Calculating quantities of ice gel for cooling of fresh-cut melon in temporary storage box during distribution

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Abstract. Temperature reduction can be done by adding a cooling media, one of which is ice gel. The use of ice gel as a cooling medium should take notice of the load heat during distribution because the load of heat that is removed by ice gel is limited. The calculation of the required heat load that needed to be removed to determine the amount of ice gel required during distribution. The calculations include the heat load of the storage box, the heat load of the fruit, and the heat load of the fruit respiration. The temporary storage box is made of thermotec heat shield material and has 3 shelves. This study uses fresh-cut melon as a sample of stored fruit. The result of calculating the ice gel needed in the distribution and storage for the top shelf and middle shelf respectively as many as 3 ice gel and the bottom shelf is 2 of ice gel 0.496 grams to storage 22 fresh-cut melon-sized 60 grams.

Keywords: fresh-cut melon, distribution, ice gel, thermotec heat shield.

1. Introduction

High fruit production in Indonesia has not been followed by proper post-harvest handling. The handling of post-harvest fruit should be increased so that the fruit can be served in a fresh condition for the consumers. After plucked, fruit respiration continues and major biochemical processes occur after harvesting. The respiration rate is an indicator of the metabolic activity of fruit. High respiration rate of fruit cause product decay and short shelf life. Fruit product decay can be slowed down by lowering the respiration rate of fruit that can be obtained by cold storage [1].

The easiest to serve the fruits are in fresh-cut fruit type. One of the popular fruits served in fresh-cut type is melon (Cucumis melo L.). The fresh-cut melon is very susceptible to quality degradation because the fresh-cut melon lost skin as its protection. Proper storage is necessary for keeping the good quality of the fruit, both physical appearance, and nutritional content. One way of storing fresh-cut fruits to keep it fresh is to store the fruit in cold temperatures [2]. The purpose of cold storage is to reduce the respiration rate, high respiration rate can accelerate the maturation of the fruit so that it can reduce the shelf life of fruit [3]. Temperature reduction can be done by adding a cooling medium, one of which is ice gel.

Ice gel is a cooling medium that is well used for fruit and vegetable storage. Ice gel is safe to use because it is non-toxic, environmentally friendly, it’s suitable for agricultural commodities [4]. The use of ice gel as a cooling medium should take notice of storage space and long storage time because the load of heat that is removed by ice gel is limited. The required heat load calculation needed to be
eliminated to determine the amount of ice gel to be used during storage. Calculation of ice gel needed also depends on the characteristics of the fruit and the storage device. Characteristics of fruits that should take notice such as the specific heat and density, because each fruit has different characteristics. And characteristics of storage device that should take notice such as heat conductivity and heat coefficient.

The purpose of this study is to know the amount of ice gel as a cooling medium that will be used during the distribution and storage of fresh-cut melon. Fresh-cut melon storage on a temporary storage box for 6 hours with the expected temperature of 18°C. The box storage made of thermotec insulated shield materials and be equipped with a temperature and humidity sensor. The box has dimensions measuring is 46x35x45 cm and has a handle bag-like design for easy distribution.

2. Materials and Methods

2.1. Material
The tools used in the research include a temporary fruit storage box. The materials used are secondary data and primary data on the characteristics of the temporary storage box, fresh-cut melon, and ice gels. Secondary data derived from reports of the research results, journals, and textbooks, and the primary data are measured directly. The temporary storage box has a dimension of 46x35x45 cm, made of thermotec heat shield material consisting of three shelves. Thermotec insulated heat shield is a combination of aluminum foil and glasswool. Aluminum foil serves as a conductor of heat so the heat spreads equally inside the box. Glasswool holds the heat so that the low temperature in the storage device can last a long time. Temporary storage box characteristics are shown in table 1.

| Characteristics | Value | Information |
|-----------------|-------|-------------|
| Length          | 0.46 m| Measurement |
| Width           | 0.35 m| Measurement |
| High            | 0.45 m| Measurement |
| Thickness       | 0005 m| Measurement |
| Heat coefficient| 0.59 W/m²°C | [5] |
| Conductivities Move Heat | 0.032 W/m°C | [6] |

The samples that used are fresh-cut melon with a weight of 60 grams with the amount of 22 pieces, with a total weight of 1.320 kilograms. The characteristics of fresh melon are shown in table 2.

| Characteristics | Value   | Source |
|-----------------|---------|--------|
| Weight          | 1.32 kg | Measurement |
| Density         | 0.905 g/ml | [7] |
| Specific Heat melon | 3926 J/kg°C | [8] |
| Respiration Rate| 51.8 ml/kg.hourCO₂ | Measurement |
| Fruit temperature| 25°C | Measurement |

Ice gel can serve as a replacement for ice cubes that can be worn repeatedly in maintaining the cold temperature. Ice gel has the advantage of staying dry when temperatures start to increase. In addition, ice gel is safe to use because it is non-toxic and environmentally friendly, making it suitable for cold storage of foodstuffs [3]. Ice gel characteristics are shown in table 3.
### Table 3. Characteristics of ice gel

| Characteristics       | Value     | Source |
|-----------------------|-----------|--------|
| Gross weight          | 496 gram  | Measurement |
| Dimensions            | 17 x 15 cm | Measurement |
| Freezing temperature  | -7°C      | [9]    |
| Melting temperature   | 0°C       | [9]    |
| Final temperature     | 25°C      | [9]    |
| Specific heat         | 3583.9 J/kg °C | [10] |

#### 2.2. Method

The research begins with the calculation of ice gel needed to be used to cool the temporary storage box for 6 hours.

a. Calculate the heat load of the temporary storage box. [10]

\[ Q = \frac{1}{\left( \frac{1}{h} + \frac{1}{k} \right)} A(T_a - T_r) \]  

*Description:*
- \( Q \): Loads through walls (W)
- \( k \): Conductivity of packaging (W/m·°C)
- \( h \): Heat coefficient (W/m²·°C)
- \( T_a \): Initial temperature (°C)
- \( T_r \): Final temperature (°C)
- \( x \): Thickness (m)
- \( A \): Surface area (m²)

b. Calculate the heat load of the fruit. [10]

\[ Q = m \cdot C_p \cdot (T_a - T_r) \]  

*Description:
- \( Q \): Heat load of fruit (J)
- \( m \): Weight of fruit (Kg)
- \( C_p \): Specific heat of fruit (J/Kg·°C)
- \( T_a \): Initial temperature (°C)
- \( T_r \): Final temperature (°C)

c. Calculate the heat load of respiration fruit [10]

\[ Q = \frac{R \times p \times 61.2 \times m \times 4.186 \times 1000}{60 \times 21600} \]  

*Description:
- \( Q \): Heat load of respiration fruit (W)
- \( m \): Weight of fruit (kg)
- \( R \): Density of fruit (g/ml)
- \( p \): Respiration rate of fruit (ml/kg·jamCO₂)

d. Calculate the total heat load that should be removed [10]

\[ Q_{\text{total}} = Q_{\text{box}} + Q_{\text{fruit}} + Q_{\text{respiration}} \]  

e. Calculate the load drop of ice gel [10]

\[ Q_{\text{ice gel}} = \text{weight of ice gel} \times \text{specific heat} \times \text{final temperature} \]
f. Calculate the amount of ice gel needed [10]

\[ N = \frac{Q_{\text{total}}}{Q_{\text{ice gel}}} \]  

Description
N: Amount of ice gel

Assumptions used in the calculation of ice gel needed:

a) Heat the type of ice gel used is equal to the heat of the type found in the reference.
b) The Effect of fan and plywood ignored.
c) Respiration rate and the density of melon fruit from the reference are considered equal to fresh-cut melon.

3. Result and Discussion

3.1. Calculating quantities of ice gel

The calculation of the use of ice gel begins by calculating the heat load to be eliminated. The source of the heat load comes from the storage device, heat load to cool down the fresh-cut melon, and the respiration that load by the fresh-cut melon.

3.1.1. Calculate the heat load of the temporary storage box. Storage consists of the top shelf, middle shelf, and bottom shelf. The storage of melon fruit is done on the top shelf and the middle shelf while the bottom shelf contains only a device of temperature and humidity sensor inside the temporary storage box. Results measurement of dimensions and surface area of shelves on temporary storage box are shown in table 4.

| Table 4. Dimensions and surface area of shelves on storage tool |
|---------------------------------------------------------------|
| Top shelf | Long (m) | Wide (m) | Tall (m) | Surface area (m²) |
|-----------|----------|----------|----------|--------------------|
|           | 0.46     | 0.35     | 0.18     | 0.6136             |
| Middle shelf | 0.46     | 0.35     | 0.16     | 0.5812             |
| Bottom shelf | 0.46     | 0.35     | 0.11     | 0.5002             |

The heat load calculation of the storage tool is used to know the heat loads that should be eliminated to get a lower temperature on the temporary storage box. The calculation takes notice of the conductivity and heat coefficient of the temporary storage box, in this case is the thermotec heat shield. It also takes notice of the surface area of the storage and temperature that want to keep. The surface area and initial temperature are obtained by measuring. The surface area of the temporary storage box is shown in table 4.

The \( h \) equal to heat coefficient of thermotec is 0.59 W/m² °C based on the references and \( k \) equal to thermotec conductivities is 0.032 W/m °C according to Table 1. The \( x \) equal to thermotec thickness is 0.005 m obtained from measurements. The surface area is based on Table 4 and the cooling temperature decrease is from initial temperature 25 °C to cooled temperature 18 °C. The result of the calculation heat-load of the temporary storage box for the top shelf amounted to 2.3203 W; the middle shelf is 2.1978 W. and the bottom shelf is 1.8915 W.

3.1.2. Calculate the heat load of the fruit. Fresh-cut melons are stored only on the top shelf and middle shelf. Both shelves are filled with 11 pieces of melon cut with a total weight of 0.66 kilograms. The calculation formula of the fruit heat load refers to the formula (2). Calculation of heat load fresh-cut melon is used to know the heat load that needs to be eliminated to make the fresh-cut melon have a specified temperature of 18°C. Specific heat of fresh-cut melon by 3926 J/Kg °C based on Food Agricultural Organization data. The heat load is calculated during the distribution and the storage process is 6 hours to be obtained top shelf and middle shelf respectively 0.8397 W, while the bottom shelf of 0 W or does not have a heat load of the fruit because it is not used as storage.
3.1.3. Calculate the heat load of respiration fruit. The calculation of the melon fruit respiration load is also only on the top shelf and middle shelf because only both shelves are used for the storage of fresh-cut melon. The calculation formula for a fresh-cut melon respiration loads refers to the formula (3). The calculation of the respiration heat load is purposed to knowing the heat load produced by the fresh-cut melon during respiration. The respiration of the fruit produces energy, so it is calculated to know the load to be derived from the respiration process.

The respiratory rate of the melon fruit 51.8 ml/kg.hourCO$_2$ obtained from the measurement results already done before. Density 0.905 g/ml of melon fruit obtained from table 2. The number 61.2 is used to convert mg/kg.CO$_2$ to kcal/tons of day. The calculation of the heat production of respiration evidence that 1 mg of CO$_2$/kg.hour indicates heat production 61.2 kcal/metric tons of day [11]. So by knowing the rate of CO$_2$ in the respiration can be predicted also heat produced. From the results of the calculations obtained heat loads top shelf and middle shelf respectively at 0.3670 W, while the bottom shelf of 0 W because it is not used as a fruit storage.

3.1.4. Calculate the total heat load that should be removed. The total heat load or Q total is the overall load of heat that needs to be eliminated. Q total consists of a heat load of the temporary storage box, the heat load of fresh-cut melon, and heat loads of fresh-cut melon respiration. The formula of Q total refers to the formula (4). The result of calculating the total load to be removed is the top shelf of 3.5270 W; the middle shelf of 3.4044 W and the bottom shelf amounted to 1.8915 W.

3.1.5. Calculate the load drop of ice gel. The load drop by ice gel is a load that can be lowered by one ice gel during the storage and distribution process. Q Ice Gel is calculated by multiplying the weight of ice gel with specific heat and the temperature wants to achieve which is then divided during storage time and distribution. The formula of decreased load by ice gel refers to the formula (5). The specific heat of ice gel of 3583.9 J/kg °C was based on table 3. Storage and distribution calculations were performed for 6 hours. The result of decreased load calculation by ice gel is 1.4823 W.

3.1.6. Calculate the amount of ice gel needed. Ice gel needed is calculated for each shelf. The formula of calculation of ice gel needed refers to the formula (7). Ice gel needed is calculated to find out how much ice gel is needed to lower the temperature up to 18°C. Ice gel needed are calculated by dividing Q total with Q ice gel. The result of the calculation of the top shelf ice gel needed is 2.3809; the middle shelf ice gel needed is 2.2982 and the bottom shelf is 1.2769.

| Calculation                      | Top shelf | Middle shelf | Bottom shelf | Units | Formula |
|----------------------------------|-----------|--------------|--------------|-------|---------|
| The heat load of the box         | 2.3203    | 2.1978       | 1.8915       | W     | Eq.1    |
| The heat load of the fruit       | 0.8397    | 0.8397       | 0            | W     | Eq.2    |
| The heat load of respiration fruit | 0.367    | 0.367        | 0            | W     | Eq.3    |
| Total heat load that should be removed | 3.527 | 3.4044       | 1.8915       | W     | Eq.4    |
| Load drop of ice gel            | 1.4813    | 1.4813       | 1.4813       | W     | Eq.5    |
| Amount of ice gel needs         | 2.38      | 2.2984       | 1.2764       |       | Eq.6    |

So the distribution and storage for fresh-cut melon is needed ice gel for the top shelf and the middle shelf respectively as many as 3 ice gel and the bottom shelf is 2 of ice gel 0.496 grams.

4. Conclusion
The use of ice gel as a cooling medium should take notice of media or storage and type of agriculture commodity. Each type of storage media and agriculture commodity has different characteristics and heat
loads, so the use of ice gel takes place effectively and efficiently. Based on this study the distribution and storage for fresh-cut melon is needed ice gel for the top shelf and the middle shelf respectively as many as 3 ice gel and the bottom shelf is 2 of ice gel 0.496 grams to storage 22 fresh-cut melon-sized 60 grams.

References
[1] Swadianto, Stanley. 2010. Effect of Temperature on the Rate of Respiration and Production of Ethylene in Post-Harvest Mangosteen. Thesis. Faculty of Mathematics and Science. IPB University. Bogor.
[2] Sitohang, Aci H. 2017. Effect of Fruit and Vegetable Storage Systems on the Quality of Food Products Cold Kitchen Grand Swiss Belheatel Medan. Paper works. The University of North Sumatera. Medan.
[3] Samad, M Yusuf. 2018. The Effect of Post-Harvest Handling to Horticultural Commodity Quality. Indonesian Journal of Science and Technology 8 (1): 31-36
[4] Novitasari, Rizkia D. 2014. Use of Ice Gel as cooling Media on sale of Papaya fruit (Carica papaya L.) Cut. Thesis. Faculty of Agricultural Technology. IPB University. Bogor.
[5] Khalif, Abdul Jabbar N., and Al Mousawi, I. R. A. 2016. Comparison of Heat Transfer Coefficient in Free and Forced Convection Using Circular Annular Finned Tubes. International Journal If Application or Innovational In Engineering & Management 5 (4): 194-204
[6] Thermotec Pipe Brochure-Thermotec Australia Ltd. Profile. https://www.spec-net.com.au/
[7] Kohsnam, F., Namjoo, M., Golbakhshi, H., and Dowlati, M. 2016. Physical And Mechanical Changes In Ripening Melon Fruits. Article Research. Faculty of Agriculture. Jiroft University. Iran.
[8] Food Agricultural Organization. 1992. Thermal Properties Melon. Thailand.
[9] Fatima, G. A. Y. 2013. Study of use of Ice Gel as cooling packaging Media for green Sawi distribution. Thesis. Department of Mechanical and Biosystem. Faculty of Agricultural Technology. IPB University. Bogor.
[10] Nurkusumaprama, A., Darmawati, E., and Purwanto, Y. A. 2014. Ice Gel application on packaging for transportation and temporary storage Oyster mushroom (Pleurotus Ostreatus). Agricultural Engineering Journals 2 (2)
[11] Saltviet, M.E. 2010. Measuring Respiration. Thesis. California University. California.