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Global trends in halal food detection

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ABSTRACT

The growth of the halal food industry has had a positive impact on the global economy. Unfortunately, halal food adulteration is a prevalent issue that has prompted researchers to develop new tools for halal food detection. This study aimed to examine the trends in halal food detection tools. To achieve this, we conducted a global trend analysis of halal food detection tools by reviewing their development, assessing research reference relationships, and identifying future research directions. This study utilised 170 articles published between 2006 and 2024 that focused on halal food detection tools. This study employed both qualitative and quantitative methods using bibliometric analysis. *Biblioshiny* and *Vos Viewer* software were used for data analysis. Polymerase Chain Reaction (PCR) has emerged as the most widely used halal food detection tool. Among these institutions, *Universiti Putra Malaysia* produced the largest number of publications. Malaysia and Indonesia conducted the most research and were frequently cited as references. Rohman was the author with the highest number of citations (277). The goal of this bibliometric analysis was to provide valuable scientific insights that will support future research in the field of halal food detection. Additional studies are strongly recommended to develop more effective tools for halal food detection.

Keywords: Global Trends, Halal Food Detection,

INTRODUCTION

The global halal food industry is experiencing significant growth and increased awareness and demand for products that meet halal standards. The halal market extends beyond the food sector to include cosmetics, pharmaceuticals, medical equipment, and service sectors, such as tourism, logistics, marketing, print and electronic media, packaging, and branding **[1]**. The global community's growing interest in halal products is not solely driven by religious beliefs but also by the assurance of superior quality in terms of ethics, health, safety, and environmental sustainability **[2]**. The increasing availability of safe halal food products for the Muslim population, the largest global population, is of paramount importance. The emerging halal food sector presents new opportunities to propel global economic growth and development. With its substantial population and growing demand for halal products, Indonesia has the potential to become a frontrunner in the halal industry. This is not limited to countries with a Muslim majority but also extends to nations with minority Muslim communities that contribute to the growth of the halal industry. According to the State of the Global Islamic Economy (SGIE) report, Indonesia's halal industry is projected to rank third by 2023, following Malaysia and Saudi Arabia.

Enhancements in halal criteria, monitoring procedures, and fundamental principles have led to a growing demand for halal commodities, particularly in the food sector **[3]**. Over the years, the scope of halal food has expanded beyond animal slaughter, alcohol use, and pork use. It now encompasses the entire process from

creation to consumption. Therefore, the assurance of halal food is imperative. This can be realized by understanding the certification process comprehensively and confirming the authenticity of halal products. Halal certification not only pertains to halal claims, but also ensures that production materials, equipment, processes, storage, distribution, and the Halal Guarantee System adhere to Islamic law, involving several procedures **[4]**. With advances in food processing and technological progress, it has become increasingly difficult to directly determine the halalness of a product because of the variety and number of food additives (BTP) used in the production process, whose halal qualities are not yet clear. Moreover, haram materials, such as pork, are diverse and easier to process than similar materials, such as cows, buffalo, sheep, and goats. All pig parts can be processed into various products, and pig breeding is faster and less expensive than other animals. Human limitations also play a significant role, as detecting halal foods using the senses takes considerable time. Therefore, a halal-food detection tool is required.

Halal food detection tools are important considering the high number of cases of food adulteration that have occurred for a long time. Halal food counterfeiting is common, and there are various ways to counterfeit halal food. The halal food detection tools used varied according to the food's characteristics. However, no research on the types of halal detection devices has been thoroughly studied. *How many lots and what types of halal detection devices have been studied?* The more types of halal food detection devices are studied, the better the diverse and complex characteristics of processed food. Ideally, a halal food detection tool should be easy and fast to use to increase the effectiveness and efficiency of the testing process and ensure compliance with established halal standards.

Research question:

R1: Which halal detection tools are most widely used?

R2: What types of halal food detection tools have been used thus far?

Therefore, halal detection tools are important to ensure that the products to be consumed are by Islamic Sharia law. This study aimed to evaluate the extent of research developments related to halal food detection tools that have been applied to food products. This study uses bibliometric analysis to answer these questions. It is hoped that this study will guide research areas that have not yet been explored to encourage the expansion and progress of the halal food industry.

This study investigated the progress and application of halal food detection instruments using bibliometric analysis. Using Scopus, it provides a thorough overview of the scientific developments, trends, and key contributors in halal food detection in recent years. The novelty of this study lies in its systematic and quantitative methods to comprehensively understand the landscape of halal food detection instruments, offering valuable insights into their evolution, significant research areas, and future directions for food safety and religious compliance. By mapping intellectual structure and research dynamics, this bibliometric study addresses a gap in the literature regarding the lack of comprehensive reviews on the advancements and effectiveness of various halal food detection methods. This study also highlights the need for future research to develop more user-friendly, cost-effective, and accurate detection tools to identify non-halal components in complex food matrices. Such research can significantly inform policymaking and enhance the overall reliability and accessibility of halal food-detection technologies.

METHODS

This study applied a bibliometric analysis. Bibliometric analysis is a quantitative method used to describe the characteristics of a group of published literature, such as journal articles or conference proceedings reviews, book chapters, etc. This method involves collecting bibliographic data from publications, including information about the author, journal, and year of publication, and applying statistical techniques to analyse and interpret the data **[5]** and **[6]**. This study aimed to identify reputable international articles related to the study of biomaterials for *Halal Food Detection*. Data were collected from the Scopus database between 2006 and 2024. Research articles were searched using the applications *publish or perish*. Data were collected in

June 2024. The keywords used were TITLE-ABS-KEY ("Halal Food Detection") AND PUB YEAR >2006 and PUB YEAR <2024. The software packages *Biblioshiny* **[7]** and *Vosviewer* 2024 were used in social network analysis for network visualisation. After obtaining raw data (CSV format) from Scopus, the data were converted to. xls format before analysis.

This study revealed several findings based on methodological steps. In identifying the relevant studies step, 181 articles were found using halal food detection keywords. The first criterion was the Scopus category, which applied the inclusion and exclusion criteria. Searches can only include the article abstract, title, and keywords. This study refined the initial results from the subject area and reduced the findings from 181 articles to 170. This can be seen in Figure 1

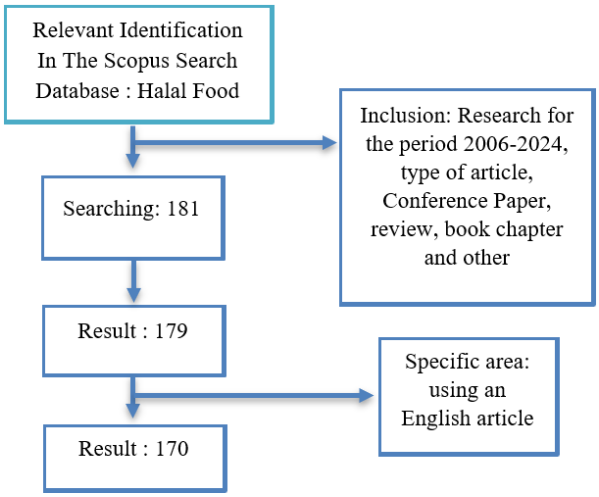


Figure 1 Prisma Flow Diagram.

RESULTS AND DISCUSSION

Halal food detection

With the increase in food a3) dulteration, halal detection tools are needed to guarantee that our food is safe. Some of the tools used in this study include the HPLC method carried out by **[8]** to classify and differentiate pork fat from other animal fats, such as chicken, goat, and beef, based on the composition of triacylglycerol (TAG), which is known to be very important in the differentiation of meat species. Some authors **[9]** and **[10]** used high-performance liquid chromatography-tandem mass spectrometry (HPLC–MS/MS) to detect lupine (*Lupinus angustifolius*), peas (*Pisum sativum*), and soybeans (*Glycine maxima*) in meat products with high sensitivity. The PCA analysis of the spectral data showed that spectrometers FT-NIR in *mode-attenuated total internal reflection* can differentiate chicken, pork, and turkey meat based on their infrared spectrum **[11]**. However, only FTIR combined with attenuated total reflectance (ATR) regression and partial least squares (PLS) regression has been used to detect lard in chocolate formulations **[12]** and **[13]**.

"Halal food detection" or "halal food verification technology" refers to various methods and technologies used to authenticate the halal status of food products, ensuring that they comply with Islamic law **[14]**. Halal food detection involves various analytical techniques to ensure food products are free of non-halal components, particularly pork derivatives **[15]**.

Next, in this discussion, food detection tools with more than 3 articles are explained, as shown in the following table

Table 1 Halal food detection use by researchers.

No	Halal Food Detection	Publications (2006-2024)
1	Polymerase Chain Reaction (PCR)	70
2	Biosensors	26
3	Spectroscopy	18
4	Clustered Regularly Interspaced Short Palindromic Repeats	15
5	Near-infrared (NIR) Spectroscopy	9
6	Electronic Nose	8
7	Gas Chromatography (GC)	5
8	High-Pressure Liquid Chromatography (HPLC)	4

From the table above, it can be explained that most researchers who publish their work in Scopus use the halal food detection tool Polymerase Chain Reaction (PCR), with 70 publications from 2006-2024, followed by Biosensors with 26 publications, Spectroscopy with 18, Clustered Regularly Interspaced Short Palindromic Repeats (CRISPR) with 15, Near-Infrared (NIR) Spectroscopy with 9 publications, Electronic Nose with 8 publications, Gas Chromatography (GC) with 5 publications, and High-Pressure Liquid Chromatography (HPLC) with 4 publications. Meanwhile, less than four publications are not discussed in this research. Next, a discussion of each food detection tool used by researchers is presented as follows:

1) Polymerase Chain Reaction (PCR), a molecular biology technique, is based on specific oligonucleotide hybridisation with the target DNA and its synthesis **[16]**. PCR can detect even 1% pork in a mixture of other meats and has proven effective in identifying pork adulteration in food **[17]** and **[18]**. PCR's sensitivity of PCR in detecting specific DNA segments, identifying animal species in food products, and its accuracy in detecting animal-derived ingredients in food are its key advantages. However, PCR requires specialised training, limits user accessibility without specific expertise, and incurs high operational costs.

2) Biosensors are analytical devices used to detect biological molecules, such as DNA samples, through various processes such as denaturation, hybridisation, and voltammetric analysis **[19]**. Biosensors are highly sensitive and specific for detecting target molecules, provide rapid results, and are cost-effective compared to traditional analytical methods **[19]** and **[20]**. However, biosensors are less accurate in complex sample matrices, require skilled personnel, and require proper storage conditions to maintain performance over time **[18]**, **[19]** and **[21]**.

3) Spectroscopy is a technique used to study the interaction between matter and electromagnetic radiation, providing valuable information about the composition, structure, and properties of substances **[22]** and **[23]**. Spectroscopy allows for the efficient confirmation of DNA amplification and provides reliable results for detecting forbidden animal DNA in food samples **[24]**. This tool offers rapid analysis, non-destructive testing, and cost-effectiveness **[23]**. However, it is less accurate and has the risk of missing contaminant detection **[25]**; **[26]**.

4) CRISPR is a tool for detecting infectious diseases quickly, sensitively, and specifically with its nucleic acid target. CRISPR has a wide range of applications in genetic engineering, including gene therapy, agriculture, and biotechnology **[27]**. CRISPR technology is also capable of cutting DNA. However, CRISPR has the potential for off-target effects that can cause unwanted genetic modifications and safety concerns.

5) Near-infrared (NIR) spectroscopy is a technique based on measuring the absorption of electromagnetic radiation in the wavelength range of 750–2500 nm. Several studies have demonstrated the capability of NIR spectroscopy to evaluate meat quality, including predicting chemical components, technological parameters, sensory properties, carcass fat quality, and meat product quality, as well as classifying and identifying various types of meat **[20]**. NIR Spectroscopy offers rapid analysis and cost-effectiveness as it does not require

chemicals. However, data interpretation is complex, and sample preparation variability affects the results' accuracy and reproducibility, necessitating standardisation for consistent analysis **[28]**.

6) Electronic nose (e-nose) uses chemical gas sensors to mimic human olfaction, recognise complex aromas, and evaluate volatile compounds using statistical methods **[29]**. E-nose requires minimal sample preparation, offers rapid analysis, has high specificity for oxidised compounds, and is inexpensive. However, the e-nose is less selective for certain compounds, operates at high temperatures, has limited sensitivity to low-molecular-weight gases, and has high power consumption **[30]**, **[22]** and **[31]**.

7) Gas Chromatography (GC) separates and analyses volatile compounds without decomposition. GC is often used in meat adulteration to determine product purity and identify fatty acid composition, a specific indicator of adulteration **[32]**. GC offers high separation efficiency and sensitive detection of compounds, even at low concentrations. GC is suitable for volatile compounds (low molecular weight). 8) High-Performance Liquid Chromatography (HPLC): The advantages of HPLC in pork fat analysis include high sensitivity, selective detection with UV detection, and the ability to analyse triglycerides (TGA) and fatty acids quantitatively. Integration with chemometrics, such as PCA, enhances discriminant analysis between beef and pork meatballs **[33]**. However, HPLC has drawbacks, such as being slow, expensive, invasive, and lacking a universal detector. Its separation efficiency is lower than that of Gas Chromatography (GC), and column costs are high **[28]** and **[33]**. With the various halal detection tools that already exist, it is hoped that simpler detection tools that are still capable of detecting the presence of non-halal components in low concentrations within complex food matrices can be developed in the future.

According to the Scopus Database, using the keywords "halal food detection," we found 170 documents.

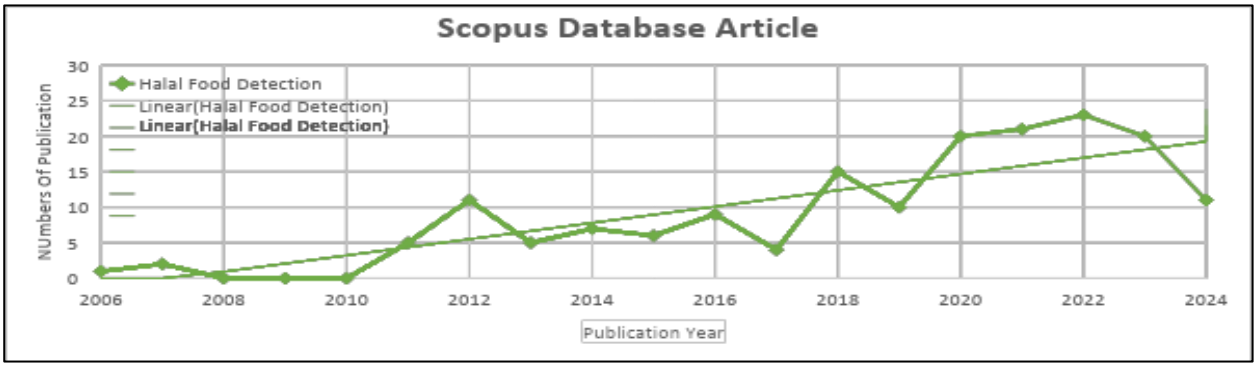


Figure 2 "Halal Food Detection" Research Graph from 2006-2024.

The characteristics of research results on halal food detection are related to the number of articles published annually from 2006 to 2024, as shown in Figure 2. Figure 2 shows that in 2006 there was research on Halal Food Detection, which increased in 2007. However, from 2008 to 2010, no one had researched it; in 2012, there was a sharp increase. In 2013-2017, there was a decline and a significant increase in 2020. This follows the opinion of **[34]** and **[35]**, halal food is becoming an increasingly interesting topic, especially due to the discovery that Many foods that are supposed to be halal contain pork. This has increased concern and attention to the authenticity of food products and the importance of ensuring that consumed food complies with halal principles. Figure 1 shows a linear increase, indicating that the growth rate of the publications was sustainable. The relationship between x and y was $y = 1.2211x - 2477.2$ ($R^2 = 0.7$) for Halal Food Detection. The coefficient of determination of each search shows that the linear regression line is consistent with the actual results, indicating that the number of publications continues to increase. In 2024, there will only be around 10 articles because this year hasn't ended yet.

Publication based on keywords

Keywords in an article serve as a reflection of its core content. As observed in Figure 3, Figure 4, and Figure 5, the keywords can be classified into dominant colour-coded groups: red, green, blue, and yellow. Each group represents a specific domain related to halal food detection, adulteration, and biomaterial analysis.

The Red Group focuses on adulteration and includes keywords like "Halal Authentication," "Analytical Method," and "Mass Spectrometry." These terms relate to verifying food compliance with halal standards, utilising analytical techniques such as mass spectrometry to examine food components. The red group also contains "Principal Component Analysis (PCA)," a statistical technique for data dimensionality reduction, and "Chemometrics," which applies mathematical and statistical methods for experimental design and chemical data analysis. This group emphasises analytical methods like High-Performance Liquid Chromatography (HPLC) and Fourier Transform Infrared Spectroscopy (FTIR), essential for detecting food adulteration and ensuring food quality.

The Blue Group represents halal food detection tools and is dominated by molecular detection techniques. Keywords include "PCR (Polymerase Chain Reaction)," "mitochondrial DNA," and "processed foods," which highlight the molecular tools used to identify halal food authenticity. These techniques are crucial for examining genes and DNA, especially in processed foods, to verify compliance with halal standards.

The Green Group focuses on biomaterials and incorporates terms like "biomaterials," "mammals," "non-human," "cattle," and "pig," reflecting the study of animal-based products in the context of food production. This group is particularly important in halal food analysis, as it detects animal ingredients that might conflict with halal or kosher requirements.

Lastly, the Yellow Group serves as a linking group between the other three categories, illustrating the connections between molecular detection techniques (blue group), analytical methods (red group), and biomaterials (green group). Keywords such as "DNA," "genes," and "food adulteration" bridge these concepts, highlighting the interdisciplinary approach required for halal food detection, adulteration analysis, and biomaterial identification.

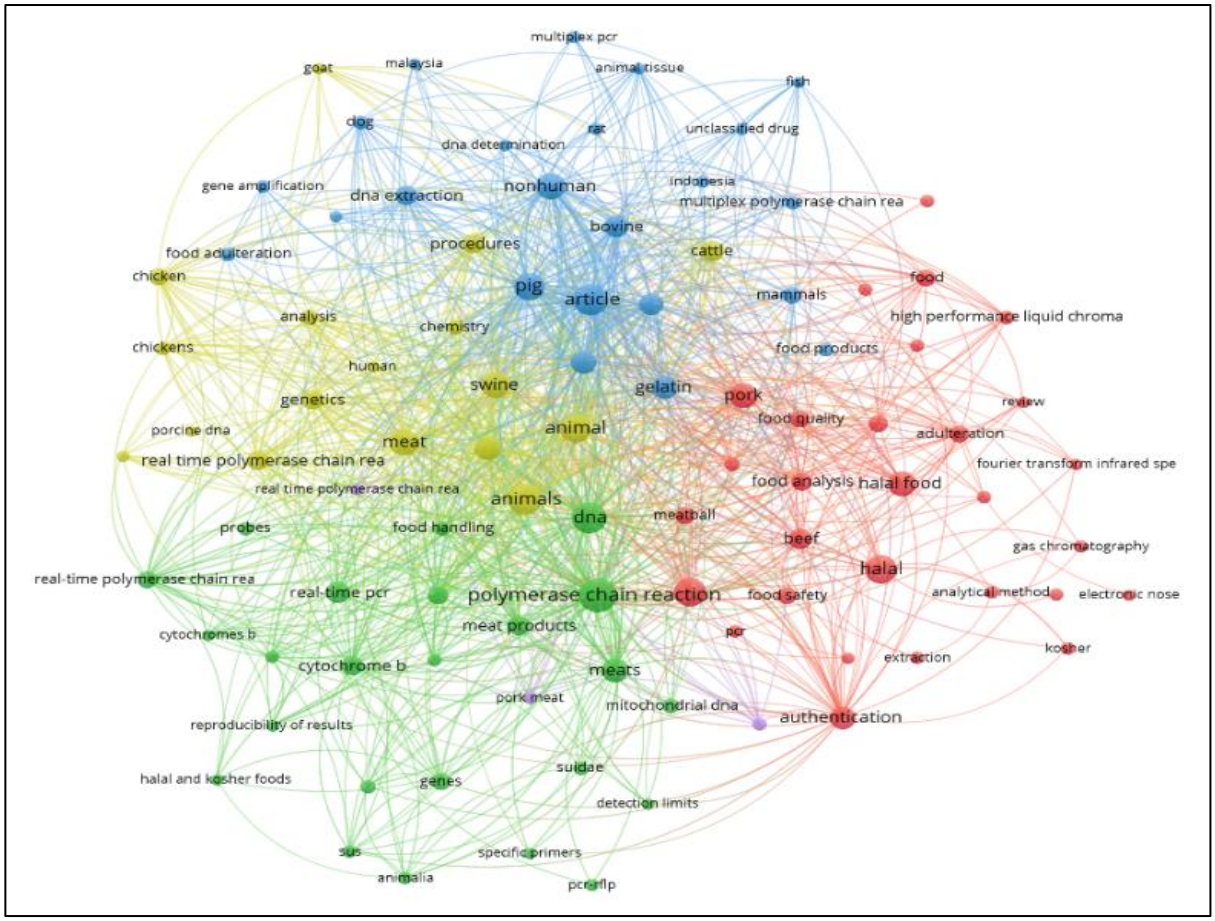


Figure 3 *VosViewer* Keyword Halal Food Detection.

Figure 4 shows a network visualisation of the relationship between various keywords in research *on Halal Food Detection.*

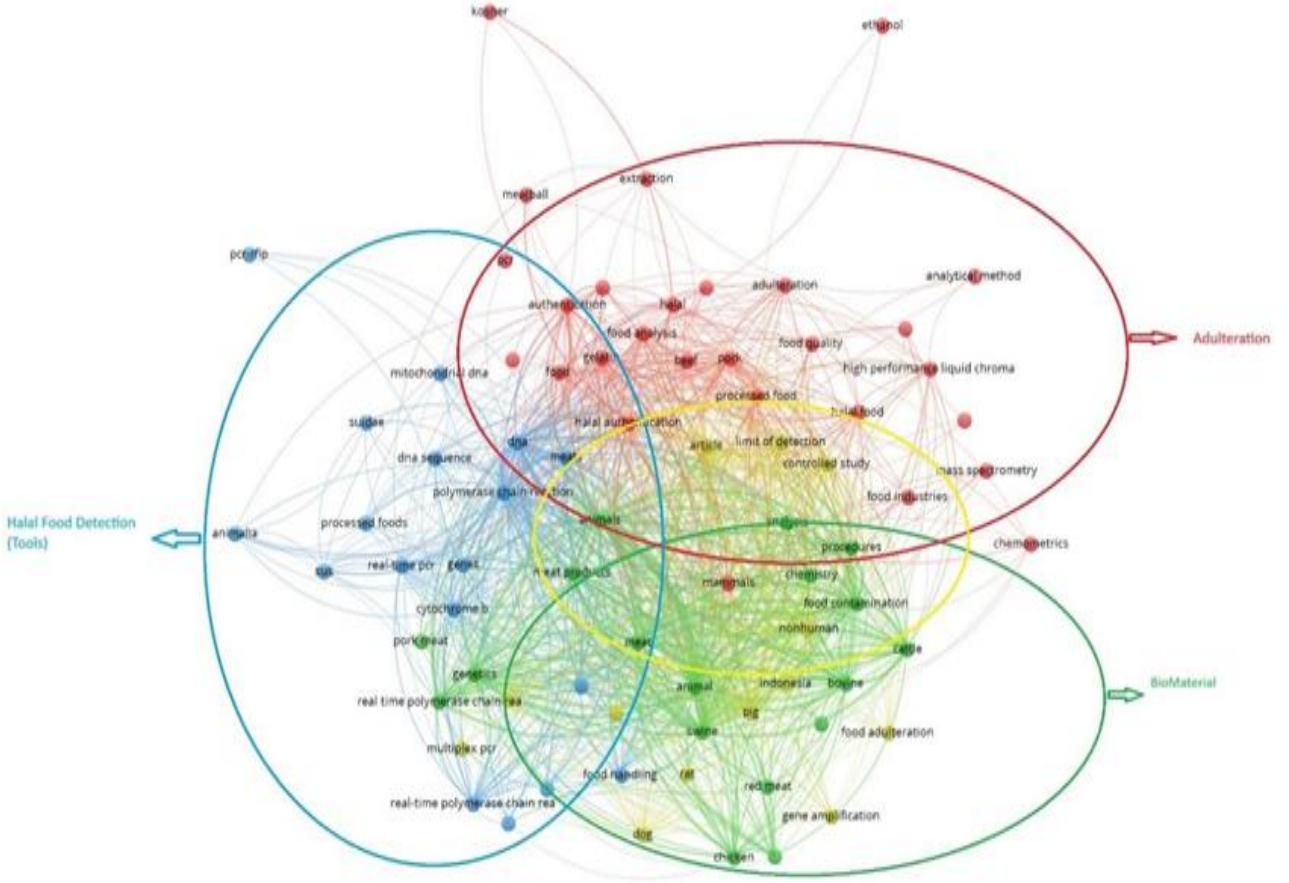


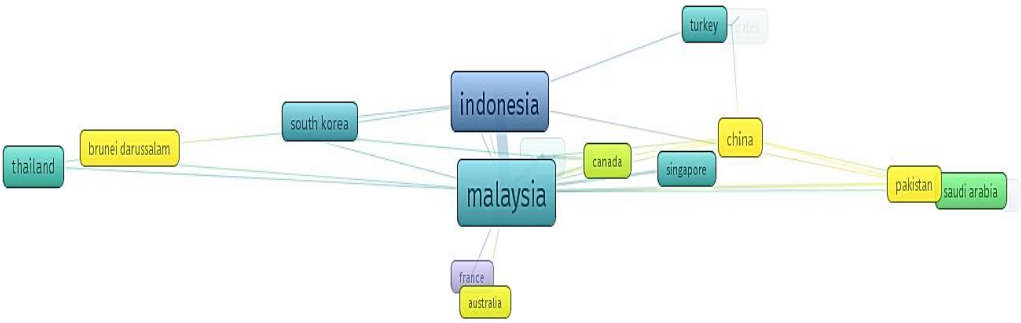
Figure 4 Keywords based on Color Clusters.

The green group focuses on terms like "*Food Contamination*," which relates to the contamination of food by harmful or undesirable substances, and terms such as "*Swine," "Cattle," "Bovine,"* and "*Pig*," which are often the subject of food analysis. Types of meat such as "*Red Meat," "Pork*," and "*Meat*" Meat are often analysed for their safety or authenticity. "Food Adulteration" refers to adding impure or fake ingredients to food; at the same time, a "Controlled Study" is a scientific study that uses controls to ensure the validity of the results. The yellow group includes terms such as "Non-human," "Rat," and "Dog," which are often used in food analyses. "Gene Amplification" is the process of increasing the number of copies of a particular gene for further analysis, and "DNA Extraction" is the process of taking DNA from a sample for analysis. Specificity" measures the performance of a diagnostic test, with sensitivity referring to the test's ability to detect positives and specificity to detect negatives correctly. "Limit of Detection" is the lowest concentration of a substance that can be detected but is not necessarily quantified as an exact value.

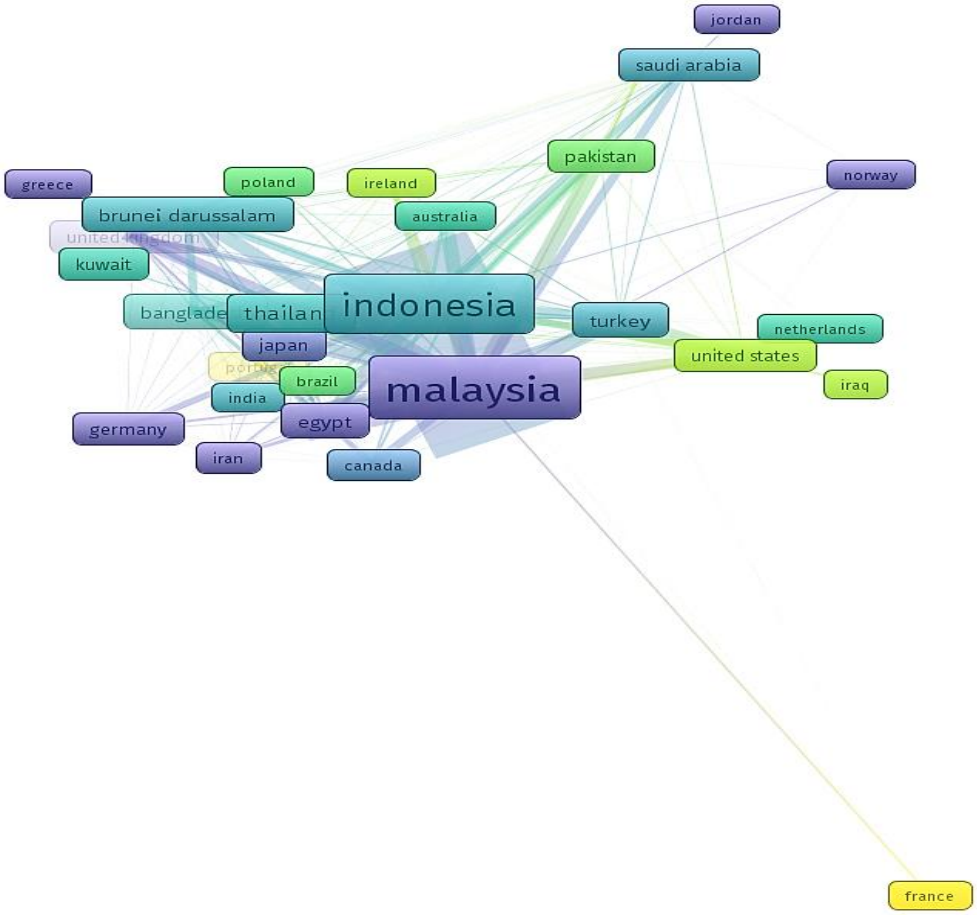
The blue group focuses on molecular biology techniques, such as “Real-Time Polymerase Chain Reaction (PCR),” which amplifies and simultaneously measures the amount of target DNA in a sample. DNA Sequence refers to the sequence of bases in DNA that determines genetic information.

“Genes” and “Genetics” refer to the study of genes and heredity. "Mitochondrial DNA" is the DNA in mitochondria that is often used to analyse heredity and evolution. “Reproducibility” indicates the ability of an experiment or study to be reproduced with consistent results, and “Cytochrome b” is a protein in the electron transport chain often used in phylogenetic analysis. Thus, it can be concluded that this image shows the complex relationship between various aspects of food analysis and authentication, demonstrating how different scientific methods are used to ensure the safety and authenticity of food products, particularly meat and animal products.

Bibliometric analysis on Scopus database



A



B

Figure 5 Number of publications by country (A), bibliographic coupling, and cooperation between countries in this research (B).

Based on the visualisation of images A and B (Figure 5), it can be explained that Indonesia and Malaysia are the two countries with the strongest links in Halal Food Detection research **[36]** and **[23]**, which can be seen from the large size of the nodes and the many lines connecting these two countries with other countries. These two countries have many research references compared to other Asian countries. Indonesia and Malaysia also have significant links with Southeast Asian countries, such as Thailand, Brunei Darussalam, and Bangladesh, indicating strong regional references in Halal Food Detection research. Additionally, there are clear links between Southeast Asian countries and countries in the Middle East, such as Saudi Arabia, Pakistan, and Iran, indicating great cooperation and attention toward Halal Food Detection in countries with significant Muslim populations **[37]**. Several Western countries, such as the United States, Germany, and the Netherlands, are also involved in this research network, showing that Halal Food Detection research is not only limited to

Muslim-majority countries but is also attracting global attention. According to **[1]**, halal food is a global market opportunity where various countries aim to position themselves strategically in the global economy and take advantage of the growing Muslim consumer base. Although France has weaker links than Western countries, it remains connected to the research network. Other countries such as Japan, India, Australia, and Brazil were also involved in this research **[38]**, showing wide geographic diversity in Halal Food Detection research references. Overall, this linkage map illustrates that Halal Food Detection research is a global issue with broad references between countries on various continents, reflecting the importance of this issue to Muslim communities worldwide and concerns about the safety and authenticity of food products.

Word TreeMap and Word Cloud Halal Food Detection

TreeMap was used to identify the available keywords. Figure 6 shows that the most dominant keywords in halal food detection were "polymerase chain reaction" and "DNA," each with a percentage of 6%. Correspondingly, word clouds (Figure 7) were used to identify the focus of this study. Larger words in a word cloud indicate a higher frequency of occurrence in the scientific literature.

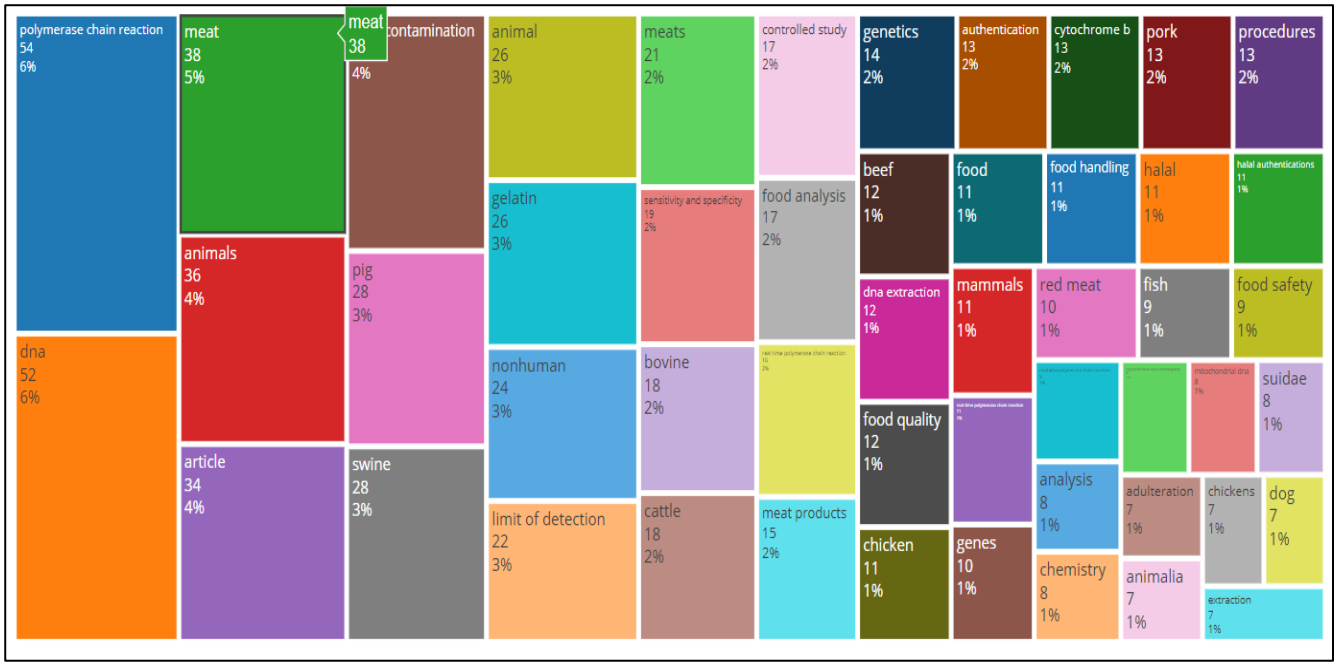


Figure 6 Word TreeMap Halal Food Detection.

Figure 7 Word Cloud Halal Food Detection.

Development and future research directions

With technological advances, halal food detection tools are expected to become more sophisticated, accurate, practical, and rapid. Technological innovations such as spectroscopy, DNA analysis, and portable devices will simplify the halal verification process in real time and at various stages of production. Developing software that can quickly process data and provide reliable results is also helpful. With halal food detection tools, it can become more economical and can be accessed by producers and consumers. Reducing halal detection tools' production and distribution costs will enable small- and medium-sized businesses to utilize them, thereby increasing quality standards and consumer confidence in halal products. This has the potential to open new markets and increase exports of halal products to countries with large Muslim populations, thus positively impacting the global economy.

The need for halal products continues to increase with the growth of the Muslim population worldwide and greater awareness of the importance of consuming products that comply with halal principles. This will help ensure that the halal products circulating in the market meet specified requirements, providing consumers with security and trust.

Another hope is that halal food detection tools will be easier to use, even for those without a technical background. Easy-to-operate tools will enable more people to detect halal products independently at home and in business.

Legislation

Halal certification has become a key component in food regulation across many countries. The legislation regarding halal certification varies depending on the country and local policies. At the regional level, institutions such as the Department of Islamic Development Malaysia (JAKIM), the Indonesian Council of Ulama (MUI) through the Halal Product Assurance Agency (BPJPH), and the Islamic Religious Council of Singapore (MUIS) play an important role in ensuring that products circulating both in domestic and international markets comply with Islamic law. JAKIM, for instance, sets strict standards concerning animal slaughter processes, cleanliness in production, and food processing. These standards apply for local consumption and export, especially to Middle Eastern countries that require halal certification for imported products.

At the global level, international trade standards, as regulated by the World Trade Organization (WTO), affirm that importing countries must respect local regulations regarding halal certification. Many non-Muslim countries also implement halal certification standards due to the increasing demand for halal products worldwide, driven by both the growth of the Muslim population and increasing consumer awareness of halal products, which are considered cleaner and safer.

In Indonesia, halal certification is regulated by Law No. 33 of 2014 on Halal Product Assurance (JPH), strengthened by Government Regulation No. 31 of 2019. This law mandates that all food, beverage, cosmetic, and pharmaceutical products circulating in Indonesia must have a halal certificate issued by BPJPH with a halal fatwa from MUI. Besides the domestic market, this certification is also crucial for enhancing the competitiveness of Indonesian products in international markets. Implementing halal certification requires halal detection tools, such as Polymerase Chain Reaction (PCR) and mass spectrometry, which detect non-halal contaminants, such as pork. This technology is becoming increasingly relevant to ensure compliance with legal requirements in local and export markets. According to research published in the “Food Control Journal“ and “Comprehensive Reviews in Food Science and Food Safety“, these technologies have improved accuracy in detecting non-halal contamination and support the enforcement of halal standards.**[39] [22].** Certification bodies such as JAKIM in Malaysia, MUI in Indonesia, and MUIS in Singapore have become the main references for many countries in setting their halal standards.

Certification

The halal certification process not only focuses on the final product but also includes the certification of management systems to ensure that every stage of production and distribution complies with Islamic principles. This certification is known as the Halal Assurance System (HAS), which is implemented to ensure

that the entire halal supply chain, from raw materials to final distribution, is properly monitored. In Malaysia, the Department of Islamic Development Malaysia (JAKIM) oversees the implementation of HAS as part of the halal quality management system **[40]**. This halal management system certification includes worker training, separation of production facilities to avoid cross-contamination with non-halal materials, and comprehensive documentation of every process. This system is applied across various sectors, such as the food, cosmetics, pharmaceutical, and logistics industries, and is a mandatory requirement for companies seeking JAKIM halal certification. In Indonesia, halal certification also includes management system oversight through the Indonesian Council of Ulama (MUI) and the Halal Product Assurance Agency (BPJPH) under Law No. 33 of 2014.

Halal food certification is a key focus of certification bodies. This certification involves rigorous audits of raw materials, production processes, and the distribution chain for food and beverage products. Ingredients used in halal products must not contain forbidden substances (such as pork and its derivatives, carrion, blood, alcohol, or ingredients from animals not slaughtered according to Islamic law, as well as toxic plants). The Islamic method of animal slaughter involves invoking the name of Allah, cutting the throat and major arteries, and requiring that the person performing the slaughter is a Muslim. In Indonesia, products that have been halal-certified by BPJPH receive a special logo or mark indicating that the product has passed the halal audit. This mark assures consumers that the product is safe and halal for consumption. In Malaysia, products certified by JAKIM are also labelled with a globally recognised halal logo, which is round and contains the word "HALAL" in Arabic and "Malaysia Halal" at the bottom.

This certification is important in international trade, as many countries, especially in the Middle East, require imported products to have globally recognised halal labels. The certification process involves several stages: application, audit and inspection, laboratory testing (if needed), halal fatwa issuance, and certification. As food materials, processes, and technology become more complex, accurate, easy, and affordable detection tools are increasingly necessary. Halal detection tools in certification have also advanced, with technologies such as Polymerase Chain Reaction (PCR) and mass spectrometry frequently recommended for detecting traces of non-halal substances, such as pork or alcohol, during halal certification audits, although they are not always mandatory. However, certification bodies like JAKIM, BPJPH, and the Halal Monitoring Committee (HMC) actively encourage using these tools to improve accuracy and transparency in the certification process. According to a study in the *Food Control Journal*, these technologies enhance the effectiveness of halal certification by supporting audits and inspections of products for both domestic consumption and export markets.
[39].

The global halal certification management system involves complex steps involving multiple parties (certification bodies to industry), from standards and testing to supervision. With the increasing demand for halal products, especially in the global market, this halal certification system is becoming increasingly important. It continues to evolve with the support of technology and the harmonisation of standards worldwide. Cooperation between countries and halal certification bodies ensures that halal products are recognised and traded globally without regulatory barriers. Standards such as those developed by OIC/SMIIC and JAKIM play an important role in maintaining the quality and consistency of halal products in the global market.

Laboratory testing

Laboratory testing ensures that a product's raw materials, additives, production processes, and facilities do not contain forbidden elements. The involvement of laboratories in halal testing must comply with ISO/IEC 17025 standards, which play an important role in ensuring consistency, accuracy, and international recognition of test results. Adherence to this standard ensures that laboratories possess the technical competence and effective quality management systems, making test results, such as the detection of non-halal substances, reliable on a global scale. **[41]**. This is crucial in international trade, where various countries recognise halal certificates. In Malaysia, the Department of Islamic Development Malaysia (JAKIM) requires laboratories involved in halal testing to have ISO 17025 accreditation, while in Indonesia, the Indonesian Council of Ulama (MUI) mandates the same through cooperation with the Institute for Food, Drug, and Cosmetic Studies

(LPPOM) **[39]**. This standard ensures that laboratory methods, such as Polymerase Chain Reaction (PCR) for detecting pork DNA, provide consistent and valid results.

For example, accredited laboratories like the Chemistry Department in Malaysia, recognised by JAKIM, and BPJPH laboratories accredited by the National Accreditation Committee (KAN) in Indonesia, recognized by MUI, use advanced methods in halal analysis **[22]**. In the Middle East, countries such as the United Arab Emirates also accredit halal testing laboratories based on ISO 17025 through local certification bodies. This laboratory accreditation covers a range of testing, from raw material identification to final product testing, to ensure the absence of non-halal contamination. Laboratory methods such as PCR and mass spectrometry are the primary techniques for detecting forbidden substances, such as pork contamination, with minimal measurement uncertainty. The measurement uncertainty governed by ISO 17025 is key to ensuring that test results are reproducible and validated with high confidence, which is an essential requirement for halal certification **[41]**. According to a study published in the "Journal of Halal Research", laboratories that meet ISO 17025 standards ensure the accuracy of results and guarantee international recognition for the halal products tested, enhancing consumer confidence and facilitating access to global markets **[41]**.

CONCLUSION

Based on search results, research trends in halal food detection have identified 17 different detection tools, with many researchers currently focusing on Polymerase Chain Reaction (PCR), Spectroscopy, and Liquid Chromatography–Mass Spectrometry (LCMS). This bibliometric analysis, the first to explore global trends in halal food detection using Scopus-based data over the past 18 years, offers valuable insights for future research. PCR stands out due to its high sensitivity and specificity in detecting unwanted DNA components, such as pork, even in minute quantities. However, its limitations include high costs, the need for advanced laboratory equipment, the risk of cross-contamination, and its inability to detect non-DNA components like oils. Therefore, future research should focus on enhancing the precision of bibliometric analyses and providing more comprehensive information to improve the accuracy and reliability of halal food detection methods.

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