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Animal Fat-Commercial Based Solid Soap Quality Test and Identification Using FTIR

Uji Kualitas dan Identifikasi Sabun Padat Komersial Berbasis Lemak Hewan Menggunakan FTIR

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Abstract

Background: Solid soap is produced by saponification of fatty acids with strong bases, and its quality is influenced by the type of fat used. **Objective:** This study aims to evaluate the physical and chemical quality of solid soap made from beef tallow and lard and to identify compound profiles using Fourier Transform Infrared Spectroscopy (FTIR). **Method:** The methods include dry-rendering fat extraction, solid soap formulation, and soap quality tests (organoleptic properties, pH, moisture content, and foam height). FTIR analysis was conducted to compare the absorption spectra of each soap. **Results:** The results showed that soaps derived from both fat sources met all quality requirements specified in the Indonesian National Standard (SNI). FTIR analysis revealed generally similar spectral patterns; the lard solid soap exhibited a characteristic absorption band at approximately 3009 cm^{-1}, corresponding to =C-H stretching vibrations of unsaturated fatty acids. In contrast, this band was not detected in the solid soap made from beef tallow. In addition, the CH_2 rocking vibration around 720 cm^{-1} was more pronounced in the beef tallow solid soap, indicating a higher proportion of long-chain saturated fatty acids. **Conclusion:** FTIR effectively identifies fat types and can be used in raw material authentication, especially in product halalness.

Keywords: *Solid soap, Animal fat, FTIR, Quality test, Fat identification.*

Abstrak

Latar belakang: Sabun padat merupakan produk dari reaksi saponifikasi antara asam lemak dan basa kuat, dengan kualitasnya dipengaruhi oleh jenis lemak yang digunakan. **Tujuan:** Studi ini bertujuan untuk mengevaluasi kualitas fisik dan kimia sabun padat dari lemak sapi dan lemak babi, serta mengidentifikasi profil senyawa menggunakan Spektroskopi Inframerah Transformasi Fourier (FTIR). **Metode:** Metode yang digunakan meliputi ekstraksi lemak dengan pengeringan, formulasi sabun padat, dan uji kualitas sabun (organoleptik, pH, kandungan air, dan ketinggian busa). Analisis FTIR dilakukan untuk membandingkan spektrum penyerapan masing-masing sabun. **Hasil:** Hasil pengujian menunjukkan bahwa sabun dari kedua jenis lemak memenuhi seluruh persyaratan mutu berdasarkan Standar Nasional Indonesia (SNI). Analisis FTIR memperlihatkan pola spektrum yang relatif serupa, namun sabun lemak babi menunjukkan puncak serapan khas pada sekitar 3009 cm^{-1} yang mengindikasikan vibrasi ulur =C-H dari asam lemak tak jenuh, sedangkan puncak tersebut tidak teramati pada sabun lemak sapi. Selain itu intensitas vibrasi rocking CH_2 pada sekitar 720 cm^{-1} lebih dominan pada sabun lemak sapi, mencerminkan kandungan asam lemak jenuh yang lebih tinggi. **Kesimpulan:** FTIR secara efektif mengidentifikasi jenis lemak dan dapat digunakan dalam autentikasi bahan baku, terutama dalam hal kesesuaian kehalalan produk.

Kata Kunci: *Sabun batang, Lemak hewani, FTIR, Uji kualitas, Identifikasi lemak.*

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Introduction

Soap is a surfactant product produced through a saponification reaction between fatty acids from vegetable oils or animal fats with a strong base such as sodium hydroxide (NaOH) or potassium hydroxide (KOH) [1]. This reaction produces salts of fatty acids (soap) and glycerol as a by-product. [2]. Soap contains long carbon chains, generally C12, C16, and C18, that provide cleaning, foaming, and emollient properties. In addition, skin-safe fragrances and colorants are often added to soap formulations to enhance consumer appeal. [3].

The development of soap technology has diversified both in form, function, and composition. Currently, various types of soaps, such as bath soap, laundry soap, household appliance washing soap, and industrial soap, are widely available in the market. [4]. Variations in the types and properties of these soaps depend on the source of fatty acids, the type of alkali used, and the additives added during formulation. [5]. Solid soaps generally use sodium hydroxide (NaOH) to produce a hard product, while soft or liquid soaps use potassium hydroxide (KOH) [6].

In soap making, animal fats such as beef tallow and lard are widely used sources of fatty acids because their triglyceride composition is rich in saturated fatty acids. However, the use of animal fats, especially those from pigs, raises significant religious and ethical concerns, particularly regarding the product's halal status, so an analytical method is needed to ensure the authenticity of the raw material. According to halal certification principles and previous studies, the presence of lard, even in non-food products such as cosmetics and personal care items, may compromise halal compliance, highlighting the importance of reliable analytical approaches for raw material authentication [7,8].

One widely used analytical technique is Fourier Transform Infrared Spectroscopy (FTIR), which can identify specific functional groups in organic compounds based on their infrared absorption patterns. FTIR is particularly advantageous because it is a rapid, non-destructive, and cost-effective method that is sensitive to variations in functional groups, allowing differentiation of lipid sources based on molecular structure and degree of fatty acid saturation, even in processed matrices such as solid soap [9,10].

This study aims to evaluate and compare the quality of solid soaps made from beef tallow and lard by conducting soap quality tests based on physical and chemical parameters. In addition, FTIR analysis was performed to determine the profiles of compounds and functional groups present in the soap and to support the identification of the type of fat used in soap making. Differences in fatty acid composition, particularly the higher proportion of unsaturated fatty acids in lard compared to beef tallow, are expected to produce characteristic infrared absorption bands that can be used as markers for fat authentication [8]. The results of this study are expected to provide valuable scientific information on the effect of fat type on soap quality and to demonstrate the potential of FTIR as an accurate method for identifying soap raw materials.

Experimental Section

Methodology

This research uses the Fourier Transform Infrared Spectroscopy (FTIR) method to analyze fatty acids in bar soap. The study was conducted at the Halal Centre Laboratory, Faculty of Pharmacy, Ahmad Dahlan University, Yogyakarta.

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Tools and Materials

The tools used in this study include: Erlenmeyer flask, beaker, measuring cup, separatory funnel, stirring rod, dropper pipette, filter paper, vortex mixer, stirrer, water bath, mixer, pH meter, oven, desiccator, and cup.

The materials used in this study include: cucumber extract, NaOH (Merck), beef tallow, lard, stearic acid, glyceryl (Sigma), sodium lauryl sulfate (Sigma), NaCl (Merck), distilled water, Na_2SO_4 (Merck), Chlorophom (Merck), and HCl (Merck).

Extraction of Beef Tallow and Lard

Beef tallow and lard were obtained by dry rendering, a method used to extract animal fat by heating without water [11]. 1 kg of beef and pork fat was washed, cut into small pieces, and heated in an oven at 90-100 °C for 2 hours until melted. Filter the melted fat with a flannel cloth, then add anhydrous (Na_2SO_4). The centrifuge is set to 3000 rpm for 20 minutes. The oil layer is separated, vortexed, and centrifuged again, then filtered through Whatman filter paper and stored in a closed container.

Solid Soap Manufacturing and Formulation

Weigh all ingredients according to the formulation in Table 1. Dissolve NaOH first with distilled water. Stearic acid is melted at 60 °C until it melts, then the fat is added. After adding homogeneous stearic acid and fat, add cucumber extract, glycerin, sodium lauryl sulfate, and NaCl, and stir to homogeneity. After the solution becomes homogeneous, mix for 1 minute. Then add the NaOH solution and mix for 2 minutes until a homogeneous soap mass forms. The homogeneous mixture is poured into a silicone mold and allowed to cool at room temperature [12].

Table 1. Formulation of 100% Beef Tallow and 100% Lard Solid Soap [12]

Component Materials	Formula (grams)		Function
	Beef Tallow Solid Soap	Lard Solid Soap	
Cucumber extract	1	1	Active substance
Beef tallow	50	-	Fatty acid source
Lard	-	50	Fatty acid source
NaOH	9	9	Source of alkali
Stearic acid	3	3	Soap hardener and foam stabilizer
Glycerin	10	10	Humectants
Sodium lauryl sulfate	1	1	Surfactants and foam formers
NaCl	0,2	0,2	pH neutralizer
Aquadest	Ad 100	Ad 100	Solvents

Note: Beef tallow and lard used in this formulation were neutral animal fats (triglycerides) obtained through dry rendering extraction before the saponification process.

Solid Soap Testing Parameters

a. Organoleptic Test

The texture, color, and aroma show organoleptic testing on solid soap [12].

b. pH Test

Soap was weighed out in 5-gram increments and dissolved in 10 ml of distilled water. pH was measured on each solid soap formula using a pH meter. Solid soap is qualified if it has a pH value of 9-11 [14].

c. Moisture Content Test

Testing the moisture content of soap involves weighing a porcelain cup that has been dried in an oven at 105 °C for 30 minutes. Weigh 5 grams of soap into a porcelain cup that has a known weight. Heat in an oven at 105 °C for 1 hour, cool in a desiccator to room temperature, then weigh. Repeat the work until the weight of the preparation remains [15].

Calculation:

$$\text{Moisture content} = \frac{W1 - W2}{W} \times 100\%$$

Description:
W1 = Weight of sample + porcelain cup before heating (grams)
W2 = Weight of sample + porcelain cup after drying (grams)
W = Sample weight (grams)

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d. Foam Height Test

A total of 2 grams of soap was put into a test tube containing 10 ml of distilled water, then shaken with a vortex for 1 minute. The foam formed was measured using a ruler. The requirement for soap foam height is 1.3 - 22 cm [16].

Analysis Using FTIR

Solid soap of beef tallow and lard was isolated first, and the isolation results were placed on a crystal plate and scanned using FTIR spectroscopy at a predetermined wave number range of 4000-400 cm^{-1}. After each measurement, the plate was rinsed with hexane twice until no oil remained, then dried with tissue. After the scan process was complete, the air spectrum was taken. All measurements were replicated three times [16].

Results and Discussion

Soap Quality Test Results

In this study, the quality of solid soap was tested in the fourth week after production. The selection of this time aims to ensure that the soap has gone through an optimal curing process where the saponification reaction takes place completely, the water content decreases, and the soap structure becomes more stable [17]. The maturation process is important to produce soap with fixed physical and chemical properties, such as a dense texture, balanced pH, and consistent foam-forming ability [18]. Tests conducted at this stage include organoleptic parameters (texture, color, and aroma), pH, moisture content, and foam height. All of these parameters are evaluated against the Indonesian National Standard (SNI) to assess whether the soap's quality meets the standard. The test results for the two soap formulas, namely beef tallow- and lard-based, are shown in Table 2.

Table 2. Quality Test Results of Solid Soap of Beef Tallow and Lard

Parameters	Beef Tallow Solid Soap	Lard Solid Soap	SNI [19,20,21]
Organoleptic	Solid texture, white color, characteristic aroma	Solid texture, white color, characteristic aroma	Shape, color, and aroma
pH	10	11	9-11
Moisture content	8%	3%	<15%
Foam height	7 cm	7.5 cm	1.3-22 cm

Organoleptic testing of solid soap preparations across all formulas shows a solid, white texture and a soap aroma typical of beef tallow and lard. Organoleptic observation aims to determine changes in the physical form of solid bath soap preparations [22]. The organoleptic observation results indicate that the soap's shape in all formulations is solid or hard. The solid form of soap demonstrates that it meets the requirements of the Indonesian National Standard (SNI). The results of testing in this solid bath soap research showed that a solid form of soap, supported by Sukawaty [23] Research resulting in a solid or hard form of soap. The results show that all formulations in this study met the SNI standards.

The pH test showed a range of 10 in beef tallow soap formulations and 11 in lard soap. The pH values of all preparations have met the requirements of a good pH, which is within the standard pH of solid soap, which ranges from 9 to 11 [24]. This shows that both types of soap have acidity levels that are still within safe limits for skin use, so they do not cause irritation or other disorders that typically result from a pH that is too low or too high. In addition, the stability of pH in this range also contributes to the cleaning and foaming power of soap, which is an essential indicator in assessing the overall quality of soap preparations [25]. Despite the use of identical NaOH concentrations in both formulations, the observed difference in pH values can be attributed to variations in fatty acid composition and saponification behavior. Lard contains a higher proportion of unsaturated fatty acids, which may lead to lower saponification efficiency and incomplete alkali consumption, resulting in higher residual alkali content and, consequently, a higher final pH than beef tallow solid soap.

The moisture content analysis showed that lard-based solid soap had a lower moisture content (3%) than beef tallow-based solid soap (8%). Both formulations complied with the Indonesian National Standard for solid soap (SNI 2016), which specifies a maximum moisture content of 15% [26]. The observed difference

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in moisture content can be attributed to variations in fatty acid composition and the resulting structure of the soap matrix. Beef tallow, which is richer in saturated fatty acids, tends to form a more rigid, crystalline structure that retains water within the soap matrix. In contrast, the higher proportion of unsaturated fatty acids in lard produces a less crystalline structure, which facilitates more efficient water evaporation during curing, leading to lower residual moisture. Additionally, the similar amounts of NaOH used in both formulations may explain the relatively comparable moisture levels, as NaOH is hygroscopic and readily absorbs moisture from the surrounding environment [27]. Overall, the moisture contents obtained are consistent with previous studies and meet established quality standards for solid soap.

The foam height for all solid soap formulas is 7-7.5 cm, which meets the SNI 2016 standard of 1.3-22 cm. The foam height values show that, when beef fat and lard are present at the same percentage in each formulation, the resulting foams differ little. From the results of Listari [28]The foam height was 8.0-9.2 cm, which was due to the surfactant used, and it met the predetermined requirements.

FTIR Analysis

Analysis of beef tallow, solid soap, and lard can be done using an FTIR spectrophotometer (Figure 1). The FTIR spectrophotometer has the advantage of producing a fingerprint spectrum, where each compound or sample has a unique IR spectrum. Variations in the number of peaks, peak intensities, or wave numbers can distinguish the IR spectra of two compounds.

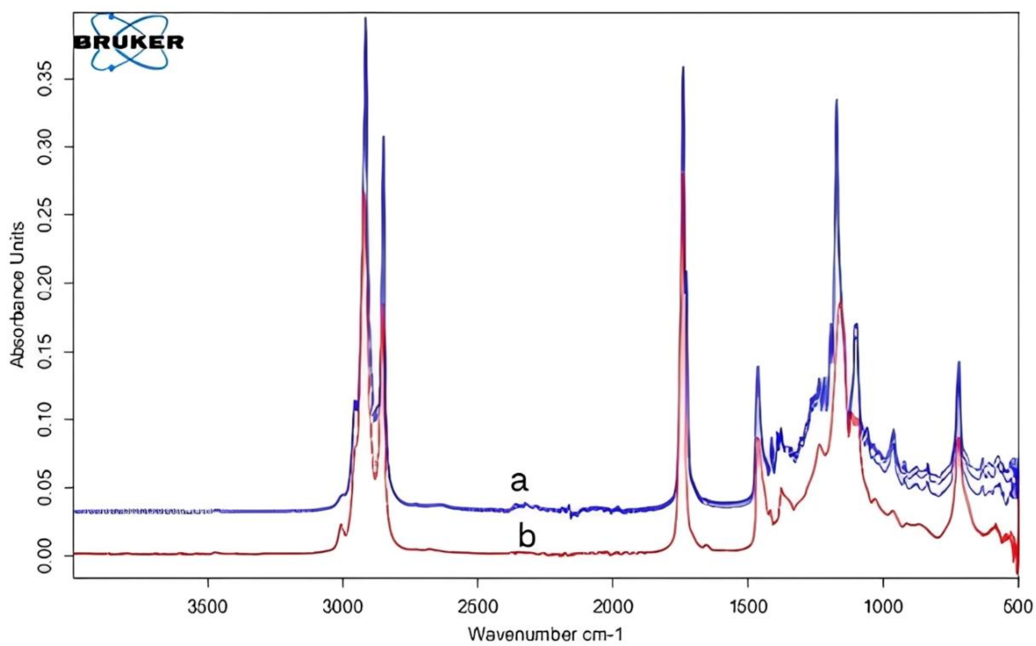

Figure 1. FTIR spectra of beef tallow solid soap (a) and lard solid soap (b)

Functional groups in solid soaps made from beef tallow and lard. FTIR spectroscopy is an analytical method that relies on the interaction of infrared signals with chemical compounds to detect bond vibrations between atoms in a molecule [30]. The results of the analysis are displayed as a spectrum showing the wave number (in cm-1) of the functional group that absorbs infrared radiation at a particular wavelength. [31].

Based on the spectra obtained, soaps from beef tallow and lard show similar spectra because both are derived from triglyceride-based materials and produce ester compounds through saponification. However, there are differences in the position of wave numbers and the intensity of certain absorption peaks that can be used as indicators to distinguish the chemical composition between the two types of fat [32].

Both samples showed strong absorption bands at approximately 2923-2921 cm^{-1} and 2843-2842 cm^{-1}, corresponding to asymmetric and symmetric stretching vibrations of aliphatic C-H bonds from methyl ($-CH_3$) and methylene ($-CH_2-$) groups in long hydrocarbon chains. A key distinguishing feature was the presence of an absorption band at approximately 3009 cm^{-1} in the lard solid soap, which was absent or barely detectable in the beef tallow solid soap. This band is attributed to =C-H stretching vibrations of alkenes. It is a well-

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established indicator of unsaturated fatty acids with cis double bonds, such as oleic acid (C18:1), confirming the higher unsaturated fatty acid content in lard [8,32].

Table 3. Functional Groups of Solid Soap of Beef Tallow and Lard

Wave number (cm^{-1})			Intensity	Function Group
Beef Tallow Solid Soap	**Lard Solid Soap**	**Reference Pavia [29]**		
	3009	3100-3000	Weak	=C-H
2923	2921	3000-2850	Strong	CH_3
2843	2842	3000-2850	Strong	CH_2
1743	1741	1750-1730	Strong	C=0
1450	1451	1450-1375	Weak	CH_2
1241	1240	1300-1000	Strong	C-O
1171	1169	1300-1000	Strong	C-O
721	719	723	Weak	CH_2

Analysis using Fourier Transform Infrared Spectroscopy (FTIR), based on Table 3, aims to identify the absorption band at approximately 1740 cm^{-1}, which was observed in both soaps and is assigned to the carbonyl (C=O) stretching vibration of ester-derived structures. The minor shift between beef tallow (1743 cm^{-1}) and lard (1741 cm^{-1}) is not considered significant and should not be used as a primary distinguishing parameter. Additional bands at around 1450-1451 cm ^{1} correspond to CH_2 bending vibrations, while bands in the regions of 1241-1240 cm^{-1} and 1171-1169 cm^{-1} are attributed to C-O stretching vibrations of ester-related functional groups. Furthermore, absorption bands at approximately 721 cm^{-1} (beef tallow) and 719 cm^{-1} (lard) correspond to CH_2 rocking vibrations of long methylene chains, with higher intensity observed in beef tallow soap, indicating a higher content of long-chain saturated fatty acids.

Overall, although both soaps exhibit similar FTIR spectral profiles due to their common triglyceride origin, the presence of the diagnostic =C-H stretching band at 3009 cm^{-1} in lard soap together with differences in CH_2 rocking intensity clearly differentiates the two fat sources. These findings confirm that FTIR is an effective and informative method for identifying and authenticating the source of fat in soap products, which is very important in the context of halal analysis, quality control, and tracing of raw materials for cosmetic and pharmaceutical products.

Conclusion

The solid soaps produced from beef tallow and lard comply with all physical and chemical quality requirements specified by the Indonesian National Standard (SNI), including organoleptic properties, pH, moisture content, and foam height, indicating acceptable quality as solid bath soaps. Although both formulations exhibited similar general characteristics, FTIR analysis identified specific spectral features that allow differentiation of the fat sources. The detection of the =C-H stretching vibration at approximately 3009 cm^{-1} in lard solid soap is associated with a higher degree of unsaturation, while the more prominent CH_2 rocking vibration at approximately 720 cm^{-1} in beef tallow solid soap reflects a greater contribution of long-chain saturated fatty acids. These results indicate that the combined evaluation of the =C-H (3009 cm^{-1}) and CH_2 rocking (720 cm^{-1}) bands can be applied as a reliable basis for distinguishing soaps derived from lard and beef tallow. FTIR effectively identifies fat types and can be used in raw material authentication, especially in product halalness.

Conflict of Interest

The authors declare no conflict of interest.

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