BIOACTIVE LIPID COMPOUNDS PROFILING OF LAI FRUIT SEEDS (*Durio kutejensis*) BASED ON GC-MS ANALYSIS AND ITS POTENTIAL AS A FUNCTIONAL FEED

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Abstract

Lai fruit seeds (*Durio kutejensis*) represent a local biomass source with potential as a valuable lipid fraction for the development of functional feed ingredients. This study aimed to identify the lipid compound profile of Lai fruit seed extract based on Gas Chromatography-Mass Spectrometry (GC-MS) analysis and to evaluate its potential in supporting the development of functional feed materials. Lai seed samples were dried, ground, and extracted using n-hexane through a maceration process. The lipid compound profile was analyzed using a Thermo Scientific ISQ762309017 GC-MS system through spectral matching against a mass spectral library. The results showed that the n-hexane extract of Lai seeds exhibited a complex lipid profile, with 68 compounds tentatively identified. The predominant compounds based on relative area were n-hexadecanoic acid (8.33%), oleic acid (7.95%), and methyl 2-octylcyclopropene-1-octanoate (7.42%), along with various fatty acid derivatives, fatty acid esters, phytosterols, and triterpenes. The presence of these compounds indicates that Lai seed extract has potential as a value-added lipid source that may be developed as a candidate functional feed ingredient based on local resources. However, further studies are required to evaluate its nutritional characteristics, digestibility, bioavailability, and biological responses in livestock to confirm its practical application potential.

Keywords: *Durio kutejensis*; Lai seed; GC-MS; lipid compounds; functional feed

1. Introduction

Indonesia is recognized as one of the world’s megadiverse countries, possessing a wide variety of local fruit species with significant economic potential and opportunities for development as sources of functional ingredients. One of the indigenous fruits from Kalimantan is Lai (*Durio kutejensis Hassk. Becc.*), a member of the genus Durio that is naturally distributed across Borneo. Lai fruit exhibits distinct morphological and sensory characteristics compared with durian (*Durio zibethinus*), particularly its yellow-to-orange flesh color and relatively mild aroma. Previous studies on local Durio species from Borneo have demonstrated that D. kutejensis contains potential bioactive compounds, including high ascorbic acid content and considerable antioxidant activity compared with other Durio genotypes (Teh et al., 2024). These findings suggest that *D. kutejensis* has potential as a source of natural functional compounds; however, previous investigations have mainly focused on the edible fruit pulp.

The utilization of Lai fruit has predominantly been limited to the consumption of its pulp, whereas the seeds remain underutilized and are commonly discarded as by-products of fruit processing. Nevertheless, seeds from various fruit species are known to contain valuable components, including starch, protein, fiber, lipids, and bioactive compounds, which may be utilized for food and feed applications. Previous studies have demonstrated that Lai seeds possess promising physicochemical characteristics. Fiqtinovri (2015) reported that Lai seed starch had a yield of approximately 13.06% on a dry matter basis with an amylose content of 22.01%, while Sa'adah et al. (2022) demonstrated that Lai seed starch exhibited functional characteristics suitable for pharmaceutical applications. These findings indicate that Lai seeds represent not merely agricultural waste but also a potential source of valuable compounds that can be further developed through sustainable local resource utilization.

In livestock production, the development of locally available feed resources containing functional components has become an important strategy to support sustainable animal production systems. Functional feeds are designed not only to fulfill nutritional requirements but also to provide additional physiological benefits through bioactive compounds. Plant-derived bioactive compounds, including fatty acids, phytosterols, polyphenols, and other secondary metabolites, have been extensively studied due to their potential roles in enhancing antioxidant status, modulating gut microbiota, supporting immune function, and improving nutrient utilization efficiency in livestock (Valenzuela-Grijalva et al., 2017; Lillehoj et al., 2018). However, the effectiveness of functional feed ingredients depends on plant species, plant tissues, bioactive compound composition, bioavailability, and processing methods. Therefore, chemical characterization is an essential preliminary step before evaluating their biological effects in livestock.

The potential of Lai seeds from a livestock nutrition perspective has recently been investigated. Fajrih et al. (2025) reported that Lai seed meal contained 14.35% resistant starch and supported the growth of lactic acid bacteria, including Lactobacillus plantarum and Lactobacillus casei, in an in vitro evaluation. The presence of resistant starch suggests that Lai seeds may serve as a functional carbohydrate source capable of supporting beneficial microbial fermentation. Resistant starch behaves similarly to dietary fiber because it escapes digestion in the upper gastrointestinal tract and can be fermented by gut microbiota, producing metabolites such as short-chain fatty acids (SCFAs) that contribute to intestinal health (Birt et al., 2013). However, previous research has primarily focused on nutritional characteristics, resistant starch content, and prebiotic potential, while information regarding other bioactive components, particularly lipid compounds, remains limited.

Plant-derived lipid compounds represent an important group of functional components in feed development because they serve as concentrated energy sources and provide physiologically active molecules. Fatty acids, including oleic acid, linoleic acid, and linolenic acid, play important roles in lipid metabolism and may influence the fatty acid composition of animal tissues and animal-derived products (Palmquist, 2009). Furthermore, phytosterols such as β-sitosterol and stigmasterol have been reported to exhibit biological activities associated with cholesterol metabolism regulation and antioxidant properties (Moreau et al., 2018). Therefore, identification and characterization of lipid compounds from local plant resources are important steps in evaluating their potential as candidate functional feed ingredients.

Information regarding the bioactive compound profile of *D. kutejensis* has been reported in several other parts of the plant. Manurung et al. (2022) conducted phytochemical screening and GC-MS analysis of methanolic extracts of Lai leaves and successfully identified 43 compounds belonging to several groups, including phenolic compounds, aromatic compounds, fatty acids, aldehydes, and sesquiterpenoids. These findings indicate that *D. kutejensis* possesses a diverse range of metabolites with potential biological activities. However, the metabolite profile of the leaves cannot be directly used to represent the chemical composition of the seeds because the distribution of metabolites is strongly influenced by tissue type and the physiological functions of the plant.

In addition to studies on the leaves, investigations of the volatile compound profile of Lai fruit using an SPME-GC-MS approach have demonstrated the presence of various groups of volatile compounds, including esters, alcohols, aldehydes, ketones, organic acids, and sulfur-containing compounds, which contribute to the characteristic aroma of the fruit (Belgis et al., 2017). However, these studies have primarily focused on aroma characterization and differences in volatile profiles among cultivars rather than on the exploration of chemical constituents in the seeds that may be developed as functional ingredients. To date, information on the profile of bioactive lipid compounds in Lai seeds remains very limited, particularly regarding the presence of fatty acids, fatty acid esters, and phytosterols that may support the development of functional feed ingredients.

Gas Chromatography–Mass Spectrometry (GC-MS) is one of the widely used analytical methods for the initial screening and identification of volatile and semi-volatile compounds based on their retention times and mass fragmentation patterns. Identification using GC-MS is performed by comparing the mass spectra of sample components with those available in a mass spectral library, thereby providing preliminary information on the types and diversity of compounds present in a material. Based on this background, this study aimed to identify and characterize the profile of bioactive lipid compounds in Lai seeds using GC-MS analysis and to evaluate their potential as candidate functional feed ingredients. The findings are expected to complement previous information regarding the resistant starch content and prebiotic potential of Lai seeds and to provide a basis for further research on quantitative characterization, biological activities, and their application in livestock feed formulation.

2. Materials and Methods

2.1 Study Period and Location

The study was conducted in July 2026 at the Integrated Laboratory, Mulawarman University, Samarinda, East Kalimantan, Indonesia. The study aimed to characterize the lipid compound profile of Lai seeds using Gas Chromatography–Mass Spectrometry (GC-MS) as an initial approach for identifying bioactive compounds with potential for development as functional feed ingredients. GC-MS analysis was performed using a Thermo Scientific ISQ762309017 GC-MS system equipped with Chromeleon software version 7.3.2.10759.

2.2 Sample Preparation and Extraction

Lai seeds were obtained from ripe Lai fruits purchased at a local market in Samarinda, East Kalimantan, Indonesia. The seeds were manually separated from the fruit pulp and thoroughly washed with clean water to remove adhering pulp and other impurities. The cleaned seeds were then oven-dried at 60°C until a constant weight was obtained. This temperature was selected to reduce moisture content while minimizing potential thermal degradation of lipid components, particularly unsaturated fatty acids, which are susceptible to heat and oxidation.

The dried seeds were ground using a grinder to obtain a homogeneous powder. A total of 200 g of Lai seed powder was extracted with 2 L of n-hexane at a sample-to-solvent ratio of 1:10 (w/v). Extraction was carried out by maceration to obtain the lipid fraction of the Lai seeds. n-Hexane was selected as the extraction solvent because its nonpolar nature facilitates the extraction of nonpolar lipid components, including fatty acids, fatty acid esters, triglycerides, and other lipophilic compounds. Following extraction, the mixture was filtered to separate the solvent extract from the solid residue. The resulting filtrate was concentrated using a rotary evaporator under controlled temperature conditions until a concentrated lipid extract was obtained. The extract was transferred into a tightly sealed container and protected from light until GC-MS analysis.

2.3 GC-MS Analysis

The lipid compound profile of the Lai seed extract was analyzed using a Thermo Scientific ISQ762309017 Gas Chromatography–Mass Spectrometry (GC-MS) system equipped with Chromeleon software version 7.3.2.10759. The analysis was performed using the operating conditions established for the GC-MS system. Chromatographic separation was conducted using a capillary column with a nonpolar stationary phase based on 5% phenyl methylpolysiloxane. Helium was used as the carrier gas under constant-flow conditions. The analytical parameters included the column specification, injector temperature, oven temperature program, carrier gas flow rate, injection volume, and mass spectrometer operating conditions.

The separated compounds were detected using mass spectrometry with electron ionization (EI) at an ionization energy of 70 eV. The resulting total ion chromatogram (TIC) provided the chromatographic profile of the extract, with individual components represented by their respective retention times. Compound identification was performed by comparing the mass spectra obtained from the samples with reference spectra available in the mass spectral library. The identified compounds were evaluated based on their Similarity Index (SI), retention time, molecular weight, and characteristic mass fragmentation patterns. The relative abundance of each detected compound was expressed as a percentage of its peak area relative to the total peak area of the chromatogram. Compounds exhibiting the highest relative peak area percentages were considered the predominant components of the extract and were used to describe the lipid compound profile of Lai seeds.

2.4 Data Analysis

The GC-MS chromatographic data were analyzed descriptively. The detected compounds were identified and classified according to their respective chemical groups. The parameters evaluated included retention time, Similarity Index (SI), peak area, and relative peak area percentage. The relative abundance of each compound was determined from its peak area relative to the total chromatographic peak area. Compounds with the highest relative peak area percentages were considered the predominant compounds and were used as the basis for describing the lipid compound profile of the Lai seed extract. The identified compounds were subsequently interpreted based on their reported chemical characteristics and potential biological functions to provide an initial assessment of their potential as functional feed ingredients.

3. Results

3.1. GC-MS Chromatogram Profile of Lai Fruit Seeds

GC-MS analysis revealed that the n-hexane extract of Lai seeds produced a chromatographic profile consisting of several detected peaks within a retention time range of 4.64–43.34 min (Figure 1). The Total Ion Chromatogram (TIC) illustrates the distribution of volatile and semi-volatile compounds based on their retention times, with several dominant peaks observed within the retention time range of approximately 21–26 min. The predominance of peaks within this range indicates the presence of lipid-related compounds, particularly long-chain fatty acids and their derivatives.

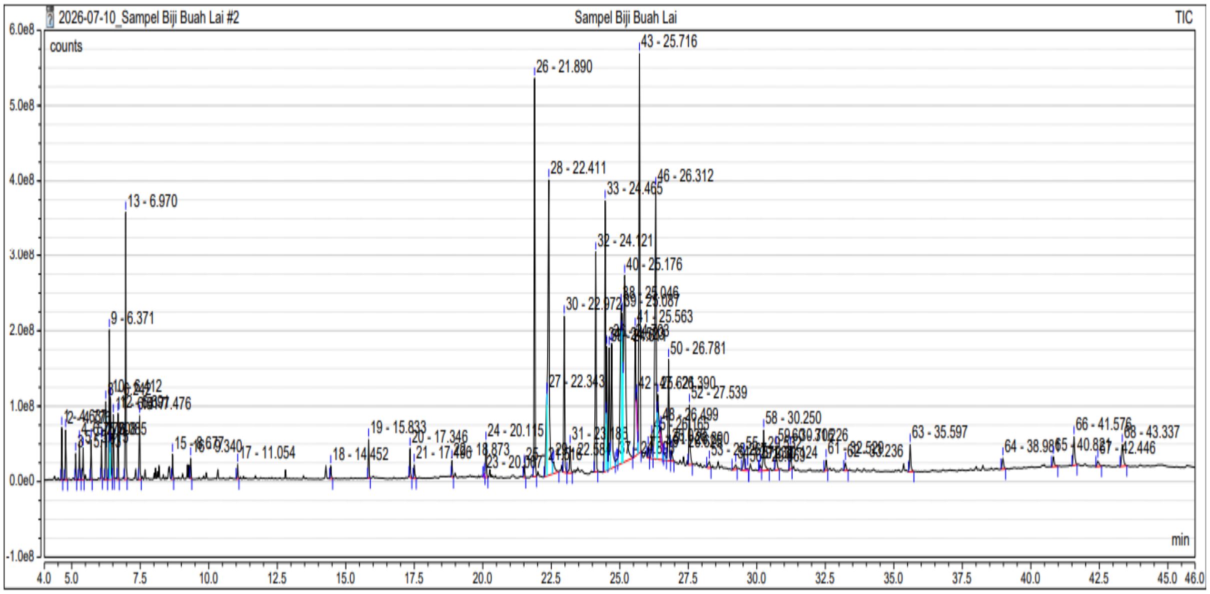

Figure 1. GC-MS chromatographic profile of the n-hexane extract of Lai seeds.

Based on the comparison of mass spectra against the mass spectral library, a total of 68 compounds were tentatively identified according to the similarity of the Similarity Index (SI) values, retention times, molecular weights, and mass fragmentation patterns.

Table 1. Dominant Lipid Compounds Identified in Lai Fruit Seed Extract Based on GC-MS Analysis

No.	Compound	Retention Time (min)	Similarity Index (SI)	Relative Area (%)
1	n-Hexadecanoic acid	22.41	931	8.33
2	Oleic acid	25.18	860	7.95
3	Methyl 2-octylcyclopropene-1-octanoate	25.72	871	7.42
4	9-Octadecynoic acid	26.31	830	7.41
5	Hexadecanoic acid, methyl ester	21.89	955	6.15
6	9,12-Octadecadienoic acid (Z,Z)-,methyl ester	24.46	936	4.76
7	9,12-Octadecadienoic acid (Z,Z)-	25.05	901	4.67
8	9,12-Octadecadienoic acid, ethyl ester	25.56	827	3.72
9	9-Octadecenoic acid (Z)-, methyl ester	24.61	927	2.38
10	9,12,15-Octadecatrienoic acid, methyl ester	24.52	919	2.08
11	β-Sitosterol	41.58	775	0.75
12	Squalene	35.60	837	0.60
13	Stigmasterol	40.82	712	0.27

Note: GC-MS analysis data of n-hexane extract from Lai fruit seeds (*Durio kutejensis*), 2026.

The identified compounds indicated that Lai seed extract was predominantly composed of lipid-related compounds, including saturated fatty acids, unsaturated fatty acids, fatty acid esters, and minor lipid components such as phytosterols and triterpenes. Compounds exhibiting the highest relative area values were selected as the dominant components to characterize the lipid profile of Lai seed extract, as presented in Table 1.

Based on the relative area percentage, the dominant compounds in Lai seed extract were primarily composed of fatty acids and their derivatives. n-Hexadecanoic acid (palmitic acid) exhibited the highest relative abundance, accounting for 8.33% of the total chromatographic area, with a SI value of 931, followed by oleic acid with a relative area of 7.95% and a SI value of 860. Other lipid compounds detected at relatively high levels included methyl 2-octylcyclopropene-1-octanoate (7.42%), 9-octadecynoic acid (7.41%), hexadecanoic acid methyl ester (6.15%), and 9,12-octadecadienoic acid methyl ester (4.76%). The predominance of these compounds indicates that the n-hexane fraction of Lai seeds possesses characteristics of a lipid-rich extract, mainly consisting of long-chain fatty acids and their derivatives.

4. Discussion

4.1. Dominant Fatty Acids in Lai Fruit Seeds

The major compounds identified in the Lai seed extract were predominantly long-chain fatty acids. n-Hexadecanoic acid (palmitic acid) exhibited the highest relative abundance, accounting for 8.33% of the total chromatographic area, with a Similarity Index (SI) value of 931 and a retention time of 22.41 min. The second most abundant component was oleic acid, with a relative area of 7.95% (SI = 860), followed by 9-octadecynoic acid with a relative area of 7.41% (SI = 830). In addition, 9,12-octadecadienoic acid (Z,Z)- (linoleic acid) was identified with a relative area of 4.67% and an SI value of 901. The predominance of palmitic acid in Lai seeds indicates that the lipid fraction possesses characteristics similar to several plant oils rich in long-chain fatty acids. Palmitic acid is one of the most commonly occurring saturated fatty acids in plant storage tissues and serves as a major component of triglycerides as an energy reserve. According to Gunstone (2011) and Rahman et al (2022), palmitic acid is a predominant fatty acid found in various tropical vegetable oils and contributes to their physicochemical properties, including melting point and oxidative stability.

The presence of oleic acid as the second most abundant compound indicates that Lai seeds also contain monounsaturated fatty acids (MUFA). Oleic acid is a major MUFA commonly found in plant seeds and is known to exhibit greater oxidative stability compared with polyunsaturated fatty acids. According to Putri and Yudha (2024), oleic acid plays an important role in lipid metabolism in livestock and may contribute to modifications in the fatty acid profile of animal products when supplied through feed ingredients. In addition to palmitic and oleic acids, the identification of 9,12-octadecadienoic acid (linoleic acid) indicates the presence of polyunsaturated fatty acids (PUFA) in Lai seeds. Linoleic acid is an essential fatty acid that cannot be synthesized de novo by animals and therefore must be supplied through dietary sources. In animal nutrition, linoleic acid is considered an important component because it serves as a precursor for various lipid metabolites and may influence the fatty acid composition of animal tissues and livestock products (Toral et al, 2018).

4.2. Fatty Acid Esters as Derivative Lipid Components

In addition to free fatty acids, GC-MS analysis revealed the presence of various fatty acid ester compounds with relatively high abundance in Lai seed extract. Methyl 2-octylcyclopropene-1-

octanoate exhibited a relative area of 7.42%, followed by hexadecanoic acid methyl ester with 6.15%. Other identified fatty acid esters included 9,12-octadecadienoic acid (Z,Z)- methyl ester (4.76%), 9,12-octadecadienoic acid ethyl ester (3.72%), 9-octadecenoic acid (Z)- methyl ester (2.38%), and 9,12,15-octadecatrienoic acid methyl ester (2.08%). The presence of these fatty acid esters indicates the complexity of the lipid fraction present in Lai seeds.

Fatty acid esters represent common storage forms of plant lipids, particularly as components of triglycerides and other neutral lipid fractions. Christie and Han (2012) and Surakhsa et al., (2026) stated that fatty acid ester derivatives are important components in plant lipid characterization because they reflect the composition of fatty acids constituting energy storage compounds. The predominance of palmitic acid, oleic acid, and linoleic acid derivatives in Lai seeds indicates that this material has potential as a lipid source containing both saturated and unsaturated fatty acids. This lipid profile is comparable to that of various oilseed crops, which typically contain a combination of triglycerides, free fatty acids, and lipid esters as major components of energy reserves.

4.3. Minor Bioactive Lipid Compounds: Phytosterols and Squalene

Besides fatty acids and fatty acid esters, GC-MS analysis also identified several minor lipid compounds with potential functional value, including β-sitosterol, squalene, and stigmasterol. Among these compounds, β-sitosterol exhibited the highest relative area within this group (0.75%), followed by squalene (0.60%) and stigmasterol (0.27%). Phytosterols, such as β-sitosterol and stigmasterol, are minor lipid constituents commonly found in plant cell membranes and vegetable oil fractions. Moreau et al. (2018) reported that phytosterols possess potential biological activities through mechanisms related to cholesterol absorption inhibition and antioxidant activity.

Meanwhile, squalene is a triterpene hydrocarbon that serves as a precursor in sterol biosynthesis and exhibits biological activities associated with protection against oxidative stress (Reddy & Couvreur, 2009). Although detected at relatively lower levels compared with major fatty acid components, the presence of phytosterols and squalene indicates that Lai seeds may serve not only as a lipid energy source but also as a source of minor bioactive compounds that contribute additional functional value.

4.4 Potential of Lipid Compounds from Lai Seed Extract as Functional Feed Components

The GC-MS analysis revealed that Lai fruit seeds possess a lipid compound profile with potential for development as a candidate functional feed ingredient. The presence of long-chain fatty acids, fatty acid esters, and minor lipid compounds indicates that Lai seeds may serve not only as an energy source but also as a source of bioactive components that provide additional value in feed formulation. Plant-derived lipids serve as concentrated energy sources and provide metabolic precursors involved in various physiological processes in livestock (Palmquist, 2009; Meliandasari et al., 2016).

The presence of oleic acid and linoleic acid derivatives in Lai seeds represents an important finding, as unsaturated fatty acids play significant roles in lipid metabolism and may influence the fatty acid composition of animal tissues and livestock products through dietary lipid metabolism (Jenkins et al., 2008). Furthermore, the detection of minor lipid compounds such as phytosterols indicates the potential contribution of plant-derived bioactive compounds in supporting the development of functional feed ingredients (Moreau et al., 2018 ; Gou et al., 2020). However, the GC-MS results obtained in this study represent an initial chemical screening stage; therefore, further investigations regarding nutritional value, digestibility, bioavailability, and physiological responses in livestock are required to confirm the practical application potential of Lai seeds as a functional feed ingredient.

5. Conclusion

The n-hexane extract of Lai fruit seeds exhibits a lipid compound profile with potential for development as a functional feed ingredient derived from local resources. GC-MS analysis revealed that the predominant compounds consisted of n-hexadecanoic acid (8.33%), oleic acid (7.95%), and methyl 2-octylcyclopropene-1-octanoate (7.42%), along with various fatty acid derivatives and minor lipid compounds. The presence of these compounds indicates that Lai seed extract may serve as a value-added lipid source; however, further studies are required to evaluate its nutritional characteristics, digestibility, and biological responses in livestock.

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Conflict of Interest

The authors declare no conflict of interest.

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