

Chapter 10:

The Role of Halal Industry in Economic Development: Fats and Oils Detection and Verification

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The halal industry plays a pivotal role in driving global economic development, with significant contributions to the fats and oils sector. This article examines the impact of halal certification on sustainable development and its role in addressing critical social and economic challenges. It explores the complexities involved in the detection and verification of halal compliance in fats and oils, highlighting technological advancements and procedural methodologies that facilitate accuracy and efficiency. The analysis also addresses the economic implications of halal verification, emphasizing how robust analytical tools and laboratory technologies ensure product integrity and consumer trust. By fostering transparency, authenticity, and confidence in halal products, the industry not only supports economic growth but also enhances its global competitiveness and relevance in diverse markets. This article underscores the broader implications for policymakers, industry stakeholders, and consumers, advocating for innovation and collaboration to overcome the challenges of halal compliance in fats and oils.

1 Introduction

Halal-certified businesses must genuinely commit to sustainability initiatives for the greater good of society to avoid the risk of losing customers and employees (Jaiyeoba & Azam, 2023). These businesses have the responsibility to address social challenges by supporting poverty alleviation, education, and healthcare in ways that positively impact community well-being (Ferreira, 2021). Halal detection of fats and oils involves advanced tools to investigate the halal status of products containing fats and oils or related materials, such as foods, cosmetics, and pharmaceuticals. Analysts in halal-testing laboratories face difficulties, such as sample handling and choosing suitable analytical techniques. It also requires establishing validated and verified analytical methods and utilizing multivariate data analysis. Additionally, challenges include the economics of laboratory analytical instruments, consumables, and the need for skilled analysts (Sani, Nordin, & Elgharbawy, 2023).

Fats and oils are an important and basic ingredient of the diet for all people, including Muslims. Fats are necessary to carry the flavour and nutrients, especially fat-soluble vitamins such as vitamins A, D, E, and K. Oils are used in cooking, baking, frying, and as a salad dressing. The most common and the cheapest vegetable oils are from the seeds of soybean, rapeseed, sunflower, palm, and palm kernel, corn, cottonseed, and groundnut. The use of vegetable oils is increasing at the expense of animal fats for nutritional and health reasons. Since Muslims are a large and growing part of the world population (Koehrsen, 2021), there is considerable interest in the production of edible vegetable oils, to make sure that not only the oil and fat production process is Halal but also that the source of the vegetable oil is Halal (Hájek et al., 2021; Toldrá-Reig et al., 2020). In the Quran, Allah (SWT) describes it as Hidaya (guidance/law) for mankind, and consuming Halal food and drinks is obeying this law as a way of life for all Muslims (Al-Teinaz, 2020).

"O mankind, eat from whatever is on earth [that is] lawful (Halal) and good (Tayyib) and do not follow the footsteps of Satan. Indeed, he is to you a clear enemy."

Surah Al-Baqarah (2:168)



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Therefore, the Halal concept covers not only the slaughtering method but also the sources of food and drinks that can come from agriculture, industry, etc. As a result of the fast-growing Muslim population, there is increased demand for Halal food products. The food industry has recognized this demand and many food products are labelled as Halal. Unfortunately, the increase in demand for Halal products has led to cheating and food adulteration, thus preventing Muslims from fully practicing their religion. Muslims believe that by consuming Halal products they are obeying the will of Allah (SWT) and will be spiritually rewarded, both in this life and in the hereafter. It is therefore important that the Halal status of all food products is correctly labelled (Abdullah & Azam, 2020; Danjuma, 2021).

This chapter reviews these issues, discusses the halal industry's economic development in fats and oils detection and verification, and recommends suitable analytical testing laboratory tools.

1.1 Background and Significance

The halal market is growing globally. In order to foster this growth, there should be a focus on innovation and investment throughout the halal food chain, from producers to retailers. The growth of the halal industry is not only beneficial to Muslim-majority countries but also to non-Muslim-majority countries. Muslims can be assured of a diverse range of halal food in all parts of the world. For non-Muslims, the development of the halal industry presents an opportunity to provide not only halal food for Muslims, but it is also perceived as a means of ensuring food safety and security. This point is underscored by the fact that Muslims and non-Muslims have shown interest in halal food standards, which are based on Islamic rules, as well as having the characteristics of being clean, hygienic, healthy, environmentally friendly, and safeguard animal welfare (Akram, 2022).

The role of the halal industry in economic development has gained large attention from Muslims and non-Muslims, as halal is not only concerned with Islamic teachings, but it is also an epitome of cleanliness and purity. Over the past few years, the role of the halal industry in economic development has increased via formalizing halal laws, establishing halal quality infrastructure, and promoting Muslim-non-Muslims dialogue. However, there are challenges in the halal industry (Izzudin & Adinugraha, 2021). These include halal fraud, accidental contamination, cross-contacts, etc. Scientific research on halal assurance and verification is key when it comes to preventing the above-mentioned challenges (Zin et al., 2021).

1.2 Research Objectives

Research and development on other potential halal products are necessary to explore new sources of economic growth for Malaysia, enabling the country to diversify its halal product portfolio and maintain its competitive edge in the global market. By expanding into categories such as cosmetics, pharmaceuticals, and halal-certified fats and oils, Malaysia can tap into emerging markets and cater to the growing demand for halal products worldwide. This diversification not only enhances the resilience of Malaysia's economy but also positions the country as a global leader in the halal industry, fostering innovation, attracting foreign investment, and creating new opportunities for economic and social development.

One of the primary research efforts is to establish and develop halal science through the provision and facilitation of religion-based and value-based systems in science, technology, and industry. The primary aim is to help Muslims make decisions about products by determining and validating their halal status. The term halal science refers to the systematized body of knowledge that may be generated when halal requirements are examined and studied according to the 'high quality' and 'excellence' attributes of knowledge. In this context, several more objectives exist for this research project and paper. Firstly, to generate new knowledge within the field of halal science. Secondly, to create awareness about the importance of knowing the halal status of products and the necessity to determine this through halal science. Thirdly, to promote positive attitudes of Muslims towards edible products by assuring their halal status. This will help in increasing consumption and demand for such products, and ultimately benefit local producers of edible oils. Finally, the research also intends to verify some of the existing and develop new detection methods for halal edible oils.

2 Halal Industry: Concepts and Principles

The halal industry has grown significantly over recent decades, driven by increasing consumer demand for halal products. This demand extends beyond food to include cosmetics, pharmaceuticals, and other goods containing fats and oils. Ensuring the halal status of these products is crucial for maintaining consumer trust and expanding market reach. The economic development of the halal industry is closely tied to the ability to accurately detect and verify halal compliance, which supports broader economic growth and development.

Over the years, not only have the Muslims come to know the concept of halal, but the non-Muslims have also learned about it. With the increase in the Muslim population and their spending power, Muslims have become an important consumer group in the world (Mahaputra & Saputra, 2022; Randeree, 2020). Today, the halal concept is an important factor influencing Muslims' buying behavior. The Muslims require proof that a product, its ingredients, and the process through which it has passed are in accordance with the Islamic rules before they purchase it. Otherwise, they will not buy it and will consume a similar product that fulfils the halal requirements. The Muslims' need to verify the halal products has led to the establishment of the halal industry. The halal industry is relatively new compared to other industries, and it is still in the process of development (Lubis et al., 2022; Akram, 2022).

The concept of halal is not restricted only to acts of worship, but it extends to all aspects of human life, including goods and services. Halal is an Arabic word which means permitted, allowed, lawful, or legal according to Islamic law. In the Quran, Allah has told Muslims that they should eat the halal things and perform the good deeds. In addition to the Quran, the sayings of the Prophet Muhammad also guide Muslims and indicate to them what is halal and what is haram. Halal is a concept that brings Muslim close to Allah, and observing halal is a religious prescription that is obligatory to fulfil unless in cases of extreme necessity (Ilahan-Bakil, 2021; Butt et al., 2021). In Islam, there are some dietary laws that apply to Muslims. Muslims are not allowed to eat specific foods that do not meet Islamic requirements (Chouraqui et al., 2021). For Muslims, it is very important to know that the food they are consuming is halal, which means that it is permitted according to Islamic rules.

3 Economic Impact of Halal Industry

Many detection methods have been applied; however, fats and oil compounds remain challenging to analyze accurately. The economic impact of the halal industry is closely linked to the overall development of a country's economy, particularly in two key areas: income and employment. The primary driver of economic development is the growth of income. Islamic principles prevent Muslims from earning money through activities that are harmful, unethical, dishonest, or unjust, such as gambling and theft. Meanwhile, a country's economic development reaches a high level when unemployment rates are low or moderate, indicating that the economy has successfully absorbed a significant portion of the unemployed population (Azam & Abdullah, 2020; Jailani & Adinugraha, 2022).

The constant practice of Muslims in spending certainly affects the development of the economy. The halal industry is not only able to absorb the followers' own economy but also absorb the general economic development (Muyassaroh et al., 2021). The impact of the halal industry on a country's economic development is a subject of extensive discussion among various stakeholders, including governments. Consequently, numerous countries have implemented policies to support the production of halal products. These governmental initiatives aim to stimulate the growth of the halal industry, thereby contributing to the nation's economic advancement. A notable example is Malaysia's Halal Industry Master Plan 2030, which outlines strategies to position the country as a global leader in the halal sector (HDC Global).

The detection and verification of halal products are intrinsically linked to advancements in science and technology, particularly in the analysis of compounds. Analytical methods such as DNA polymerase chain reaction (PCR), Fourier transform-infrared spectroscopy (FTIR), and gas chromatography-mass spectrometry (GC-MS) are employed to ensure product compliance with halal standards. These

technologies are grounded in disciplines like chemistry, biology, and genetics, underscoring the critical role of scientific innovation in maintaining the integrity of halal products (Karim & Muhamd, 2018).

The intersection of supportive governmental policies and scientific advancements is pivotal in fostering the halal industry's growth, which in turn contributes to broader economic development.

4 Fats and Oils: Importance in Halal Industry

Process sulphated castor oil is harmless and does not leave residues involved in the synthesis of lubricants used in engineering subjected to thermal stressing and low thermal stability. During the synthesis of some liquid aliphatic mono-esters of sulphur-containing acids, and because of thermal stability, the ester oils are useful as carriers for lubricant additives, as well as lubricants themselves. Their products are used in hydraulics, officer temporary protection of cast parts, and for moistening explosives (Dhanuskar et al., 2021). The reducing agents used in the catalytic hydrogenation of nitro compounds are based on products derived from castor oil. Nitro compounds with special interest in explosives include those widely used as plasticizers for nitrocellulose in propellants. In addition, the use of polyurethanes derived from hydroxylated castor oil as binders in solid propellant formulations has been reported (Mohd et al., 2020).

Halal industry plays an important role in economic development. Developing and Muslim countries have a significant future in their economic development through the specialization and trade of halal products and services. In order to be certified as Halal in the Halal industry, the conditions are very strict. There are two main sectors in the Halal Industry. The first sector is food and beverages. The second sector is non-food products, such as cosmetics, pharmaceuticals, and tourism services. Fats and oils are important ingredients in the food industry. It is also an important factor in other sector of Halal industry (Ab et al., 2022; Karimullah, 2023). In recent years, the interest of Halal consumers has increased, and Muslims are beginning to ask about the source of fats and oils to ascertain whether they are Halal or not. Both Muslims and Halal Certification Bodies request analytical techniques to detect and verify Halal-unknown fats and oil (Usman et al., 2023; Jannah & Al-Banna, 2021).

Global Halal Food Market Share By Product (In %), 2023

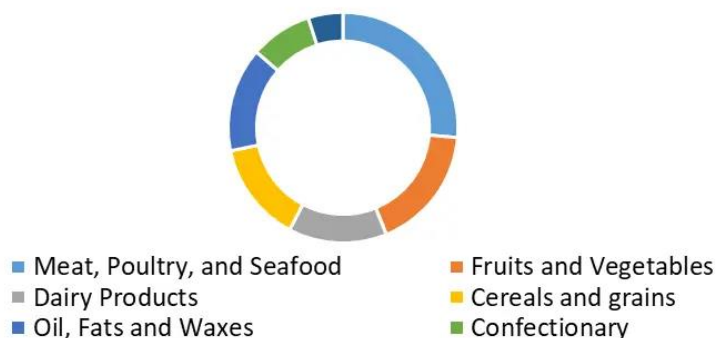


Figure 10.1: Shows the market share of fats and oil in the halal industry in 2023

(Source: <https://www.maximizemarketresearch.com/market-report/global-halal-food-market/28343/>)

Halal-certified oils, fats, and waxes play a vital role in the preparation of halal meals. Vegetable oils, cooking fats, and waxes used in food and non-food applications must adhere to strict halal guidelines. This segment includes products such as halal-certified cooking oils, margarine, and various types of fats used in food processing.

4.1 Types of Fats and Oils Used

Marine oils are rich in omega-3 long-chain polyunsaturated fatty acids, which are known for their health benefits and are recommended as essential nutrients. Including these special fatty acids into the diet of Muslim people is needed to replace fats from haram animals. There is a great demand from the Muslim

market for halal or kosher-certified products, creating a lucrative market for these types of products. With this in mind, the challenge for manufacturers of Muslim foods is to replace non-halal or kosher-compliant ingredients with halal or kosher-certified ingredients to produce products for the Muslim market (Khan et al., 2023; Zhou et al., 2023). The solution is to use marine sources or their derivatives, such as fish oil or algae oil, which are considered halal and provide a sustainable option for fats and oils in the halal industry. This helps to ensure the halal industry's economic development while meeting consumers' dietary needs (Azmi et al., 2021).

Four main types of fats and oils are used in Islamic countries: saturated animal fats, unsaturated vegetable oils, fish oils, and marine animal oils. The chemical composition of these fats and oils is quite different. Saturated fats/oils are generally of animal origin, like cattle, sheep, and goats, and are relatively solid at normal temperatures (Mortas et al., 2022; Srinivasan et al., 2022). Unsaturated oils are generally of vegetable origin (e.g., soybean, canola, cottonseed, corn) and are usually liquid at room temperature. Fish and marine animal oils are sources of long chain n-3 polyunsaturated fatty acids. Sometimes marine fat is added to food and other products because of their health benefits and easier certification compared to animal fats (Machado et al., 2023; Lewandowski et al., 2020).

4.2 Key Considerations for Halal Compliance

The foundation of accurate halal compliance lies in the application of Muslim religious perspectives, particularly through the interpretation and implementation of Shari'ah (Islamic Law). One of the most significant challenges in this process is addressing the Halal Critical Point (HCP) problem, which involves identifying and mitigating any potential risks of contamination or non-compliance throughout the supply chain. HCP analysis requires a thorough understanding of Islamic jurisprudence, ensuring that products not only meet the spiritual and ethical requirements of Muslim consumers but also align with technical standards for food safety and quality. This dual compliance enhances trust among consumers and promotes the credibility of halal certifications on both local and global levels.

Ensuring halal compliance necessitates a comprehensive and systematic approach involving validation, verification, certification, and surveillance at every stage of the supply chain. Validation involves confirming that products and processes meet halal standards from the outset, particularly during the design phase of a product or service. Verification further strengthens this foundation by monitoring adherence to halal requirements during production, storage, and distribution. Certification acts as an authoritative endorsement, granting businesses access to global halal markets, while ongoing surveillance ensures continuous compliance. Embedding halal characteristics at the earliest stages of product development not only prevents potential non-compliance issues but also reflects a proactive commitment to meeting consumer expectations and adhering to Shari'ah principles (JAKIM).

In addition to technical and procedural measures, raising awareness and knowledge about halal principles is vital for fostering compliance. Educating the Muslim community about their religious obligations and rights regarding halal consumption plays a crucial role in strengthening compliance frameworks. Awareness campaigns, training programs, and collaborative efforts among religious scholars, policymakers, and industry stakeholders can bridge knowledge gaps, ensuring that halal products are not only accessible but also understood. Furthermore, such educational initiatives can influence consumer behaviour, encouraging greater demand for halal products and driving industry growth. By addressing these key considerations, the halal industry can achieve a balance between religious integrity and economic development, solidifying its relevance in both academic discourse and practical application.

5 Challenges and Solutions

The halal status of foods fried in oils previously used for non-halal items, such as pork, raises significant concerns regarding cross-contamination and adherence to Islamic dietary laws. Islamic jurisprudence emphasizes the necessity for purity in food preparation, and the use of shared cooking mediums can compromise this standard. Scholars assert that consuming food fried in oil that has been used for non-halal

products is impermissible, as the oil may absorb impurities from haram substances, rendering it impure (Berti et al. 2020).

Addressing these concerns necessitates the implementation of rigorous detection methods to identify potential contamination in fats and oils. Analytical techniques such as Fourier Transform Infrared (FTIR) Spectroscopy, Gas Chromatography-Mass Spectrometry (GC-MS), and Polymerase Chain Reaction (PCR) are employed to detect the presence of non-halal substances, including pork derivatives, in food products. These methods enable precise identification of contaminants at molecular levels, ensuring the integrity of halal-certified foods (Azmi et al. 2024).

The integration of scientific innovation with halal dietary laws is crucial for enhancing transparency and trustworthiness within the halal industry. By adopting advanced analytical techniques, the industry can effectively monitor and verify compliance throughout the supply chain, thereby reinforcing consumer confidence and supporting economic development. This collaborative approach between science and religious guidelines ensures that halal products meet both spiritual and quality standards, facilitating the industry's growth in both Muslim and non-Muslim markets.

6 Challenges in Halal Detection of Fats and Oils

6.1 Sample Handling and Analytical Techniques

Proper sample handling is a cornerstone of accurate and reliable analysis in halal compliance testing. The handling process ensures that the samples adequately represent the entire batch or lot of goods, taking into account potential variability within the storage environment. This representation is essential to avoid skewed results that could mislead the compliance assessment. For instance, if contamination occurs in only a portion of the stored goods, improper sampling could either miss or exaggerate the extent of the issue. Therefore, rigorous sampling protocols must be followed, incorporating statistical methods to guarantee reliability. As Vangel (2002) recommends, the saddle point method is an effective technique for deriving an accurate approximation of the joint cumulative distribution function (CDF) of the mean and extremum of a normal sample, ensuring robust data interpretation.

Documentation is equally critical in sample handling. Each sample collection must be recorded in detail, noting the method, time, storage conditions, and other variables affecting the sample's integrity. This thorough documentation forms the foundation for traceability, a key requirement in halal compliance. Traceability ensures that if any irregularities are found during testing, they can be traced back to their source, whether it be a specific supplier, storage condition, or manufacturing process. Additionally, documenting these details builds transparency and trust in the certification process, a vital aspect of maintaining consumer confidence and meeting regulatory standards. Such meticulous attention to sample handling and documentation reflects the industry's commitment to quality and integrity.

Equally significant is the choice of analytical techniques used to evaluate the samples. Advanced methods like chromatography and mass spectrometry are standard in detecting non-halal substances or verifying the purity of fats, oils, and other compounds. These techniques demand precision in calibration, operation, and data interpretation to avoid false positives or negatives that could compromise the analysis. Researchers, such as Sani, Nordin, and Elgharbawy (2023), emphasize the importance of tailoring analytical methods to the specific characteristics of the sample. For example, liquid chromatography-mass spectrometry (LC-MS) is particularly effective in identifying minute traces of contaminants in complex mixtures. Ensuring the accuracy of these methods not only strengthens halal certification systems but also upholds the scientific credibility of the halal industry as a whole.

6.2 Validation and Verification of Analytical Methods

Key indicators of a measuring instrument's quality are its reliability and validity. Establishing validated and verified analytical methods involves rigorous testing to ensure they are reliable and reproducible across different laboratories and conditions. This process is resource-intensive and requires skilled analysts

proficient in advanced analytical techniques (Sani, Nordin, & Elgharbawy, 2023). The main technological limitation in the current state of halal verification technology is that it relies heavily on the determination of certain forbidden or *najis* (unclean) components in a product.

To increase the efficacy and acceptance of halal verification, a different approach could be taken to shift the focus from the detection of haram (forbidden) components to the verification of the whole process right from the raw material used up to the end product. This could be done by using rapid detection tools at each critical control point during the production process (Sani, Nordin, & Elgharbawy, 2023).

Indeed, it is essential to detect the presence of these components to verify the halal authenticity of a product, especially when a large variety of products from all over the world are manufactured at an industrial scale. However, there is potential for developing new technological tools which may be used to perform the verification required to certify the halal authenticity of a product (Azmi et al. 2024).

6.3 Reliability and Stability

According to Crocker and Algina (1986), the test developer is responsible for “identifying the sources of measurement error that would be most detrimental to useful score interpretation and designing a reliability study that permits such errors to occur so that their effects can be assessed.” Pretesting or pilot testing an instrument allows for the identification of such sources. Errors could be minimized by fine-tuning of the instrument. Reliability is determined by the correlation of the scores from two or more independent raters (for ratings on a continuum) or the coefficient of agreement of the judgments of the raters. Cohen’s (1960) kappa is commonly used for categorical variables to determine the coefficient of agreement (Nunnally, & Bernstein, 1994). Reliability estimates are used to evaluate the stability of measures administered at different times to the same individuals or using the same standard (test-retest reliability) or the equivalence of sets of items from the same test (internal consistency) (Kimberlin & Winterstein, 2008).

Ensuring the stability of measurements, commonly referred to as test–retest reliability, is essential for the credibility of laboratory analyses. This concept involves administering the same test to the same individuals at different points in time and then assessing the correlation between the two sets of scores. A high correlation indicates that the measurement tool produces consistent results over time, reflecting its reliability. This principle is crucial in various fields, including psychological testing and medical diagnostics, where consistent measurement outcomes are vital for accurate assessments (Groff et al., 2016).

In the context of laboratory instrumentation, particularly those employing detectors for imaging or spectral analysis, maintaining high stability and repeatability is paramount. Instruments must consistently produce reliable data across multiple sessions to ensure the validity of experimental results. Variations in detector performance can lead to discrepancies in measurements, potentially compromising the integrity of the data. Therefore, regular calibration and maintenance of laboratory instruments are necessary to uphold their performance standards and ensure the accuracy of the measurements they produce (Kimberlin & Winterstein, 2008). Understanding and mitigating errors within the data pipeline are critical for achieving reliable measurements. By systematically analyzing how errors propagate through the measurement process, researchers can identify potential sources of variability and implement strategies to minimize their impact. This approach enhances the precision of measurements and contributes to the overall reliability of the analytical results. Employing robust statistical methods to assess and control measurement errors is a fundamental aspect of quality assurance in laboratory settings, ensuring that the data generated is both accurate and dependable (Vaz et al., 2013).

6.4 Economic Considerations

The economics of laboratory analytical instruments and consumables present significant challenges, particularly in the context of halal detection and verification. State-of-the-art instruments, such as gas chromatography-mass spectrometry (GC-MS) and liquid chromatography-mass spectrometry (LC-MS), are essential for identifying non-halal components like porcine derivatives in food products. However, the high acquisition costs of these instruments, coupled with expenses for regular maintenance and calibration, can

be prohibitive for smaller laboratories and developing countries. Additionally, the continuous need for consumables, including reagents and specialized columns, adds to the financial burden, potentially limiting the capacity for comprehensive halal testing (Sani, Nordin, & Elgharbawy, 2023).

Strategic planning is crucial to balance the need for advanced analytical capabilities with economic constraints. Laboratories must conduct thorough cost-benefit analyses to determine the most appropriate instruments and methodologies that align with their budgetary and operational goals. This involves evaluating the sensitivity, specificity, and throughput of various analytical techniques to ensure that investments yield reliable and efficient results. Collaborative efforts, such as sharing resources among institutions or outsourcing specific analyses to specialized facilities, can also optimize costs while maintaining high standards of halal verification (Ayad & Sbeiti, 2017).

Moreover, the development and adoption of standardized analytical methods can enhance efficiency and reduce costs. Implementing uniform protocols facilitates method validation and inter-laboratory comparisons, leading to more consistent and reliable results. Training personnel to proficiently operate equipment and interpret data is equally important, as it maximizes the utility of existing resources and minimizes errors that could necessitate costly reanalysis. By integrating strategic planning, resource optimization, and standardization, laboratories can effectively navigate the economic challenges associated with halal detection and verification, thereby ensuring compliance with halal standards and fostering consumer trust (Jaswir et al. 2016).

6.5 Recommendations for Analytical Testing Laboratory Tools

To address these challenges, it is recommended that halal-testing laboratories invest in suitable analytical tools and technologies, including:

Advanced Chromatography and Mass Spectrometry Equipment and Spectroscopy. These tools offer the high precision and sensitivity necessary for detecting trace amounts of non-halal substances in complex matrices. The first example of using spectroscopy was by Che Man and Mirghani (2000), who successfully used Fourier transform infrared (FTIR) spectroscopy to detect lard mixed with body fats of chicken, lamb, and cow. To reduce human error and improve the consistency and reliability of sample preparation. It is advisable to introduce automated sample handling systems; however, this may increase the initial cost of establishing the laboratory but will ensure accuracy and save time and labour costs. Comprehensive training programs should be scheduled and conducted regularly to ensure that analysts are well-trained in the latest analytical techniques and technologies. This is crucial for maintaining high testing standards.

Engaging in collaborative efforts with academic and research institutions fosters innovation and the development of cost-effective and efficient analytical methods. Thus, it is essential to be involved in collaborative research and development to stay updated since new products are entering the market almost daily.

Exploring more affordable yet reliable analytical instruments and consumables can help mitigate the financial strain on laboratories (Harrison, et al., 2019). That may be achieved by the involvement of some suitable investment in economic alternatives.

7 Future Directions

While considerable progress has been made in halal detection and verification, several challenges remain unaddressed, paving the way for future innovations. One critical area for improvement is the development of fast, real-time, portable, and non-destructive detection technologies. These technologies could revolutionize halal verification by allowing for on-site testing without damaging the product, thereby increasing efficiency and reducing costs. Portable tools could be particularly beneficial in remote areas or for small-scale industries that lack access to fully equipped laboratories. By leveraging advancements in microfluidics, biosensors, and artificial intelligence, researchers can design systems capable of providing instant and reliable results.

Another promising avenue is increasing the sensitivity and detectability of existing technologies. Many contaminants, such as porcine-derived ingredients or alcohol-based solvents, can exist in minute quantities, yet their presence can render a product non-halal. Enhancing the precision of techniques like mass spectrometry or nuclear magnetic resonance (NMR) to detect these contaminants at ultra-trace levels is essential. Additionally, there is a need for more robust sample preparation protocols to ensure contaminants are not lost or degraded during analysis, which is critical in maintaining the integrity of results. Addressing the complexity of multi-component samples is also a priority for future research. Foods and cosmetics often contain complex mixtures of ingredients, making it challenging to identify and verify individual components. Advanced computational tools, such as machine learning algorithms and predictive modelling, can help unravel these complexities by analyzing data patterns and identifying anomalies. Furthermore, the use of high-throughput analytical techniques, such as multi-dimensional chromatography, could facilitate the separation and identification of components in complex samples, making halal verification more efficient and reliable.

Smart and adaptive systems represent another exciting direction for future innovation. These systems could incorporate machine learning and artificial intelligence to learn from previous analyses, adapting to new challenges and identifying novel contaminants or fraud tactics. For instance, AI-driven systems could flag irregularities in supply chain data or detect fraudulent labeling practices, serving as an additional layer of quality control.

Lastly, fostering collaboration with industries, government bodies, and certification authorities is critical for the practical implementation of advanced technologies. Standardizing these technologies and integrating them into routine halal verification protocols would not only streamline the process but also build consumer trust and industry credibility. Governments and regulatory agencies could incentivize research and development in this area by offering grants, tax breaks, or subsidies to companies investing in halal innovation. This collaborative approach will ensure that halal verification keeps pace with the rapidly evolving food and consumer goods industries.

8 Conclusion and Recommendations

The halal industry's growth and economic development are intrinsically linked to the ability to accurately detect and verify halal compliance in fats and oils. By addressing the challenges in sample handling, analytical techniques, validation, verification, and economic constraints, the industry can ensure the integrity of halal-certified products. Using tests or instruments that are valid and reliable to measure such constructs is a crucial component of halal analytical results quality. Investing in advanced laboratory tools and training significantly enhances the reliability of halal detection processes, thereby supporting the industry's expansion and consumer confidence. The halal industry of the 21st century should extend and innovate by incorporating research and development (R&D) initiatives to be competitive and adapt to the changing conditions of the business environment. The R&D sectors of the halal industry of fatty products should concentrate on ways to innovate and verify the improvements. Since scarcity of natural resources and climate change are becoming more prominent, R&D should also focus on them to become more environmentally friendly. This approach could be more internationally accepted and be used to verify the authenticity of halal products and add value to products from all religions, not only Islam. In this way, the development of tools to perform the verification task could address the need to secure food for all people, regardless of their religious background.

9 Publisher's Note

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