

Study on the Formation of Tomato Juice Caviar Spheres (*Lycopersicum Esculentum* Mill) Using Sodium Alginate ($\text{NaC}_6\text{H}_9\text{O}_7$) and Calcium Lactate ($\text{C}_6\text{H}_{10}\text{CaO}_6$) Through Spherification Technique

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Abstract

The objective of this study was to produce caviar spheres from tomato juice using sodium alginate and calcium lactate. The research method was conducted in two stages: preliminary research and main research. The preliminary study involved analyzing the vitamin C and β -carotene content in the raw materials. The experimental design used was a factorial pattern (3x3) in a Randomized Block Design (RBD) with three replications. The treatments consisted of two factors: sodium alginate concentration (N) with 3 levels 0.6%, 0.8%, and 1% and calcium lactate concentration (K) with 3 levels 0.6%, 0.8%, and 1% resulting in 27 experimental units. The response variables analyzed included chemical responses (vitamin C content, β -carotene content, pH) and organoleptic responses (color, shape, sour taste, texture, and aftertaste). The preliminary results showed that the tomato juice contained 27.46 mg/100g of vitamin C and 47 ppm of β -carotene. The main study results revealed that sodium alginate concentration significantly affected β -carotene content, color, shape, and texture, but did not significantly affect vitamin C content, sour taste, and aftertaste. Calcium lactate concentration significantly affected β -carotene content, shape, and texture, but not vitamin C content, color, sour taste, or aftertaste. The interaction between sodium alginate and calcium lactate concentrations significantly affected shape and texture, but not β -carotene content, vitamin C content, color, sour taste, or aftertaste. The best sample was obtained from treatment n1k1 (0.6% sodium alginate and 0.6% calcium lactate) with average scores: color 4.10, shape 2.41, sour taste 3.21, texture 3.70, aftertaste 2.18, vitamin C 14.75 mg/100g, and β -carotene 18.82 ppm.

INTRODUCTION

Tomato (*Lycopersicum esculentum* Mill) is one of the most widely recognized horticultural commodities by the public. This plant is an annual shrub or bush that can be cultivated in highlands, midlands, or lowlands depending on its variety. Tomatoes are widely cultivated, making them abundant and easy to find. Market demand for tomatoes continues to increase, due to their significant role as a horticultural commodity, especially as a vegetable crop.

Tomatoes contain a good nutritional profile, including proteins, fats, vitamins, and minerals that are beneficial to the human body. Additionally, they contain folic acid, malic acid, citric acid, saponins, and bioflavonoids (including lycopene, α - and β -carotene) (Canene et al., 2005). According to Sumual et al. (2014), vitamins A and C are particularly prominent in tomatoes.

Red-colored fruits and vegetables, such as tomatoes, are the main sources of lycopene. Cooked or crushed tomatoes release more lycopene, making it easier for the body to absorb. Tomatoes are also a natural source of antioxidants. Compounds such as lycopene, β -carotene, vitamin C, and vitamin E act as antioxidants that help prevent the entry of free radicals into the body (Sulistiadi, 2007).

However, tomatoes are classified as perishable commodities if not handled properly. Their shelf life is relatively short, as tomatoes continue to undergo physiological, mechanical, enzymatic, and

microbiological changes after harvest. Their high water content—up to 94% of total weight—makes them highly susceptible to spoilage (Cahyono, 2008).

Tomatoes can be processed into various food products such as tomato sauce, juice, jam, canned tomatoes, and one form of product diversification is by processing them into artificial caviar spheres. Today, beverage product variations are increasingly diverse, especially among drink vendors who combine milk, creamer, flavors, tea, and even coffee with various toppings such as boba, popping boba, jelly, pudding, and biscuits. Caviar products are gaining popularity among the public. Caviar is a product resulting from the spherification technique that forms thin-membrane spheres. These have a semi-solid exterior and liquid interior, giving a unique mouthfeel when consumed (Fischbacher et al., 2011).

The spherification technique used in this study is basic spherification. This method is ideal for creating spheres with very thin membranes that easily burst in the mouth (Winarno and Sergio, 2017).

Caviar formation occurs through contact between sodium alginate and calcium salts. Lee and Rogers (2013) stated that this technique involves sodium alginate and calcium salts as the medium for forming the caviar spheres. When sodium alginate comes into contact with calcium ions, the outer part undergoes gelling. Sodium alginate is a gelling agent used in caviar production.

Sodium alginate has thickening properties and increases viscosity, so when in contact with calcium solution, it forms a gel (Winarno and Sergio, 2017). Calcium salts that can be used include calcium lactate, calcium chloride, and calcium gluconate. Calcium lactate is recommended for spherification over calcium chloride as it does not impart a bitter taste even after rinsing. The addition of calcium salt to the sodium alginate solution results in a thin gel layer on the surface, indicating a successful reaction (Winarno and Sergio, 2017).

Factors that influence gel formation include the composition of alginate, the calcium salt source, and acidity (pH). pH affects alginate viscosity and thus impacts the fruit juice used. This study used tomato juice, where fresh tomatoes have a pH ranging from 4.0 to 4.2, making spherification possible. If the liquid's pH is too low (below 3.6), gelification will not occur because sodium alginate is insoluble below pH 3.7 (Winarno and Sergio, 2017).

RESEARCH METHODS

Materials and Equipment

The materials used in the production process of tomato juice caviar include Selvi F1 variety apple tomatoes aged 3 months sourced from Kuningan, West Java; sodium alginate and calcium lactate obtained from Buana Chem store; water; sucrose obtained from Borma Setiabudi; and glucose syrup purchased from the Chemical Retail Shop.

The materials used for the analysis of tomato juice caviar include buffer solutions with pH 4 and 7, pure vitamin C, HPO_3 solution, 3% HPO_3 solution, DFIF solution, distilled water (aquadest), pure β -carotene,

10% alcoholic KOH solution, alcohol, and acetone.

The equipment used in the tomato juice caviar production process includes knives, cutting boards, digital scales, analytical balances, juicers, blenders, sieves, syringes, spoons, bowls, wooden stirrers, stainless steel pans, stoves, and thermometers.

The tools used for the analysis of tomato juice caviar include analytical balances, pH meters, electric heaters, Erlenmeyer flasks, volumetric flasks, beakers, test tubes, burettes, 10 mL and 25 mL volumetric pipettes, 1 mL graduated pipettes, drop pipettes, glass stir rods, filter funnels, filter paper, cuvettes, and UV-Vis spectrophotometers.

Research Method

The research was conducted in two stages: preliminary research and main research.

Preliminary Research

The objective of the preliminary research was to determine the nutrient content of the tomato raw material by measuring the levels of vitamin C and β -carotene found in tomatoes obtained from farmers in Kuningan, West Java, as well as to measure the pH of the tomato juice and sucrose mixture.

Main Research

The main research is a continuation of the preliminary study, aimed at producing tomato juice caviar using the previously determined formulation. The main study includes the formulation of treatments, experimental design, response design, and response analysis. Factor (N): Sodium alginate concentration, consisting of 3 levels—n1 (0.6%), n2 (0.8%), and n3 (1%). Factor (K): Calcium lactate concentration, consisting of 3 levels—k1 (0.6%), k2 (0.8%), and k3 (1%).

1. Experimental Design

The experimental design used in this study was a Randomized Block Design (RBD) with a 3 x 3 factorial pattern and three replications for each treatment combination, resulting in 27 experimental plots. The factorial design using RBD is appropriate for experimental units that are not homogeneous.

2. Characterization

- Vitamin C Content This test was conducted using the DFIF method (Sudarmadji, 2010).
- β -carotene Content This test was conducted using the UV-Vis spectrophotometry method (Sibaweh Laboratory).

RESULTS AND DISCUSSION

Preliminary Study

Raw Material Analysis

The preliminary study involved analyzing the raw tomato material that had been processed into tomato juice, including vitamin C and β -carotene content, and pH testing of the tomato juice and sucrose mixture.

Table 1. Chemical Analysis in Preliminary Research

No	Raw Material	Vitamin C (mg/100g)	β -carotene (ppm)	pH
1	Tomato Juice	27,46	47,64	4,8
2	Tomato Juice and Sucrose Mixture	19,25	41,80	4,2

The level of vitamin C in tomatoes varies. The vitamin C content in each fruit is different based on its ripeness, differences in the environment where it is grown, the use of various types of fertilizers, and others. According to Rachmat (2016), whole tomatoes have the highest vitamin C content compared to tomatoes without skin and seeds. This shows that the skin and seeds of tomatoes contain vitamin C. So that the content of vitamin C will be reduced if the skin or seed components of tomatoes are not included.

Decreased vitamin C levels can be caused by the blanching process during the processing process. This is also strengthened by the statement of Farikha, et al (2013) that the loss of vitamin C is due to heating during processing which can cause vitamin C degradation so that it can accelerate the oxidation of vitamin C. Blanched tomato juice contains 33.07 mg/100 grams of vitamin C (Tasbihah, 2017). In general, the effect of bleaching treatment will reduce the nutritional value in food such as vitamin C levels.

Tomatoes contain carotenoid pigments, especially lycopene and β -carotene which are the main components of color determinants in ripe tomatoes (Setiady, 2018). β -carotene is a nutrient that is susceptible to degradation after exposure to heat, light and oxygen (El-dahshan & Singab 2013; Maramag et al. 2010). Other factors that can affect the difference in β -carotene content from tomatoes are tomato varieties, ripeness levels, differences in tomato picking places or areas and other environmental factors.

Carotenoids will decrease, especially in processing with a longer time, higher temperatures and the process of cutting and destroying materials. Cutting and crushing of materials causes the surface area of the material to be wider than originally so that the contact with oxygen becomes greater (Aini, 2014). Amaya and Kimura (2004) also stated that the process of filtering and adding water can affect β carotene levels during treatment.

The degree of acidity (pH) is measured to determine the stability of the fruit juice sole that will be used to produce tomato cider caviar grains. pH has an effect on the formation of gels, this is because pH can affect the viscosity of the alginate.

In addition, it will affect the juice used. Acidic solutions, such as lemon juice and white vinegar, cannot be used because sodium alginate is insoluble at a pH below 3.7 so deposits will form and if the pH is more than 10 sodium alginate is unstable. Therefore, it is necessary to add sodium citrate to reduce acidity to around pH 5 and allow the gelification process to occur. However, the taste can change due to the use of sodium citrate (Winarno and Sergio, 2017). Sodium alginate will be stable at pH 4-10 while calcium lactate will be stable at pH 4-8.

Main Research

Vitamin C Levels

The results of the calculation based on ANAVA data showed that factor N (sodium alginate concentration), K factor (calcium lactate concentration) and NK interaction (sodium alginate concentration and calcium lactate concentration) did not have a real effect on vitamin C levels of tomato cider caviar grains.

The vitamin C content in tomato raw materials decreased after being processed into tomato cider caviar grain products. Loss of ascorbic acid in products can be caused by several factors such as pH, oxygen, addition of catalysts, enzymes or metals, storage time, heat, low relative humidity (RH), physical damage due to low temperatures (chilling injury), and salt and sugar concentrations.

The vitamin C levels of tomato cider caviar grains decrease during the processing process and immersion in glucose solutions caused by oxidation and sunlight. Ardiyaningtyas (2012) also stated that during immersion in the glucose solution, the degradation of ascorbic acid due to light exposure and the influence of the glucose solution used continues to cause a decrease in vitamin C levels.

Vitamin C is easily degraded, both by temperature, light and air during storage, so vitamin C levels are reduced. According to Winarno (2008), vitamin C is the most perishable vitamin compared to other types, which is very water-soluble, and easily decomposes in the oxidation process due to exposure to light or high temperatures. Research conducted by Constantia (2012) states that the decrease in vitamin C in median orange juice ravioli is more likely to be caused by external influences, namely, temperature, oxidation, and water-soluble vitamin C. The longer the storage the more external influences can affect vitamin C.

β-carotene levels

The results of the calculation based on ANAVA data showed that factor N (sodium alginate concentration) and K factor (calcium lactate concentration) had a real effect on the β-carotene content

of tomato cider caviar grains while the NK interaction (sodium alginate concentration and calcium lactate concentration) did not have a real effect on the β -carotene content of tomato cider caviar grains.

Table 2. Effect of Sodium Alginate Concentration on β -carotene Levels of Tomato Cider Caviar Grains

Sodium Alginate Concentration (%)	Average Score
0,8	14,48 ^a
0,6	16,53 ^b
1,0	18,80 ^c

Remarks: The average value marked with the same letter shows no significant difference at the level of 5% according to Duncan's follow-up test.

Table 2. showed that there was a noticeable difference in factor N (sodium alginate concentration) to the β carotene levels of tomato cider caviar grains. Significant differences were shown in the treatment of n3 (1%) against n2 (0.8%) and n1 (0.6%).

Table 3. Effect of Calcium Lactate Concentration on β -carotene Levels of Tomato Cider Caviar Grains

Calcium Lactate Concentration (%)	Average Score
1,0	14,48 ^a
0,8	16,53 ^b
0,6	18,80 ^c

Remarks: The average value marked with the same letter shows no significant difference at the level of 5% according to Duncan's follow-up test.

Table 3. It shows that the use of calcium lactate concentrations is significantly different from β -carotene levels. The decrease in β -carotene levels of tomato juice into caviar grain products reached 59.81%-69.45% where in the results of the preliminary analysis carried out the β -carotene level in tomato juice was 47 ppm and then dropped to 14.36-18.89 ppm.

Carotenoids have a high level of stability at neutral, alkaline pH, but are unstable in acidic conditions, the presence of air or oxygen, light and heat and are more stable in storage with low temperature conditions. So that when it reacts, isomerization occurs which can result in a change in the structure of the carotenoids from trans to cis forms. This is in agreement with Wahyuni and Widjanarko (2015), who stated that carotenoids are pigments that have properties that are easily isomerized in acidic and alkaline conditions. Ladislav et al., (2005) also stated that the isomerization of carotenoids from trans to cis results in more unstable and more susceptible to oxidation which can result in degradation.

β -carotene oxidizes easily when exposed to air. This is due to the presence of a double bond structure in β -carotene molecules. Oxidation will take place faster in the presence of light, high-temperature heating, and metal catalysts (Srinovia, 2015). In the k1 treatment (0.6%) has a high average β -carotene level value of 18.80, which means that with the concentration of k1 (0.6%) there is a real effect. Factors that affect the stability of carotene other than pH are due to the presence of air or oxygen, light and heat (Legowo, 2005).

Organoleptic Color Attributes

Table 4. Effect of Sodium Alginate Concentration on the Color Attributes of Tomato Juice Caviar Grains.

Sodium Alginate Concentration (%)	Average Score
1,0	2,67 ^a
0,8	3,37 ^b
0,6	3,90 ^c

Remarks: The average value marked with the same letter shows no significant difference at the level of 5% according to Duncan's follow-up test.

Table 4. It shows that the use of sodium alginate concentrations is significantly different from the color attributes of tomato cider caviar grains. Treatments with the lowest sodium alginate concentration (0.6%) had a redder grain color when compared to 0.8% and 1% sodium alginate concentrations. This is because the amount of dissolved solids in the juice solution increases as the concentration of sodium alginate increases. According to Anggraini, et al., (2016), the presence of hydrophilic sodium alginate can bind water and prevent sediment, so that it can reduce the color intensity in each sample added with sodium alginate.

According to Flinn Scientific (2016), sodium alginate will form a colorless, slightly gray and viscous solution. The process of mixing sodium alginate into tomato juice using a blender can cause bubbles to form that are trapped in a thick solution, so that the presence of these air bubbles can make the color of the solution paler or lighter (Cambodia, 2019).

Organoleptic Shape Attributes

Table 5. Effect of Interaction of Sodium Alginate Concentration and Calcium Lactate Concentration on the Shape Attributes of Tomato Cider Caviar Grain Shape

Sodium Alginate Concentration (%)	Calcium Lactate Concentration (%)		
	0,6	0,8	1,0
0,6	2,41 A a	2,72 A b	2,96 A c
0,8	2,97 B b	3,12 B b	3,27 B c
1,0	3,30 C c	3,33 C a	3,47 C b

Remarks: Lowercase letters are read horizontally, capital letters are read vertically, the average value of treatment marked with different letter notations shows a marked difference based on the Duncan test at 5%.

Table 5. It shows that the concentration of sodium alginate and the concentration of calcium lactate have a significant effect on the shape attributes in the sample code N3K3, the higher the concentration of sodium alginate and the concentration of calcium lactate the shape of the resulting caviar grains tends to be more rounded. This happens because the amount of Ca^{2+} ions that bind to alginate affects the shape of caviar. The greater the number of alginate polymers that make up caviar, the greater the cross-linking that must occur between the polymers, so that a larger Ca^{2+} cation is needed to allow the cross-linking to occur (Constantia, 2012).

Yuliasih (2017) stated that increasing the concentration of sodium alginate will increase viscosity. The higher the binding power of water and its viscosity, the greater the strengthening of the gel structure so that the caviar produced is more stable. According to Fischbacher et al (2011), the formation of gel fruit caviar occurs when the extract or juice of the fruit that has been mixed with sodium alginate, is dipped in a calcium solution. At this stage, there is a diffuse exchange of ions between Ca^{2+} and Na^{+} ions and produces a gel layer.

Organoleptic Attributes of Sour Taste

The results of the calculation based on ANAVA data showed that factor N (sodium alginate concentration), K factor (calcium lactate concentration) and NK interaction (sodium alginate concentration and calcium lactate concentration) did not have a significant influence on the sour taste attributes of tomato cider caviar grains produced. The average value of the results of the organoleptic test of sour taste attributes ranges from 2.64-3.21 which means sour.

The absence of the effect of the concentration of sodium alginate and calcium lactate respectively explains that these ingredients do not cause changes in the taste of caviar grains. The sour taste of

tomato juice caviar grains comes from tomatoes so it is dominated by the taste of the tomato fruit itself. Sugar solution as.

Organoleptic Texture Attributes (Mouthfeel)

Table 6. Effect of Interaction of Sodium Alginate Concentration and Calcium Lactate Concentration on the Texture Attributes of Tomato Juice Caviar Grains.

Sodium Alginate Concentration (%)	Calcium Lactate Concentration (%)		
	0,6	0,8	1,0
0,6	3,70 B a	3,51 C a	3,41 C a
0,8	3,31 A a	3,18 B a	3,17 B a
1,0	3,27 A c	2,83 A b	2,58 A a

Remarks: Lowercase letters are read horizontally, capital letters are read vertically, the average value of the treatment marked different letter notations indicating a noticeable difference based on the Duncan test at the level of 5%.

Table 6. It shows that the concentration of sodium alginate and the concentration of calcium lactate have a significant effect on the texture attributes in the sample code N1K1, the lower the concentration of sodium alginate and the concentration of calcium lactate the more easily the texture is broken. This happens because a low concentration of sodium alginate will result in a thinner layer of gel so that the process of diffusion of Ca^{2+} ions runs slower.

The higher the concentration of sodium alginate and calcium lactate added, the thicker the tomato juice solution will be so that the liquid in the caviar will be thicker and the outer layer of caviar will be thicker so that the texture of caviar will be more solid or hardened. This (2006) states that when sodium alginate comes into contact with calcium ions, a freezing process occurs on the outside. The longer the product is left in the calcium solution, the liquid inside will form a gel and the liquid part will be fewer.

Organoleptik Atribut After Taste

The results of the calculation based on ANAVA data showed that factor K (calcium lactate concentration) and NK interaction (sodium alginate concentration and calcium lactate concentration) did not have a real influence on the after taste attributes of tomato cider caviar grains. The average value of the results of the organoleptic test of after taste attributes ranged from 2.18 - 2.67 which means that it was rather strong.

The absence of the effect of the respective concentrations of sodium alginate and calcium lactate explains that the addition of these ingredients does not cause changes in the after taste. It is different if the calcium salt used is calcium chloride. The use of calcium chloride in high concentrations can form a strong gel but can cause a bitter taste. Conversely, the use of low concentrations can have an effect on gel formation (Lee and Roger, 2013). Wahyuni (2019) also stated that the addition or immersion in calcium lactate does not cause a change in taste and does not produce a bitter after taste in the product.

CONCLUSION

1. Based on the results of the research that has been carried out, the following conclusions are obtained: 1. In the preliminary study, the test results of vitamin C content of tomato juice were obtained of 27.46 mg/100 grams and β -carotene content of 47 ppm.
2. Sodium alginate concentration affects β -carotene levels, color, shape, and texture but does not affect vitamin C levels, sour taste, and after taste of tomato cider caviar grains.
3. Calcium lactate concentration affects β -carotene levels, shape, and texture but does not affect vitamin C levels, color, sour taste, and after taste of tomato cider caviar grains.
4. The interaction between sodium alginate concentration and calcium lactate concentration affects the shape and texture but does not affect the β carotene content, vitamin C content, color, sour taste, and after taste of tomato cider caviar grains.
5. Based on organoleptic testing and chemical analysis, the main research obtained the selected products, namely in the n1k1 treatment (concentration of sodium alginate 0.6% and calcium lactate 0.6%) with an average color value of 4.10, shape of 2.41, sour taste of 3.21, texture of 3.70, after taste of 2.18, vitamin C content of 14.75 mg/100 grams and β -carotene content of 18.82 ppm.

Declarations

Author Contribution declaration :

Hari Hariadi (analysis of variance of lab and Data, Main Idea, Write)

Asep Dedy Sutrisno (analysis of variance of lab and Data, Main, Write)

Yusman Taufik (analysis of variance of farm and Data, Write)

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