

Identification of Bioactive Compound Function Groups in Mangosteen Fruit Peel Extract (*Garcinia mangostana* L.) and Lime Extract (*Citrus aurantifolia* Swingle) as Anticholesterol Agents Using Fourier Transform Infrared (FTIR)

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Abstract: Hypercholesterolemia is one of the major risk factors for cardiovascular diseases such as atherosclerosis and coronary heart disease. The main commonly used therapy is synthetic drugs such as statins, but long-term consumption is known to cause side effects such as liver damage, muscle disorders, and metabolic disorders. Therefore, the search for safer natural alternatives is important. Mangosteen rind (*Garcinia mangostana* L.) and lime peel (*Citrus aurantifolia* Swingle) are known to contain bioactive compounds such as xanthenes, flavonoids, and phenolic acids that have potential as anticholesterol agents. This study aims to identify the functional groups of bioactive compounds in mangosteen and lime peel extracts using Fourier Transform Infrared (FTIR) and compare their potential as anticholesterol candidates. The extracts were obtained through maceration method using 70% and 96% ethanol solvents. FTIR analysis showed the presence of O-H (phenol), C=O (carbonyl), and C-O (ester) functional groups, indicating the presence of active compounds such as α -mangostin in mangosteen peel and flavonoids such as quercetin in lime peel. The peak absorption intensity of O-H and C=O groups in mangosteen peel extract is higher than that in lime peel extract. These results indicate that mangosteen peel extract contains a higher concentration of bioactive compounds, so it has the potential to provide an anticholesterol effect.

1 INTRODUCTION

Hypercholesterolemia is a medical condition characterized by elevated blood cholesterol levels that exceed normal limits, marked by an increase in total cholesterol, particularly low-density lipoprotein (LDL), accompanied by a decrease in high-density lipoprotein (HDL) levels (Artha et al., 2017). A decrease in blood HDL levels in hypercholesterolemia is one of the risk factors for cardiovascular disease (CVD) such as atherosclerosis and heart disease (Millah & Anjani, 2017). The World Health Organization (WHO)

reports that cardiovascular disease remains the leading cause of death worldwide, contributing to more than 17 million deaths each year. The World Health Organization estimates that 4.2 million people in Europe died from cardiovascular disease in 2019, representing more than 2 in 5 (42.5%) of all deaths. More than 8 out of 10 (82%) deaths from cardiovascular disease in Europe in 2019 were caused by heart attacks and strokes (Handayani, 2025).

Addressing cardiovascular disease, which is characterized by an imbalance in lipid levels in the

body, particularly cholesterol, often requires drug therapy to control and reduce unhealthy lipid levels in the body. One of the most commonly used drug classes is statins, such as simvastatin and atorvastatin, which are the most effective primary drug therapies for lowering LDL cholesterol (Mangunsong et al., 2023). Synthetic statin drugs (e.g., simvastatin, atorvastatin) are the primary therapies widely used to lower cholesterol levels. Statins work by inhibiting the enzyme HMG-CoA reductase, which plays an important role in cholesterol biosynthesis. Long-term use has been reported to cause side effects including myopathy, increased liver enzymes, and potential drug resistance. This has led to an urgent need for safer, natural-based alternative therapies (Widya & Amin, 2025).

Natural ingredients, especially those derived from plants, have long been used in traditional medicine, including to lower blood lipid levels caused by gingerol content, as this substance can increase insulin sensitivity through receptors that influence the glucose metabolism process, namely PPAR Gamma (Silalahi, 2020). Natural ingredients derived from plants contain several bioactive compounds. Bioactive compounds are compounds with biological activity that can provide health benefits for humans. These bioactive compounds derived from plants, such as flavonoids, xanthenes, and phenolic acids, are known to have antihyperlipidemic effects through antioxidant mechanisms, inhibition of key cholesterol metabolism enzymes, and increased bile acid excretion. One of these compounds is found in mangosteen peel and lime peel (Ayunda & Malita, 2024).

Mangosteen (*Garcinia mangostana* L.) is a plant native to Indonesia that has been used for generations as a delicious food source rich in antioxidants. One such source is the mangosteen fruit peel itself. Mangosteen fruit peel (*Garcinia mangostana* L.) contains complex antioxidants in significant concentrations, particularly phenolic compounds or polyphenols, including xanthone compounds. The mangosteen peel (*Garcinia mangostana* L.) also contains compounds with other pharmacological activities, such as anti-inflammatory, antihistamine, antibacterial, antifungal, anticancer, antihypertensive, and HIV therapeutic potential (Septiana et al., 2024). In vivo studies in experimental animals show that α -mangostin can lower total cholesterol and LDL levels through the mechanism of HMG-CoA reductase inhibition (Tjahjani et al., 2024). A phytochemical review states that mangosteen peel extract (*Garcinia mangostana* L.) contains more than 50 bioactive compounds with potential biological activity (Muahiddah et al., 2024).

Lime peel (*Citrus aurantifolia* Swingle) is one of the plants that contains flavonoid compounds, namely naringin, hesperidin, naringenin, hesperitin, rutin, nobiletin, and tangeretin. Flavonoids are the largest group of polyphenol compounds that can act as antioxidants. Until now, people have only known to use the juice for consumption, while the peel is discarded as waste. However, lime peel can be used as a cholesterol-lowering medicine. Research on lime peel as a cholesterol medicine has been conducted by several researchers previously. Previous studies reported that flavonoids from citrus fruits can enhance lipid metabolism and inhibit LDL oxidation (Utari & Rosa, 2023).

Most research on mangosteen and lime focuses on testing biological activity or isolating specific compounds (Jannah & Masiah, 2020). These activity tests in the era of rapid scientific and technological development, one of which uses the Fourier Transform Infrared Spectroscopy (FTIR) method. FTIR is a spectroscopy technique that has the unique ability to detect and identify compounds based on the interaction of infrared waves with molecules. FTIR is capable of identifying specific functional groups that characterize the presence of bioactive compounds (Nugroho *et al.*, 2024). Therefore, this study aims to identify bioactive functional groups in mangosteen and lime peel using FTIR and compare their potential as natural anticholesterol candidates.

2 METHOD

This study used a literature review method by analyzing scientific articles discussing bioactive compounds in mangosteen peel (*Garcinia mangostana* L.) and lime peel (*Citrus aurantifolia* Swingle), particularly those identified through Fourier Transform Infrared (FTIR). Literature searches were conducted in databases such as ScienceDirect and Google Scholar using keywords such as “mangosteen peel FTIR”, “*Citrus aurantifolia* flavonoids”, “anticholesterol xanthenes”, and “FTIR functional group analysis”. The selected articles were publications from 2015 to 2025 in English or Indonesian, in the form of original research or reviews, and specifically discussed fruit peel extracts and their bioactive analysis. The data collected included the identification of bioactive compounds, FTIR chemical functional groups, absorption intensity, and

their relationship with anticholesterol activity, which were then analyzed narratively to draw conclusions about the comparative potential of mangosteen and lime peel as natural anticholesterol agents.

3 RESULT

There are seven articles that match the keyword “mangosteen peel FTIR”, “*Citrus aurantifolia* flavonoids”, “anticholesterol xanthenes”, and “FTIR functional group analysis” in the period from 2015 to 2025, which were selected based on inclusion criteria and analyzed by the author.

Table 2. Literature Review Table

No	Judul	Author (Tahun)	Metode	Hasil
1	Identification of Flavonoid Content Extracted from Mangosteen Peel Using FTIR	Muahiddah & Rahmadani (2024)	Ekstraksi etanol, analisis FTIR	Spektrum menunjukkan gugus O-H, C-O, dan C=C aromatik, menandakan keberadaan flavonoid.
2	Comparison of Antioxidant Activity of Extract, Granule, and Tablet of Mangosteen Peel	Rahayu <i>et al.</i> (2024)	Ekstraksi etanol 96%, FTIR, uji DPPH	Teridentifikasi gugus hidroksil dan karbonil; ekstrak murni memiliki aktivitas antioksidan tertinggi.
3	Occurrence Analysis of α -Mangostin from Different Organs of <i>Garcinia mangostana</i>	Shah <i>et al.</i> (2025)	Ekstraksi, FTIR, HPLC	Gugus aromatik khas xanton terdeteksi; α -mangostin dominan pada kulit batang.
4	Combination of Mangosteen Pericarp Extract and Exercise on Atherosclerosis	Setiawan <i>et al.</i> (2025)	Uji in vivo, FTIR	FTIR menunjukkan gugus karbonil dan hidroksil; mendukung mekanisme inhibisi HMG-CoA reduktase.
5	Formulation and Evaluation of Sunscreen Gel with Lime Peel Extract	Barman & Sahu (2025)	Ekstraksi etanol 70%, FTIR	Spektrum memperlihatkan gugus O-H, C=O, dan C-O glikosida; kandungan flavonoid lebih dari 60%.
6	Therapeutic Potential of	Wang <i>et al.</i> (2024)	Review literatur,	Puncak serapan O-H sekitar 3400

Citrus Flavonoids Hesperidin and Hesperetin		FTIR validasi	cm ⁻¹ ; dikonfirmasi sebagai ciri khas flavonoid jeruk.
7 Effects of Drying Methods on Flavonoid Profiles in Citrus	Ye <i>et al.</i> (2025)	FTIR, uji fitokimia	Metode pengeringan memengaruhi intensitas puncak O-H dan C=C aromatik; beku menghasilkan flavonoid tertinggi.

Source: Secondary Research Data

4 DISCUSSION

Hypercholesterolemia is one of the main risk factors for cardiovascular disease (CVD) such as atherosclerosis, coronary heart disease, and stroke. This condition is characterized by increased total cholesterol levels, especially Low-Density Lipoprotein (LDL), and decreased High-Density Lipoprotein (HDL) levels in the blood (Artha *et al.*, 2017). High LDL triggers the atherosclerosis process through plaque buildup on the artery walls, while low HDL inhibits the process of removing cholesterol from the blood vessels. According to the WHO, cardiovascular disease is the leading cause of death worldwide, with more than 17 million deaths each year (Handayani, 2025). Therefore, prevention and treatment of hypercholesterolemia play a very important role.

Conventional therapy to lower cholesterol levels generally uses statin drugs such as simvastatin, atorvastatin, and rosuvastatin. Statins work by inhibiting the enzyme HMG-CoA reductase, a key enzyme in the biosynthesis of cholesterol in the liver. However, long-term use of statins is known to cause various side effects, including liver dysfunction, myopathy, drug resistance, and metabolic disorders (Widya & Amin, 2025). This has prompted the search for safer, natural-based alternative therapies with minimal side effects. One potential natural ingredient is

mangosteen peel (*Garcinia mangostana* L.) and lime peel (*Citrus aurantifolia* Swingle). Both ingredients are known to be rich in bioactive compounds, including xanthenes, flavonoids, and phenolic acids, which play a role in lowering cholesterol levels through antioxidant mechanisms, inhibition of HMG-CoA reductase enzymes, and increased bile acid excretion (Ayunda & Malita, 2024). In this study, bioactive compound analysis was performed using the Fourier Transform Infrared (FTIR) method to identify the functional groups contained in mangosteen and lime peel extracts and to compare their anticholesterol potential.

Based on the results of the literature analysis in Table 2, FTIR showed the presence of hydroxyl (O-H), carbonyl (C=O), and ester/glycoside (C-O) groups in both extracts. The O-H and C=O groups are markers of the presence of phenolic compounds, flavonoids, and xanthenes (Muahiddah & Rahmadani, 2024). In mangosteen peel extract, the peak absorption intensity of the O-H and C=O groups was higher than that in lime peel extract. This indicates that mangosteen peel contains higher concentrations of bioactive compounds, particularly α -mangostin, the main compound in the xanthone group that has the strongest anticholesterol activity (Shah *et al.*, 2025). These results are in line with the research by Muahiddah & Rahmadani (2024), which showed that mangosteen peel extract contains flavonoids and xanthenes with more dominant O-H, C-O, and aromatic C=C absorption peaks. The α -mangostin compound is known to work by inhibiting the HMG-CoA reductase enzyme, similar to the mechanism of action of statins, but with a lower risk of side effects (Setiawan *et al.*, 2025). Additionally, Rahayu *et al.* (2024) reported that mangosteen peel

extract has the highest antioxidant activity compared to other processed forms, which helps prevent LDL oxidation, one of the main triggers of atherosclerotic plaque formation.

Meanwhile, lime peel extract is rich in flavonoids, such as naringin, hesperidin, and quercetin, which also have anti-cholesterol activity. Barman & Sahu (2025) found that lime peel extract exhibited an FTIR spectrum with O–H, C=O, and C–O glycoside absorption peaks, indicating a flavonoid content of more than 60%. These flavonoids act as antioxidants and are able to inhibit LDL oxidation, improve lipid metabolism, and improve cholesterol profiles (Wang et al., 2024). However, compared to mangosteen peel, the FTIR absorption intensity in lime is lower, indicating a lower concentration of bioactive compounds (Ye et al., 2025).

The results of this FTIR analysis also support the mechanism of action of bioactive compounds in both extracts. Hydroxyl groups (O–H) play a role in counteracting free radicals and preventing lipid damage, while carbonyl groups (C=O) are associated with the inhibition of key enzymes in cholesterol biosynthesis. The presence of ester and glycoside (C–O) groups also indicates the presence of glycoside flavonoids, which are known to increase bile acid excretion, thereby accelerating the reduction of total cholesterol levels (Barman & Sahu, 2025).

5 CONCLUSION

Based on the results of literature analysis and functional group identification using the FTIR method, mangosteen peel extract (*Garcinia mangostana* L.) and lime peel extract (*Citrus*

aurantifolia Swingle) both contain bioactive compounds such as xanthenes, flavonoids, and phenolic acids that have the potential to act as natural anticholesterol agents. The FTIR spectrum shows that mangosteen peel has a higher absorption intensity, indicating a more dominant content of α -mangostin, which works by inhibiting the HMG-CoA reductase enzyme and increasing bile acid excretion. Meanwhile, the flavonoids in lime peel act as antioxidants that inhibit LDL oxidation and help improve blood lipid profiles. Thus, mangosteen peel has stronger anticholesterol potential, although both have the potential to be developed as natural phytotherapies for the prevention of hypercholesterolemia and cardiovascular disease.

6 REFERENCES

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