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Analysis of Physicochemical Properties and Quality Testing of Beef Tallow and Lard Oil Along with Identification using FTIR and GC-MS

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Abstract: The halal industry is expanding quickly worldwide, especially in Indonesia, which has the largest Muslim population and plenty of natural resources. This study aims to analyze the physicochemical properties and quality of beef tallow and lard oil, as well as to identify differences in FTIR and GC-MS spectra to tell these two animal fats apart. The results show that lard oil has a higher extraction yield (30%) compared to beef tallow (17%). Lard oil also has a higher iodine value (53 mg/gr), indicating more unsaturated fatty acids, making it suitable for cooking. Conversely, beef tallow has a lower peroxide value (5 meq O_2/kg), which suggests better resistance to oxidation. FTIR analysis shows differences in functional groups, with lard oil displaying a higher degree of unsaturation. GC-MS analysis finds key compounds like 9-octadecenoic acid methyl ester in lard oil, while beef tallow is mainly composed of tetradecanoic acid methyl ester. This study highlights the need to develop Indonesian National Standards (SNI) to ensure product quality and halal compliance. These findings offer valuable insights for the halal industry and food safety in Indonesia and encourage further research on the composition of animal fats.

Keywords: adulteration, beef tallow, FTIR, GC-MS, halal authentication, lard oil

1. INTRODUCTION

The halal industry has developed into a significant global trend, evidenced by its consistent year-on-year growth prospects and strategic role in driving economic progress. Indonesia has a privileged position in the global halal industry landscape thanks to its large Muslim population and abundant natural resources, including maritime wealth, fertile land, and valuable mineral reserves such as gold, nickel, tin, copper, and oil deposits in various regions. This abundance provides a solid foundation for developing various halal industry sectors, including food, clothing, shelter, tourism, pharmaceuticals, and cosmetics. As an integral part of national production activities, the halal industry must meet the needs of the community with products that are not only affordable, safe, and of high quality but also in harmony with the religious values, beliefs, and culture of the population. To realize this, a comprehensive production system is needed that guarantees protection for producers and consumers, ensures that the products produced meet the established halal standards, and contributes positively to the national economy through optimal utilization of Indonesia's abundant natural resources.

Beef tallow and lard oil have different fatty acid compositions and triglyceride structures, which affect physicochemical properties such as melting point, viscosity, and oxidative stability. Although both are animal fats, differences in the metabolism and diet of the animals they come from cause variations in the fatty acid profile and other minor components. An in-depth understanding of these characteristics is not only important for identification purposes but also for evaluating product quality and authenticity [1] [2].

Differentiating beef tallow and lard oil based on physical and chemical properties is a significant challenge, as their characteristics are often similar and overlapping. This opens up the potential for oil mixing or adulteration, especially in cosmetic products that demand clarity of raw material sources for compliance with halal standards. Conventional methods that have been used for animal

oil identification often have limitations in terms of speed, accuracy, and the ability to detect specific admixtures. Some analytical methods that can be used for authentication are gas chromatography-mass spectrometry (GC-MS) [3], differential scanning calorimetry (DSC) [4], nuclear magnetic resonance (NMR)[5], and Fourier transform spectroscopy (FTIR) [6].

Attenuated Total Reflection-Fourier Transform Infrared (ATR-FTIR) spectroscopy is an effective analytical method for the detection and identification of components in edible sesame oil. Over the past decade, FTIR spectroscopy has become an invaluable food analysis instrument, enabling the characterization of ingredients based on their chemical functional groups. This method offers significant advantages of process speed and high sensitivity, supported by flexibility in sampling techniques. As an alternative to conventional methods, ATR-FTIR provides a practical and efficient method for identifying functional groups in compounds and differentiating between various types of animal fats, making it a valuable tool frequently used in halal authentication.The popularity of this technique is increasing because it requires only a minimal amount of sample, the testing process is short, and it is non-destructive, so as not to damage the integrity of the sample being analyzed.

The GC-MS method can be used to evaluate the halal status of products containing animal fats, especially lard, by converting the fatty acids in the sample into their ester derivatives, which are then analyzed. This technique allows for the precise identification of animal fats, such as lard oil or beef tallow, and makes it a valuable tool for halal authentication in food products, cosmetics, and pharmaceutical preparations. Through esterification, free fatty acids from triglycerides are converted into esters. This method can determine the amount of saturated and unsaturated fats contained in the product [8],[9].

This study aims to analyze the physicochemical properties and quality parameters of beef tallow and lard oil and identify differences in FTIR and GC-MS spectra that can be used as markers to distinguish the two animal fats. The main issue in fat authentication is the difficulty of accurately distinguishing between beef tallow and lard oil due to their similar physical and chemical characteristics, which increases the risk of mixing or adulteration. Although several methods have been applied, they still have limitations in terms of speed, accuracy, and sensitivity to detect complex mixtures. Therefore, this study emphasizes the importance of developing a fast, sensitive, and non-destructive analytical method by utilizing ATR-FTIR combined with GC-MS analysis to obtain clear and reliable authentication markers. This approach is crucial for ensuring compliance with halal standards, increasing consumer confidence, and supporting the growth of Indonesia's halal industry on a global scale.The results of the study are expected to contribute significantly to the development of analytical methods for the detection of animal fat adulteration and ensure product authenticity in the market.

2. MATERIALS AND METHODS

2.1.Materials

This study utilized a range of laboratory equipment and reagents. The tools employed included an Oven (Memmert), an FTIR (BRUKER ALPHA II), glassware (pyrex), a pycnometer, an Abbe refractometer, an analytical balance (OHAUS), a basin container, and filter paper. The materials used are: Beef tallow obtained from Sentul market in Yogyakarta, lard obtained from an agent in Bantul Regency, Na_2So_4, N-hexane (Bratachem, PT. Brataco, Indonesia), chloroform (Emsure®, merck KGaA, Germany), acetic acid (Emsure®, merck KGaA, Germany), KI 15%, amylum 0.5%, sodium thiosulfate ($Na_2S_2O_3$) 0.1 N (Emsure®, merck KGaA, Germany), Wijs reagent (Emsure®, merck KGaA, Germany), KOH, ethanol, PP indicator (phenolphthalein), KOH-ethanolic.

2.2. Methods

2.1.1. Animal determination of cattle and pigs

This non-experimental research was conducted on October 1, 2024, in the Ahmad Dahlan University Yogyakarta laboratory. Determination was carried out at the Ahmad Dahlan University Biology laboratory.

2.1.2. Preparation of beef tallow and lard oil

Extraction of beef and pork fat was carried out using the dry rendering method. The stages of fat extraction involved preparing 1.5 kg of beef fat and 1.5 kg of pork fat, followed by sorting. The beef and pork fat were melted in an oven at 85°C to 100°C for 6 hours, repeated twice. The oil obtained was separated from the remaining water using a separating funnel, then purified with n-hexane, and evaporated to remove all n-hexane residues. Finally, sodium sulfate (Na_2SO_4) was added to remove any residual water. The resulting oil was then stored in a glass container

2.1.3. Oil yield

The yield of cow and pig oil was obtained using the formula [11] :

$$\frac{\text{Weight of oil obtained}}{Weight\ of\ animal\ fat\ used}\ x\ 100\%$$

2.1.4. Test of Physical Properties of Beef Tallow and Lard Oils

The comprehensive physical property testing of beef tallow and lard oils involves multiple analytical procedures, beginning with organoleptic evaluation where color characteristics are assessed through careful visual observation using the sense of sight, and odor profiles are distinguished through the sense of smell to identify distinctive aromatic compounds [12]. Specific gravity determination is meticulously performed using a calibrated 25 mL pycnometer with three replications to ensure statistical reliability, with calculations incorporating temperature correction factors to account for thermal expansion effects during experimentation [13]. Refractive index measurement is precisely conducted at a controlled temperature of 20°C using an Abbe refractometer in triplicate to quantify light refraction through the oil medium as an indicator of molecular density and purity [14]. Comprehensive solubility profiling is executed by systematically introducing the oils to an array of solvents spanning the polarity spectrum—including non-polar (N-Hexane and benzene), polar (ethanol and distilled water), and semi-polar (diethyl ether, acetone, and chloroform)—at an exact 1:1 volumetric ratio of 10 mL oil to 10 mL solvent until complete dissolution and formation of transparent solutions, thus characterizing the oils molecular interaction capabilities across different chemical environments.

2.1.5. Chemical properties test of beef tallow and lard oils

The comprehensive chemical characterization of beef tallow and lard oils involves three critical analytical procedures: the peroxide value determination, which quantifies oxidative rancidity by weighing approximately 1.0 g of oil sample in a 250 mL glass Erlenmeyer flask, adding 30 mL of chloroform acid mixture (2:3), homogenizing thoroughly, introducing 0.5 mL of saturated potassium iodide solution followed by dark incubation for precisely one minute, then adding 1 mL of 0.5% amylum indicator solution before titrating with standardized 0.1 N sodium thiosulfate until the characteristic blue coloration completely disappears from the titrate [15]. The iodine value assessment, which measures unsaturation levels by precisely weighing 300 mg of sample into a 250 mL erlenmeyer flask, dissolving it in 10 mL chloroform with 25 mL Wijs reagent (1% iodine chloride in acetic acid), allowing reaction progression for 30 minutes in a light-protected environment, adding 10 mL of 15% potassium iodide solution and 50 mL of carbon dioxide-free distilled water, titrating with 0.1 N sodium thiosulfate until a pale yellow color develops, adding 2 mL of 0.5% amylum indicator, and continuing titration until complete blue color dissipation [16]. The acid value determination, which evaluates free fatty acid content by by dissolving the sample in an ethanolic solution, adding phenolphthalein indicator, and titrating with a standardized ethanolic potassium hydroxide (KOH) solution until a persistent pink endpoint is reached [17].

2.1.6. Analysis using FTIR Alpha II

FTIR analysis of beef tallow and lard oil samples was performed by pipetting a small drop (~5 µL) of oil covering the surface and in contact with the base plate of the ATR sample at controlled room temperature (30 °C). The plate was carefully cleaned twice with acetone and dried with soft tissue

before being filled with the next sample. The background spectrum was scanned before each sample measurement to ensure accuracy. Spectral scans were recorded over a wavenumber range of 4000–500 cm^{-1}. Each sample was scanned 32 times, and the resulting spectra were averaged to improve the signal to noise ratio[18].

2.1.7. Analysis using GC-MS QP2010 SE (*Shimadzu*)

The GC-MS instrument used was the Shimadzu GCMS-QP2010 SE. Helium served as the carrier gas, with a maximum column flow rate of 4 mL per minute. The system operated in Electron Ionization (EI) mode and covered a mass range from m/z 1.5 to 1000. Two mL of both beef tallow and lard oil were taken and added to 7 mL of n-hexane and 5 mL of NaOH solution in methanol. Then, 7 mL of BF_3 solution was added, and the mixture was heated for 10 minutes. To precipitate sodium glycerolate, the sample was allowed to cool, and 5 mL of saturated sodium chloride was added. Subsequently, it was vortexed for 10 minutes. The supernatant containing fatty acid methyl ester (FAME) derivatives was collected and injected into the GC-MS system. This process is a sample preparation method through derivatization, where fats are converted into FAMEs so that they can be analyzed by GC-MS [19]. After derivatization was complete, 0.2 μL of the derivatized oil sample was placed into a 5 mL vial. A 0.2 μL aliquot of the oil sample was injected into the GC-MS using an autosampler syringe. The injector temperature was 250°C with an injection volume of 0.2 μL, a split ratio of 1:200, and the temperature was ramped from 50°C for 2 minutes to 99°C and finally reached 250°C [20].

3. RESULTS AND DISCUSSION

Table 1 presents a comparison of two types of animal fats. Both have distinct organoleptic characteristics and chemical compositions, affecting their use in the food industry, cosmetics, and other applications. Additionally, the table includes physical and chemical parameters such as density, refractive index, peroxide value, iodine value, and acid value, each test was performed in three replication to ensure accuracy and reliability of the data. This information is essential for understanding the physical properties of both fats and how they interact with solvents and other materials. The dry rendering method affects the oil yield obtained because the extraction time is directly proportional to the yield value [24].

Table 1. Physico-chemical properties of beef tallow and lard oil

Parameters	Lard oil	Beef Tallow
Organoleptic	Yellow color and typical lard odor	Yellow and typical beef tallow odor
Yields of Oils	30%	17%
Color	Yellow	Yellow
Odor	Specific pig	Specific beef
Density (g/mL)	0.90	0.91
Refractive index		1.470
Peroxide value (meq O_2/kg)	6	5
Iodine value (mg/gr)	53	40
Acid value (mg KOH/gr)	1.029	0.935
Solubility	Soluble in hexane, benzene, ether, acetone, and chloroform Not soluble in alcohol and water	Soluble in hexane, benzene, ether, acetone, and chloroform Not soluble in alcohol and water

Based on Table 1, lard oil distinguished by its remarkably superior yield of 30% compared to beef tallow's 17% presents a more economically advantageous and resource-efficient extraction process,

making it potentially more appealing from a large-scale production standpoint, while both oils share a common yellow coloration and demonstrate comparable solubility characteristics in nonpolar solvents such as hexane and benzene, their unique and readily distinguishable odors, stemming from their distinct animal origins, coupled with their disparate chemical compositions, serve to effectively differentiate them and dictate their suitability for various applications; specifically, lard oil's elevated iodine value of 53 g, in contrast to beef tallow's 40 g, serves as a clear indicator of a greater proportion of unsaturated fatty acids incorporated within its molecular structure, potentially leading to a softer, more pliable, and more easily spreadable texture, making it desirable in certain culinary applications, but also simultaneously rendering it more susceptible to degradation through oxidation processes, potentially shortening its shelf life and requiring careful handling and storage, whereas beef tallow's marginally lower peroxide value of 5 meq O_2/kg suggests an enhanced inherent resilience against oxidative degradation and the development of rancidity, a beneficial characteristic that is further bolstered by its reduced acid value of 0.935 mg relative to lard oil's 1.029 mg, implying a diminished presence of free fatty acids, which can contribute to off-flavors and reduced stability, and suggesting a potentially more refined and less hydrolyzed condition, resulting in a longer shelf life and improved flavor stability, consequently, this positions lard oil as a more suitable candidate for applications that prioritize a softer mouthfeel, enhanced spreadability, or specific textural attributes in the final product, such as in pastry making or certain types of confectionery, while simultaneously positioning beef tallow as a more appropriate and robust choice for scenarios that necessitate augmented thermal stability, extended shelf life, or a high degree of resistance to oxidative breakdown, such as demanding high-temperature cooking applications like deep frying, the production of durable and long-lasting soaps and candles, or long-term storage scenarios where flavor and texture stability are paramount. Nevertheless, a truly comprehensive and nuanced understanding of their respective strengths, limitations, and optimal application domains necessitates a more exhaustive and in-depth investigation encompassing a detailed analysis of their individual fatty acid profiles, including the specific types and proportions of saturated, monounsaturated, and polyunsaturated fatty acids present, precise and experimentally determined melting points, which dictate their behavior at different temperatures, and a thorough examination of the intricate influence of both the specific processing methodologies employed during extraction and refinement, such as rendering techniques and bleaching processes, and the precise animal dietary regimens followed during livestock rearing, which can significantly impact the fatty acid composition of the resulting fats, on their ultimate physical and chemical properties, sensory attributes, and nutritional profiles, as these multifaceted factors collectively contribute to their diverse performance characteristics, impacting everything from flavor nuances and textural qualities to overall stability, nutritional value, and safety, and ultimately determining their suitability for a wide and varied array of culinary, cosmetic, pharmaceutical, and industrial applications, thereby underscoring the critical importance of adopting a holistic and multi-dimensional assessment approach that extends far beyond the initially presented set of limited parameters to fully appreciate their unique potential and limitations and to make informed decisions regarding their appropriate use [26].

The absence of Indonesian National Standards (SNI) for lard oil and beef tallow highlights a significant regulatory gap, potentially opening opportunities for adulteration and complicating quality control of products in the Indonesian market; existing characterization data, including organoleptic properties, yield, density, peroxide value, iodine value, acid value, and solubility, can serve as a strong foundation for further research aimed at developing comprehensive SNI standards; this research should focus on in-depth analysis of fatty acid composition and volatile compounds, the impact of processing methods on quality, identification of distinctive differentiating parameters, determination of safe maximum contamination limits, and stability studies to ensure product safety and quality for consumers.

The detection of adulteration when two fats are mixed is a critical concern in fat authentication. Gas Chromatography-Mass Spectrometry (GC-MS) is a powerful technique widely used for this purpose due to its ability to analyze and differentiate fatty acid compositions and volatile compounds that serve as specific markers for various animal fats. Additionally, chemometric methods like

orthogonal projection to latent structures-discriminant analysis (OPLS-DA) applied to GC-MS data have demonstrated high sensitivity in detecting low levels of adulteration in animal fats.

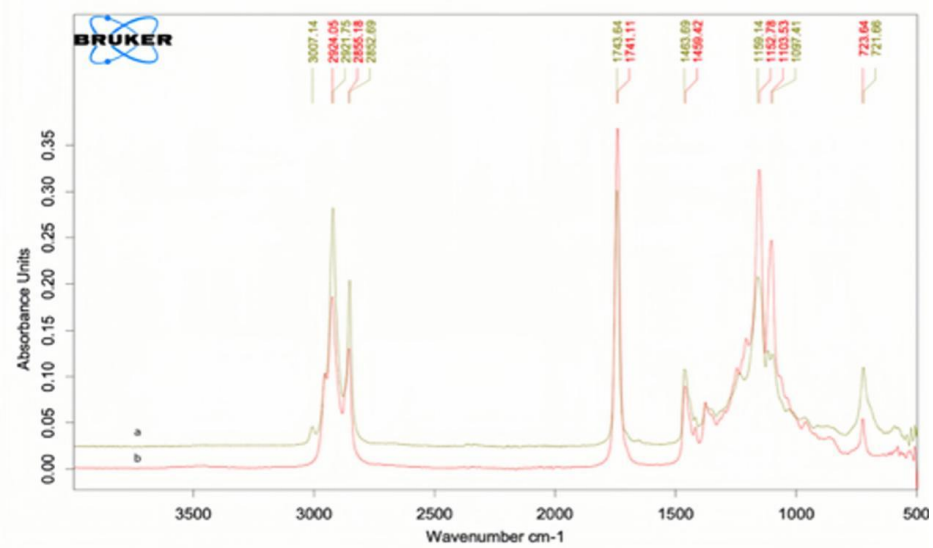

Figure 1. Beef tallow and lard oil spectra: a) lard oil; b) beef tallow

Figure 1 shows the infrared (IR) spectroscopy analysis of lard (a) and beef tallow (b), providing information about the chemical composition and molecular structure of each. This spectrum displays the relationship between wavenumber (cm^{-1}) and absorption intensity, along with the functional groups as shown in Table 2.

Table 2. Functional groups of beef tallow and lard oil [21]

Wavenumber (cm^{-1})		Intensity	Functional Groups[25]
Lard oil	Beef tallow		
3007.14		Weak	C=C
2921.75	2924.05	Medium	CH_2
2852.69	2855.18	Medium	CH_2
1743.64	1741.11	Strong	C=O
1463.69	1459.42	Weak	CH_2
1159.14	1152.78	Strong	C-O
1097.41	1103.53	Strong	C-O
721.66	723.64	Weak	CH_2

The FTIR spectral analysis in Table 2 reveals a shared compositional foundation between lard oil and beef tallow, both exhibiting characteristic functional groups indicative of their triglyceride-rich nature, as evidenced by the presence of CH_2 aliphatic chains, with asymmetric stretching observed around 2921-2924 cm^{-1} and symmetric stretching around 2852-2855 cm^{-1}, reflecting the long hydrocarbon tails of the constituent fatty acids; strong carbonyl (C=O) ester linkages, detected at approximately 1741-1743 cm^{-1}, definitively confirm the presence of ester bonds linking glycerol and fatty acids, the fundamental building blocks of triglycerides and C-O stretching vibrations, prominent at 1152-1159 cm^{-1} and 1097-1103 cm^{-1} further corroborate the presence of ester linkages and the glycerol backbone, providing a comprehensive fingerprint of the triglyceride structure. However, a notable distinction emerges with the presence of a weak C=C peak at 3007.14 cm^{-1} exclusively in the lard oil spectrum, suggesting a discernibly higher degree of unsaturation within its fatty acid composition relative to beef tallow, implying a greater proportion of unsaturated fatty acids containing carbon-carbon double bonds, which can influence fluidity and susceptibility to oxidation; furthermore, the relative intensities of the CH_2 bending peaks (observed around 1459-1463 cm^{-1}),

associated with scissoring vibrations, and the CH_2 rocking peaks (observed around 721-723 cm^{-1}), although weak in both samples, provide subtle yet valuable insights into the average chain length and the overall packing arrangement of the fatty acid molecules within each oil matrix, potentially reflecting subtle differences in the distribution of saturated versus unsaturated fatty acids, the presence of cis versus trans double bonds, and the influence of these compositional variations on their macroscopic physical properties, such as melting point, viscosity, oxidative stability, and overall suitability for various applications ranging from culinary uses to industrial processes [7].

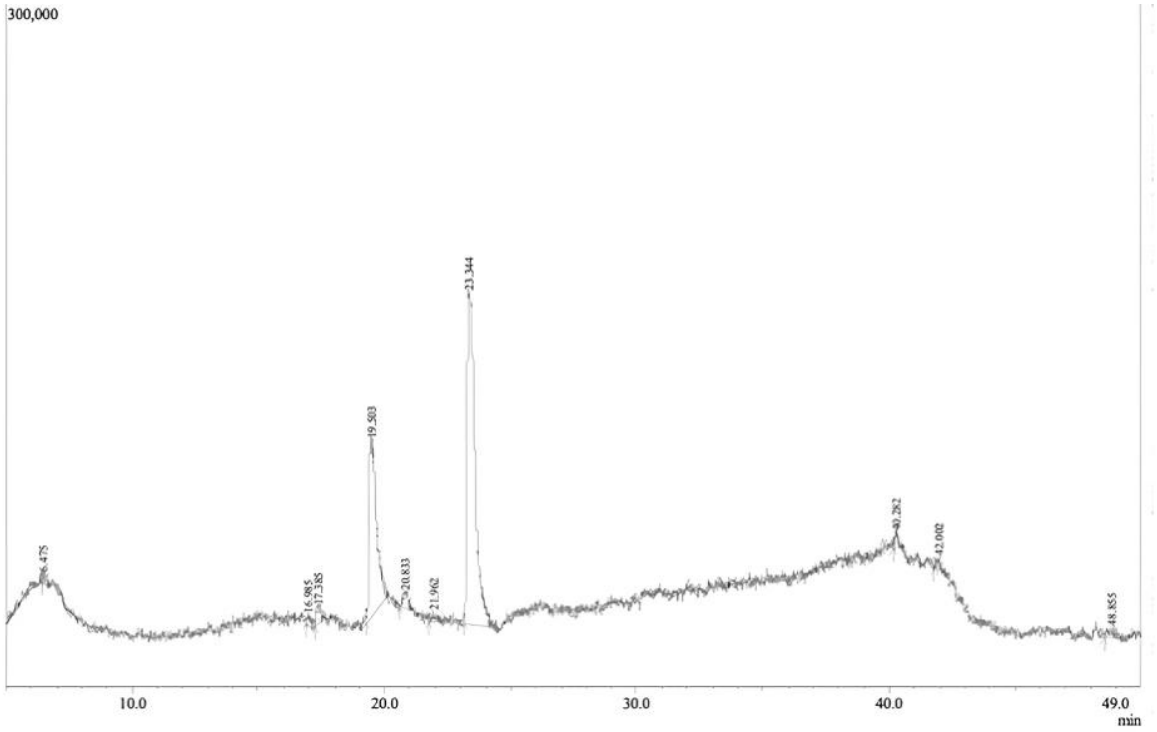

Figure 2. GC-MS chromatogram of lard oil

Figure 2 shows the chromatogram profile of lard oil, where each peak represents a compound separated based on its retention time. Two main peaks at 18.903 and 23.344 minutes indicate the presence of compounds with the highest abundance in the sample. Other smaller peaks are scattered along the chromatogram, indicating the presence of minor compounds with lower concentrations. A feature at 6.475 minutes indicates volatile compounds, while a broad feature at the end of the chromatogram indicates high-boiling point compounds. Further interpretation requires mass spectra data for accurate compound identification without further information regarding the sample and analysis conditions.

Table 3. The total fatty acid composition of lard oil using GC-MS

Retention time	Compound	Compound formula	SI (%)	Molecular weight (g/mol)	Relative presentation (%)
19.503	Hexadecanoic acid, methyl ester (CAS)	$C_{17}H_{34}O_2$	96	270	31.99
20.833	Hexadecanoic acid, methyl ester (CAS)	$C_{17}H_{34}O_2$	95	270	1.92
23.344	9-Octadecenoic acid, methyl ester, (E)-(CAS)	$C_{19}H_{36}O_2$	93	296	57.62

The chromatogram data shows three main compounds detected in Table 3, the samples cointain fatty acid esters. First, Hexadecanoic acid methyl ester was detected at a retention time of 19.503 minutes with an integration percentage of 96% and a molecular weight of 270 g/mol. The relative presentation of this compound reaches 31.99%, indicating that it is a significant component in the sample and has potential importance for industrial applications, such as in products that require emollient properties. Second, Hexadecanoic acid methyl ester was also detected at a retention time of 20.833 minutes with an integration percentage of 95%. Although its relative presentation is only 1.92%, its presence remains significant and may reflect variations in the extraction or separation methods. Third, 9-Octadecenoic acid methyl ester (E) was detected at a retention time of 23.344 minutes with an integration percentage of 93% and a molecular weight of 296 g/mol. This compound is the most dominant in the sample, with a relative presentation of 57.62%. This indicates a great potential for industrial applications in the food and cosmetic industries, functioning as an emulsifier and thickening agent [22]. Overall, this analysis indicates the presence of three fatty acid esters in the sample. The main component, 9-Octadecenoic acid methyl ester, shows significant value for various applications, while Hexadecanoic acid methyl ester also contributes significantly to the composition. This data is useful for understanding the characteristics and benefits of these compounds across different fields. Moreover, the fatty acid methyl esters (FAME) profile obtained from GC-MS should be linked with specific biochemical markers indicative of halal status. Hexadecanoic acid, methyl ester is a common marker, while certain fatty acids and metabolites are characteristic of non-halal fats.

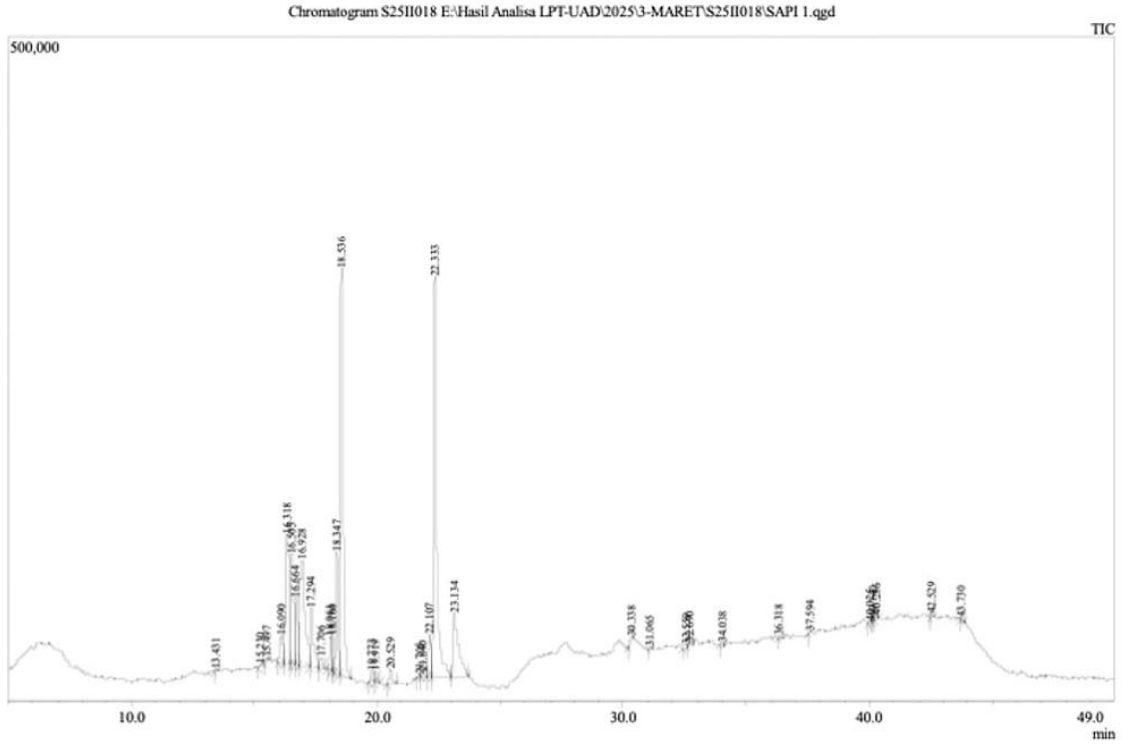

Figure 3. GC-MS chromatogram of beef tallow

The Figure 3 shows GC-MS chromatogram of the beef tallow sample shows the two highest peaks detected at retention times of 18.536 minutes and 22.333 minutes. The peak at a retention time of 18.536 minutes is identified as a significant compound, likely a fatty acid ester commonly found in beef tallow. With a high integration percentage, this compound indicates that it is the dominant component in the sample, contributing to the organoleptic properties and nutritional value of beef tallow. Next, the peak at a retention time of 22.333 minutes also indicates an important compound, although its relative presentation may be lower compared to the first peak.

Table 4. The total fatty acid composition of beef tallow using GC-MS

Retenion time	Compound	Compound formula	SI(%)	Molecular weight (g/mol)	Relative presentation (%)
16.318	Tetradecanoica cid,methyleste r(CAS)	$C_{15}H_{30}O_2$	95	242	9.79
18.348	9-Hexadecenoica cid,methyleste r,(Z)-(CAS)	$C_{17}H_{32}O_2$	96	268	3.83
18.536	Pentadecanoic acid, 14-methyl ester	$C_{17}H_{34}O_2$	96	270	19.70
22.333	Methyl 9,9-dideutero-octadecanoate	$C_{19}H_{34}D_2O_2$	90	296	22.19

Table 4 shows the GC-MS chromatogram data of two main compounds detected in the sample. At a retention time of 16.318 minutes, Tetradecanoic acid methyl ester ($C_{15}H_{30}O_2$) was identified with an integration percentage (SI) of 95% and a molecular weight of 242 g/mol. This compound has a relative presentation of 9.79%, indicating that it is the dominant component in the sample. Next, at a retention time of 18.348 minutes, 9-Hexadecenoic acid methyl ester (Z) ($C_{17}H_{32}O_2$) was detected with an SI of 96% and a molecular weight of 268 g/mol. This compound has a relative presentation of 3.83%, suggesting that although it is present in smaller amounts compared to Tetradecanoic acid methyl ester, it remains significant in the analysis. Although the compound contains a carbon-carbon double bond (C=C), the characteristic absorption band for C=C stretching, typically observed around 1650 cm^{-1}, may be weak, overlapped, or masked by the strong absorption of other functional groups in the molecule, such as the ester carbonyl (C=O) group, which shows a prominent peak near 1740 cm^{-1}. Additionally, the intensity of the C=C stretching vibration depends on the change in polarity during vibration, and since aliphatic C=C bonds usually produce relatively weak infrared absorptions, their signals can be difficult to distinguish in the presence of overlapping bands.

Lard oil and beef tallow have significant differences in their compound composition; lard oil contains hexadecanoic acid and 9-octadecenoic acid, with 9-octadecenoic acid reaching a relative presentation of 57.62%, indicating a dominance of unsaturated fatty acids, while beef tallow contains tetradecanoic acid and 9-hexadecenoic acid, but with a lower presentation of tetradecanoic acid (9.79%), reflecting a higher proportion of saturated fatty acids. In terms of retention time, hexadecanoic acid in lard oil is detected at 19.503 and 20.833 minutes, while 9-hexadecenoic acid in beef tallow is detected at 18.348 minutes, indicating that the structure of the compounds affects detection time. Lard oil is more suitable for culinary and cosmetic applications that require good organoleptic properties due to its higher relative presentation of unsaturated fatty acids. The content of unsaturated fatty acids in lard provides excellent softness and viscosity in cosmetic products, thereby enhancing texture and absorption on the skin. Additionally, lard is frequently used as a viscosity enhancer in moisturizing creams. However, the use of lard must also take into account regulations and certifications, including compliance with halal standards and safety labeling. Furthermore, attention must be given to the quality of raw materials and processing during production to maintain the physicochemical stability and sensory properties of cosmetic products. [23].

Organoleptic evaluation provides preliminary sensory information, such as color and odor, which offers a practical yet subjective means to differentiate animal fats. FTIR spectroscopy complements this by rapidly identifying molecular functional groups through characteristic

absorption bands, enabling a more objective and precise chemical profiling of fats. Meanwhile, GC-MS analysis further refines the assessment by detailing specific fatty acid methyl esters present, allowing for precise identification of fat sources based on their fatty acid composition. Combined, these methods create a comprehensive analytical framework in which organoleptic results align with molecular and compositional data, thereby enhancing accuracy in fat authentication and supporting halal compliance verification.

4. CONCLUSION

This study successfully analyzed the physicochemical properties and quality parameters of beef tallow and lard oil, as well as identified differences in FTIR and GC-MS spectra that can be used to distinguish between the two. The results showed that lard oil has a higher extraction yield (30%) and a higher iodine value, indicating a greater presence of unsaturated fatty acids. Conversely, beef tallow has a lower peroxide value, indicating better resistance to oxidation. FTIR analysis revealed differences in functional composition, while GC-MS analysis detected important compounds such as fatty acid esters, indicating potential industrial applications. This research also emphasizes the need for the development of Indonesian National Standards (SNI) to prevent adulteration and ensure product quality. These findings provide valuable insights for the halal industry and food safety in Indonesia. However, limitations exist in the authentication methods. FTIR may face challenges in distinguishing overlapping spectral features and detecting low-concentration compounds without advanced data processing. GC-MS requires intensive sample preparation and incurs higher costs, with potential noise affecting accuracy. Both methods depend on comprehensive spectral libraries, which may limit their applicability in some contexts. Therefore, integration with complementary techniques and improved data analysis is recommended to enhance accuracy.

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