-cooler was placed in front of the stacks to draw the cold air through the stacks via the ventilation holes. Another room cooling experiments were also executed concurrently as a comparison. The fruits were then stored in a cold room for four weeks. Durian reduced its temperature to 9 °C from its initial temperature of 20 °C, while pineapple reached 14 °C from initial temperature of 25 °C after 7 hours of precooling experiments. The trials did not able to reach the seventh-eight cooling time however the fruits had a similar quality of fruits with cold room cooling experiments. Nevertheless, the cooling profiles showed a lower curved than cold room cooling. Recommendations and improvements to reach the desired seventh-eight cooling time were discussed.

Keywords: precooling, forced-air-cooler, durian, pineapple

Introduction

Horticultural produce is a biological material, that is even after separated from the parent plant, is still respiring and transpiring. Therefore, precooling is employed to slow down the metabolism, minimizing the respiratory heat generation, hindering the ripening, prevent moisture loss and microbial spoilage. Precooling was done rightly after harvest, to remove the field heat from the fresh produce. Various methods of precooling are available, including natural convective cooling, evaporative cooling, vacuum cooling and hydrocooling. Nevertheless, the most flexible and cost effective cooling method is forced-air-cooling (Ambaw et al., 2018; Elansari & Mostafa, 2018).

Tropical fruits are usually susceptible to chilling injury therefore they need to be cool to individual temperature requirement rapidly (ASHRAE, 2010). Pineapple is amongst one of the tropical fruits that has a short postharvest life span in ambient temperature and tends to deteriorate easily (Mandal et al., 2015). While durian, which is known as "Malaysian King of fruit" has wide acceptance for commercial market therefore a proper temperature management during postharvest handling is required. For forced-air-cooling of banana, Kuan et al. (2015) reported that the forced-air-cooled banana had lower pH and showed less chilling injury symptoms than the untreated banana.

In this study, a mobile precooler is developed as a direct cooling using air as a refrigerant coolant in cold room (Ambaw et al., 2018). During forced-air-cooling (FAC), cold airs are pushed through pallets via the ventilation holes in the stacked or palletized cartons (Wu et al., 2018). This paper discusses the development of the mobile precooling and its efficiencies in lowering the field heat of pineapples and durian.

Materials and methods

Plant Materials

Musang King variety of Durian and MD2 variety of pineapple were used in this study. After receiving, the durian and pineapple was kept at 25°C overnight. Four pieces of fruits were placed in each box (53x40x20 cm).

Mobile forced-air-cooling apparatus

The mobile forced air cooling apparatus was developed based on the concept of drawing the cold air to the stacks of produces. This mobile forced-air-cooling has a dimension of 0.6x0.15x1.3 m, equipped with five blades nylon impeller axial fan (EPMB-4E-350, Massive Fan, Malaysia) with 1425 RPM fan capacity. The developed mobile forced air cooler was depicted as in Figure 1. Tarpaulin sheet was used to cover the stacks of the fruit.

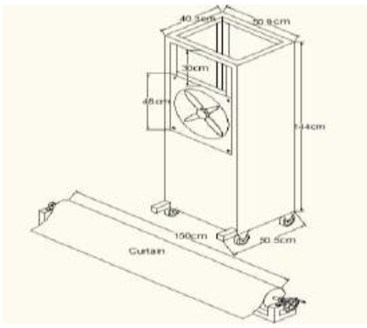

Figure 1. Mobile forced-air-cooler unit to precool horticultural produces

Experimental Setup

The developed mobile forced-air-cooler was placed inside a 20.6 m^3 cold room. The setting temperature of the cold room was predetermined (10 °C for durian and 7°C for pineapple). Five boxes of fruits were stacked on a pallet and placed in front of the forced-air-cooling unit. The arrangement of the stacked boxes was illustrated in the Figure 2. Tarpaulin sheet curtain was pulled to cover the whole stacks of boxes. The same configuration for cold room cooling was replicated at another cold room. The experiments were carried out concurrently. The forced-air-cooling was initiated by switching on the fan and stopped after seven hours of precooling trial.

Three temperature probes (HOBO, Massachusets) was drilled to the core of the fruits to log the core temperature of the fruits at every five minutes interval.

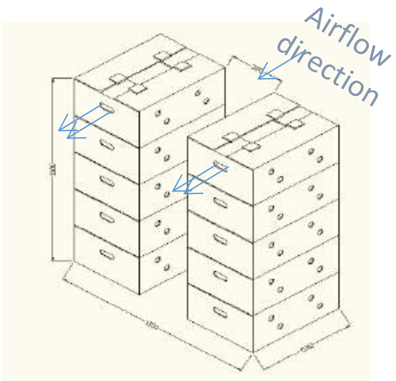

Figure 2. Fruits arrangement during forced-air-cooling experiments

Fruit quality assessment

After precooling experiments were carried out, the fruits were then stored for four weeks in the cold room. The fruit qualities were assessed subjectively by scoring in visual quality scoring indices for their visual appearances. The visual quality scoring indices used as described by Abdullah et al. in Mandal et al. (2015)

Results and discussion

Time-temperature response

The time-temperature response of the two different fruit commodities were showed in graph as in Figure 2. The cooling curves for both fruits did not significantly different when precooled with FAC techniques. The durian fruits reached 9.37 ° C after cold room cooling and 9.67° C after precooled using mobile FAC after seven hours. The pineapple reached 14.0 °C in cold room cooling and reached 13.6 °C after seven hours of precooled using mobile FAC. Linear regression was used to determine the line of best fit in the semilog graph in Figure 3, in which the slope of the regression line is the cooling coefficient, C ($hr^{-}1$). The steeper the slope of the graphs indicated the faster the cooling rate. The cooling coefficient was demonstrated as in Table 1. The highest cooling coefficient was from durian that was precooled using cold room cooling (-1.6625 hr^{-1}), while the pineapple that is precooled with mobile FAC unit has higher cooling coefficient (-1.3358 hr^{-1}) than the pineapple precooled using FAC unit (-1.292 hr^{-1}). Due to small difference in the cooling coefficient for both techniques of precooling, this might indicate that the mobile FAC did not significantly able to precool the fruits after seven hours.

Fruit Quality

The visual appearance of durian and pineapple after precooling treatment was demonstrated as in Figure 4 sample, after stored up to week 4. Durian also resulted in a comparable quality between the forced-air-cooling and cold room cooling samples after stored up to week 2.

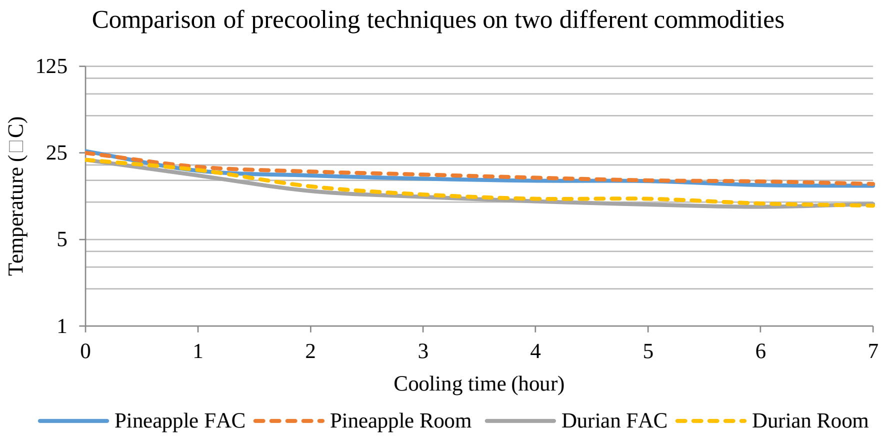

Figure 3. Time-temperature response of two different commodities on the forced-air-cooling techniques. Complete line (---) indicated the forced- air-cooling techniques, while the dash (- - -) indicated the room cooling techniques

Table 1: The cooling coefficient, C and R^2 of the fruit commodities at two different precooling treatments

Fruits	Treatment	Cooling Coefficient, C (hr^{-1})	R^2
Durian	RC	-1.6625	0.8031
	FAC	-1.5673	0.7320
Pineapple	RC	-1.2920	0.7906
	FAC	-1.3358	0.6275

*FAC is forced air cooling treatment
*RC is cold room cooling

Observations from the existing mobile precooler indicated that some improvement may be done to increase the efficiency of the precooler. Some recommendations for improvement are listed below for future references.

Fan type

The existing mobile precooler is using an axial fan with a 1425 m^3/h fan capacity. Axial fan moves the air parallel to the direction of inlet air. The air flow created by axial fan usually are low pressure but large in volume. It was recommended to use the centrifugal type fan. The prototype developed by Elansari and Mostafa (2018) and Mukama et al. (2017) used centrifugal fan. Centrifugal fan removes the air perpendicular to the direction of the inlet air. Differential pressure difference that created when the air flow is directed to the ducts resulted to higher pressure airflow.

Packaging type

In this experiment, a box was used as the packaging material for the fruits. The vent ratio of the box, at the front and the back is 3.3%, at the sides' 2.4 % and 29.8 % at the top. This vent ratio indicated that only 5% vent area to the total box area is provided to the fruits. Therefore, the increase of vent areas in the packaging is expected to improve the efficiency of the precooling.

Air flow distribution

The limitation or system boundary of this study is that the precooling experiment was carried out in the pre-existing facilities. The airflow distribution in the pre-existing cold room was found not uniform, and the largest air flow was at the point D in Figure 5 (A = 0.8 m^3/s, B = 0.4 m^3/s, C = 1.7 m^3/s, D = 2.4 m^3/s, E = 1.8 m^3/s, F = 0.3 m^3/s). As air flow also contributed to the effectiveness of the precooling method, the manipulation of this limitation should be considered in the future works.

Conclusions

The preliminary results from precooling using mobile forced-air-cooling unit showed that the cooling curve for forced air cooling was slightly lower than the cold room cooling curve when plotted linearly. When plotted in a semilog graph, the cooling coefficient showed a similar cooling rate, indicating that the forced-air-cooling efficiency was poor. The fruit quality also showed a comparable characteristic with cold room cooling.

Some recommendations are also discussed in this paper, such as fan type, packaging type and the airflow distribution. Further investigations on the forced-air-cooling with improvement on the observed parameters are needed to increase the efficiency of this precooling method.

Figure 4a. Pineapple fruits at week 0

Figure 4b. Cold room cooling pineapple at week 4

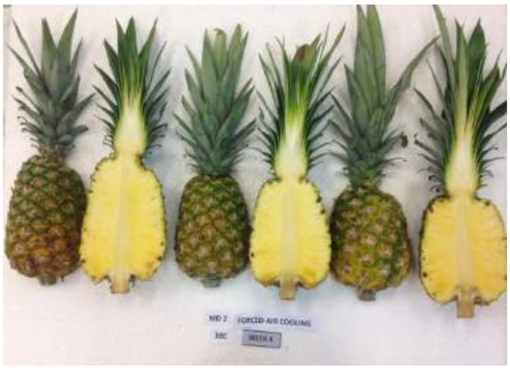

Figure 4c. Forced air cooling pineapple at week 4

Figure 4. The overall appearance of pineapples after storage up to week

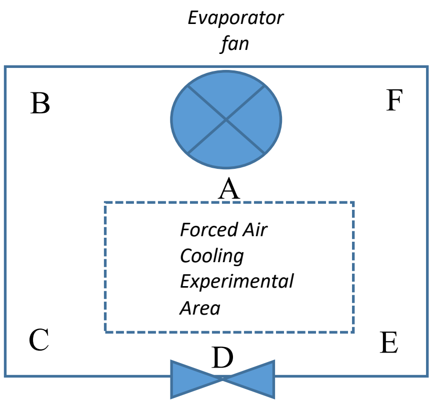

Figure 5. Air flow distribution in the pre-existing cold room

Figure 6a. Durian fruits at week 0

Figure 6b. Durian fruits at week 2 after cold room cooling

Figure 6c. Durian fruits at week 2after force air cooling

Figure 6. The overall appearance of durian fruits after storage up to week 2

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