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Pectin extraction from *Nephelium lappaceum* (Binjai variety) peel using pulsed electric field

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ABSTRACT

The peel of *Nephelium lappaceum* is an underutilized agricultural by-product that contains cellulose, hemicellulose, lignin, and pectin. Pectin is a polygalacturonate compound commonly used as an emulsifying agent. This study aimed to evaluate the effects of electric field intensity, extraction time, and feed-to-solvent (f/s) ratio on pectin yield from *Nephelium lappaceum* (Binjai variety) peel using Pulsed Electric Field (PEF) extraction. The experimental design followed a One Factor at a Time (OFAT) approach consisting of three stages, with each stage conducted in duplicate. Data were analyzed using Analysis of Variance (ANOVA), followed by the Duncan Multiple Range Test (DMRT) at a 95% confidence level using SPSS v.27.0.1. The results showed that the optimal electric field intensity was 20 kV/cm, yielding 3.41%; the optimal extraction time was 10 minutes, yielding 3.48%; and the optimal f/s ratio was 1:30 w/v, yielding 3.48%. This study demonstrates that PEF extraction can efficiently produce pectin from rambutan peel, offering a sustainable method to utilize agricultural waste while also contributing to the diversification of currently limited pectin sources.

1. Introduction

The global production of *Nephelium lappaceum* reached approximately 2.5 million tons in 2018, with an expected growth rate of 3.6% by 2023 [1]. Binjai is one of the *Nephelium lappaceum* varieties, categorized as a medium thickness skinned fruit [2,3]. This variety is characterized by its round shape and red color, with spines that are red at the base and green at the tips [4,5].

Nephelium lappaceum is generally consumed for its flesh, leaving the peel and seed. *Nephelium lappaceum* peel accounts for approximately 43.7% to 57.4% of the total fruit weight [6]. Organic materials such as fruit peels have the potential to release methane gas, which can degrade water and soil quality [7]. On the other hand, pectin extracted from *Nephelium lappaceum* peel using conventional methods with mineral acids has a yield of 6.51% and 1.9% [8,9]. Pectin is widely utilized as an emulsifying agent and viscosity enhancer in jelly and jam products [10,11].

Commercial pectin extraction is generally performed using conventional methods, characterized by the use of mineral acids, high temperatures, and extended extraction times, which may affect yield quality and have environmental impacts [12,13]. Therefore, green extraction serves as an alternative that can be applied to reduce extraction time and the use of mineral acids [14]. The combination of Pulsed Electric Field (PEF) and citric acid as a solvent is one of the methods that can be utilized in the green extraction process [15].

Organic acids have lower dissociation constants than mineral acids, allowing for a reduced risk of pectin depolymerization, which can decrease the viscosity of the extracted yield [16]. Commonly used organic acids in the extraction process include citrate, tartrate, acetate, lactate, and malate. Pectin yield obtained from the extraction of melon peel, jackfruit peel, and apple solid waste using citric acid has shown the highest yield compared to other acid solvents [17,18,19].

Ability of PEF in carrying out the extraction process is highly dependent on strength of the electric field, extraction time, and feed-to-solvent (f/s) used. PEF enhances cell wall permeability by breaking down skin tissue and inducing irreversible electroporation, facilitating solvent penetration and pectin release [20]. Increasing intensity of the electric field can lead to a higher yield and reduce extraction time [21,22]. On the other hand, solvent used to break the polygalacturonate bond with material on the cell wall is influenced by its ratio to material. Increasing f/s ratio can enhance pectin yield, but excessive ratios may result in degradation into pectic acid, reducing yield value [23].

The selection of optimal electric field strength, time, and f/s ratio is essential for increasing pectin yield during the extraction process. This study aims to examine the impact of electric field strength intensity, extraction time, and f/s ratio on pectin yield from *Nephelium lappaceum* (Binjai variety) peel using citric acid as the extraction solvent.

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2. Materials and Methods

2.1. Materials

The materials for this research were *Nephelium lappaceum* (Binjai variety) obtained from Pasar Baru Porong, Sidoarjo. The chemicals used in the extraction process were aquadest, technical citric acid monohydrate ($C_6H_8O_7$) (Bohr Chemical), and technical 96% ethanol obtained from UD. Sumber Ilmiah Persada, Surabaya.

2.2. Methods

2.2.1. Production of Nephelium lappaceum peel powder flour

The *Nephelium lappaceum* peel is separated from the fruit and then washed with clean water to remove any adhering dirt. The cleaned and dried peel is then cut into small pieces before being dried in a food dehydrator at 70°C for 8 hours [8]. The dried *Nephelium lappaceum* peel is ground using a blender. The powder is then sieved using an 80-mesh sieve and stored with added silica gel to maintain its moisture content.

2.2.2. Extraction of pectin from Nephelium lappaceum peel using PEF

Preparation of a 0.1 mol/L citric acid solvent was conducted by dissolving citric acid monohydrate in distilled water under continuous stirring until fully solubilized. The prepared solvent was subsequently mixed with *Nephelium lappaceum* peel powder, and the resulting suspension was transferred into the PEF machine chamber. The sample was subjected to PEF treatment with controlled voltage and duration parameters. Following treatment, the sample was incubated in a water bath shaker at 70°C for 60 minutes [24]. The extract was then filtered using a nylon filter and further separated by centrifugation at 3,500 rpm for 20 minutes. The supernatant was precipitated with 96% ethanol at a 1:1 (v:v) ratio and left for 24 hours to facilitate precipitation.

2.2.3. Calculation of pectin yield

The pectin yield from *Nephelium lappaceum* peel flour is determined by comparing the weight of the extracted pectin to the initial weight of the flour used, expressed as a percentage [24]. The formula for calculating pectin yield is as follows:

$$\text{Yield (\%)} = \frac{Weight\ of\ pectin\ (g)}{Weight\ of\ initial\ flour\ (g)}\ x\ 100\% \quad (1)$$

2.2.4. Research design

The study was conducted using the One Factor at a Time (OFAT) method in three stages. In the first stage, the pulsed electric field (PEF) intensity was determined at 5 kV/cm, 10 kV/cm, 15 kV/cm, and 20 kV/cm, with fixed variables including an extraction time of 15 minutes and the f/s ratio of 1:30 w/v. The second stage involved determining the extraction time at 5 minutes, 10 minutes, 15 minutes, and 20 minutes, using a fixed electric field intensity selected from the first stage and the f/s ratio of 1:30 w/v. In the third stage, the f/s ratio was evaluated at 1:10 w/v, 1:20 w/v, 1:30 w/v, and 1:40 w/v, with fixed variables including the selected electric field intensity and extraction time from the previous stage. Each stage was conducted in duplicate.

2.2.4. Data analysis

One-way Analysis of Variance (ANOVA) was used to analyze data in this study to determine differences between treatments. Duncan's Multiple Range Test (DMRT) at a 95% confidence level (α = 0.05) using SPSS software version 27.0.1 was then performed if significant differences were observed between treatment groups.

3. Results and Discussion

3.1. Raw material analysis

Table 1 presents the yield analysis results for the production of *Nephelium lappaceum* (Binjai variety) peel flour, which yielded 27.35% from 500 grams of fresh binjai *Nephelium lappaceum* peel. The moisture content of the flour was analyzed at 9.315%, while the ash content was 4.06%. These findings align with the results reported by previous study that indicating a moisture content of 10.5% in *Nephelium lappaceum* peel flour [25], and an ash content of 4.19% [26].

Table 1. *Nephelium lappaceum* peel flour analysis results

Parameter	***Nephelium lappaceum* Peel Flour**	
	Result	**Literature**
Yield (%)	27,35±0,028	-
Water content (%)	9,315±0,007	10,5[25]
Ash content (%)	4,08±0,028	4,19[26]

The lower water content of the material (9.32%) compared to the value reported in the previous study (10.5%) is attributed to differences in drying methods. In this study, *Nephelium lappaceum* peel was dried using a food dehydrator at 70°C, whereas previous study utilized sun drying [25]. Food dehydrators are equipped with temperature regulators, airflow control, and ventilation systems, ensuring more uniform air circulation and optimized drying [27]. In contrast, sun drying is influenced by weather conditions and natural air humidity, which may not always be optimal [28].

Ash content refers to the residual inorganic matter remaining after material combustion [29]. The lower ash content observed in this study (4.06%) compared to the literature (4.19%) is likely due to a more thorough raw material cleaning process, reducing the presence of contaminants such as soil and dust. Assertion that ash content reflects the purity and cleanliness of the material [29].

3.2. The effect of pectin yield at various electric field strength of PEF

The yield of the extracted pectin was calculated. The relationship between electric field strength and pectin yield is presented in Table 2. The data were analyzed using one-way ANOVA at a 95% confidence level (α = 0.05) in SPSS. A significance value (p-value) of $<\alpha$ indicates that the electric field strength has a significant effect on the pectin yield from *Nephelium lappaceum* peel.

Table 2. Relationship between electric field strength and average yield

Electric Strength (kV/cm)	Yield (%)
5	1,29^{c}±0,003
10	2,42^{b}±0,062
15	3,36^{a}±0,088
20	3,41^{a}±0,054

Treatment with an electric field intensity of 5 kV/cm resulted in the lowest pectin yield (1.29%), while the highest yield (3.41%) was obtained at 20 kV/cm. However, the yield increase from 15 kV/cm to 20 kV/cm tended to stagnate, as indicated by the results of the DMRT further test, which showed no significant difference between the yields at 15 kV/cm and 20 kV/cm.

Increase in PEF electric field strength leads to a higher pectin yield, as shown in Figure 1. Pectin yield continues to rise from 5 kV/cm to 20 kV/cm. A higher electric field strength enhances pectin yield by promoting cell wall disintegration, facilitating solvent penetration into the cells. PEF induces the diffusion of intracellular components, resulting in the partial rupture of the material's skin tissue [20,24].

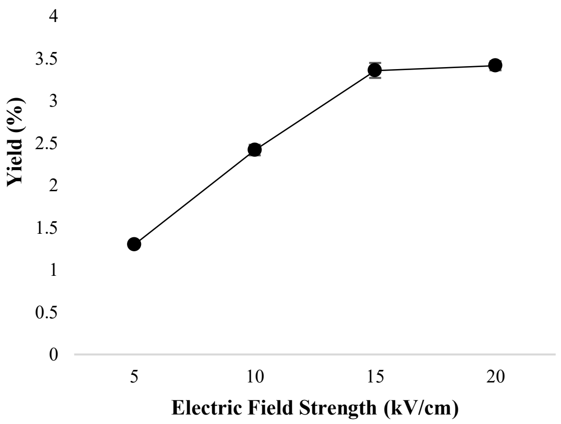

Fig. 1. The effect of electric field strength on average pectin yield

Increase in cell wall permeability by PEF facilitates penetration of acid solvents into cells [20]. Acid solvents release H^+ ions, which replace calcium and magnesium ions in protopectin bonds with cell wall components through the acid hydrolysis process [30]. Cleavage of the protopectin polygalacturonate glycosidic bond through this hydrolysis produces pectin with a shorter chain that is soluble in water, thereby increasing the resulting yield [31].

3.3. The effect of pectin yield at various times

Pectin extraction is determined not only by the electric field strength of PEF but also by the extraction time. The relationship between extraction time and pectin yield is presented in Table 3. One-way ANOVA analysis showed a significant effect of extraction time on pectin yield. Further analysis using DMRT identified group differences based on the harmonic mean value, indicating whether they belong to the same or different columns [32].

Table 3. Relationship between extraction time and average yield

Extraction Time (minute)	Yield (%)
5	2,33^{b}±0,314
10	3,48^{a}±0,111
15	3,41^{a}±0,054
20	2,12^{b}±0,043

Figure 2 illustrates the effect of extraction time on pectin yield. The pectin yield increases with longer extraction times. However, excessive extraction durations result in a decline in yield. This finding aligns with the study by [32], which reported that pectin yield from kluwih peel increased with longer extraction times, although excessively prolonged extraction reduced the yield. The highest pectin yield was observed at a 10 minute extraction time (3.48%), which was not significantly different from the yield at 15 minutes (3.41%). Conversely, the lowest yield was recorded at 20 minutes (2.12%), which was not significantly different from the yield at 5 minutes (2.33%).

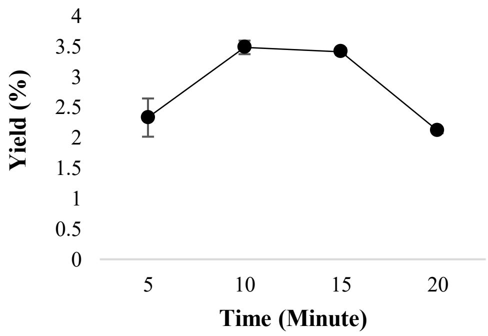

Fig. 2. The effect of extraction time on average pectin yield

The pectin yield increased from 2.33% at the 5th minute to 3.48% at the 10th minute. This increase is attributed to the prolonged interaction between the solvent and protopectin in the material, which enhances the hydrolysis of protopectin into pectin, thereby increasing the yield. This finding aligns with the statement by [33], that the pectin yield from banana peel (Ambon and Kepok variety) increased with extended extraction time, due to the increased frequency of acid solvent contact with protopectin.

The pectin yield decreased at the 15th minute (3.41%) and continued to decline at the 20th minute (2.12%). The reduction in pectin yield over prolonged extraction times was attributed to the further degradation of dissolved pectin into pectic acid [34]. Pectic acid is a compound containing galacturonic acid, which has largely been stripped of its methyl ester groups [35]. As a result, pectic acid is unable to form a gel [31].

3.4. The effect of pectin yield at f/s ratio

The f/s ratio determines the pectin yield in the extraction process, as the solvent has a limited capacity to bind compounds at specific ratios, making it necessary to establish an optimal f/s ratio for efficient pectin extraction [32]. The relationship between the f/s ratio and the resulting pectin yield is presented in Table 4. The findings indicate that the f/s ratio had a significant effect on pectin yield, as evidenced by a p-value (sig) < α (0.05) in the one-way ANOVA test.

Table 4. Relationship between f/s ratio and average yield

F/S Ratio (w/v)	Yield (%)
1:20	1,44^{b}±0,397
1:30	3,48^{a}±0,111
1:40	2,92^{a}±0,038
1:50	1,78^{b}±0,013

Effect of the f/s ratio on pectin yield can be observed in Figure 3. Pectin yield increased at a f/s ratio of 1:30 w/v (3.48%) compared to 1:20 w/v (1.44%), but decreased at 1:40 w/v (2.92%) and continued to decline at 1:50 w/v (1.78%). These findings align with the research by [32], that an increase in the f/s ratio enhances pectin yield in kluwih fruit peel. However, excessive f/s ratios result in a decline in yield. The yield obtained at a f/s ratio of 1:20 w/v (1.44%) was not significantly different from that at 1:50 w/v (1.78%), while the yield at 1:30 w/v was also not significantly different from that at 1:50 w/v (1.78%).

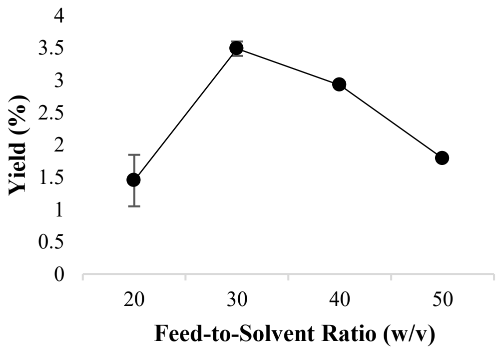

Fig. 3. The effect of f/s ratio on average pectin yield

The increase in the f/s ratio is attributed to the greater availability of solvent molecules that can interact with the material, facilitating the breakdown of protopectin bonds within the cell wall [32]. A higher f/s ratio also leads to an increase in the yield of cocoa peel pectin, as observed according to [23]. This is due to the enhanced ability of the solvent to dissolve protopectin into pectin, thereby increasing the yield. Additionally, the interaction between particles in contact becomes more significant with a higher f/s ratio during the extraction process, resulting in a greater number of bound particles, which further contributes to the increase in pectin yield [36].

Pectin yield decreased at f/s ratios of 1:40 (2.92%) and 1:50 (1.78%) due to pectin degradation into pectic acid, which could not be coagulated with alcohol during precipitation. These findings are consistent with the study by [32], which reported a decrease in pectin yield at high f/s ratios due to an increase in H^{+} ion concentration. The elevated H^{+} ion levels destabilize the pectin by breaking glycosidic bonds, ultimately hydrolyzing pectin into pectic acid.

4. Conclusion

The yield of *Nephelium lappaceum* peel pectin obtained from the extraction process using PEF is influenced by several factors, including electric field strength, extraction time, and f/s ratio.The PEF electric field intensity that yields the highest average pectin recovery of 3.41% is 20 kV/cm. The optimal extraction time resulting in the highest average pectin yield of 3.48% is 10 minutes. The most effective f/s ratio, using 0.1 mol/L citric acid, which achieves the highest average yield of 3.48%, is 1:30 w/v. The results demonstrate that PEF provides a sustainable method for pectin extraction, and the utilization of rambutan peel as a pectin source contributes to reducing agricultural waste.

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References

[1] M. D. Mota, A. N. B. Morte, L. C. R. C. e Silva, F. A. Chinalia, Sunscreen protection factor enhancement through supplementation with Rambutan (*Nephelium lappaceum L*) ethanolic extract, Journal of Photochemistry and Photobiology B: Biology, 205 (2020) 111837

[2] J. M. Hutagalung, G. Murdikaningrum, M. Yulianti, and S. Nurcahyani, Potensi limbah kulit dan biji rambutan (*Nephelium lappaceum L*) sebagai bioetanol, Composite: Jurnal Ilmu Pertanian, 5 (2023) 76-85

[3] Kuswandi, Sobir, and W. Suwarno, Keragaman genetik plasma nutfah rambutan di indonesia berdasarkan karakter morfologi, Jurnal Hortikultura, 24 (2014) 289-298

[4] N. P. Minh, T. T. Vo, Q. V Trung, L. T. Dat, N. Van Bay, and H. T. Loc, Application of CMC, Xanthan Gum as biodegradable coating on storage of rambutan (*Nephelium Lappaceum*) fruit, Journal of Pharmaceutical Sciences and Research, 11 (2019) 1063-1067

[5] D. P. Nashira, W. Wisanti, and E. K. Putri, Penanda karakter varitas rambutan (*Nephelium lappaceum L.*) berdasarkan karakter morfologi, Lentera Bio: Berkala Ilmiah Biologi, 11 (2022) 247-254

[6] K. Mahmood, H. Kamilah, A. K. Alias, and F. Ariffin, Nutritional and therapeutic potentials of rambutan fruit (*Nephelium lappaceum L.*) and the by-products: a review, Journal of Food Measurement and Characterization, 12 (2018) 1556-1571

[7] B. B. Subagio, A. Nursyahid, M. N. Mara, and R. A. Rochmatika, Pengolahan limbah kulit buah dan sayuran menjadi obat luka, Jurnal Pengabdian Masyarakat Indonesia, 3 (2023) 667-672

[8] Y. Laiya, M. Lasindrang, and Z. Antuli, "Karakteristik fisikokimia pektin dari limbah kulit rambutan *(Nephelium lappaceum Linn*), Jambura: Journal of Food Technology, 3 (2021) 1–9

[9] O. Normah, H. Ku, and A. Ku, Pectin content of selected local fruit by-products, Journal of Tropical Agriculture and Food Science, 28 (2001) 195-201

[10] L. N. Gerschenson, E. N. Fissore, A. M. Rojas, A. M. Idrovo Encalada, E. F. Zukowski, and R. A. Higuera Coelho, Pectins obtained by ultrasound from agroindustrial by-products, Food Hydrocolloids, 118 (2021) 106799

[11] Fakhrizal, F. Rizqi, Y. Ristianingsih, Pengaruh konsentrasi pelarut HCl pada ekstraksi pektin dari kulit pisang ambon, Konversi, 4 (2015) 7-11

[12] M. C. N. Picot-Allain, B. Ramasawmy, and M. N. Emmambux, Extraction, characterisation, and application of pectin from tropical and sub-tropical fruits: a review, Food Reviews International, 38 (2022) 282-312

[13] M. Marić, A. N. Grassino, Z. Zhu, F. J. Barba, M. Brnčić, and S. R. Brnčić, An overview of the traditional and innovative approaches for pectin extraction from plant food wastes and by-products: Ultrasound-, microwaves-, and enzyme-assisted extraction," Trends Food Science Technology, 76 (2018) 28–37, 2018

[14] L. Benassi, I. Alessandri, and I. Vassalini, Assessing green methods for pectin extraction from waste orange peels, Molecules, 26 (2021) 1766

[15] V. Bansal, A. Sharma, C. Ghanshyam, M. L. Singla, and K. H. Kim, Influence of pulsed electric field and heat treatment on Emblica officinalis juice inoculated with Zygosaccharomyces bailii, Food Bioproducts Processing, 95 (2015) 146-154

[16] D. Panwar, P. S. Panesar, and H. K. Chopra, Green extraction of pectin from *Citrus limetta* peels using organic acid and its characterization, Biomass Conversion and Biorefinery, 14 (2024) 159-171

[17] Z. Raji, F. Khodaiyan, K. Rezaei, H. Kiani, and S. S. Hosseini, Extraction optimization and physicochemical properties of pectin from melon peel," International Journal of Biological Macromolecules, 98 (2017) 709-716

[18] S. Y. Xu, J. P. Liu, X. Huang, L. P. Du., F. L. Shi, R. Dong, X. T. Huang, K. Zheng, Y. Liu, K. L. Cheong, Ultrasonic-microwave assisted extraction, characterization and biological activity of pectin from

jackfruit peel, Lwt, 90 (2018) 577-582, 2018
[19] K. Gazala, F. A. Masoodi, H. D. Masarat, B. Rayees, and M. W. Shoib, Extraction and characterisation of pectin from two apple juice concentrate processing plants, International Food Resesearch Journal, 24, (2017) 594-599
[20] M. Gavahian, Y. H. Chu, and S. Sastry, Extraction from food and natural products by moderate electric field: mechanisms, benefits, and potential industrial applications, Comprehensive Reviews in Food Science and Food Safety, 17 (2018) 1040-1052
[21] O. Parniakov, E. Roselló-Soto, F. J. Barba, N. Grimi, N. Lebovka, and E. Vorobiev, New approaches for the effective valorization of papaya seeds: Extraction of proteins, phenolic compounds, carbohydrates, and isothiocyanates assisted by pulsed electric energy, Food Research International, 77 (2015) 711-717
[22] R. Fan, L. Wang, J. Fan, W. Sun, and H. Dong, The pulsed electric field assisted-extraction enhanced the yield and the physicochemical properties of soluble dietary fiber from orange peel, Frontiers in Nutrition, 9 (2022) 1–16
[23] A. Prasetyo, M. Nadir, W. E. Sari, and Z. Z. Rahmaniar, Ekstraksi pektin kulit kakao (*Theobroma cacao L.*) menggunakan metode microwave assisted extraction dengan asam klorida, Jurnal Teknik Kimia Vokasional, 3 (2023) 44-54
[24] Y. Du, S. Zhang, G. I. N. Waterhouse, T. Zhou, F. Xu, R. Wang, D. Sun-Waterhouse, P. Wu, High-intensity pulsed electric field-assisted acidic extraction of pectin from citrus peel: Physicochemical characteristics and emulsifying properties, Food Hydrocolloids, 146 (2024) 109291
[25] A. F. Khumaida A., Mulyawati D., Irawati I., Prawati N., Formulasi tablet Effervescent berbahan baku ekstrak kulit buah rambutan (*Nephelium lappaceum*) sebagai antioksidan, Jurnal Sains dan Teknologi Farmasi Indonesia, 6 (2018) 27-36
[26] A. D. E. Saputra, Pengaruh penambahan kulit rambutan (*Nephelium lappaceum*) pada briket tongkol jagung (*Zea mays L*) menggunakan perekat daun jati (*Tectona grandis*), Politeknik Negeri Jember, 2021.
[27] M. B. Shodikin, E. S. I, E. R. Khailani, Analisis kinerja food dehydrator dalam mengurangi kadar air pada daun salam, Prosiding SAINTEK, 6 (2024) 77-82
[28] A. Chandra and J. R. B. Witono, Pengaruh berbagai proses dehidrasi pada pengeringan daun stevia rebaudiana, Jurnal Teknik Kimia, (2018) 1-6
[29] R. S. D. Gita and S. Danuji, Studi pembuatan biskuit fungsional dengan substitusi tepung ikan gabus dan tepung daun kelor, Jurnal Pendidikan Biologi dan Sains, 1 (2018) 155-162
[30] A. P. Wicaksono, F. A. Afandi, G. R. Wira, M. Fayzza, and N. K. Erliyanti, Characterization of essential oil from red citronella leaves (*Cymbopogon nardus L.*), 13 (2024) 61-67
[31] A. Aji, S. Bahri, and T. Tantalia, Pengaruh waktu ekstraksi dan konsentrasi HCl untuk pembuatan pektin dari kulit jeruk bali (*Citrus maxima*), Jurnal Teknologi Kimia Unimal, 6 (2018) 33-44
[32] Y. Febriyanti, A. R. Razak, and N. K. Sumarni, Ekstraksi dan karakterisasi pektin dari kulit buah kluwih (*Artocarpus camansi Blanco*), KOVALEN: Jurnal Riset Kimia, 4 (2018) 60-73
[33] T. Abubakar, L. Budiyarti, E. N. Fitriana, Karakterisasi pektin dengan memanfaatkan limbah kulit pisang menggunakan metode ekstraksi, Konversi, 2 (2013) 21-27
[34] N. A. Zahro and V. A. Wahyudi, Pengaruh konsentrasi asam klorida (HCl) dan waktu ekstraksi pada karakteristik pektin kulit jeruk bali (*Citrus maxima*), 6 (2023) 58-72
[35] H. N. Rusman, Potensi limbah kulit buah sebagai bahan baku dalam pembuatan Edible film, Jurnal Penelitian dan Pengembangan Agrokompleks, 2 (2019) 92-98
[36] Astuti, G. S. Hutomo, and A. Noviyanty, Ekstraksi dan karakterisasi pektin dari buah jeruk lemons (*Citrus limon L*) dengan menggunakan pelarut HCl, Jurnal Agrotekbis, 10 (2022) 572-580.