JURNAL IPTEK
MEDIA KOMUNIKASI TEKNOLOGI
homepage URL : ejurnal.itats.ac.id/index.php/iptek

Potential Of Pineapple Peel Waste With Tapioca Starch in Making Edible Film

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ARTICLE INFORMATION

Jurnal IPTEK – Volume 30
Number 1, May 2026

Page:
23 – 30
Date of issue :
May 31, 2026

DOI:
10.31284/j.iptek.2026.v30i1
.8264

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PUBLISHER

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ABSTRACT

Most pineapple peels are discarded as waste, although they contain 8.3% pectin, a valuable component for edible film production. This study aimed to examine the effects of temperature and extraction time on pectin yield and to evaluate the texture of edible films produced with glycerol. The overall process consisted of three stages: pineapple peel pretreatment, pectin extraction, and edible film preparation. Results showed that extending extraction time increased the amount of pectin obtained. The maximum yield was recorded at 125 minutes and 100°C, reaching 8.985 grams. In terms of tensile strength, higher extraction temperatures accelerated gelatinization and improved film strength. The best tensile strength was obtained at 70°C for 150 minutes, achieving 34.898 N/mm. Organoleptic evaluation involved 208 responses, where 49.5% rated the film as normal (103 responses), 37.5% as like (78 responses), 4.8% as really like (10 responses), and 8.2% as don't like (17 responses). Overall, edible films made from pineapple peel and tapioca were considered acceptable. The highest preference was observed for texture, followed by color, while taste and flavor scored lower. These findings highlight the potential of pineapple peel films, although further formulation improvements are needed for better consumer acceptance.

Keywords: *Extraction; pineapple peels; pectin; edible film.*

ABSTRACT

Sebagian besar kulit nanas biasanya dibuang sebagai limbah, padahal kulit nanas mengandung 8,3% pektin yang bernilai tinggi sebagai bahan pembuatan edible film. Penelitian ini bertujuan untuk mengetahui pengaruh suhu dan waktu ekstraksi terhadap rendemen pektin serta mengevaluasi tekstur edible film yang diproduksi dengan penambahan gliserol. Proses pembuatan terdiri dari tiga tahap, yaitu pretreatment kulit nanas, ekstraksi pektin, dan pembuatan edible film. Hasil penelitian menunjukkan bahwa semakin lama waktu ekstraksi, semakin besar massa pektin yang dihasilkan. Rendemen maksimum diperoleh pada 125 menit pada suhu 100°C sebesar 8,985 gram. Uji kekuatan tarik menunjukkan bahwa semakin tinggi suhu ekstraksi, semakin cepat proses gelatinisasi tercapai dan semakin kuat edible film yang dihasilkan. Hasil terbaik diperoleh pada suhu 70°C selama 150 menit dengan kekuatan tarik 34,898 N/mm. Uji organoleptik melibatkan 208 respon, di mana 49,5% panelis menilai normal (103 respon), 37,5% menyukai (78 respon), 4,8% sangat menyukai (10 respon), dan 8,2% tidak menyukai (17 respon). Secara umum, edible film dari kulit nanas dan tapioka dapat diterima. Preferensi tertinggi terdapat pada tekstur, disusul warna, sementara rasa dan aroma lebih rendah, sehingga perlu perbaikan formulasi untuk meningkatkan penerimaan konsumen.

Keywords: *ekstraksi; kulit nanas; pektin; edible film.*

INTRODUCTION

Foodstuffs are materials that supply nutrients and are metabolized to generate energy required for life processes. To minimize these problems, food packaging must be designed and applied in accodance with established safety standards. One approach that has received increasing attention is the use of biopolymers. When processed into edible films, biopolymers form thin layers that can coat the surface of food, are safe for consumption, biodegradable[1], and able to limit mass transfer within the product [2]. Edible films can be produced from different types of biopolymer-based materials, including proteins such as gelatin, lipids such as glycerol, and carbohydrates such as pectin or starch[3]. Several studies [4] have shown that pectin obtained from fruit peel waste can serve as an alternative polysaccharide source for edible film preparation. A variety of fruit peels have been explored for this purpose, including apple peels[5], durian peels[6], papaya peels[7], dragon fruit peels[8], cocoa peels[9], and banana peels[10]. Besides fruit peels, plant leaves have also been investigated as supplementary materials in edible film formulations. Fatisa [11], for example, reported that the incorporation of soursop leaf extract into durian seed starch–based edible films increased the antioxidant activity of the films. At the same time, the study noted changes in physical and mechanical properties, such as reduced flexibility and less homogeneous film structure. These effects indicate that the inclusion of leaf-based components often requires careful optimization of formulation composition, including the use of plasticizers, to obtain acceptable film characteristics. Overall, leaf materials tend to function mainly as functional additives rather than as the primary film-forming matrix. For this reason, fruit peels that naturally contain high levels of pectin, such as pineapple peels, are considered more suitable as the main raw material for edible film production.

Pineapple peels are an agro-industrial by-product with considerable potential for further utilization. Nevertheless, this waste material is still underutilized, even though previous reports indicate that pineapple peels contain approximately 5.25% pectin[12]. Pectin is a polysaccharide that contributes to key edible film properties, including flexibility, transparency, and mechanical strength. In this work, pectin was obtained from pineapple peels through acid hydrolysis of protopectin to produce soluble pectin suitable for film formulation[13], [2]. Starch was used as a supporting component, with tapioca starch selected due to its wide availability in Indonesia, relatively low cost, and good gel-forming ability [14]. The combination of pineapple peel pectin and tapioca starch is therefore expected to enhance the mechanical and functional performance of edible films. Accordingly, this study examined the use of pineapple peel waste in combination with tapioca starch for edible film production. The objectives were to evaluate the effects of extraction temperature and extraction time on pectin yield, as well as to assess the organoleptic properties of the resulting edible films.

LITERATURE REVIEW

Edible films are thin layers made from safe, consumable materials that protect food, and its environment by reducing moisture loss, regulating gas permeability, extending shelf life, and controlling transfer of compounds that affect appearance and nutritional quality [15][16]. Their use is increasing as a solution to plastic pollution, since many film raw materials are agroindustrial by-products containing valuable polysaccharides, fibers, proteins, and bioactive compounds [17]. To obtain desirable film properties, these materials are combined with film-forming matrices that create stable polymer networks; starch is commonly used because it is biodegradable, inexpensive, and yields transparent, flexible films.

Starch, a plant polysaccharide reserve found in cassava, corn, potato, wheat, and sago, consists of amylose and amylopectin [18]. Amylose is a linear glucose polymer (α-(1,4)-glycosidic) that forms strong intermolecular associations, producing compact films with good tensile strength. Amylopectin is branched (α-(1,4) and α-(1,6)-glycosidic) and provides elasticity and flexibility but, in excess, can weaken films and increase water uptake.

Starch-based film formation begins with gelatinization: heating in water causes granule swelling and crystalline disruption, releasing amylose and amylopectin into solution. Upon cooling and drying, hydrogen bonding among starch molecules forms a dense matrix, producing a thin, homogeneous film.

Film characteristics depend on the starch source due to varying amylose/amylopectin ratios, which affect physical, mechanical, and film-forming properties. Tapioca starch is widely studied for packaging applications because of its abundance and suitable characteristics. For instance, adding eucalyptus extract to tapioca films increased elongation from 19% to 24% and altered water vapor barrier properties via interactions with the starch matrix [19]. Roidoung [20] reported a trade-off between flexibility and strength: 100% tapioca films showed highest elongation but lower tensile strength than blends with potato starch.

Although tapioca starch is a promising film-forming matrix, films often have limitations in mechanical strength and water vapor barrier performance; thus, modifications using natural additives or other biopolymers are explored. Pineapple peel waste is a promising reinforcement source because it is abundant and contains biopolymers and bioactive compounds that may improve physical, mechanical, and functional film properties [21].

METHOD

The production of edible film from pineapple peels was conducted in three main stages: pretreatment of pineapple peels, extraction of pectin from pineapple peels, and preparation of the edible film.

Pretreatment of Pineapple Peels

Pineapple peels were first washed with running water to remove adhering impurities and surface contaminants. The cleaned peels were then blended to obtain a fine puree. The resulting puree was sun-dried for 1 h until a dry material was obtained. After drying, the material was sieved using a 50-mesh sieve to achieve a uniform particle size.

Pectin Extraction from Pineapple Peels

Pectin extraction was carried out using an acid hydrolysis method. Pineapple peel powder (12 g) was mixed with 200 mL of distilled water in a three-necked flask. The extraction process was performed using 0.1 N HCl at temperatures of 40, 70, and 100 °C for predetermined extraction times, with continuous stirring using a magnetic stirrer. After extraction, the mixture was filtered to separate the filtrate from the solid residue. The filtrate was then precipitated by the addition of 100 mL of 96% ethanol. The precipitated pectin was subsequently filtered again to obtain the final pectin extract.

Edible Film Preparation

Edible films were prepared using pectin, cassava starch, carboxymethyl cellulose (CMC), and glycerol. The pectin solution was prepared by dissolving the pectin extract in 100 mL of distilled water. Separately, a starch solution was prepared by dissolving 15 g of cassava starch in 150 mL of distilled water, while 5 g of CMC was dissolved in 15 mL of distilled water. The pectin and starch solutions were mixed and heated on a hot plate until a clear solution was obtained. Afterward, the CMC solution was added to the mixture, followed by the addition of 5 mL of glycerol as a plasticizer. The resulting solution was poured into molds (petri dishes) and dried in an oven at 80 °C for 5 h. Once dried, the edible films were carefully removed from the molds and used for further characterization.

RESULTS AND DISCUSSION

The production of edible films in this study involved three main stages: pretreatment of pineapple peels, extraction of pectin, and fabrication of edible films. The independent variables examined were extraction temperature (40°C, 70°C, and 100°C) and extraction time (100, 125, and 150 minutes). The resulting edible films were evaluated through tensile strength testing to determine their mechanical properties and organoleptic testing to assess panelist acceptance.

Pectin Production

Extraction is a separation process in which specific compounds are transferred from solid or liquid materials into a solvent under controlled temperature and time conditions. Both temperature and extraction time play crucial roles in determining extraction efficiency. Excessively high temperatures or prolonged extraction times beyond optimal conditions may lead to degradation or oxidation of the target compound, resulting in reduced yield [22]. The effects of temperature and extraction time on pectin yield are presented in Tables 1, 2, and 3.

Table 1. Pectin Mass Yield at 40°C

Extraction Time (minutes)	Pectin Mass (gram)
100	8.205 7.106 8.081
125	8.174 8.160 8.177
150	8.318 8.303 8.320

The results of the study, conducted at 40°C, are presented in Table 1. The results showed that the amount of pectin recovered increased with the length of extraction time A similar trend was reported by Yunita [23] in the extraction of pectin from noni fruit (Morinda citrifolia L.), where extended extraction time significantly increased pectin yield and affected its physicochemical properties. The consistency between the two studies suggests that longer extraction time enhances protopectin hydrolysis and promotes pectin solubilization, regardless of the fruit source. The highest yield was obtained after 150 minutes, with 8,320 grams of pectin.

Table 2. Pectin Mass Yield at 70°C

Extraction Time (minutes)	Pectin Mass (gram)
100	8.530 8.552 8.567
125	8.594 8.599 8.642
150	8.679 8.683 8.697

The results obtained at 70°C can be seen in Table 2. The mass of pectin obtained increased with increasing extraction time. The largest pectin yield was 8.697 grams in 150 minutes. This result is consistent with research conducted by Adhiksana [24], on pectin extraction from Siam orange peel using microwave-assisted extraction, which stated that longer extraction times provided extended solvent–material contact, thereby enhancing mass transfer and resulting in higher pectin yield. This

confirms that sufficient extraction time is essential to maximize pectin recovery, even when different extraction techniques are applied. Furthermore, Tables 1 and 2 also show that during the 150-minute extraction time, the pectin mass increased at extraction temperatures of 70°C and 40°C. This implies that higher extraction temperatures produce greater pectin mass.

Table 3. Pectin Mass Yield at 100°C

Extraction Time (minutes)	Pectin Mass (gram)
100	8.758 8.774 8.792
125	8.836 8.893 8.985
150	8.254 8.160 8.108

The results of this study at an extraction temperature of 100°C, as presented in Table 3, show that increasing extraction time and temperature led to a higher pectin yield. a decrease in pectin mass was observed when the extraction time was extended to 150 minutes. This decline is attributed to excessive temperature and prolonged extraction duration, which may cause further hydrolysis of pectin into pectic acid. Similar results were reported by Dwi [25] in the extraction of pectin from pineapple residue, where the optimal extraction conditions were identified at 100°C for 120 minutes, and pectin degradation occurred beyond this point. In addition, Diana [7], observed comparable behavior in pectin extraction from papaya peel waste, indicating that excessive temperature and extraction time negatively affected both pectin quality and yield. These findings collectively confirm that exceeding optimal extraction conditions leads to pectin degradation and reduced pectin recovery.

Tensile Strength

Tensile strength represents the maximum force that an edible film can withstand before breaking and reflects its mechanical strength and flexibility. Tensile strength and elongation tests were conducted at the Textile Manufacturing and Testing Laboratory, Faculty of Technology, Universitas Islam Indonesia (UII), Yogyakarta, using a Tenso Lab Type 168E instrument. The tensile strength test results are presented in Table 4.

Table 4. Tensile Strength Test Results

Temperature (°C)	Time (minute)	Strength Value (N/mm)				Elongation (%)
		1	2	3	Average	
40	100	10.791	13.734	10.791	11.772	28.667
	125	13.734	15.696	12.753	14.061	29.833
	150	30.411	25.506	26.487	27.468	46.750
70	100	27.468	29.43	30.411	29.103	33.500
	125	17.658	21.582	19.62	19.62	30.917
	150	31.392	31.392	42.183	34.989	28.667
100	100	28.449	27.468	25.506	27.141	43.833
	125	27.468	30.411	33.354	30.411	40.667
	150	26.487	24.525	23.544	24.852	36.583

As shown in Table 4, the highest tensile strength value (34.989 N/mm²) was obtained from edible films prepared using pectin extracted at 70°C for 150 minutes. This result suggests that moderate extraction temperatures favor gelatinization and contribute to the formation of a stronger polymer network, resulting in improved tensile strength. A similar trend was reported by Handayani

[26] in bioplastic films produced from avocado seed starch, where increased processing temperature enhanced gelatinization and strengthened intermolecular interactions within the starch matrix. However, a decrease in tensile strength was observed at an extraction temperature of 100°C. This reduction is likely due to excessive thermal conditions, which may reduce the solubility and compatibility of starch and glycerol, leading to a less uniform film structure. Handayani [19] also reported that overly severe processing conditions could negatively affect film integrity and mechanical performance.

Table 4 also presents the elongation values of the edible films. Elongation reflects the maximum strain a film can endure before rupture and serves as an indicator of elasticity. According to Siskawardani[27], elongation values of edible films are classified as poor (<10%), good (10–50%), and very good (>50%). Based on this classification, the elongation values obtained in this study fall within the good category (0–50%). The highest elongation value (46.75%) was observed for films prepared at an extraction temperature of 40°C for 150 minutes. This result aligns with the findings of Siskawardani [27], who reported that appropriate glycerol addition and moderate processing conditions enhance polymer chain mobility, thereby increasing film flexibility and elongation.

Organoleptic Testing

Organoleptic testing was conducted to evaluate panelist acceptance of the edible films produced from pineapple peel pectin and tapioca starch. The parameters assessed included taste, texture, color, and aroma. A total of 52 untrained panelists from the general public participated in the evaluation. The organoleptic test results are summarized in Table 5.

Table 5. Organoleptic Test Results

Type of Testing	Level of Preference (person)			
	Really Like	Like	Normal	Don't Like
Taste	2	22	22	6
Texture	2	26	21	3
Color	4	23	22	3
Flavor	2	7	38	5
Total	10	78	103	17

1. Taste

Most panelists rated the taste of the edible film as "like" (22 respondents) or "normal" (22 respondents). Only a small number of panelists reported "really like" (2 respondents) or "don't like" (6 respondents). These results indicate that the edible film is acceptable in terms of taste, although it has not yet achieved a high level of preference. The relatively neutral taste may be attributed to the inherent characteristics of pectin and starch, which do not possess strong flavors.

2. Texture

Texture received the most favorable response among all parameters. Twenty-six panelists rated the texture as "like," 21 rated it as "normal," two rated it as "really like," and only three panelists expressed dislike. This indicates that the edible film exhibited desirable textural properties, such as being thin, flexible, and non-brittle. The combination of pectin and tapioca starch likely contributed to improved film flexibility.

3. Color

The color of the edible film was generally well accepted, with 23 panelists indicating "like," 22 "normal," four "really like," and three "don't like." The visual appearance of the edible film is influenced by solution clarity and homogeneity during the casting process, which may explain the relatively positive response.

4. Flavor

The aroma parameter received the lowest acceptance score. Most panelists rated it as "normal" (38 respondents), while seven rated it as "like," two as "really like," and five as "don't like." This lower preference may be associated with the characteristic aroma of pineapple peel or

tapioca starch, which may not be entirely neutral to panelists. Overall, the majority of panelists rated the edible film as "normal" (103 responses) or "like" (78 responses). Only a small proportion expressed strong preference ("really like," 10 responses) or dislike (17 responses). These results indicate that the edible film produced is generally acceptable, particularly in terms of texture and color. However, improvements in taste and aroma are still required.

CONCLUSION

The conclusion from the results of the research that has been carried out is that:

1. Extraction time had a significant effect on the amount of pectin obtained. In general, longer extraction times resulted in higher pectin yields. The highest pectin mass, 8.905 g, was obtained at an extraction temperature of 100°C with an extraction time of 125 minutes. However, when the extraction time was extended to 150 minutes at the same temperature, a decrease in pectin yield was observed. This reduction indicates that excessive extraction duration promotes further hydrolysis of pectin into pectic acid, leading to pectin degradation and reduced recovery.
2. the mechanical properties of the edible films were influenced by the extraction conditions. The highest tensile strength value, 34.989 N/mm², was obtained from films prepared using pectin extracted at 70°C for 150 minutes. This result suggests that moderate extraction temperatures favor effective gelatinization and the formation of a stronger polymer network, thereby enhancing tensile strength. In contrast, elongation values obtained in this study fell within the good category (10–50%). The highest elongation value, 46.75%, was achieved at an extraction temperature of 40°C for 150 minutes, indicating improved film flexibility under milder extraction conditions.
3. The organoleptic evaluation showed that the edible films produced from pineapple peel pectin and tapioca starch were generally acceptable to panelists. Out of 208 total responses, 49.5% of the ratings were categorized as "normal," 37.5% as "like," 4.8% as "really like," and 8.2% as "don't like." Among the evaluated parameters, texture received the highest level of preference, followed by color, while taste and aroma obtained relatively lower scores. These findings indicate that although the edible film is acceptable overall, further formulation optimization is needed, particularly to improve sensory attributes related to taste and aroma.

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