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Effectiveness of Using Ice Gel Packs as an Alternative Coolant

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ABSTRACT

This research aims to evaluate the effectiveness of ice gel packs based on tapioca flour mixed with natural ingredients such as vinegar, lemon and lime as a cooling alternative. Ice gel pack is made through a process of mixing the ingredients until homogeneous, heating to form a gel, and freezing. Characteristic tests carried out include pH, freezing time, and temperature changes. The research results show that the acidity level of ingredients affects product performance. Ice gel packs with lime have the lowest pH (pH = 2) and show the best ability to maintain cold temperatures, while vinegar with the highest pH (pH = 4) freezes the fastest but is less effective in maintaining temperature. This research proves that a combination of natural ingredients can produce ice gel packs that are environmentally friendly, efficient, and have wide application potential as a modern cooling solution.

Keywords: ice gel pack, natural ingredients, cooling

1. INTRODUCTION

Ice gel/pack is a cooling medium that is in a solid or flexible container and can be used repeatedly with various ingredients with the aim of lowering the freezing point of the ice pack mixture[1, 2]. Ice gel is a gel medium for the process of storing materials at low temperatures. Ice gel functions as a substitute for ice cubes and dry ice that can be used repeatedly and can maintain cold temperatures for up to 12 hours in containers such as Styrofoam boxes. The advantage of ice gel is that it remains dry or does not condense when the cold temperature begins to decrease[3].

One of the main ingredients that can be used to make ice gel is tapioca flour. Tapioca flour with the right ratio can be used to make ice gel because the starch from tapioca flour has thickening and gelling properties. In addition to tapioca flour, the ingredients mixed to make ice gel are salt and vinegar[4, 5, 6]. The advantage of ice gel is that the gel remains dry or does not condense when the cold temperature begins to

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decrease. In addition, ice gel is safe to use, non-toxic, environmentally friendly and suitable for cold storage of agricultural commodities such as fruit. Ice gel is generally used for storing medicines, but currently its use has been utilized for post-harvest handling in horticulture, especially in distribution[7].

Ice gel added with table salt has also been shown to be able to maintain cold longer than mineral water-based coolers[8]. The use of ice gel that can be reused has been shown to reduce operational costs significantly. This is because ice gel can be used repeatedly after being refrozen, unlike ice cubes that melt and cannot be used again[9].

Innovation of new ideas that will be developed in this research is the use of natural solutions such as lemon solution, vinegar solution, and lime solution as the main ingredients in the ice gel pack formulation. Lemon solution containing ascorbic acid, vinegar solution containing acetic acid, and lime solution rich in citric acid, have interesting natural properties to be used as alternatives. Coupled with a mixture of salt, these solutions have a low specific heat capacity and the ability to lower the freezing point[10]. The use of these natural solutions is expected to increase cooling efficiency, extend the duration of cold release, and maintain temperature stability longer than conventional materials[11]. In addition, this formulation offers advantages in terms of environmental sustainability, because the materials used are biodegradable and safe for the ecosystem.

The main objective of this research is to explore the potential of the three solutions in creating an ice gel pack formulation that is not only effective in terms of performance, but also environmentally friendly. With this innovation, it is expected to provide a new, better solution for cooling needs. In the study of ice gel packs using lemon, lime, and salt solutions, the chemical reactions that occur can produce a cooling effect. The acid content in lemon, lime, and vinegar will mix with water, producing ions that absorb energy from the environment, so that the surrounding temperature drops. In addition, when salt is dissolved in water, this process also absorbs energy and lowers the temperature.

2. EXPERIMENTAL

2.1. Chemicals, Equipment and Instrumentation

This study uses an experimental method. This method is a method used to determine the effect of certain treatments on other treatments under controlled conditions. This study was conducted on November 22, 2024, which took place at Jl. Puri Gg. Madrasah, Kota Matsum I, Kec. Medan Area at 10.00 WIB. The first step is to prepare tools and materials. The prepare tools were: a) 3 pieces pots; b) 3 pieces tablespoons; c) 3 pieces stirring spoons; d) a 500 ml measuring cup; e) 3 pieces containers; f) 3 pieces stoves; g) a mercury thermometer; h) freezer; and i) a styrofoam box. The prepare ingredients were: a) 500 ml/sample Water (H_2O); b) 200 grams/sample Tapioca flour (($C_6H_{10}O_5$)n); c) 200 grams/sample Fine salt (NaCl); d) 15 drops/sample Food coloring; e) 10 tablespoons/sample Vinegar (CH_3COOH); f) 10 tablespoons/sample Lime ($C_6H_8O_7$); g) 10 tablespoons/sample Lemon ($C_6H_8O_6$); and h) 10 pieces Plastic clips.

2.2. Research Procedure

This research procedures instead of ten steps[12], namely: a) Put 500 ml of water in each sample; b) Put 200 grams of tapioca flour in each sample into a container that has been filled with water and stir until evenly distributed; c) add 200 grams of salt to each sample; d) add 10 tablespoons of vinegar to the first sample, 10

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tablespoons of lemon to the second sample and 10 tablespoons of lime to the third sample; e) Add 15 drops of dye (blue) to each sample; f) stir again until all ingredients are evenly mixed; g) Turn on the stove with low heat then put the mixture in a pan and cook until it clumps into a gel; h) Let the gel sit for 5 minutes to cool; i) put the gel into the plastic clip that has been provided until the desired thickness; and j) the plastic clip/pack that has been filled with gel is put into the freezer.

3. RESULTS AND DISCUSSION

3.1. Analysis of Characterization Results

Figure 1. The result of making an ice gel pack with a mixture of vinegar, lemon and lime

Based on the pH test graph of the ice gel pack, it can be seen that vinegar has the highest pH value (pH = 4) compared to lemon and lime. This shows that vinegar has the lowest acidity level among the three ingredients. Although vinegar is acidic, the acetic acid contained in it is weaker than the citric acid in lemon and lime. Therefore, the ice gel pack solution with vinegar is more neutral than the other ingredients. Lemon has (pH = 3), which indicates a moderate acidity level. Lemon contains strong ascorbic acid. This acidity gives the characteristics of a solution that is more acidic than vinegar, but not as strong as lime. Lime has the lowest pH (pH = 2), which indicates its most acidic nature among the three ingredients. This is due to the high concentration of citric acid in lime. The high acidity makes the ice gel pack solution with lime have the lowest pH.

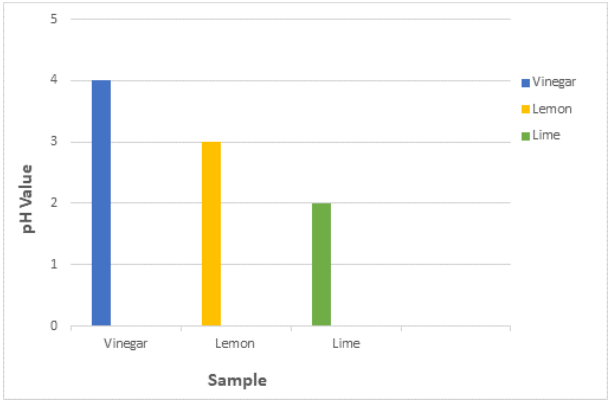

Figure 2. pH Test

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This difference in pH value indicates the level of acidity that can affect the physical properties of the ice gel pack solution, such as freezing point. Solutions with a lower pH (more acidic) usually have a lower freezing point, so they take longer to freeze. Therefore, the solution with lime mixture (pH = 2) is likely to freeze the slowest, the solution with lemon mixture (pH = 3) is slightly faster, and the solution with vinegar (pH = 4) is likely to freeze the fastest, because it has the lowest acidity. Therefore, the difference in pH between vinegar, lemon, and lime reflects the different levels of acidity, with vinegar being the most neutral and lime being the most acidic. This property affects the performance of the ice gel pack, especially in terms of freezing and solution stability.

Lime has the lowest pH among lemons and vinegar, at around pH = 2, indicating that it is very acidic. The acidity of lime is mainly due to its high citric acid content. Citric acid is an organic acid commonly found in citrus fruits and is responsible for its sharp sour taste. The concentration of citric acid in lime is higher than in lemon, resulting in a lower pH and stronger acidity. On the other hand, lemon has a pH of around 3, indicating a moderate level of acidity. The main content that causes acidity in lemon is also citric acid, although the concentration is lower compared to lime. In addition to citric acid, lemon contains compounds such as ascorbic acid (vitamin C), which also contributes to its sour taste, although in smaller amounts. This difference in citric acid concentration explains why lemon tastes less sour than lime and has a higher pH. Meanwhile, vinegar has the highest pH among the three ingredients, at around pH = 4, indicating the lowest level of acidity. The acidity of vinegar mainly comes from the acetic acid content, which is an organic acid formed during the ethanol fermentation process by acetic acid bacteria. The acetic acid content in vinegar usually ranges from 4-8%, depending on the type of vinegar[13]. Although acetic acid is quite strong, its concentration in vinegar is lower than the citric acid content in limes and lemons, resulting in a higher pH and a weaker acidity level.

Thus, the acidic nature of these three ingredients is determined by the type and concentration of the dominant organic acids in them. Limes, which are rich in citric acid, have the lowest pH, followed by lemons with a lower citric acid concentration, while vinegar with its acetic acid content has a higher pH. Based on the ice gel pack freezing time test graph, there is a difference in the time required by the additional ingredients (vinegar, lemon, and lime) to freeze. This result can be explained by relating the freezing time to the acidity level (pH) of each ingredient.

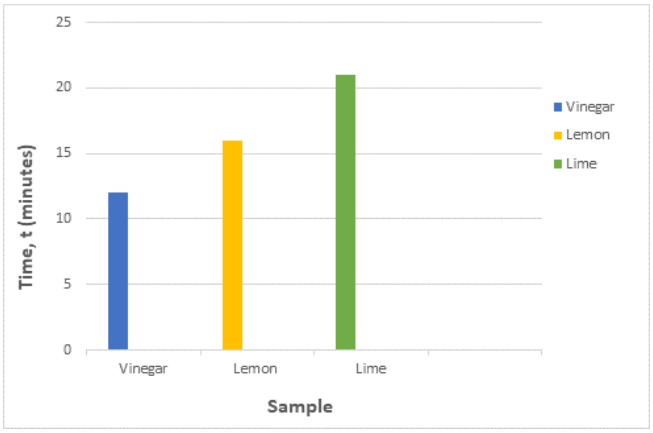

Figure 3. Freeze time test

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In the vinegar sample, the freezing time of the ice gel pack with vinegar is the fastest compared to the other ingredients. This is in accordance with the previous pH test, where vinegar has the highest pH value (pH = 4), which indicates the lowest acidity level. Solutions with a higher pH (less acidic) have a higher freezing point, so vinegar takes less time to freeze. In the lemon sample, the ice gel pack with lemon takes longer to freeze than vinegar but faster than lime. Lemon has (pH = 3), which indicates moderate acidity. The higher acidity compared to vinegar causes the solution with lemon to have a lower freezing point, so it takes longer to reach frozen conditions.

In the lime sample, the freezing time of the ice gel pack with lime is the longest compared to the other ingredients. This is in accordance with the results of the pH test, where lime has the lowest pH (pH = 2), which indicates the highest acidity level. High acidity lowers the freezing point of the solution, so the solution with lime takes the longest to freeze. Therefore, the vinegar sample freezes the fastest because it is the least acidic (pH = 4), so its freezing point is higher. The lemon sample takes longer because its acidity level is moderate (pH = 3). Meanwhile, the lime sample freezes the slowest because it has the highest acidity level (pH = 2), which lowers the freezing point of the solution significantly. The relationship between pH and freezing time shows that the lower the pH (the more acidic the solution), the longer it takes to achieve freezing. This confirms that the acidity level has a direct effect on the thermal characteristics of the ice gel pack.

The difference in freezing time of vinegar, lemon (ascorbic acid), and lime (citric acid) is influenced by the chemical content in each ingredient, especially the solute and its physicochemical properties. Vinegar contains acetic acid (CH_3COOH) with a concentration of around 5-10% in water. This acetic acid is a solute that lowers the freezing point of water through colligative effects[14]. However, because the concentration of solute in vinegar is relatively low compared to other ingredients, vinegar has a higher freezing point and tends to freeze faster. Lemon contains ascorbic acid (vitamin C), natural sugar, and water. As a result, the lemon solution takes longer to freeze. The content of solutes such as ascorbic acid and sugar lowers the freezing point of the solution more significantly than vinegar. In addition, the natural sugar content in lemons also plays a role in lowering the freezing point of the solution and slowing down the freezing process. Limes contain citric acid with a higher concentration than the ascorbic acid content in lemons. Citric acid is a very effective substance in lowering the freezing point of a solution. In addition, limes also contain natural sugars and other compounds that contribute to lowering the freezing point. Because of its higher solute concentration, lime takes the longest to freeze compared to vinegar or lemon. Based on the table of temperature changes in the ice gel pack, there is a difference in the temperature decrease of each ingredient (vinegar, lemon, and lime) over a certain period of time (40 minutes, in 10-minute intervals).

Table 1. Temperature Change Test

Sample	0 minute (°C)	10 minute (°C)	20 minute (°C)	30 minute (°C)	40 minute (°C)
Vinegar	25	22	20	19	19
Lemon	25	20	15	12	12
Lime	25	18	13	9	9

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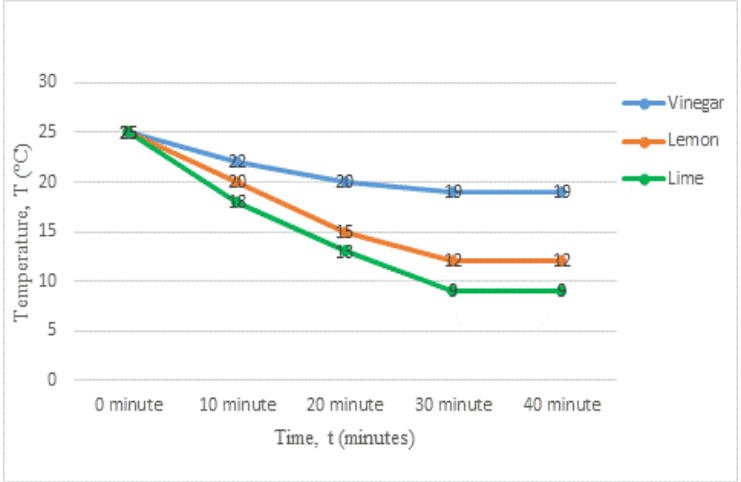

Figure 4. Temperature Change Test

In the vinegar sample, the initial temperature was at 25°C, the same as the other ingredients. After the first 10 minutes, the temperature decreased to 22°C, then continued to decrease until it stabilized at 19°C in the 30th and 40th minutes. Vinegar showed a slower temperature decrease than lemon and lime. This could be due to the chemical properties of vinegar which has a higher pH (less acidic) so that its ability to absorb and retain cold is lower. Furthermore, in the lemon sample, the initial temperature was also 25°C, then decreased faster than vinegar, to 20°C in the first 10 minutes, then 15°C in the 20th minute, and finally stabilized at 12°C in the 30th to 40th minutes. This sharper temperature drop indicates that the lemon mixture has a better ability to lower the temperature than vinegar, possibly due to its higher acidity level (lower pH).

And finally, in the lime sample, like the other ingredients, the initial temperature started at 25°C. However, the temperature drop was most significant, reaching 18°C in the first 10 minutes, then dropping further to 13°C in the 20th minute, and finally stabilizing at 9°C in the 30th to 40th minute. Lime showed the best performance in lowering the temperature, which can be attributed to its highest acidity level (lowest pH) among the three ingredients, making it more effective in absorbing heat energy and lowering the temperature. The content of vinegar, lemon, and lime in lowering temperature and maintaining cold is influenced by their respective chemical compositions[15]. Vinegar contains acetic acid with a concentration of around 4-8% and most of the rest is water. Acetic acid has a lower ability to absorb heat than citric acid, so vinegar is slower to lower temperature and has a lower ability to maintain cold than lemon and lime. Lemon contains 5-8% citric acid, vitamin C (ascorbic acid), and other organic compounds such as flavonoids. The citric acid content has a higher capacity to absorb heat, so lemon lowers temperature faster than vinegar. In addition, the thermal properties of citric acid allow heat from the environment to be absorbed more effectively, making lemon superior in lowering temperature. Lime has a similar composition to lemon, but its citric acid concentration is higher, which is around 6-9%. In addition, lime contains more vitamin C and volatile compounds such as limonene. The higher citric acid content provides a better ability to absorb heat, so lime is more effective than lemon in lowering temperature. The combination of strong citric acid, water content, and volatile compounds makes lime the most efficient ingredient in the temperature reduction process among the three.

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4. CONCLUSION

The ice gel pack was successfully made using tapioca flour mixed with natural acid solutions (vinegar, lemon, and lime). The process involves homogeneous mixing, heating, and freezing. Organic acids play an important role in forming the gel and affect the freezing point and cooling capacity. This study shows that natural materials can be an environmentally friendly and safe alternative. The results showed that lime (pH = 2) was the most effective in maintaining cold temperatures, lemon (pH = 3) had moderate performance, and vinegar (pH = 4) excelled in fast freezing time. This ice gel pack offers an efficient solution while supporting environmental sustainability.

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