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Application of Ice Gel for Edible Flowers Distribution Packaging of Butterfly Pea

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Abstract

Butterfly pea (Clitoria ternatea) is a popular edible flower in Indonesia that is rich in antioxidants. However, they are perishable and sensitive to temperature changes during storage and transportation. The use of ice gel in distribution packaging has been identified as an effective solution to maintain its quality. This study aimed to determine the optimal positioning of ice gel in two types of distribution packaging: a Styrofoam box and an insulated box. The experiment involved cooling 36 g of flowers per distribution package over 2 h of simulation using six pieces of ice gel at two different positions (positions 1 and 2). The results showed that the ice gel placed in position 2 reduced the temperature inside the packaging more rapidly and maintained the lowest temperature for a longer period than the ice gel placed in position 1. Therefore, placing the ice gel in position 2 is the best option for application in the distribution package. Ice gel position 2 can reduce the flower's temperature from 20°C to 10.7°C in the Styrofoam box and from 20°C to 11°C in the insulated box during simulation.

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1. Introduction

Telang flower (*Clitoria ternatea*) or commonly called *butterfly pea* or *blue pea* is a flower that has an attractive color and contains many antioxidants and antibacterials. Telang flowers can be used in their fresh form after being picked as *edible flowers* and in other processed forms. However, edible flowers should be consumed in a fresh form, as they contain more nutrients than the processed form (MIcek and Rop, 2011). Processed forms, such as dried products, contain fewer nutrients because some components are lost during processing. Fresh Telang flowers, such as edible flowers, include perishable products or products that are easily damaged after harvesting. High moisture content and respiration rates cause flowers to deteriorate faster and shorten their shelf lives. Once harvested, the flowers are susceptible to petal abscission, discoloration, wilting, dehydration, and browning (Kou et al., 2012).

During distribution, spring-flower suppliers usually rely only on simple packaging in the form of polypropylene (PP) plastic boxes as primary packaging, and there are few suppliers who distribute edible flowers in large quantities over long distances because they are worried that the flowers will be damaged during the journey. Therefore, secondary packaging is required for distribution packaging to maintain the quality of edible flowers. Refrigerated distribution packaging is widely used to store fresh and frozen products during transportation, such as meat, cut fruits, vegetables, milk, and medicines. However, research on the refrigerated distribution packaging of edible flowers is limited. Refrigerated packaging typically uses ice cubes, dry ice, or ice gels. However, ice gel is considered to be more effective than other cooling media (Ismanto et al., 2013).

Therefore, distribution packaging using ice gel cooling media is an alternative to cold distribution systems that do not use more expensive refrigerated modes of transportation. The purpose of this research was to design refrigerated packaging by assessing the best position of ice gel to be applied to Styrofoam boxes and insulated boxes.

2. Materials and methods

2.1 Tools and Materials

The tools used in this study were digital and analytical scales, ovens, desiccators, refrigerators, freezers, gas analyzers, transporting simulator tables, thermocouples, and hybrid recorders. The materials used were dark blue single petal flowers, clear ice gel, zip packaging for repack, polypropylene (PP) plastic boxes or thin wall packaging, 1 cm thick Styrofoam boxes and 0.6 cm thick insulated boxes.

2.2 Research Procedure

2.2.1 Preparation of Materials

The blossoms were harvested in the morning and stored at 10°C in a refrigerator for 3 h to reduce the heat load when placed in the packaging. After storage, the temperature of the flowers was measured again and the flowers were placed in a thin wall covered with tissue. Each distribution pack consisted of four thin walls and six ice-gel repacks. Each thin wall contained 25 florets; therefore, one distribution pack consisted of 100 florets or 36 g flowers. The thinwall and ice gel repack used were 17.5 cm × 12 cm × 4 cm (500 ml) and 8 cm × 12 cm × 0.5 cm, respectively.

2.2.2 Measuring the water content of butterfly pea flowers.

The water content was measured by the thermogravimetric method using Equation 1 (AOAC, 2005).

$$\text{Water content (\%bb)} = \frac{B-C}{B-A} \times 100\% \quad (1)$$

where A= Mass of the empty cup (g), B= Mass of the cup plus the initial flower sample (g), and C= Mass of the cup plus the final flower sample (g).

2.2.3 Calculation of the heat of butterfly pea flower types

The empirical equation used to estimate the specific heat of agricultural materials is as follows: According to ASHRAE (2005), 4.187 is the specific heat of water at 15 °C.

$$Cp = 4.187 \times (0.6 \times \mathrm{Ka} + 0.4) \tag{2}$$

where Cp= Specific heat of flowers (J/kg°C) and Ka= Moisture content of flowers (%).

2.2.4 Measurement of respiration rate of butterfly pea flowers

The closed-system method using Equation 3 was used to measure the respiration rate (Hasbullah, 2007).

$$R = \frac{v}{w} \times \frac{dx}{dt} \tag{3}$$

where R= Respiration rate (ml/kg h), v is the free volume of the container (ml), w is the sample weight (kg), and dx/dt is the rate of change of the CO_2 concentration (%/h).

2.2.5 Calculation of heat load and ice gel requirements

The need for ice gel is determined by the amount of heat load that must be removed from the package wall, sprouts, respiration of sprouts, and the ability of the ice gel to absorb heat. The following equations were used to determine the heat load required by the ice gel:

2.2.6 Calculation of packaging wall heat load

The heat on the packaging wall was calculated using Equation 4 (Nurkusumaprama et al., 2014).

$$Q_{\mathrm{dk}} = \frac{1}{\left(\frac{1}{h} + \frac{x}{k}\right)} \times A \times (T_a - T_r) \tag{4}$$

where Qdk denotes the heat load of the package wall (W), h denotes the heat transfer coefficient (W/m^2°C), k denotes the thermal conductivity of the package (W/m°C), Ta denotes the temperature of the outer surface of the package (°C), Tr denotes the temperature to be achieved (10°C), x denotes the package wall thickness (m), and A denotes the surface area of the package wall (m^2).

2.2.7 Calculation of the heat load of butterfly pea flowers

The heat generated by butterfly pea flowers was calculated using Equation 5:

$$Q_{bt} = \frac{m \times Cp \times (T_a - T_r)}{t} \tag{5}$$

where Qbt= Heat load of the butterfly peaflower (W), m is the mass of the butterfly peaflower (kg), Cp= Specific heat of the flower (J/kg°C), Ta= Initial temperature of the flower (°C), Tr= Temperature required to reach 10°C, and t is transportation time (s).

2.2.8 The calculation of heat load due to respiration of butterfly pea flowers

The calculation of the heat load due to respiration of butterfly pea flowers is given by Equation 6 (Nurkusumaprama et al., 2014):

$$Qr = \frac{R \times \rho \times 1000\, {}^{mg}/_{g} \times 61.2\; x\; 4.186 \times m}{1000\, {}^{kg}/_{ton} \times 86400\, {}^{Second}/_{Day}} \tag{6}$$

where Qr= Respiration heat load (W), m is the mass of the butterfly pea flower (kg), ϱ is the density of the flower (g/ml), and R is the respiration rate (ml/kg h).

2.2.9 Calculation of the ability of ice gel to absorb heat

The ability of ice gel to absorb heat can be calculated using Equations 7, 8, and 9.

$$Q_{ice\ gel}\ \text{(sensible)} = \frac{m \times Cp \times (T_a - T_r)}{t} \tag{7}$$

$$Q_{ice\ gel}\ \text{(laten)} = \frac{m \times L}{t} \tag{8}$$

$$Q_{ice\ gel} = Q_{ice\ gel}\ \text{(sensible)} + Q_{ice\ gel}\ \text{(laten)} \tag{9}$$

where m is the mass of the ice gel (kg), Cp = Specific heat of the ice gel (J/kg°C), Ta = Initial temperature of the ice gel (°C), Tr = Temperature to reach = 10°C, t is the transportation time (s), and L = Melting heat of the ice gel (J/kg).

2.2.10 Calculation of ice gel requirements

Based on the above equations, the ice gel requirement in the package can be calculated using Equation 10.

$$\text{Quantity of ice gel required} = \frac{Q_{dk} + Q_{bt} + Q_r}{Q_{ice\ gel}} \tag{10}$$

2.2.11 Determination of distribution packaging dimensions

The distribution packaging dimensions were determined by inputting thin-walled dimensions based on Equations 11, 12, and 13.

$$PK = TLT + TTIG(1) + TTKD \tag{11}$$

$$LK = TPT + TTIG(1) + TTKD \tag{12}$$

$$TK = TTT + TTIG(1) + TTKD \tag{13}$$

where PK= Pack length (cm), LK= Pack width (cm), TK= Pack height (cm), TLT= Total thinwall width (cm), TPT= Total thinwall length (cm), TTT= Total thinwall height (cm), TTIG(1)= total thickness of ice gel position 1 (cm), and TTKD= Total thickness of distribution pack (cm).

2.2.12 No-load Temperature Distribution Measurements

Determination of the best ice gel position is based on the speed of the temperature distribution in the package and the length of time the ice gel can maintain the lowest temperature in the package. There are 14 temperature measurement points for each distribution package, namely, six points on the ice gel and eight points on the thin wall, as shown in Figure 1.

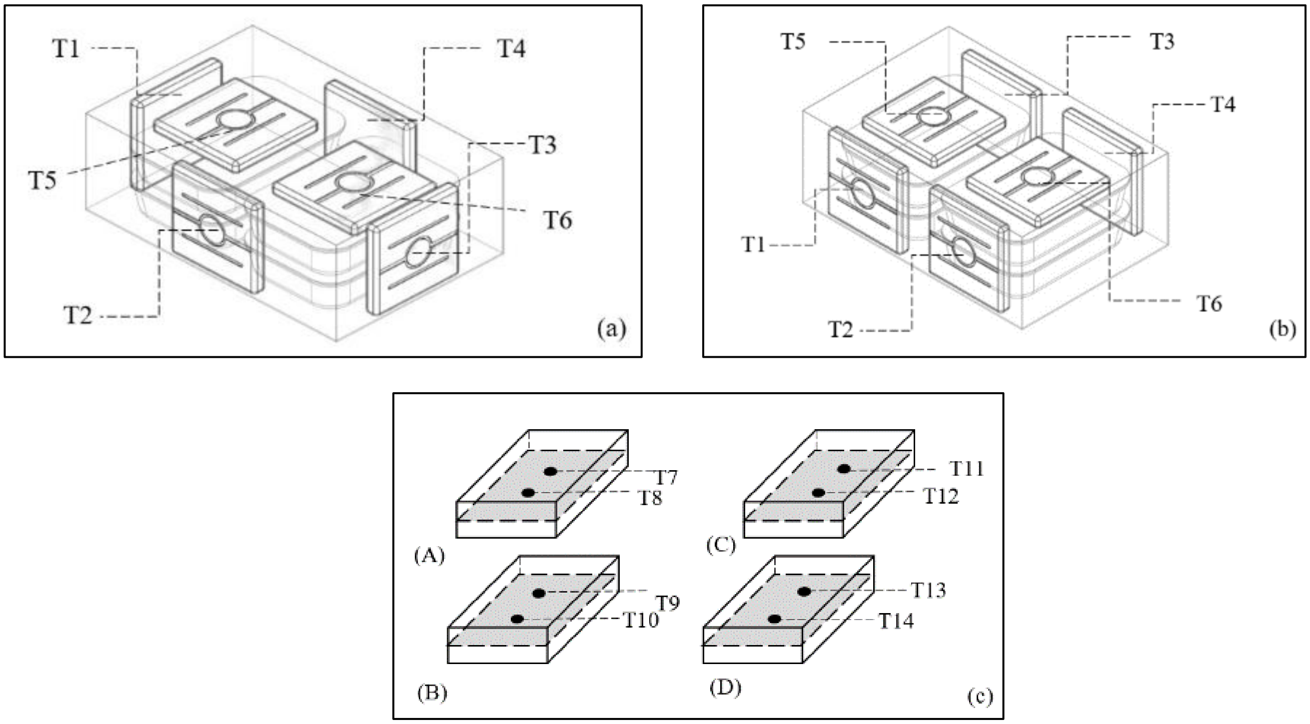

Figure 1. Temperature measurement points at ice gel position 1 (a), ice gel position 2 (b), and thin wall (c).

2.2.13 Transportation simulation

Before the simulation, the ice gel with the best position generated based on the temperature distribution without a load was placed into the distribution package that had been subjected to a load, which was the butterfly pea flower. The treatments were the Styrofoam box (A1), insulated box (A2), without ice gel (B1), and with ice gel (B2), so there were four treatment combinations, namely A1B1, A1B2, A2B1, and A2B2. During the simulation, temperature measurements were performed on the flowers inside the four thin walls every 30 min. Based on the calculation, the transportation simulation was carried out for 2 h with an average amplitude of 3.006 cm and an average frequency value of 4.26 Hz, which is equivalent to a distance of 103.9 km on a road outside the city at a speed of 60 km/h.

3. Result and discussion

3.1 Characteristics of ice gel

The ice gel used in this study was designed to cool 36 g of Telang flowers at an initial temperature of 20^0C – 10°C for 2 h of transportation. The ice gel used in this study was a clear-colored repack with dimensions 8 × 12 × 0.5 cm. Based on the measurements, the freezing temperature of the repack ice gel inside both distribution packs was -9.4°C with a melting temperature of -0.2°C. The repack ice gel melted as its temperature of the ice gel increased. The repacked ice gel in the distribution pack melted completely within 220 min. The repack ice gel melted faster than the original ice gel from the market because of its smaller surface area and volume. The original ice gel weighed 1095.5 g with dimensions of 30 × 15 × 3 cm and melted completely for 360 min at a freezing temperature of -7°C and a melting temperature of 0°C (Nurkusumaprama et al., 2014). Ice gel, which has a small surface area and volume, melts faster and vice versa (Singh et al., 2008). The original ice gel has a large weight and dimensions that cannot be applied to the distribution packaging of telang flowers, whereas the repack ice gel can be adapted to the distribution packaging and has a relatively longer defrosting time than other cooling media such as ice cubes. Therefore, ice gel repacks have the potential to maintain the temperature of butterfly pea flowers.

3.2 Packaging characteristics

The types of distribution packaging used in this study were Styrofoam boxes and insulated boxes, as shown in Figure 2. Styrofoam boxes made of polystyrene are insulation materials that are widely used in cold packaging because they are lightweight, rigid, and malleable (Khairulmaini et al., 2020). Polystyrene has a low thermal conductivity of 0.033 W/m°C, and thus, it can maintain heat transfer. The insulated box consists of 1-layer corrugated cardboard on the outside and an aluminum foil bubble on the inside. The aluminum foil bubble was composed of aluminum foil and polyethylene bubbles with a thermal conductivity of 0.038 W/m°C. The heat transfer coefficient value on the Styrofoam box was 1.032 W/m2^{o}C and that on the insulated box was 1.083 W/m^2°C (Khairulmaini et al., 2020).

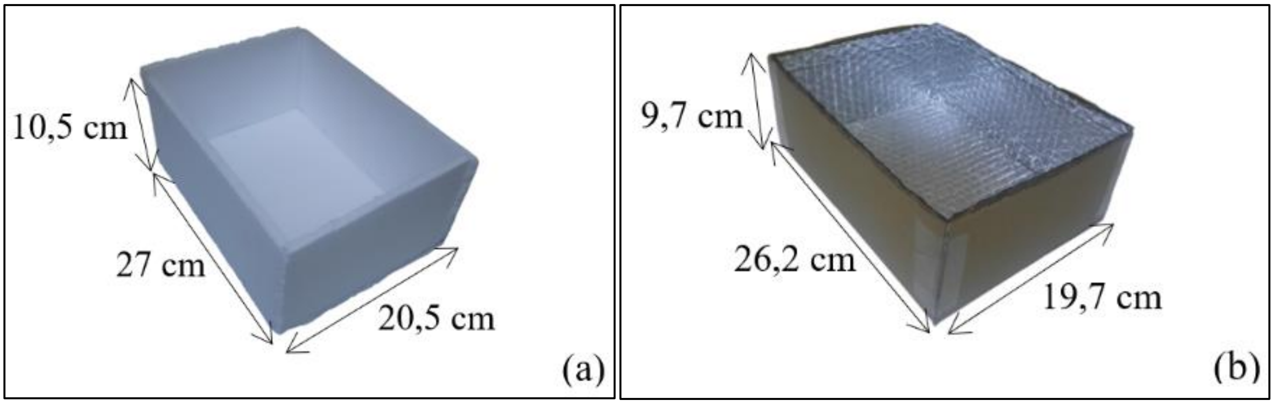

Figure 2. Dimensions of the Styrofoam box (a) and insulated box (b).

3.3 Ice gel needs

The ice gel requirement was obtained by dividing the amount of heat load released by the amount of heat absorbed by the ice gel. The total heat load released was 2,659 W in the Styrofoam box and 2,856 W in the insulated box. The heat load of the insulated box is greater because it has a greater conductivity value; thus, more heat is generated. Butterfly pea flowers with an initial moisture content of 88.52% and a specific heat of 224.05 J/kg°C had a small heat load of 0.00336W, as well as a respiration heat load of 0.00045 W. This was influenced by the total weight of the cooled flowers. The heavier the product, the greater the heat load generated. In this study, only 36 g of flowers were used, so the heat load generated or released was very small. The total load absorbed by the ice gel was -57.113 W. Negative or negative values indicate that heat was absorbed by the ice gel. The total ice gel required is 47 g in the Styrofoam box and 50g in the insulated box with the weight of each ice gel repack being 7.7 g in the Styrofoam box and 8.3g in the insulated box.

3.4 Temperature distribution without load

The distribution of temperature without load is shown in Figure 3 and 4. Based on Figure 3, it can be seen that the lines coincide so that it can be said that the ice gel used is relatively homogeneous. The position of the ice gel affected its temperature change of the ice gel. The ice gel in the Styrofoam box melts entirely at 15.1°C and 15.2°C respectively, while the ice gel in the insulated box melts entirely at the same temperature of 15.2°C. As shown in Figures 4a and 4b, the initial temperature in the packaging room was 26°C, which decreased after ice gel was applied. A decrease in room temperature occurs because of convective heat transfer (Amalia et al., 2016). Based on the speed, ice gel positions 1 and 2 can cool the temperature of the packaging room to 16.8°C and 15.5°C in the initial 10 min, respectively. The lowest pack room temperatures achieved by ice gel positions 1 and 2 were 10.3°C and 10.1°C , respectively, which could be maintained for 100 minutes and 110 minutes. Figures

4c and 4d show the distribution of room temperature in the insulated box. Ice gel positions 1 and 2 can cool the room temperature of the package to 19.5°C and 18.9°C, respectively, in the first 10 minutes. Ice gel position 1 was able to cool the room temperature to 10.5°C for 100 min and for 110 min with ice gel position 2. Thus, it can be said that position 2 ice gel is faster in cooling the space and maintains the lowest temperature for longer in both distribution packages. Therefore, the ice gel position selected for application during the simulation was 2.

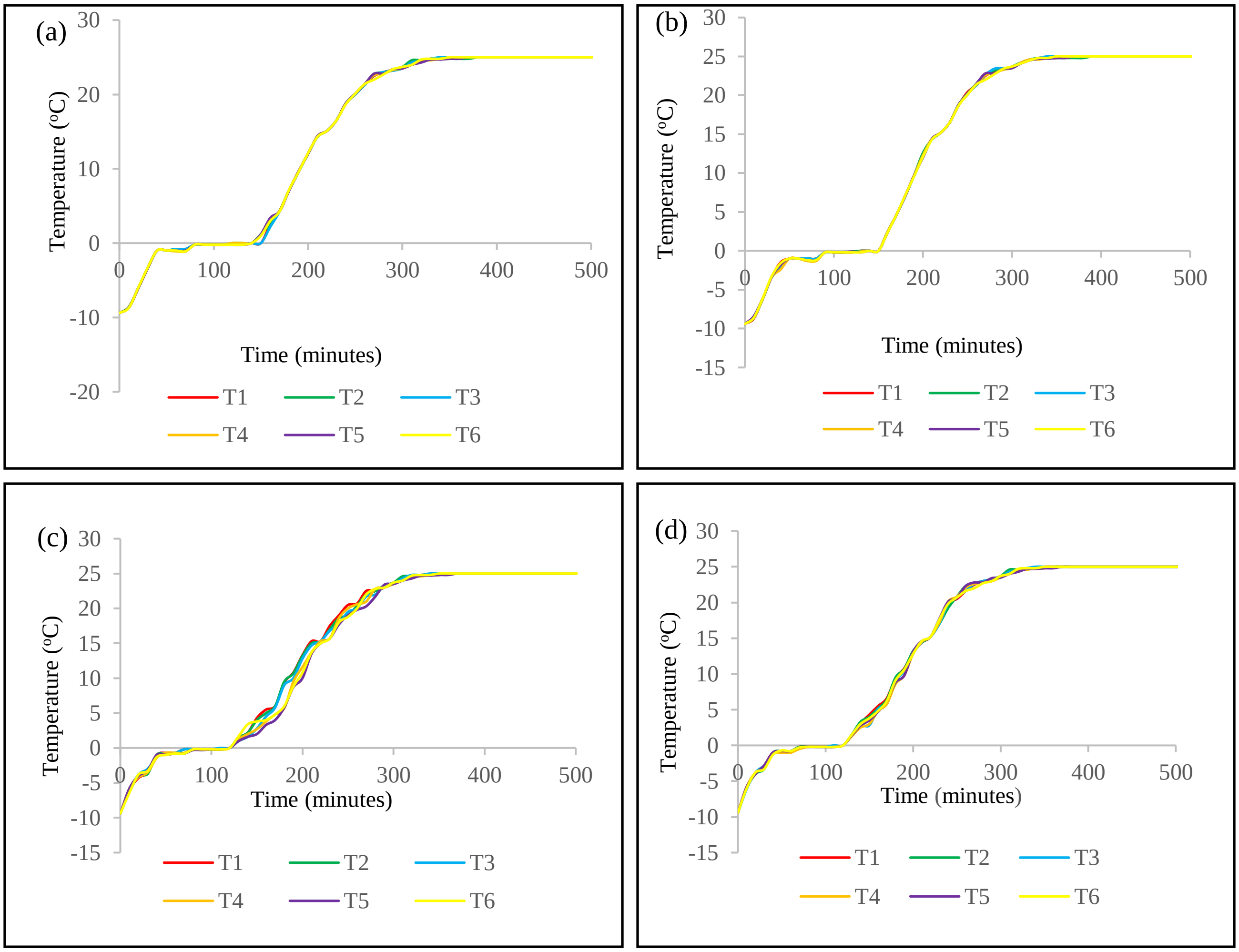

Figure 3. Temperature change of unloaded ice gel with ice gel position 1 in Styrofoam box (a), ice gel position 2 in Styrofoam box (b), ice gel position 1 in insulated box (c), and ice gel position 2 in insulated box (d).

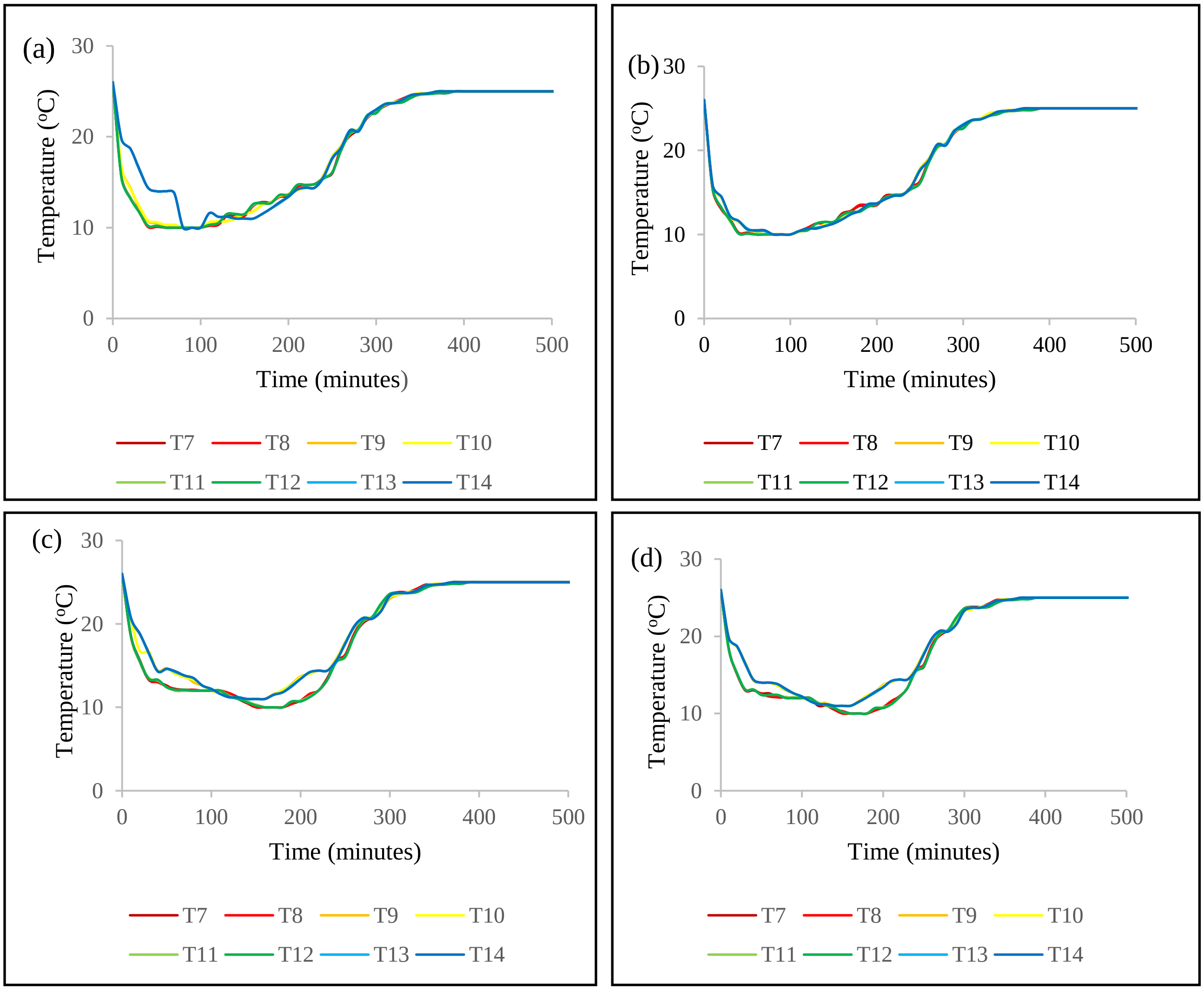

Figure 4. Changes in room temperature in unloaded packaging with ice gel position 1 in the Styrofoam box (a), ice gel position 2 in the Styrofoam box (b), ice gel position 1 in the insulated box (c), and ice gel position 2 in the insulated box (d).

3.5 Changes in temperature of butterfly pea flowers inside the thin wall during transportation.

After harvest, the flowers had a temperature of 28.7°C. After storage in a refrigerator for 3 h, the temperature was increased to 20°C. As shown in Figures 5a and 5b, there was an increase in the temperature of the flowers in the Styrofoam packaging without ice gel (A1B1) and insulated packaging without ice gel (A2B1). The increase in flower temperature occurred because neither package was provided with cooling medium. According to Amalia et al. (2016), packaging without cooling increases the respiration rate of the product; thus, the product temperature also increases. As shown in Figures 5c and 5d, there is a decrease in the temperature of flowers in Styrofoam packaging with ice gel (A1B2) and insulated with ice gel (A2B2), although they show a decrease in flower temperature that is not much different. The A1B2 treatment shows a decrease in temperature from 20°C to 10.7°C, while the A2B2 treatment shows a decrease in temperature from 20°C to 11°C. The temperature reduction patterns of the flowers differed from those of unloaded packs. After being given ice gel, the lowest room temperature in the unloaded package can be reached more quickly, which is 70 to 90 min, whereas the ice gel in the package given Telang flowers can reduce the lowest temperature of the flowers for 120 min. This was due to the additional heat load from the sprouts; thus, the lowest temperature was reached longer. Based on the results, the design of refrigerated packaging using ice gel can achieve the target of reducing the lowest packaging room temperature without loading to 10°C and when there is a load (packaging containing flowers) to 10.7°C in a Styrofoam box.

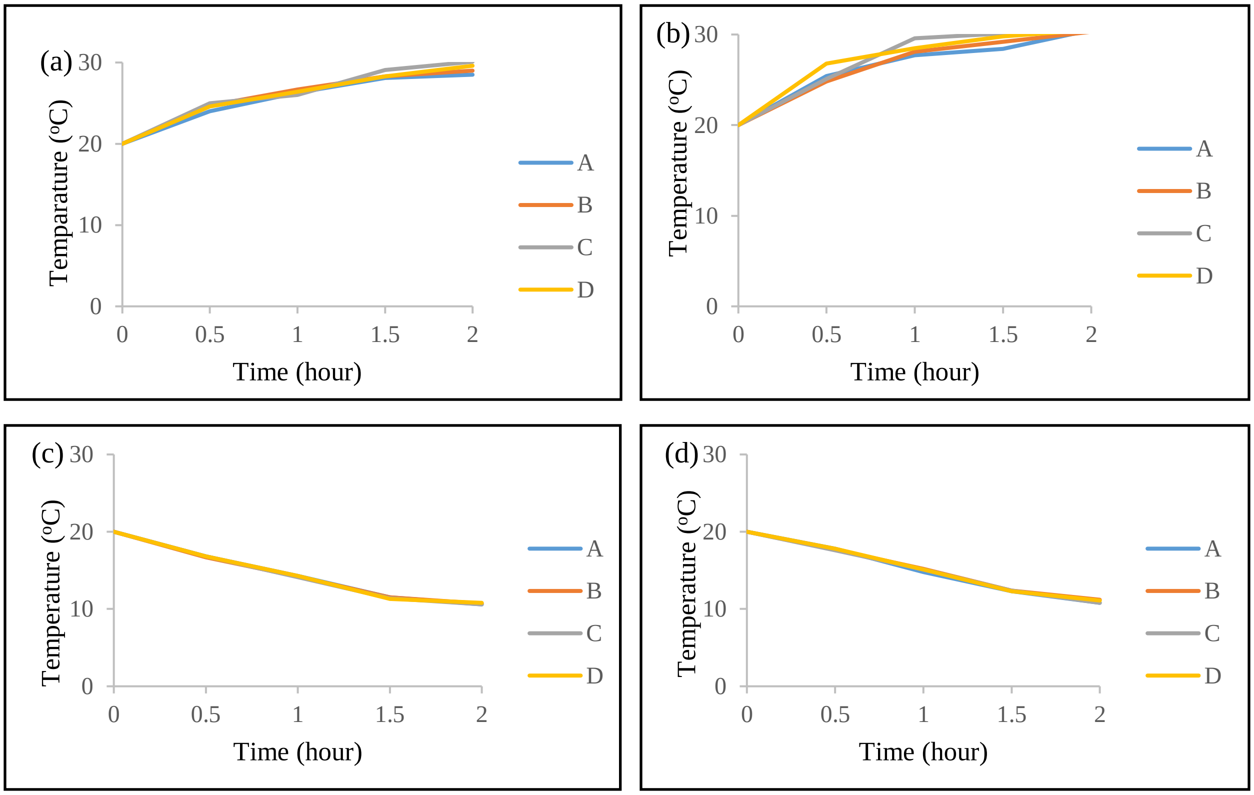

Figure 5. Change in temperature of butterfly pea flowers during the 2 h transportation period in treatments A1B1(a), A2B1(b), A1B2(c), and A2B2(d).

4. Conclusion

The position of the ice gel as a cooling source reduces the temperature of the packaging space. Ice gels with positions 1 and 2 in the Styrofoam box and insulated box reduced the temperature of the packaging space to 10°C. Position 2 ice gel in both packages could maintain room temperature longer and reach the lowest room temperature faster than position 1 ice gel. The Styrofoam box packaging type can reduce the temperature of butterfly pea flowers to 10.7°C, while the insulated box packaging type can reduce the temperature of butterfly pea flowers to 11°C. Based on the combination of treatments, the use of a Styrofoam box with ice gel (A1B2) can be recommended as refrigerated packaging for butterfly pea flowers during the 2-hour transportation period with a distance of 103.9 km on roads outside the city at a speed of 60 km/h.

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