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Effect of Sugar, Salt, and Flavorings Addition on Temperature Changes and Specific Heat Capacity in Citric Acid, Acetic Acid, and Ascorbic Acid Solutions

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ABSTRACT

This study aims to evaluate the effect of the addition of additives in the form of sugar, salt, and flavorings on changes in temperature and type heat capacity in citric acid, acetic acid, and ascorbic acid solutions. The methodology used is a quantitative experimental approach with direct observation of temperature changes as well as calculation of enthalpy changes (ΔH) in various combinations of acidic and additive solutions. The results of the analysis showed that the types of additives exerted different effects on the thermal stability and heat capacity of each acidic solution. Sugars tend to provide the most optimal thermal stability with minimal fluctuations in ΔH change, while salts cause the greatest fluctuations. Flavorings show a more varied and inconsistent pattern of change. These findings provide in-depth insights into the thermal characteristics of organic acid solutions with additive modification, contributing to the development of applications in the fields of food, pharmaceutical, and applied chemistry education.

Keywords: temperature, thermal stability, acid solution, enthalpy, additivies

1. INTRODUCTION

The concept of temperature and heat is a fundamental aspect of thermodynamics that is essential for understanding the properties and behavior of energy in various chemical systems.[1] Temperature is understood as a representation of the average kinetic energy of particles in a substance, while heat is a form of heat energy that moves due to temperature differences between systems.[2] One of the key parameters related to heat is the heat capacity type, which is the amount of heat energy required to raise the temperature of one gram of a substance by one degree Celsius.[3] The measurement of the type heat capacity of the solution provides important information regarding molecular interactions as well as the solution's ability to absorb and store heat energy.[4] For example, citric acid, acetic acid, and ascorbic acid are organic compounds that are commonly found in food, pharmaceutical, and everyday chemicals. Citric acid is known to be a major acidity regulator in fruits, acetic acid is a major component of vinegar with a wide range of industrial and domestic applications, while ascorbic acid or vitamin C acts as an antioxidant and essential nutrient.[5] The differences in molecular structure and ionizing strength of the three acids are thought to play a role in influencing the thermal response when dissolved in water.[6]

Heat capacity as a fundamental thermodynamic property has an important role in determining how substances absorb and store heat energy when subjected to temperature changes. In the context of organic acid solutions such as citric acid, acetic acid, and ascorbic acid, an understanding of the heat capacity of a type provides valuable insights into the molecular interactions and mechanisms of energy transfer in the system.[7] The addition of food additives such as sugar, salt, and flavorings can have a significant influence on these thermal properties by altering the solution's ability to regulate heat flow. The investigation of these influences not only deepens the understanding of thermal behavior in biological and food systems, but also helps optimize formulations and processing conditions to improve product stability and quality.[4]

Although important, the study of temperature changes and specific heat capacities in organic acid solutions is still relatively limited, although this understanding is very relevant both theoretically and practically. The data obtained from the heat characterization of the solution can provide insights into the energy storage process, thermal stability, and optimization of the use of organic acids in various sectors such as food, pharmaceuticals, and green chemicals.[4] In addition, the analysis can also be the basis for the development of chemistry learning methods, especially in the introduction of thermochemical concepts through the context of familiar substances in daily life.[8]

Based on these problems, this study aims to evaluate changes in temperature and type heat capacity in citric acid, acetic acid, and ascorbic acid solutions. It is hoped that the results of the research can make a significant contribution to understanding the thermal behavior of organic acid solutions and enrich the study of applied chemistry related to the concept of temperature and heat.

2. EXPERIMENTAL

2.1. Chemicals, Equipment and Instrumentation

This research was carried out through a quantitative experimental approach to examine temperature changes and specific calorific capacity in citric acid, acetic acid, and ascorbic acid solutions in the context of laboratory activities. The series of experiments carried out was simple, involving direct observation and systematic temperature measurements of each solution. The main chemicals used include citric acid ($C_6H_8O_7$), acetic acid ($C_2H_4O_2$), and ascorbic acid ($C_6H_8O_6$). Each acidic solution is interacted with additives such as sugar, salt, and flavors as a mixture.

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The laboratory equipment used includes a styrofoam cup as a solution container, an analytical thermometer for temperature recording, a styrofoam lid to minimize heat exchange with the environment, an iron mixer rod, a digital scale for precision weighing of materials, a strainer for the filtration of lime juice and pineapple extract, a blender for the pineapple extraction process, and a knife for the preparation of ingredients. The supporting ingredients for the study consisted of pineapple fruit extract, table vinegar, lime juice, table salt, sugar, and additional flavors.

The main variables observed in this study were the changes in temperature and heat capacity that occurred in each solution due to the addition of additives.

2.2. Research Procedure

a. Preparation of Filtration Samples

A total of 50 grams, 25 grams, and 75 grams of each ingredient (sugar, salt, and flavoring) were weighed separately, then mixed in a cup of cup according to the treatment. Each mixture was measured at an initial temperature using an analytical thermometer to obtain reference data prior to the addition of acid. Furthermore, the ingredients are dissolved separately using a solution of citric acid, acetic acid, and ascorbic acid.

b. Material Analysis

An acid solution (citric acid, acetic acid, and ascorbic acid) with volumes of 10 mL, 30 mL, 50 mL, and 100 mL, respectively, is put in a beaker. Whole paracetamol tablets are then dissolved into each solution. The measurement is made by recording the time it takes until the tablet is completely dissolved using the stopwatch. Each dissolution process was visually observed to identify the effect of different solution types and volumes on paracetamol dissolution time.

c. Analysis of Acidic Solutions with Various Variations

A total of 50 grams, 25 grams, or 75 grams of ingredients (vinegar, pineapple extract, and lime juice) are mixed with sugar in various ratios, namely: 50 g vinegar + 50 g sugar, 25 g vinegar + 75 g sugar, and 75 g vinegar + 25 g sugar. A similar procedure was applied to each combination of ingredients, whether in vinegar solutions, pineapple extract, or lime juice, to observe the effect of the proportion of ingredients on the characteristics of the resulting acid solution.

3. RESULTS AND DISCUSSION

The combination of food additives such as sugar, salt, and flavorings with natural acid sources including citric acid from pineapple, acetic acid from vinegar, and ascorbic acid from lime is often applied in food engineering and conventional processing to improve the taste and stability of products. One of the crucial parameters in evaluating the chemical and physical reactions of such mixtures is the change in enthalpy (ΔH), which reflects the amount of heat energy absorbed or released during chemical interactions. The variety and stability of the ΔH value is important in determining the final characteristics of the product, including taste, texture, shelf life, and food safety aspects.[7] This study aims to analyze and describe the effect of the addition

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of sugar, salt, and flavoring on changes in enthalpy (ΔH) in three food acidity systems, namely citric acid from pineapple, acetic acid from vinegar, and ascorbic acid from lime.

3.1. Effect of Sugar, Salt, and Flavoring on Enthalpy Changes (ΔH) in Citric Acid System (Pineapple)

The analysis of the following graph (fig.2) illustrates the dynamics of the temperature change of the acetic acid (vinegar) solution when combined with additives in the form of sugar, salt, and flavoring. The data displayed indicate variations in thermal characteristics in each solution system.

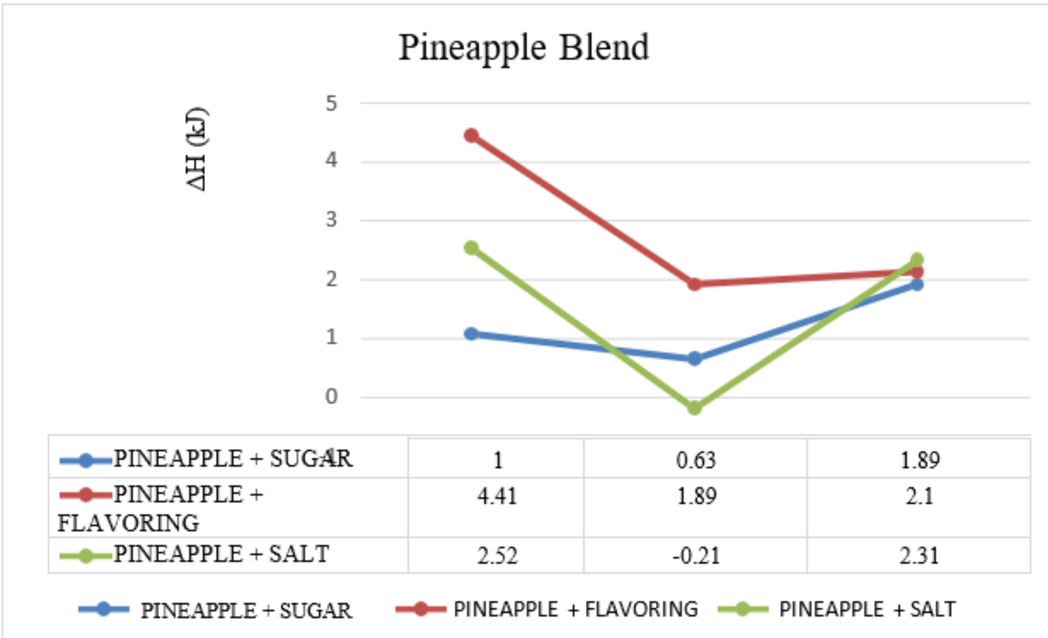

Figure 1. Comparison of Enthalpy Changes (ΔH) in Pineapple Mixture with Sugar, Salt, and Flavoring

Analysis of the graphs resulting from the pineapple juice mixture indicates that the addition of sugar results in the most stable change in enthalpy (ΔH) with minimal variation in fluctuations. This condition implies that sugar can serve as an effective stabilizing agent in food systems that require thermal resistance and sensory consistency.[9]

In contrast, the addition of flavorings triggers a sharp increase in the ΔH value in the early stages of mixing, followed by a significant decrease in the middle phase, before experiencing a rise again in the final phase. The flavoring component, which generally contains monosodium glutamate (MSG) or nucleotides, is thought to enhance the ionization reaction at the beginning of the interaction and form strong complex bonds with citric acid molecules. This phenomenon is in line with research related to the combination of natural flavor components and amino acids in liquid food matrix.[9]

Meanwhile, salt-containing mixtures (NaCl) exhibit the most unstable ΔH behavior, with values fluctuating extremely in both positive and negative directions. This instability is likely caused by ionic competition in the solution that can accelerate or slow down the heat absorption or release reaction (heat titration), as well as affect the osmotic balance between the components of the solution. This is consistent

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with findings on fermentation processes and osmotic dehydration in fruits and vegetables in the context of tropical foods.[7]

3.2. Effect of Sugar, Salt, and Flavoring on Enthalpy Changes (ΔH) in Acetic Acid (Vinegar)

This analysis examines the dynamics of temperature changes in acetic acid (vinegar) solutions when combined with sugar, salt, and flavorings. The measurement results showed that there was a variation in the characteristics of temperature changes in each type of solution. (Fig. 2)

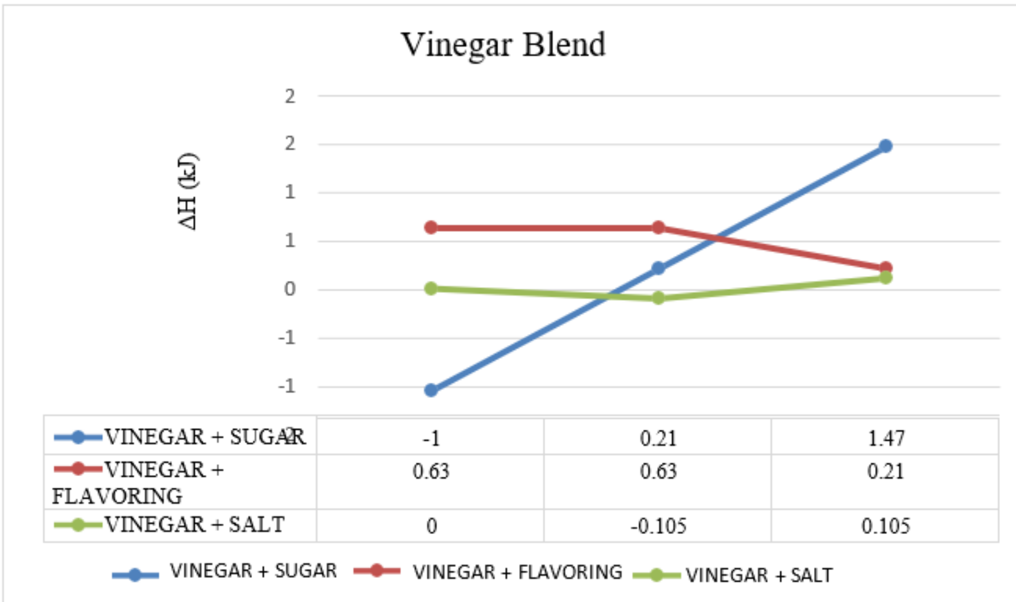

Figure 2. Comparison of Enthalpy Changes (ΔH) in Vinegar Mixture with Sugar, Salt, and Flavoring

The data show that the addition of sugar contributes the greatest to the change in enthalpy (ΔH) in the solution of acetic acid (vinegar), which is characterized by an increase in the value of ΔH from -1 to 1.47. This phenomenon confirms the role of sugar as an effective heat modulator, both in the sensory aspect—by reducing the intensity of the sour taste—and in increasing the thermal resistance of the product. On the other hand, the ΔH change curve in the vinegar-salt mixture showed relative stability, despite a minor decrease in ΔH value, which is thought to be due to the role of salt in strengthening ionic bonds without contributing significantly to the total energy change of the system.[10]

Interestingly, the addition of flavorings showed the smallest change with a near-zero trend, indicating the existence of a balancing mechanism similar to the *buffer* function in heat-mass dynamics. Findings in recent food chemistry studies show that the addition of monosodium glutamate (MSG) and hydrolyzed proteins can act as an ionic buffer, which is able to stabilize the acid-base balance in liquid and gel mediums. This mechanism effectively suppresses the volatility of thermal reactions and contributes to the overall stability of the system.[9]

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3.3. *Effect of Sugar, Salt, and Flavoring on Enthalpy Changes (ΔH) in Ascorbic Acid (Lime)*

This analysis shows the dynamics of temperature changes that occur in citric acid solutions (from lime) when combined with sugar, salt, and flavorings. The measurement results showed that each type of solution exhibited different characteristics of thermal changes.

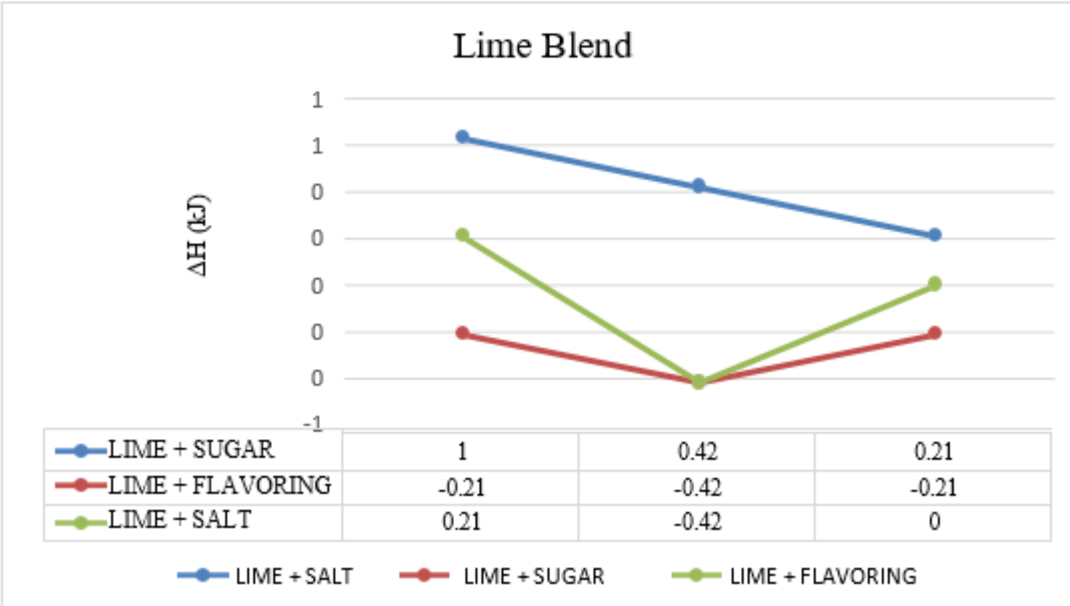

Figure 3. Comparison of Enthalpy Changes (ΔH) in Lime Mixture with Sugar, Salt, and Flavoring

Based on the graph data, sugar solutions tend to maintain the stability of the thermal system consistently, while salt solutions show a tendency to trigger heat instability. Lime mixtures with flavorings show negative and relatively constant changes in ΔH with slight fluctuations below zero, indicating buffer or counterbalancing properties in the absence of extreme heat spikes. These findings are in line with a comparative study on the process of making candied fruit and citrus soaking techniques, which confirm that the presence of sugar plays a role in slowing down ion diffusion so that it can prevent rapid temperature changes. In contrast, saline solutions encourage temperature fluctuations due to osmotic effects and high ion competition in the system.[11]

Many studies agree that sugar, especially fructose and sucrose, are the most effective additives for stabilizing the acid system in both liquid and gel foods. In the context of practical applications, the addition of sugar is not only able to improve the sensory characteristics and thermodynamic stability of the product, but also serves as a heat difference controller. [12] Liquid fructose, in particular, has been proven to be highly effective in increasing the stability of the liquid food system, for example in fish.[10] In addition, the use of sugar with high concentrations has been proven to stabilize the heat difference and reduce excessive volatility of sour and salty tastes.

In contrast, the role of salt is more often attributed as a trigger for fluctuations.[13] Various studies, for example on the fermentation of bamboo shoots and the process of making sweets, show that the presence of salt actually increases the variation of taste character (*tasting note*) while reducing physical and sensory stability. This instability is mainly influenced by the acceleration of osmosis as well as the decrease in turgor pressure in fruit and vegetable tissues.[7]

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The flavoring acts more as a buffer. Studies in the flavor industry confirm that MSG and protein hydrolysate, in addition to enriching the taste, are also able to withstand heat fluctuations both in the heating and storage stages. This ability is reflected in the reported value of a change in enthalpy (ΔH) that is relatively close to zero in an acid-mixed system with flavoring. [14]

In general, the majority of studies agree that sugar, especially fructose and sucrose, are the most effective additives to stabilize the acid system in liquid and gel foods. In practical applications, the addition of sugar not only improves sensory qualities but also improves the thermodynamic stability of the product. Instead, salt use needs to be carefully controlled to minimize the fluctuating effects on heat and undesirable changes in sensory character. [15]

4. CONCLUSION

This study shows that the addition of additives in the form of sugar, salt, and flavorings have different impacts on enthalpy changes (ΔH) as well as the thermal characteristics of citric acid (pineapple), acetic acid (vinegar), and ascorbic acid (lime) solutions. Sugar is proven to provide the most optimal thermal stability effect, characterized by the most consistent ΔH changes and minimal fluctuation variations, making it effective as a temperature stabilizing agent as well as improving the sensory stability of the product. In contrast, salts cause significant fluctuations in ΔH and reduce thermal stability due to the presence of ionic competition that accelerates heat reactions and damages the osmotic balance in the solution. Meanwhile, flavorings act as buffers that balance out ΔH changes, amplifying flavor interactions without meaningfully compromising product stability. These findings make an important contribution to the development of organic acid-based food and pharmaceutical product formulations that require a balance of thermal and sensory aspects to produce a safe, quality, and long-lasting end product.

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