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RESEARCH ARTICLE

Lemongrass oil-infused biodegradable film: Natural antioxidant for food packaging enhancement

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Abstract - The growing environmental impact of plastic packaging has accelerated interest in biodegradable alternatives such as edible films. This study investigates the incorporation of lemongrass essential oil into chitosan–alginate films to enhance their antioxidant properties. Lemongrass, widely available in Malaysia, contains bioactive compounds including citral, geraniol, and phenolics with strong radical-scavenging activity. Essential oil was extracted using hydrodistillation and microwave-assisted hydrodistillation, with the latter yielding a higher recovery (0.04%). Structural characterization using Fourier Transform Infrared (FTIR) spectroscopy indicated hydrogen bonding and possible Schiff base formation between the oil and film matrix. Antioxidant activity was evaluated by the DPPH assay, showing strong radical scavenging capacity (108.06%), suggesting retention of active compounds and improved stability. The findings demonstrate that lemongrass essential oil effectively enhances the functional properties of chitosan–alginate films, providing an eco-friendly packaging solution that may reduce reliance on synthetic preservatives while extending food shelf life.

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1. Introduction

The pervasive use of petroleum-based plastics in food packaging has raised significant environmental and health concerns due to their non-biodegradability and the accumulation of microplastics in ecosystems and human tissues. Currently, 400 million tonnes of plastic are produced annually [1]. Of the total waste in 2022, just 27.9% was recycled, while 40% went to landfills. Leftovers will be mismanaged, leaking into the environment, underscoring the urgency of alternative, sustainable packaging solutions. In response to these challenges, edible films and coatings have emerged as promising alternatives. Derived from renewable resources such as polysaccharides, proteins, and lipids, these biodegradable materials can serve as protective layers for food products, extending shelf life and reducing environmental impact [2]. Recent advancements have focused on enhancing the functional properties of these films by incorporating natural bioactive compounds with antioxidant activities [3]. Lemongrass (*Cymbopogon citratus*), widely cultivated in Malaysia, is rich in essential oils containing bioactive compounds like citral, geraniol, and phenolics [4]. These compounds have demonstrated significant antioxidant and antimicrobial properties, making lemongrass essential oil (LEO) a potential natural additive for edible films. Incorporating LEO into edible films has been shown to enhance their ability to scavenge free radicals and inhibit microbial growth, thereby improving food preservation and safety [5]. Thus, LEO is more commercialised and able to provide beneficial packaging properties. This study aims to develop and characterise edible films incorporated with lemongrass essential oil, evaluating their physicochemical properties, antioxidant capacity, and antimicrobial efficacy. By leveraging LEO's natural bioactive properties, this research aims to advance sustainable, functional food packaging solutions that address environmental concerns and food safety requirements.

2. Materials and Methods

Figure 1 shows the flowchart of the overall methodology used in this research. This research is divided into two parts. The first part comprises the extraction of essential oil by hydrodistillation from two varieties of lemongrass (*C. Citratus* and *C. Nardus*) with two types of pretreatments (no heat treatment and microwave-assisted treatment). The first part of the research characterises the extracted oil based on its yield and physical properties, and analyses volatile compound presence using gas chromatography-mass spectrometry (GC-MS). The second part of the research focused on developing a chitosan-alginate-based film infused with microwave-assisted extracted essential oil from two varieties of lemongrass (*C. Citratus* and *C. Nardus*). The films developed were analysed based on physical properties (Surface, colour, thickness and solubility) and chemical properties. In chemical analysis, Fourier Transform Infrared spectroscopy was used to identify the compounds present in the film, while antioxidant analysis using 1,1-diphenyl-2-picrylhydrazyl (DPPH assay) was conducted to determine the antioxidant capacity.

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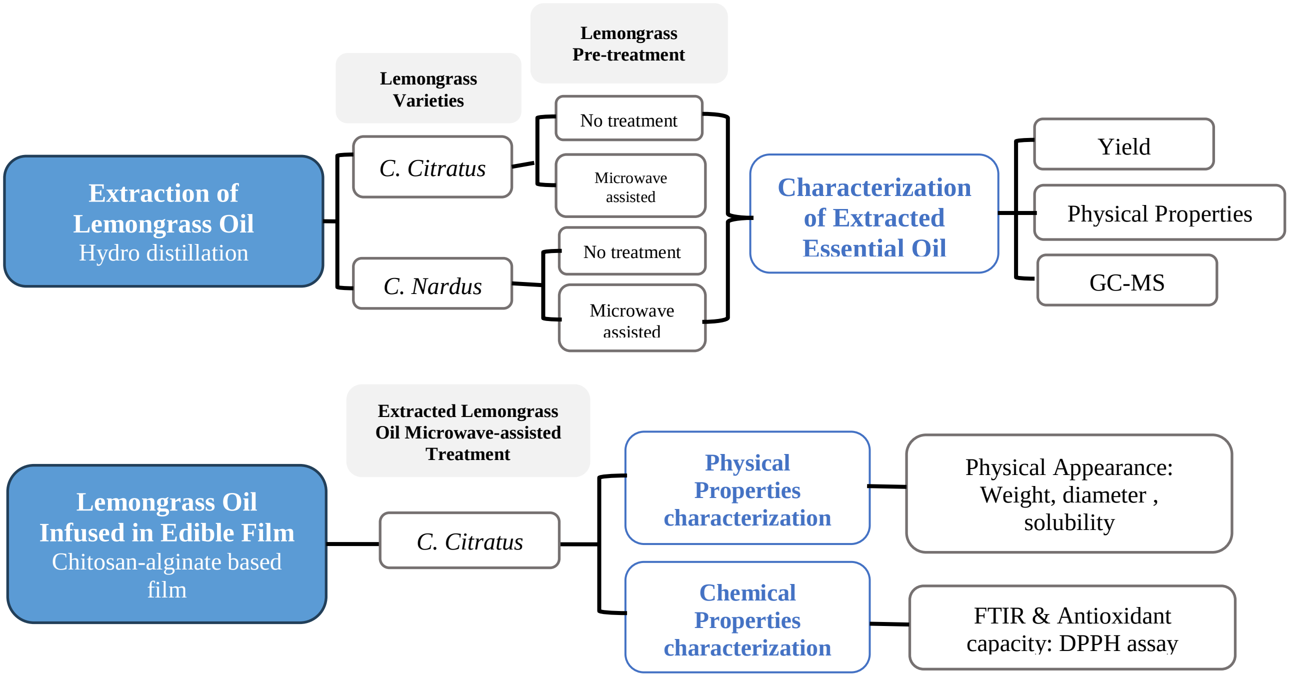

Figure 1. Flowchart for research methodology

2.1 Extraction of Lemongrass Essential Oil

The extraction of lemongrass essential oil was followed by Majewska et al. [6] and Suryanti et al. [7] with slight modifications. First, the lemongrass plant, belonging to the species *Cymbopogon citratus* and *Cymbopogon nardus*, was cut into pieces and dried in an oven for 12 hours. Each species of lemongrass pieces was weighed and ground into a smaller size. Water was added to submerge all the lemongrass pieces, and the lemongrass was added to the set-up distillation flask. 10 g of Sodium Chloride (NaCl) was added to the water containing lemongrass pieces and was heated for 12 hours for the extraction process. The mixture was condensed and collected in a separating funnel. The procedures above were repeated with microwave heating before heating for 12 hours. The oil-water mixture in the separating funnel was separated. Lemongrass essential oil is collected after dispersing all the water and unwanted components to be used in further analysis.

2.2 Characterisation of Extracted Lemongrass Essential Oil

Lemongrass essential oils of *C. citratus* and *C. nardus* are harvested and observed for appearance. The volume is recorded to compare yields across species. 10 mL of essential oil from each species is diluted using 990 mL of gas chromatography-grade ethanol. The diluted solution is injected into a Gas Chromatography-Mass Spectrometry (GCMS 7890A/5975C, Agilent Technologies, USA) with an initial temperature of 50°C, a ramp rate of 4°C/min, and a final temperature of 220°C. A HP-5MS column was used to separate the chemical components based on volatilities. The result was displayed in the program on the computer and then compared with the library data.

Table 1. Formulation of chitosan-alginate-based film infused with lemongrass essential oil

Materials	Specification	Dosage
Sodium alginate	Sisco Research Laboratories Pvt. Ltd.	6 g
Chitosan	Sisco Research Laboratories Pvt. Ltd.	3 g
Acetic acid	Universal Lab & Chemical Sdn. Bhd.	2 mL
Distilled water	UMPSA Laboratory	400 mL
Tween 80	Sisco Research Laboratories Pvt. Ltd.	1 mL
Glycerol	Sisco Research Laboratories Pvt. Ltd.	1 g
Sodium Hydroxide (NaOH)	Universal Lab & Chemical Sdn. Bhd.	0.1M until pH 5.5
Calcium chloride ($CaCl_2$)	Universal Lab & Chemical Sdn. Bhd.	1% in 1000 mL
Extracted *C. Citratus* EO	Hydrodistillation Extraction	0.5 mL

2.3 Formation of Chitosan-Alginate-based Film Infused with Lemongrass Essential Oil

The development of film infused with lemongrass essential oil followed Kumar et al [8] with slight modification using the formulation shown in Table 1. 6 g of sodium alginate was weighed and dissolved in 200 mL of distilled water. Homogenisers were used to homogenise the mixture. The mixture was slightly heated to 40 °C. Next, 3 g of chitosan powder is weighed. 3 g of chitosan powder and 2 mL of acetic acid were dissolved in 200 mL of distilled water, and the mixture was stirred constantly with a homogeniser (Panasonic Hand Helf Food Mixer, Japan) until fully dissolved. The alginate mixture was gradually added to the chitosan mixture, and the mixture was homogenised with a homogeniser until a homogeneous mixture formed. 0.5 mL of *C. citratus* lemongrass essential oil was mixed with 1 mL of Tween 80 as an emulsifier. The mixture was gradually added to distilled water under high-speed stirring to form an emulsion. The essential oil emulsion was added to the chitosan-alginate mixture and mixed well. 0.1 M dilute NaOH was added gradually into the mixture to adjust the pH to 5.5. Then, 1 g of glycerol was added to both mixtures to improve flexibility. The mixture was poured into each petri dish. The mixture was spread for uniform thickness. The cast films were immersed in the 1% $CaCl_2$ solution for 10 minutes. The cast film is dried at 45°C in a drying oven. The dried films were gently peeled off the petri dishes.

2.4 Characterisation of Chitosan-Alginate-based Film Infused with Lemongrass Essential Oil

The size of films was measured using a ruler and recorded. Each film was cut into four equal pieces. Each film was weighed and recorded, then dissolved in water for 1 hour. The films were weighed again, and the weight loss was used to calculate their solubility. The films were then returned to the water for further dissolution. The pH of water used to dissolve edible films was also measured to determine the pH of films using a pH meter [7-8]. The chemical composition of the film was analysed using Fourier Transform Infrared Spectroscopy (FTIR Spectrum 100, Perkin Elmer, USA). The edible film was cut into small pieces and placed into the ATR crystal. The FTIR was calibrated using an empty ATR crystal. Each sample was loaded into the FTIR and scanned from 4000 to 700 cm^{-1}. The spectrum was recorded and analysed. Each peak was compared to the database, and the presence of each component was identified [9]. The antioxidant capacity was measured using 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging activity [10]. The film was cut for 1 g and then dissolved in 100mL of ethanol. 3.94 mg of DPPH was dissolved in 100 mL of ethanol and then vortexed. 100 mL of film extract was added to 2.9 mL of DPPH solution as the sample. One more test tube was added with 100 mL of ethanol and 2.9 mL of DPPH solution as a control. One more test tube was added with 100 mL of film extract and 2.9 mL of ethanol as a blank. The test tubes were vortexed to mix thoroughly. The test tubes were incubated in the dark at room temperature for 30 minutes. Then, the absorbance of each sample and control was measured using a UV-Vis Spectrophotometer at 517 nm. The percentage of radical scavenging activity was calculated for each sample using Eq. (1).

$$\text{Inhibition of DPPH radicle (\%)} = \frac{A_{control} - A_{sample}}{A_{control}} \times 100\% \tag{1}$$

3. Results and Discussion

The results compared the yields from hydrodistillation and microwave-assisted hydrodistillation extraction methods, the appearance, and the properties of each lemongrass essential oil. The *C. citratus* essential oil was analysed by GC-MS and showed a few phenolic compounds. The casted films were characterised, including physical properties, slightly soluble in water and ethanol, slightly acidic, FTIR analysis showing the presence of phenolic bond from antioxidants and carboxyl and carbon bond from polysaccharide chain, and lastly, a positive result of DPPH analysis.

3.1 Extraction of Lemongrass Essential Oil

The extraction of essential oils from *C. citratus* and *cymbopogon nardus* using hydrodistillation and microwave-assisted hydrodistillation (MAHD) showed notable differences in yield and characteristics (Table 2). MAHD produced higher yields, with 0.25 mL for *C. citratus* and 0.2 mL for *C. nardus*, compared to 0.04 mL and 0.02 mL, respectively, via conventional hydrodistillation. This improvement is due to rapid, uniform heating that accelerates cell rupture and oil release [11]. *C. citratus* oils appeared pale yellow with a light lemon scent, while *C. Nardus* oils were yellowish with a ginger-lemon fragrance, attributed to their high citral and citronellal content. *C. nardus* sourcing was limited, as it is typically sold as plantlets for ornamental use, making extraction less practical. *C. citratus* oil was extracted twice to obtain a higher yield and was the only oil to be used in further analysis since the yield for *C. nardus* is limited for analysis and film formation.

Table 2. Yield and physical properties of essential oil each species in different extraction method

	HD		*MAHD*	
	C. citratus	*C. nardus*	*C. citratus*	*C. nardus*
Yield in HD	0.04 mL	0.02 mL	0.25 mL	0.1 mL
Yield %	0.008%	0.004%	0.05%	0.03%
Colour	Pale yellow	Yellowish	Pale yellow	Yellowish
Fragrance	Light lemon scent	Ginger-lemon scent	Light lemon scent	Ginger-lemon scent

HD: Hydro distillation
MAHD: Microwave-Assisted Hydro distillation

3.2 GCMS Analysis

The phytochemical profiling of *C. citratus* essential oil using GCMS was conducted revealed a rich, diverse composition with 66 bioactive compounds, predominantly monoterpenes, sesquiterpenes, and oxygenated terpenoids. Major constituents included citral (geranial and neral), geraniol, β-myrcene, linalool, β-bisabolene, and caryophyllene oxide can be seen in Figure 2. Citral, the primary component (RT 19.85 min), contributes to the oil's characteristic lemon scent and potent antibacterial activity [12]. β-myrcene (RT 8.72 min) offers analgesic, anti-inflammatory, and antimicrobial effects, while linalool (RT 13.19 min) adds antioxidant and sedative properties. Significant sesquiterpenes like β-bisabolene (RT 30.74 min) and caryophyllene oxide (RT 33.55 min) exhibit anticancer, antibacterial, and antifungal potentials [13]. The oil's profile aligns closely with previous findings on lemongrass and other medicinal plant oils, confirming the consistency and biological relevance of these compounds [14]. The synergistic effects of these phytochemicals contribute to lemongrass oil's broad-spectrum antibacterial, antioxidant, anti-inflammatory, and therapeutic applications, reinforcing its value in traditional remedies and modern pharmaceutical and food industries.

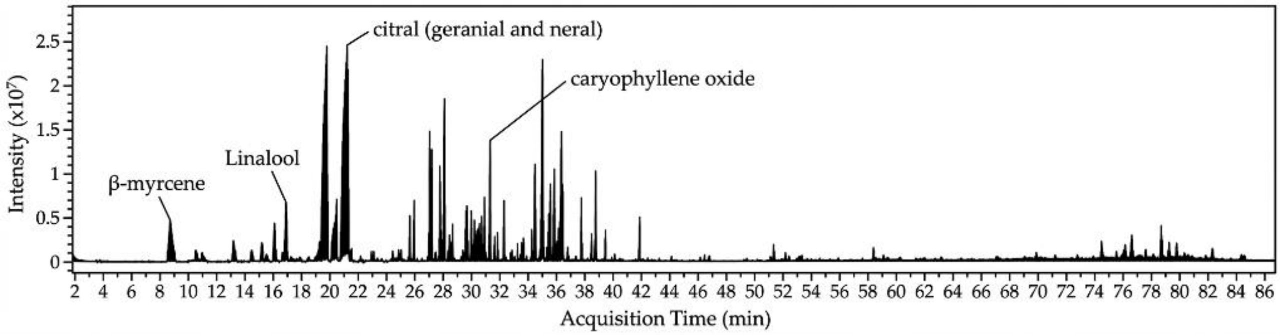

Figure 2. Counts vs. Retention Time (min) graph plot from GCMS analysis of extracted *C. citratus* using microwave-asssited hydro distillation

3.3 Chitosan-Alginate based Film Infused with Lemongrass Essential Oil Analysis

Chitosan-alginate edible films with *C. citratus* essential oil were successfully developed (Figure 3) and characterised based on Table 3. The physical appearance shows the film exhibits smooth, uniform film formation with a gritty texture due to the addition of sodium alginate. Solubility tests indicated moderate water solubility and low ethanol solubility, both enhanced by the essential oil's hydrophobicity, which promotes crosslinking with calcium carbonate and tends to confer greater stability in aqueous environments [15]. An average pH of 6.1 was measured on the developed film, which is near neutral (7.0). However, the pH recorded did not support greater antimicrobial activity to prevent the growth of most spoilage organisms, which require a more acidic condition [11]. These findings confirm the film's suitability for active food packaging with selective permeability and bioactivity with further modification.

Figure 3. Image of Chitosan-alginate edible films with *C. citratus* essential oil developed

DPPH assay showed exceptionally high radical scavenging activity (108.06%), likely due to concentrated extracts, strong phenolic content, and synergistic antioxidant effects. Results recommend optimising extract concentrations and performing dose-response studies for accurate antioxidant potential evaluation in active edible film systems [10]. FTIR analysis of chitosan-alginate films with *C. citratus* essential oil confirmed successful integration through key absorption bands shown in Figure 4: broad O-H/N-H stretching (3394.68 cm^{-1}), C-H stretching (2926.41 cm^{-1}), and COO^- asymmetric stretching (1600.27 cm^{-1}), indicating hydrogen bonding and possible Schiff base formation [16]. Changes in the fingerprint region suggested the presence of essential oil–polymer interactions, enhancing film structure and bioactivity [17].

Table 3. Physicochemical properties of Chitosan-alginate edible films with *C. citratus* essential oil

	Parameter
Average weight	1.503 g ± 0.012
Average radius	4.025 cm ± 0.314
Weight Loss in water	34.21% ± 2.45
Weight Loss in ethanol	18.68% ± 0.74
pH	6.10 ± 0.14
RSA activity	108.06% ± 0.62

n = 5

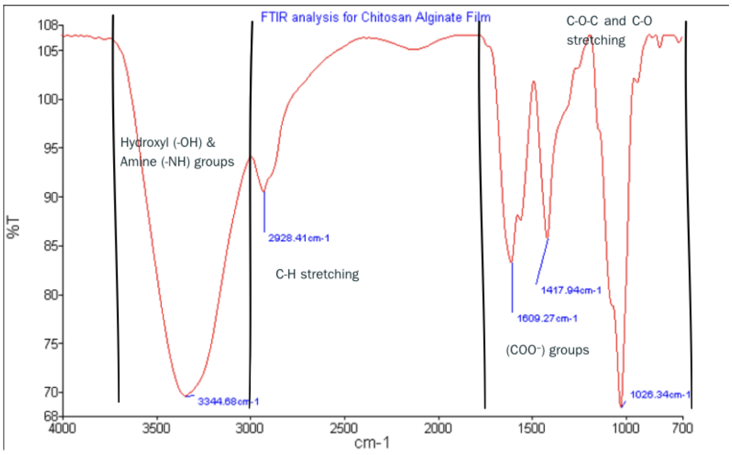

Figure 4. FTIR spectrometry graph for Chitosan-alginate edible films with *C. citratus* essential oil

4. Conclusions

Lemongrass essential oil extracted via microwave-assisted hydrodistillation is more efficient and yields better output than conventional hydrodistillation. *C. citratus* and *C. nardus*, both abundant in Malaysia, produced essential oil yields of 0.05% and 0.03%, respectively, with notable antioxidant and phenolic contents confirmed by GCMS analysis. However, the limited availability of *C. nardus* restricts its further application. Edible films infused with *C. citratus* essential oil demonstrated excellent antioxidant activity, desirable physicochemical properties, and improved mechanical strength. FTIR analysis confirmed the presence of diverse antioxidant compounds, while the film's insolubility in both polar and non-polar solvents enhances its suitability as biodegradable food packaging. Despite some irregularities in DPPH assay results, the antioxidant potential remained evident. Overall, lemongrass essential oil-infused edible films represent a promising, eco-friendly innovation aligned with the Sustainable Development Goals for future packaging solutions, with further modifications and shelf-life studies.

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Declaration of Competing Interest

The author declares no conflicts of interest.

CRediT Authorship Contribution Statement

Ang Zewei (Methodology; Data curation; Writing - original draft; Resources)
Aishah Mohd Marsin (Conceptualization; Formal analysis; Visualization; Supervision)

Availability of Data and Materials

The data supporting this study's findings are available on request from the corresponding author.

Ethics Declarations

This study did not involve human participants or animals. Ethical approval was therefore not required.

Generative Artificial Intelligence Declarations

The authors claim that artificially intelligent-assisted technologies, such as generative AI, were not used to generate content, ideas, or theories. We have just utilised AI to enhance readability and refine the language. This was used with extreme human control and oversight. The authors take full responsibility for reviewing and approving the content.

References

[1] M.R. Shekh and V. Kumar, "Impact of plastic pollution on ecosystems: a review of adverse effects and sustainable solutions," Environmental Monitoring and Assessment, vol. 197, p. 264, 2025.

[2] A.M. Marsin and I.I. Muhamad, "Effects of kappa carrageenan and glycerol in purple sweet potato starch based edible film," *Jurnal Teknologi (Sciences & Engineering)*, vol. 78, no. 6, pp. 163-168, 2016.

[3] I. Ishak, I.I. Muhamad, A. Mohd Marsin, and T. Iqbal, "Development of purple sweet potato starch base biodegradable film," *Jurnal Teknologi (Sciences & Engineering)*, vol. 77, no. 31, pp. 75-78, 2015.

[4] O.A. Adeyemo, E. Osibote, A. Adedugba, O.A. Bhadmus, A.A. Adeoshun, and M.O. Allison, "Antioxidant activity, total phenolic contents and functional group identification of leaf extracts among lemongrass (Cymbopogon citratus) accessions," *NISEB Journal*, vol. 18, no. 2, pp. 83-91, 2018.

[5] S. Subramanya, K. Sumanth, P. K. Gupta, V. Chayapathy, E. Keshamma, and K. Murugan, "Formulation green nanoemulsions for controlling agriculture insects," in *Bio-Based Nanoemulsions for Agri-Food Applications*, K. A. Abd-Elsalam and K. Murugan, Eds. Amsterdam, The Netherlands: Elsevier, 2022, ch. 11.

[6] E. Majewska, M. Kozlowska, E. Gruczynska-Sekowska, D. Kowalska, and K. Tarnowska, "Lemongrass (Cymbopogon citratus) essential oil: Extraction, composition, bioactivity and uses for food preservation - A review," *Polish Journal of Food and Nutrition Sciences*, vol. 69, no. 4, pp. 327-341, 2019.

[7] F. Suryanti, L. Qadariyah, and M. Mahfud, "Effect of addition of NaCl Salt on extraction of essential oil from lemongrass leaves by microwave hydro-distillation method," *Indonesian Journal of Chemistry*, vol. 23, no. 4, pp. 974-983, 2023.

[8] L. Kumar, D. Ramakanth, K. Akhila, and K.K. Gaikwad, "Edible films and coatings for food packaging applications: A review," *Environmental Chemistry Letters*, vol. 20, no. 1, pp. 875-900, 2022.

[9] I. Arzate-Vázquez, J.J. Chanona-Pérez, G. Calderón-Domínguez, E. Terres-Rojas, V. Garibay-Febles, A. Martínez-Rivas, et al., "Microstructural characterization of chitosan and alginate films by microscopy techniques and texture image analysis," *Carbohydrate Polymers*, vol. 87, no. 1, pp. 289-299, 2012.

[10] D. R. Wicakso, D. Fortuna, and I. A. Hernadin, "Characterization of corn starch edible films by the addition of chitosan as a vegetable oil packaging material," *Konversi*, vol. 12, no. 2, pp. 62-65, 2023.

[11] B. A. Riyandari, Y. T. Rizki, and M. Ramdani, "Synthesis of polyelectrolyte complex films of chitosan-alginate by addition of kelor leaves extract (moringa oleifera) for food packaging," *Jurnal Kimia Riset*, vol. 7, no. 2, pp. 133-140, 2022.

[12] K. Mishra, H. Ojha, and N. K. Chaudhury, "Estimation of antiradical properties of antioxidants using DPPH-assay: A critical review and results," *Food Chemistry*, vol. 130, no. 4, pp. 1036-1043, 2012.

[13] M. N. Boukhatem, M. A. Ferhat, M. Rajabi, and S. A. Mousa, "Solvent-free microwave extraction: an eco-friendly and rapid process for green isolation of essential oil from lemongrass," *Natural Product Research*, vol. 36, no. 2, pp. 664-667, 2022.

[14] R. Ahmad, A. Alqathama, M.M. Alam, M. Riaz, A.N. Abdalla, M. Aldholmi, et al., "Biological quality and phytochemical profiling of olive fruits using gas chromatography–mass spectrometry (GCMS) analysis," *Chemical and Biological Technologies in Agriculture*, vol. 10, no. 1, p. 45, 2023.

[15] L.F. Tan, E. Elaine, L.P. Pui, K.L. Nyam, and Y.A. Yusof, "Development of chitosan edible film incorporated with chrysanthemum morifolium essential oil," *Acta Scientiarum Polonorum, Technologia Alimentaria*, vol. 20, no. 1, pp. 55-66, 2021.

[16] D. Kain, S. Kumar, A. V. Suryavanshi, and A. Arya, "FTIR and GCMS analysis of Euphorbia hirta L. and its in-vitro antibacterial and antioxidant activities," *Indo Global Journal of Pharmaceutical Sciences*, vol. 12, pp. 104-109, 2022.

[17] A. Mohd Marsin, I.I. Muhamad, S.N.S. Anis, W.C. Liew, N.H. Dolhaji, and N.A. Md Lazim, "The Application and Challenges of Essential Oils as Natural Pesticides," *Journal of Soil, Environment & Agroecology*, vol. 2, no. 1, pp. 1–14, 2024.