Physical properties and food safety of edible bioplastic films prepared from nata de tomato blend

Fionna Fabiola Adristi [1], Fransisca Romana Titis Suniati [2], Joko Sulistyo [3]*

[1,2,3] *Universitas Ciputra, Indonesia*

Corresponding author: joko.sulistyo@ciputra.ac.id

Journal of Tourism, Culinary, and Entrepreneurship

e-ISSN: 2776-0928

Publisher:
School of Tourism, Universitas Ciputra Surabaya, Indonesia

Keywords:
Edible-Film
Nata de Tomato
Characteristics
Food-Safety
Edibility

Received: *April 6, 2025*
Revised: *May 23, 2025*
Accepted: *July 10, 2025*

ABSTRACT

Edible film is a thin layer that can be digested by the body and used as food packaging. The manufacture of edible films utilizes bacterial cellulose fibers from nata de tomato as a reinforcing material. This study evaluates the physical characteristics, structure, and food safety of edible films made from nata de tomato. The tested sample contains 2.5% nata de tomato with 1% glycerin and other additives. Physical analysis includes thickness, tensile strength, elongation, density, opacity, moisture content, and water solubility. The structure was examined using FTIR and SEM, while food safety testing involved heavy metal analysis (As, Cd, Pb, Hg) and microbiological testing (*Escherichia coli*, *Salmonella spp*., and *Staphylococcus aureus*). The results show that physical characteristics such as thickness, tensile strength, density, opacity, moisture content, and water solubility meet feasibility standards, although the low elongation requires the addition of glycerin. FTIR and SEM analyses indicate that cellulose polymers are the main component of the edible film. The edibility test shows that the edible films made from nata de tomato are safe from heavy metal and microbial contamination.

1. INTRODUCTION

Tomato, as a climacteric fruit, continues to metabolize even after harvest, with a water content of up to 94%, making it prone to damage and decay. In Indonesia, tomato waste from traditional markets amounts to 500 kg per day. This waste can be utilized for fermentation products, one of which is nata de tomato, which has the potential as a raw material for making edible film, as an alternative eco-friendly food packaging, especially edible sachets.

Nata de tomato contains cellulose produced by the bacterium Acetobacter xylinum. This cellulose has a regular molecular structure, high tensile strength, elasticity, and is easily biodegradable, making it ideal for replacing plastic in food packaging. Edible film made from nata de tomato not only reduces the use of plastic, but is also easily degradable in nature.

The physical characteristics of the edible film were tested based on the SNI 06-3735-1995 standard and Japanese Industrial Standard (JIS). Important parameters tested include thickness, tensile strength, opacity, moisture content, and solubility. Glycerin as a plasticizer increases the flexibility of the film, while high thickness and tensile strength provide protection for the packaged product. Edible films with low opacity exhibit good clarity, while low moisture content improves resistance to microbial growth.

Morphological analysis was performed using Scanning Electron Microscope (SEM), which showed an even distribution of constituent materials and a smooth surface, free of air bubbles. The chemical structure was analyzed using Fourier Transform Infrared Spectroscopy (FTIR) to identify changes in functional groups.

Food safety testing was conducted to ensure that the edible film is safe for consumption, including testing for heavy metals (arsenic, cadmium, lead, mercury) and microbes (E. coli, Salmonella spp., S. aureus). If the test results show negative values, the edible film made from nata de tomato is considered safe for consumption.

This study aims to evaluate the physical characteristics, structure, and food safety of nata de tomato-based edible films as an alternative eco-friendly food packaging.

2. METHODOLOGY

Production of Nata de Tomato

Ripe and almost rotten tomatoes are weighed, blended with water, and strained. Sugar and MSG were added to the strained tomato extract, then heated to boiling and poured into a baking dish. Vinegar was added to reach pH 4, then the baking dish was sealed and allowed to stand for 30 minutes. After that, a bacterial starter is added and incubated for 1-2 weeks. After fermentation is complete, the nata de tomato is rinsed with running water and left for 24 hours.

Production of Edible Film

Nata de tomato was cut into small pieces and mixed with tapioca starch, CMC, glycerin, and water, then blended. The mixture was heated until boiling, poured onto a baking tray, and spread evenly. Next, the film was dried in a dehydrator for 24 hours until an edible film layer was formed.

Physical Characteristics Analysis

The thickness of the bioplastic film was measured using a screw micrometer (0.001 mm) at five random points on the surface of the film, then the average was calculated. Tensile strength was measured using a texture analyzer with the formula: σ = F/A, where σ = tensile strength (MPa), F = load at break (kgf), and A = cross-sectional area (cm^2).

Elongation was calculated using the formula; $\varepsilon = \frac{Lt - Lo}{Lo}$ x 100%, where ε = elongation (%), *Lt* = discontinuous length (cm), and *Lo* = initial length (cm).

Density was calculated using the formula; $(Wi - Wf)/(A \, x \, t)$, where *Wi* = initial weight (g), *Wf* = final weight (g), *A* = film area (cm²), and *t* = film thickness (mm).

Transparency was measured using a UV-Vis spectrophotometer at a wavelength of 585 nm with the formula; T = $\frac{A585}{t}$, where T = transparency (Abs), A_{585} = absorbance at 585 nm, and *t* = film thickness (mm).

Moisture content was measured using a moisture analyzer at 105°C with a 0.5 gram sample. Water solubility was performed by immersing the film in 50 mL of distilled water for 24 hours, then drying it in an oven at 105°C for 24 hours. Solubility was calculated using the formula; Solubility (%) = (W2 - W3) / W2 x 100.

Morphological Analysis and Characterization of Physical and Chemical Structures

Morphological observations were conducted using a Scanning Electron Microscope (SEM) at an accelerating voltage of 20 kV to analyze the film's surface. Chemical Structure: Identified using Fourier Transform Infrared Spectroscopy (FTIR) to identify the functional groups in the sample, analyzed using IR Spectrophotometer.

Food Safety and Edibility Testing

Heavy metal testing was conducted using ICP-MS after pre-digestion and microwave digestion. The samples were analyzed to detect heavy metals such as arsenic, cadmium, lead, and mercury. Meanwhile, antibacterial activity testing was performed against *E. coli*, *Salmonella spp*., and *S. aureus* using the agar diffusion method. The edible films, sterilized with UV light, were placed on media inoculated with bacteria and incubated for 24 hours at 37°C. The clear zone formed indicated antibacterial activity, which was compared with the positive control ampicillin.

3. RESULTS AND DISCUSSION

Production of Nata de Tomato

Nata de Tomato is a fermented product produced from tomato extract containing sugar. The manufacturing process is similar to that of nata de coco, involving fermentation by the bacteria *A. xylinum*. These bacteria convert the sugar in tomato juice into cellulose, forming a thick layer known as nata on the surface of the fermentation liquid (Figure 1). The procedure for making edible film from nata de tomato is shown in Figure 2.

Figure 1. Nata de Tomato

Production of Edible Film and Edible Sachet

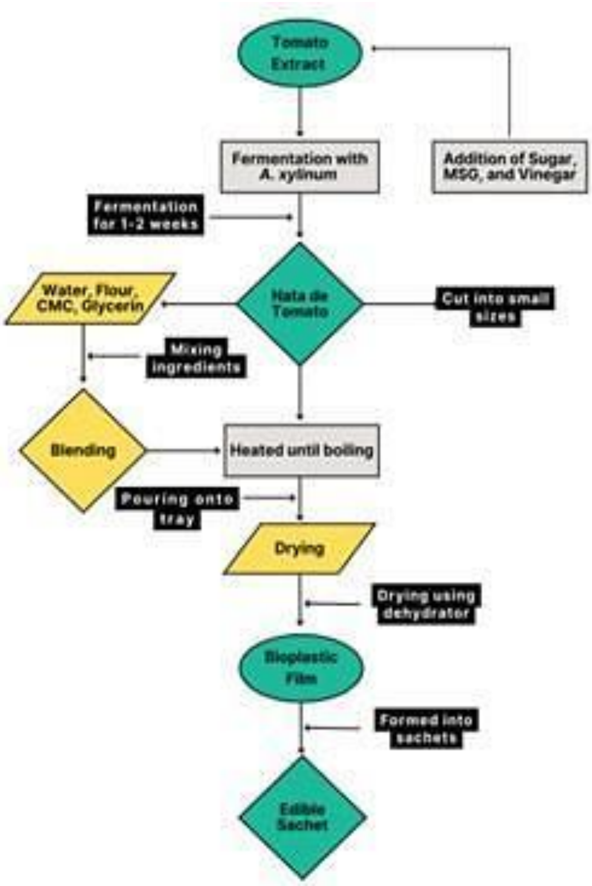

Figure 2. Flowchart of Edible Film Production from Nata de Tomato

Physical Characteristics Analysis

The mechanical strength of the film was analyzed through static tensile testing using a texture analyzer. The thickness of the film also affects the tensile strength results. In this study, the mechanical characteristics of the film were determined by measuring thickness, tensile strength, and elongation. This analytical method refers to the Japanese Industrial Standard (JIS), as shown in Table 1.

Table 1. Mechanical Properties of Edible Film Based on JIS

Characteristics	Result
Thickness	Max 0.25 mm
Tensile Strength	Min 0.39 MPa
Elongation	70%

Source: Sartika et al., (2022)

Table 2. Mechanical Properties of Nata de Tomato-based Edible Film

Treatment	Thickness Average (mm)	Tensile Strength Average (MPa)	Elongation Average (%)
2.5% nata de tomato with 1% glycerin	0.04 ± 0.01	36.32 ± 20.63	1.67 ± 1.67

The thickness of the film is one of the important factors determining the feasibility of the film as a food product packaging material. The thickness was measured using a screw micrometer with a precision of 0.001 mm at five random points on the film's surface (Ramadhani et al., 2023). The thickness of the film affects its ability to control moisture and oxygen. The thicker the film, the more effective its durability in protecting food products from exposure to moisture and air. Additionally, thickness also influences the tensile strength and elasticity of the film.

According to Deden et al. (2020), the standard thickness of edible film based on JIS is a maximum of 0.25 mm (Table 1). Based on the thickness testing results shown in Table 2, the edible film with 2.5% nata de tomato and 1% glycerin addition resulted in a thickness of 0.04 mm. This thickness meets the JIS standard as it is less than 0.25 mm.

When compared to the edible film from nata de coco tested by Ismaya et al. (2021), the film with the addition of 2% glycerin has a thickness of 0.09 mm. Both types of edible films have a thickness of less than 0.1 mm because they both contain similar bacterial cellulose. However, statistical testing showed a p-value < 0.01, indicating a significant difference between the thickness of nata de tomato (0.04 mm) and nata de coco (0.09 mm).

The difference in thickness can be explained by the higher glucose content in nata de coco compared to nata de tomato, which affects cellulose fiber formation and results in a thicker film (Gresinta et al., 2019). Research by Rahmi et al. (2022) shows that an increase in glycerin concentration can enhance film thickness, as more solid solution is incorporated into the film mixture.

Although this difference in thickness is small in the statistical context, the thickness measurement still refers to the JIS standard, which sets a maximum thickness of 0.25 mm.

Therefore, the thickness of the edible film made from a 2.5% nata de tomato blend with the addition of 1% glycerin meets the established standard.

Tensile strength is an important indicator in determining the mechanical properties and flexibility of the film. Based on the tensile strength test results shown in Table 2, the edible film from nata de tomato produced a value of 36.32 MPa. This value meets the JIS standard, which sets the minimum tensile strength at 0.39 MPa (Azwar et al., 2022), as indicated in Table 1.

These results are consistent with the study by Ismaya et al. (2021), which found that edible film made from nata de coco with 2% glycerin has a tensile strength value of 32.40 MPa. Based on statistical tests, the p value > 0.01 indicates that there is no significant difference between the tensile strength of edible films made from nata de tomato and nata de coco.

Although both types of films have different glycerin concentrations as a plasticizer, which significantly affects the film's tensile properties. The higher the concentration of glycerin, the more elastic and flexible the film, although it can cause the film to become more brittle. Glycerin weakens the bonds between polymer chains and interacts with the monomer bonds, causing the film to become more pliable and stretchable (Sartika et al., 2022).

The nata de tomato-based edible film contains CMC, which plays a role in improving the mechanical properties of the bioplastic, thereby increasing its tensile strength (Azwar et al., 2022). Therefore, the edible film in this study is suitable for use as packaging material, as the increased tensile strength indicates that the film is stronger and less likely to tear, making it more effective in protecting the packaged product.

Elongation measures the ability of the film to stretch when subjected to tension until it breaks. Elongation is an important indicator in determining the flexibility and pliability of the film. Based on the elongation testing results shown in Table 2, the edible film from nata de tomato exhibited an elongation value of 1.67%.

According to Asriani et al. (2025), the elongation standard based on JIS is a minimum of 70%. Elongation is considered poor if the value is less than 10%, and considered very good if it exceeds 50%. Therefore, the elongation value obtained in this study does not meet the JIS standard. However, the results of this study align with the findings of Ismaya et al. (2021), who reported that edible film from nata de coco with 2% glycerin had an elongation value of 1.59%. Similar findings were also reported by Harianingsih et al. (2017), who found an elongation value of 1.27% in edible film from nata de soya with 2% glycerin. Based on statistical analysis, the p value > 0.01 indicates that there is no significant difference between the elongation of edible films from nata de tomato, nata de coco, and nata de soya.

Glycerin, as a plasticizer, plays an important role in improving the flexibility of the film by reducing hydrogen bonds between adjacent polymer molecules. This weakens the attractive forces between polymer chains, making the film more pliable. An increase in glycerin concentration will enhance elongation when the film undergoes rupture (Harianingsih et al., 2017). Therefore, to meet the elongation standard set by JIS, the edible film in this study requires the addition of glycerin.

Table 3. Density and Opacity of Nata de Tomato-based Edible Film

Treatment	Density Average (g/cm³)	Opacity Average (A/mm)
2.5% nata de tomato with 1% glycerin	0.19 ± 0.08	2.06 ± 0.54

Density of Edible Film from Nata de Tomato

Density indicates the density of a sample in a given volume. In edible films, density functions as a barrier to prevent the migration of water vapor, so as to maintain the durability of packaged food products. Density is calculated using the formula (Vonnie et al., 2023); density = A × *t* (*Wi*-*Wf*), where W_i = Initial film weight before drying (g), W_f = Final film weight after drying (g), *A* = Film area (cm²), *t* = Film thickness (mm).

In testing the density of edible film, there is no definite standard value according to SNI or JIS. Based on the density test results shown in Table 3, the edible film made from nata de tomato produced a value of 0.19 g/cm³. This density value is relatively low, which gives an advantage to the physical properties of this film, namely its flexibility as a packaging material. However, low density values tend to reduce the film's ability to block water vapor and gas migration, which can affect the quality of food products.

According to Azwar et al. (2022), the average density of edible film made from corn starch is 0.96 g/cm³. Although both types of edible film have a density of less than 1 g/cm³, based on statistical results, the p value <0.01 indicates a significant difference between the density of edible film from nata de tomato and edible film from corn starch.

This difference is influenced by the type of constituent material, such as corn starch, which can absorb water and form a solid structure, resulting in a higher density. A higher density indicates that the molecules in the film are tighter, leaving less room for air inside.

Opacity and Moisture Content of Edible Film

Opacity is defined as the opposite of transparency, which is the degree to which a material is unable to pass light. If transparency measures the extent to which light can penetrate the material, opacity refers to how much light is blocked by the material (Alimi et al., 2021). In testing the opacity of edible film, there is no definite standard value according to SNI or JIS.

Based on the opacity test results shown in Table 3, the edible film in this study produced a value of 2.06 A/mm. This opacity value is in line with the research of Djenar et al. (2022), which recorded opacity values in gluten-based edible films with a range of 1.19 to 2.96%. The results of statistical analysis showed p value >0.01, which means there is no significant difference between the opacity of edible film from nata de tomato and edible film from gluten.

However, in the research of Pak et al. (2020), edible films made from Persian gum and glycerin showed a range of opacity values between 0.47-0.86%. The higher the glycerin concentration, the lower the opacity value, because glycerin increases flexibility and widens the distance between molecules in the polymer matrix. As a result, light penetrates the film more easily, making the film more transparent.

Transparent packaging is generally preferred by consumers because the product inside is clearly visible. However, high transparency also allows light to enter, which can affect product quality. Edible films with high opacity, as shown in the edible films in this study, have the advantage of inhibiting light, so they can more effectively protect the packaged product.

Table 4. Water Content and Solubility of Nata de Tomato-based Edible Film

Treatment	**Water Content** Average (%)	**Gravimetric Moisture Content** Average (%)	**Solubility** Average (%)
2.5% nata de tomato with 1% glycerin	10.46 ± 0.14	12.34 ± 0.06	22.20 ± 0.16

Moisture content in edible film is an important factor that affects the stability of the packaged product. Moisture content measurement is carried out using a moisture analyzer at 105°C. A good edible film has a low moisture content, so that when used as a packaging material, it does not add moisture to the packaged product, which can have an impact on damage and reduce product shelf life (Rusli et al., 2017). Based on the moisture content test shown in Table 4, edible film from nata de tomato has a moisture content of 10.46%.

According to Sulistiyana et al. (2024), this value meets SNI 06-3735-1995, which states that a good film has a moisture content of no more than 16%. The results of this study are in line with the findings of Hendra (2015) in Rusli et al. (2017), who reported that the moisture content of edible films made from tapioca and glycerin ranged from 10.46% to 13.88%. However, the moisture content in edible films from nata de coco with a concentration of 2% glycerin, as found in the research of Ramadhia et al. (2023), reached 30.62%.

Based on statistical analysis, the p value <0.01 of water content in edible film of nata de tomato and nata de coco showed a significant difference. This difference is due to the looser cellulose matrix in nata de coco, which can absorb more water compared to nata de tomato which has a denser structure. In addition, the difference in glycerin concentration also affects the water content. Glycerin is a hydrophilic and hygroscopic compound that has hydroxyl groups, making it easy to interact with water. The higher the glycerin concentration, the higher the moisture content of the edible film. This explains why the moisture content of edible film made from nata de coco with 2% glycerin is higher than edible film from nata de tomato (Rini et al., 2022).

The results of gravimetric water content testing on edible film from nata de tomato showed 12.34% (Table 4). Therefore, the edible film in this study is considered good because it contains low water content, making it more effective to be used as a food packaging. Films with high moisture content can be a medium for microbial growth (Rahmi et al., 2022).

Film solubility is a key characteristic that plays an important role in determining the film's resistance to moisture. Solubility is also an indicator of the solubility of edible film when consumed and assesses its biodegradability as a packaging material. The percentage of edible film solubility is the percent dry weight of the film dissolved after immersion in water for 24 hours. As shown in Table 4, the edible film in this study produced a solubility of 22.20%. According to Mustapha & Wan (2022), nata de coco edible film with 2% glycerin showed a water solubility value of 80.53%.

Based on the results of statistical analysis, the p value <0.01 indicates a significant difference between the water solubility of nata de tomato and nata de coco edible films. Edible films with high solubility have lower resistance to water and exhibit greater hydrophilic properties, making it easier to absorb water.

According to Coniawati's research (2014), cited in Unsa & Paramastri's article (2018), the type and concentration of plasticizer affect film solubility. The more plasticizer used, the greater the level of solubility. In this case, the concentration of glycerin in the edible film from nata de coco is higher than that of the edible film from nata de tomato, which leads to an increase in its solubility. Glycerin, with its hydrophilic nature, dissolves easily in water and reduces the water resistance of the film (Purnavita et al., 2020). Therefore, edible films from nata de coco are more soluble compared to edible film from nata de tomato. However, low solubility provides an advantage, as the film is less likely to deteriorate in a humid environment during storage as packaging material.

Morphological Analysis and Characterization of Physical and Chemical Structures

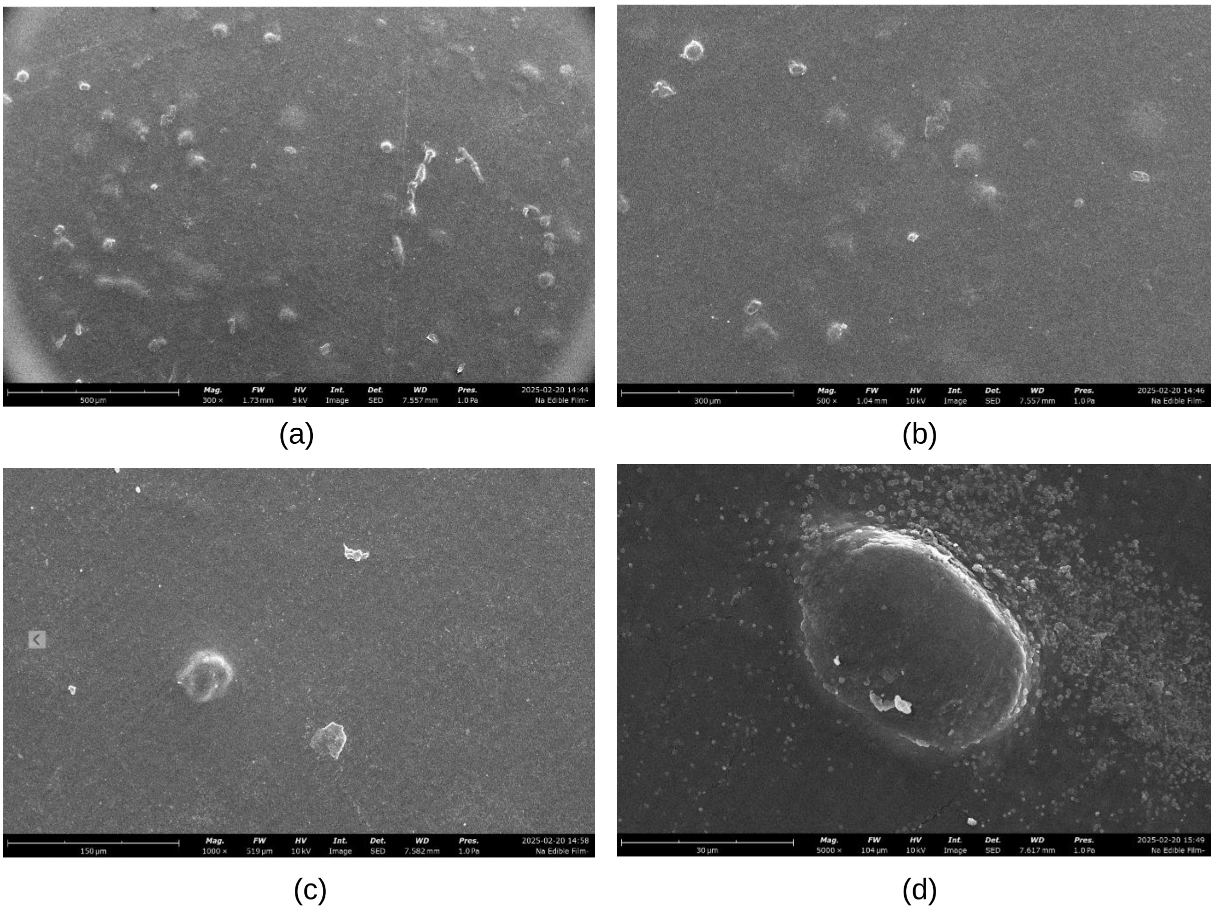

Figure 3. SEM of Nata de Tomato-based Edible Film at magnifications; (a) 300x, (b) 500x, (c) 1000x, (d) 5000x.

Table 5. EDS Results of Nata de Tomato-based Edible Film

Element Symbol	Element Name	Atomic Conc.	Weight Conc.
C	Carbon	67.218	58.200
O	Oxygen	24.881	28.700
Na	Sodium	7.900	13.100

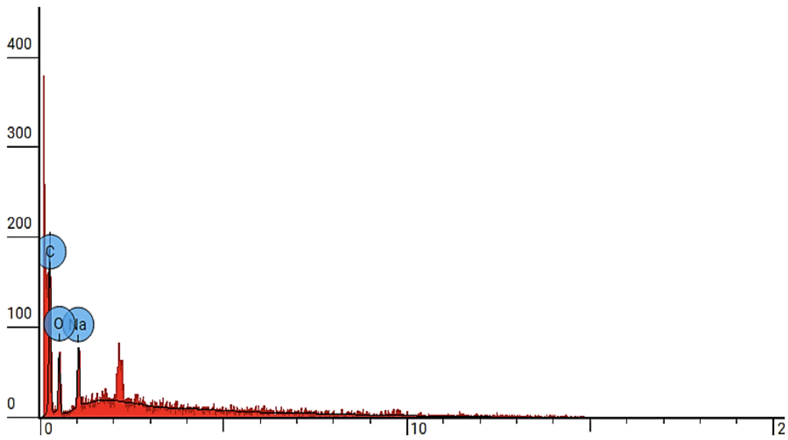

Fig 4. EDS Chart of Nata de Tomato-based Edible Film

Scanning Electron Microscope (SEM) is an analytical method used to observe the morphological structure of a material, in this case, edible film. SEM observation aims to provide information about the surface characteristics of the film, including density, cracks, and homogeneity of the film structure. Based on Figure 4, SEM observation of edible film from nata de tomato with 5000x magnification shows that there are many bubbles formed on the surface. The existence of these bubbles is in line with the findings of Azwar et al. (2022), which states that the bubbles come from less homogeneous material particles.

In addition, the surface of the edible film looks rough. This can be caused by the insufficient amount of filler used in the composition. To improve the surface quality of the film and produce a smoother, less crackable, more flexible structure, it is necessary to optimize the use of glycerin as a plasticizer can increase the flexibility and stretchability of the film, which can improve the overall surface and texture of the film.

In addition to SEM, Energy Dispersive Spectroscopy (EDS) analysis was used to detect elements contained in the edible film from nata de tomato. Based on the results of EDS analysis (Table 5), the elements detected in the edible film include; Carbon (C) was found to come from organic compounds contained in edible film forming materials, such as nata de tomato, CMC, polysaccharides from tapioca starch, and glycerin, which contains carbon in its glycerol structure. Oxygen (O) was detected mainly in hydroxyl groups (-OH) present in cellulose, glycerin, and carboxyl groups (COO-) derived from CMC. These groups play an important role in the formation of intermolecular bonds and give the film certain properties, such as moisture and elasticity. The sodium (Na) detected is likely to come from CMC which contains sodium in the form of sodium salts of the carboxylic acids present in it.

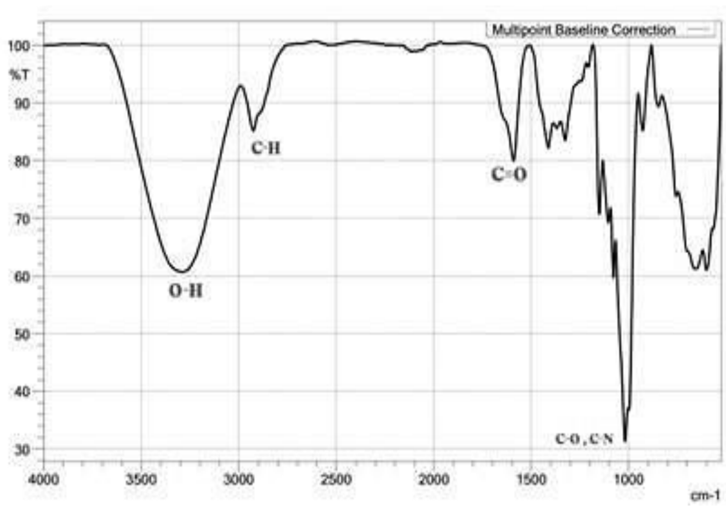

Fig. 5. FTIR Spectrum Chart of Nata de Tomato-based Edible Film

FTIR Analysis of Edible Film from Nata de Tomato

FTIR (Fourier Transform Infrared Spectroscopy) is a method used to identify the presence of functional groups or types of chemical bonds in films. This analysis aims to understand the physical and chemical changes that occur in the film material mixture, as well as its chemical characteristics. Based on the results of the FTIR spectrum of the edible film from nata de tomato, as shown in Figure 5, several functional groups were identified that provide important information about the composition of the film material.

The O-H (Hydroxyl) group, Wave Range 3200-3600 cm^{-1}, indicates the presence of hydrogen bonds, indicating the presence of a cellulose component, which is the main part of the nata de tomato raw material. In addition, these -OH groups can also come from additives such as CMC and tapioca starch, as well as the use of glycerin as a plasticizer. The C-H (Alkane) group, Wave Range 2800-3000 cm^{-1}, indicates the presence of carbon-hydrogen bonds typical of organic compounds such as those found in glycerin and some other additives. The C=O (Carbonyl) group, Wave Range 1600-1800 cm^{-1}, can be derived from ethers, alcohols, or carboxylic acids present in film-forming materials, such as CMC and tapioca starch. These groups indicate the presence of compounds containing carbonyl groups in their molecular structure. C-N (Amine) Groups, Wave Range 1000-1500 cm^{-1}, indicates the presence of compounds containing carbon-nitrogen bonds, which can be derived from polymer components or additives used in filmmaking.

Food Safety and Edibility Testing of Edible Film from Nata de Tomato

Edibility test is one of the main characteristics that indicate that an edible film can be consumed. This test is considered successful if all components in the film, such as biopolymers, plasticizers, and other ingredients, are derived from food-safe materials, and all processes and equipment used meet applicable standards in food processing (Tavassoli-Kafrani et al., 2016). Edibility testing is essential to ensure that the packaging product does not jeopardize consumer health.

One of the factors that can cause illness due to food contamination is exposure to hazardous chemicals, such as heavy metals. Heavy metals such as arsenic (As), cadmium (Cd), lead (Pb) and mercury (Hg) pose a major threat to human health due to their carcinogenic nature. Here are some types of heavy metals that are harmful to human health.

Table 6. Heavy Metal Content and Microbial Contaminants of Nata de Tomato-based Edible Film

Parameters	Unit	Results
Arsenic (As)	mg/kg	Not detected (<0.1)
Cadmium (Cd)	mg/kg	Not detected (<0.5)
Lead (Pb)	mg/kg	0.218
Mercury (Hg)	mg/kg	Not detected (<0.1)
Escherichia coli	cfu/g	$<0.1 \times 10^1$
Salmonella spp.	/25 g	Negative
Staphylococcus aureus	cfu/g	$<0.1 \times 10^1$

Based on the heavy metal test results presented in Table 6, edible film from nata de tomato does not contain arsenic (As), cadmium (Cd), and mercury (Hg). However, there is a lead (Pb) content of 0.218 mg/kg. Based on the Head of BPOM RI Regulation No. HK.00.06.1.52.4011 regarding the Determination of Maximum Limits of Contaminants in Food (2009), the maximum limit of lead contamination in food is 0.25 ppm. Therefore, the lead content found in edible film from nata de tomato is still below the maximum limit set by BPOM-RI. Thus, nata de tomato-based edible film can be declared safe for consumption, because it does not contain harmful heavy metals in levels that exceed the limit.

In addition to heavy metal testing, microbial testing is also conducted to ensure food safety from bacterial contamination. This test includes testing for several types of pathogenic bacteria, such as *E. coli, Salmonella spp. and S. aureus*. Based on the microbial testing results shown in Table 6, the nata de tomato-based edible film was not detected to contain the three types of pathogenic bacteria. This indicates that the edible film from nata de tomato meets food safety standards and is suitable for consumption.

4. CONCLUSION

Based on the research results, the nata de tomato-based edible film meets several important parameters in evaluating physical quality and food safety. The film thickness of 0.04 mm complies with the JIS standard, while the tensile strength (36.32 MPa) also meets the JIS standard, indicating that the film is strong enough and not easily torn. Although the elongation value (1.67%) does not meet the JIS standard, this is consistent with findings in other nata-based edible films. The low density (0.19 g/cm^3) indicates high flexibility, but it may affect the film's ability to block water vapor migration. The opacity of 2.06 A/mm demonstrates the film's ability to block light, which is beneficial for protecting the packaged product from light-induced damage. SEM analysis shows a rough and bubbly surface, which can be improved by optimizing the use of glycerin. FTIR results confirm the presence of characteristic functional groups of cellulose, as well as the additives CMC and glycerin. Heavy metal testing indicates that the film does not contain As, Cd, and Hg, with Pb levels remaining below the safe limit set by BPOM RI. Microbial testing shows that the film is free from pathogens such as *E. coli*, *Salmonella spp*., and *S. aureus*, making it safe for consumption. Overall, the nata de tomato-based edible film meets physical quality and food safety standards and is safe for use as food packaging material.

5. ACKNOWLEDGEMENTS

The authors would like to express their sincere gratitude to the Food Technology Laboratory Universitas Ciputra, for providing the facilities and support needed for this research. We also extend our appreciation to the Lembaga Ilmu Hayati, Teknik & Rekayasa (LIHTR) Universitas Airlangga and would like to thank Eurofins Angler Biochemlab for their collaboration and laboratory analysis contributions. This research would not have been possible without the support and dedication of these institutions.

6. REFERENCES

Alimi, B. A., Workneh, T. S., & Femi, F. A. (2021). Fabrication and characterization of edible films from acha (Digitalia exilis) and iburu (Digitalia iburua) starches. *CyTA-Journal of Food, 19*(1), 493-500.

Asriani, N., Asikin, A. N., Irawan, I., Kusumaningrum, I., & Pamungkas, B. F. (2025). Penambahan campuran plasticizer gliserol dan sorbitol terhadap karakteristik edible film karagenan. *Journal of Marine Research, 14*(1), 45-53.

Azwar, E., Asmara, P., & Darni, Y. (2022). Karakterisasi edible film dari pati jagung dengan plastisizer gliserol dan filler CMC sebagai bahan pengemas makanan. *Jurnal Teknologi dan Inovasi Industri (JTII), 3*(1).

Deden, M., Rahim, A., & Asrawaty, A. (2020). Sifat fisik dan kimia edible film pati umbi gadung pada berbagai konsentrasi. *Jurnal Pengolahan Pangan, 5*(1), 26-33.

Djenar, N. S., Suryadi, J., Nursaadah, N. S., & Putri, E. (2022). Pengaruh penambahan minyak zaitun terhadap karakteristik dan reologi edible film berbahan dasar gluten. *KOVALEN: Jurnal Riset Kimia, 8*(2), 127-141.

Gresinta, E., Pratiwi, R. D., Damayanti, F., & Putra, E. P. (2019). Komparasi yield nata de tomato dengan nata de coco berdasarkan durasi fermentasi. *IJIS Edu: Indonesian Journal of Integrated Science Education, 1*(2), 169-174.

Harianingsih, H., Suwardiyono, S., & Wulandari, R. (2017). Pengaruh penambahan gliserol terhadap tensile strength dan elongation at break edible film dari nata de soya. *Jurnal Inovasi Teknik Kimia, 2*(1).

Ismaya, F. C., Fithriyah, N. H., & Hendrawati, T. Y. (2021). Pembuatan dan karakterisasi edible film dari nata de coco dan gliserol. *Jurnal Teknologi, 13*(1), 81-88.

Mustapha, S. N. H., & Wan, J. S. (2022). Effect of hybridization composition and glycerin content on novel corn starch/nata de coco plastic film: Thermal, mechanical, and degradation study. *Food Chemistry, 373*, 131440.

Pak, E. S., Ghaghelestani, S. N., & Najafi, M. A. (2020). Preparation and characterization of a new edible film based on Persian gum with glycerol plasticizer. *Journal of food science and technology, 57*, 3284-3294.

Purnavita, S., Subandriyo, D. Y., & Anggraeni, A. (2020). Penambahan gliserol terhadap karakteristik bioplastik dari komposit pati aren dan glukomanan. *Metana, 16*(1), 19-25.

Rahmi, Q. F., Wulandari, E., & Gumilar, J. (2022). Pengaruh konsentrasi gliserol pada gelatin kulit kelinci terhadap kadar air, ketebalan film, dan laju transmisi uap air edible film. *Jurnal Teknologi Hasil Peternakan, 3*(1), 19-31.

Ramadhia, M., Indrastuti, Y. E., & Purwandani, L. (2023). Mechanical and barrier properties of biocellulose nata de coco-based edible film: Influence of purple yam (Dioscorea alata) flour and glycerol concentration. *Demeter: Journal of Farming and Agriculture, 1*(2), 61-67.

Ramdhani, R., Amalia, V., & Junitasari, A. (2022). Pengaruh konsentrasi sorbitol terhadap karakteristik edible film pati kentang (Solanum tuberosum L.) dan pengaplikasiannya pada dodol nanas. In *Gunung Djati Conference Series, 15*, 103-111.

Rini, F., Yulneriwarni, Y., & Sukara, E. (2022). Additional nata de coco on the performance of cassava starch based bioplastic. *Journal of Tropical Biodiversity, 3*(1), 43-51.

Rusli, A., Metusalach, S., & Tahir, M. M. (2017). Karakterisasi edible film karagenan dengan pemlastis gliserol. *Jurnal Pengolahan Hasil Perikanan Indonesia, 20*(2), 219-229.

Sartika, M., Rambe, F. R., Parinduri, S. Z. D. M., Harahap, H., Nasution, H., Lubis, M., & Manurung, R. (2022). Tensile properties of edible films from various types of starch with the addition of glycerol as plasticizer: A review. In *IOP Conference Series: Earth and Environmental Science, 1115*, No. 1, 012075. IOP Publishing.

Sulistiyana, S., Riyandari, B. A., Nurkamariati, N. (2024). Sintesis dan karakterisasi film pengemas aktif dari kombinasi kitosan-alginat dan asam sitrat. *ALCHEMY Jurnal Penelitian Kimia*, 120-129.

Tavassoli-Kafrani, E., Shekarchizadeh, H., & Masoudpour-Behabadi, M. (2016). Development of edible films and coatings from alginates and carrageenans. *Carbohydrate polymers, 137*, 360-374.

Unsa, L. K., & Paramastri, G. A. (2018). Kajian jenis plasticizer campuran gliserol dan sorbitol terhadap sintesis dan karakterisasi edible film pati bonggol pisang sebagai pengemas buah apel. *Jurnal Kompetensi Teknik, 10*(1), 35-47.

Vonnie, J. M., Rovina, K., ‘Aqilah, N. M. N., & Felicia, X. W. L. (2023). Development and Characterization of Biosorbent Film from Eggshell/Orange Waste Enriched with Banana Starch. *Polymers, 15*(11), 2414.