ISSN: 1675-7785
eISSN: 2682-8626

Available online at
https://scilett-fsg.uitm.edu.my/

Science Letters

Science Letters 18(1) 2024, 50 – 60.

Halal Authentication of Alcohol in Food and Beverages Products: A Review

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ARTICLE INFO

Article history:
Received 11 October 2023
Revised 23 November 2023
Accepted 5 December 2023
Online first
Published 22 January 2024

Keywords:
Halal
Authentication
Analytical
Alcohol
Khamr

DOI:
10.24191/sl.v18i1.24338

ABSTRACT

In recent years, the global *halal* food sector has developed significantly, as the *halal* industry's safety, cleanliness, and quality assurance are essential to Muslim life. The presence of alcohol in particular food and beverage products may raise doubts among some individuals; it is crucial to recognize that Islamic teachings explicitly prohibit the consumption of intoxicants. However, a nuanced exploration of Islamic legal frameworks reveals that minute amounts of alcohol utilized in food processing may be deemed permissible, provided that they do not reach intoxicating levels. Precision in adhering to these thresholds demands that consultation with scholarly authorities well-versed in Islamic jurisprudence can offer clarity and guidance, ensuring adherence to Islamic principles. This paper aims to review alcohol and the amount of permissible usage in food and beverages as discussed by Muslim scholars and to ascertain and validate the presence of alcohol in food and beverage products, ensuring that it is appropriate for Muslim consumption. Various analytical methods have been developed to confront this issue, including using gas chromatography, mass spectrometry, electronic nose, and a combination of machine learning algorithms, biosensors, and specific gravimetry methods. Although innovative techniques have been developed, the intricacies of analyzing alcohol within complex food matrices stem from various contributing factors. The presence of sugars introduces molecular interactions that can affect the stability and detection of alcohol, which pose challenges to inaccurate quantification. Additionally, fibrous materials within these matrices may impede the extraction and measurement of alcohol, adding another layer of complexity. The diverse array of substances, including fats, proteins, and additives, further complicates the solubility and separation of alcohol during analysis, necessitating advanced methodologies for precise evaluation. Ease of access to information also misleads consumers into false facts on specific issues regarding *halal* products.

INTRODUCTION

Rapid advancements in food technology have resulted in introducing a plethora of new food items and ingredients to the market; this technology allows food industry participants to create food using various

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components. From the consumer point of view, it is critical to guarantee that the items they consume are safe and genuine. Religious communities, particularly Muslims, have expressed ethical concerns about various food production operations that contradict their beliefs [1,2]. Adulteration, intentional and unintentional, is an increasing danger due to the intricate structure of the global supply chain. Though significant progress has been achieved in terms of analysis, the dispute associated with processed food and beverages creates worries over consumer's religious sentiments [2].

Muslims must eat food that meets Islamic dietary standards, known as *halal*. The word *halal* is derived from the Arabic word *halal*, which means lawful, justified, and permissible under Islamic law [3,4]. *Halal* food as defined in Malaysian Standard (2019), refers to food and drinks in which the ingredients used are permissible under *Shariah* law and meet the following criteria which are safe for consumption, non-poisonous, non-intoxicating, or non-hazardous to health, does not contain non-*halal* parts or products, does not contain *najs* as defined according to *Shariah* law and not produced or processed using equipment which is contaminated with *najs* [5]. The term *halal* is usually accompanied by *toyyib*, considered safe for consumption, as mentioned in the Quran. The definition is more towards the term *halal* in the outline provided by Codex Alimentarius since quality criteria are established and enforced by conflicting agencies [2]. In order to guarantee that a product is *halal*, the ingredients, processing, handling, packaging, storage, and distribution of the product must be wholly *halal* and according to Islamic laws. In a nutshell, the entire supply chain is involved and must be *halal*-certified [4].

Ethanol is a kind of alcohol that may be found in a variety of foods, drinks, fragrances, and medications. The hydration of ethylene and the biological fermentation of a carbohydrate source are the two primary mechanisms that produce ethanol. In contrast, the principal technique for the industrial manufacture of ethanol, which is synthetic alcohol, is the hydration of ethylene, and fermentation is the primary way for producing alcoholic drinks and fermented foods [6]. The two main fermentation end products in many foods and drinks are ethanol and acetic acid [7,8,9]. The fermentation process can be divided into two stages from the Islamic perspective. The first stage is called jackhammer, the winemaking process, and the second stage is *thallus,* the vinegar-making process [10]. The intake of *khamr* is forbidden due to its intoxicating effect. However, the consumption of vinegar is permitted. In the translation of *khamr,* which is prohibited for Muslims, to alcohol, there is a misunderstanding because, in chemistry, the term alcohol refers to more than only ethanol. *Khamr,* an Arabic phrase that means "to shroud" or "to fog," refers to any chemical that intoxicates the mind and causes the individual to lose self-control as a result of the substance's effect [11]. Although ethanol is not always *khamr*, the intoxicating ingredient in *khamr* is unmistakably ethanol [12]. A study by Gunduz et al. (2013) has shown that natural ethanol is available in soft drinks, fresh fruits, vinegar, and vegetables [13]. The source of alcohol determines the *halal* or *haram* status of food products containing alcohol. Ethanol is produced naturally in the fermentation process of food and beverage goods, and understanding the origin of this alcohol is crucial in establishing its permissibility according to Islamic principles [1].

Halal certification is required to verify that items are safe and permissible for consumption. The *halal* procedure addresses not just religious concerns but also consumer rights. The healthy, organic, environmentally friendly, cruelty-free animal welfare, ethical, and fair-trade features of *halal* certification have made the *halal* concept popular and widely accepted by all societies [14]. As a result, it is critical to conduct specific, swift, and accurate food authentication analyses to protect consumers from fraud and adulteration while ensuring food safety [15]. Although there are numerous methods for the analysis of volatile chemicals currently available, there is still a demand for creating a method that is rapid, affordable, and takes only a limited number of samples while being accurate [8]. Advanced chemometric procedures are also required to obtain reliable results, such as describing food composition, identifying possible adulteration, and developing suitable classification models [18]. This paper aims to highlight the regulations regarding alcohol in food and beverages and identify and authenticate alcohol in food and beverage products to ensure that it is consumable for Muslim consumers.

https://doi.org/10.24191/sl.v18i1.24338

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REGULATION ABOUT THE USAGE OF ALCOHOL AND BEVERAGES

Alcohol is usually used as a solvent in flavors, colors, and preservatives. A flavor compound comprises two parts: a flavor portion and a diluent portion. Alcohol is usually used in flavor as a solvent or carrier to facilitate the inclusion of several coloring, flavoring, and aromatic compounds, as a flavoring agent to enhance flavor impression, and in the extraction of citrus or essential oil [12]. Specific guidelines have been established to maintain the *halal* production of food and beverages [16, 17]. Despite differences in opinion between scholars in particular countries, the basic rules are similar. The ethanol produced is not derived from the winemaking process, does not mimic the process, and does not intoxicate. The process must be with something other than the intention of producing *khamr,* whether the *alcohol* content is high or low. However, *tapai,* which is a traditional fermented food that produces alcohol, is considered *halal* and can be eaten if it is not intoxicating.

Special *Muzakarah* of the National Council Fatwa Committee for Malaysia's Islamic Religious Affairs, which deals with Alcohol Issues in Food, Drinks, Fragrances, and Medicines on 14 to 16th July 2011 has decided that natural occurrences of ethanol in food items are permitted, while less than 1% v/v ethanol levels in drinks and 0.5% for flavoring and coloring ingredients for stabilizing purposes. Food or drinks that contain alcohol naturally, like fruits or nuts or alcohol that is produced during processing, are not *najs* and can be consumed [19]. According to the Islamic Religious Council of Singapore, using ethanol (natural and synthetic) as a solvent is permissible as long as it is not made from prohibited products like *khamr*. The use of ethanol is allowed only for flavoring purposes. Ethanol cannot be used in a food or beverage product unless used to flavor it. The flavoring should not include more than 0.5% ethanol, and the final product should not contain more than 0.1% alcohol [20]. Although Fatwa Mejelis Ulama Indonesia (MUI) No. 4, the Year 2003, stated that *khamr* includes drinks that contain a minimum of 1% ethanol. Pure ethanol compound, which is not sourced from winemaking, is considered permissible when it cannot be detected in the final product and *haram* when it is detected [21]. *Fatwa* of the Sheikhul Islam of Thailand, for naturally fermented goods, the percentage of ethanol allowed for *halal* is 1.0 % (w/v) and 0.5% (w/v) for ethanol-added products [22]. Other nations, such as Brunei, Canada, and the United Kingdom, have clarified that *halal* cuisine cannot include alcohol [12].

METHODS OF ANALYSIS

Halal authenticity issues are increasingly focusing on analytical procedures. Innovative analytical methods are being created in response to emerging challenges, as it is the only way for regulators to make proven scientific judgments. Volatile metabolites play a critical role in the sensory characteristics of various fermentation products. Although some are already present in raw materials such as fruits and grains, they may also be synthesized by microbes such as bacteria, yeast, and other fungi [8]. Those volatile compounds can be detected using various approaches such as gas chromatography, mass spectrometry, electronic noses, biosensors, and colorimetry. The advantages and limitations of each method can be found in Table 1.

Gas Chromatography and Mass Spectrometer (GC-MS)

For the study of volatile metabolites found in many biological materials, including food and drinks, GC-MS has traditionally been the most favored analytical platform [8]. Volatile substances present in food and beverages can be identified using GC-MS [23]. Several studies have reported using chromatographic-based analytical techniques based on chromatography to characterize various analytes as potential chemical descriptors of authenticity and traceability [24,16]. This technique is appropriate for determining the concentrations of various metabolites in the range of mg/L to g/L [8]. This method can also be coupled with other techniques for analyzing substances. For example, it is used in conjunction with solid-phase microextraction (SPME) [25,26] and the combination of headspace solid-phase microextraction (HS-SPME) [27] and magnetic stirring-assisted aqueous extraction [28] with GC. Studies have also been

https://doi.org/10.24191/sl.v18i1.24338
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conducted on *tape ketan* (4.30-5.34 % v/v alcohols) [29], cheeses (<100 µg/100g alcohols) [26], food seasonings and condiments (0.016-0.040% ethanol) [30], Shanxi aged vinegar [25], brewing barleys [31], gochujang, soy sauce and kimchi (limit of detection 0.79 mg/kg for methanol, 0.55 mg/kg for ethanol) [32].

Table 1: The advantages and disadvantages of analytical methods used to identify alcohol.

Methods	Advantages	Limitations/ LOD	Ref.(s)
Gas chromatography and mass spectrometer (GC-MS)	Mass spectrometry (MS) is a susceptible and selective method.	MS is not free from interferences, even though it is highly selective, molecules with identical patterns may interfere with the analysis.	[49]
	A. detection of ethanol with a wide range of concentrations, including a small amount of sample.	LOD: 0.5 mg/L (using 100 µL of the sample), <0.1 mg/L (using 500 µL of the sample) in fermented food and beverages	[8]
	The techniques are inexpensive, easy, and reliable, making them ideal for fast quantification in foods and beverages. Suitable for both targeted and untargeted volatile profiling approach		
		On-site computing is expensive, time-consuming, and complex	[38,39]
	Analytical procedures for the separation, identification, and quantification of components of complex organic mixtures that are the most sensitive and selective	Restricted to the study of volatile chemicals which is not decomposed by heat	[50]
	Good accuracy compared to specific gravimetry and refractive index method	Range of detection: 4.30-5.34 % v/v alcohol in *tape ketan*	[29]
	Has good accuracy, reproducibility, repeatability, and linearity. Able to detect various compounds simultaneously	LOD: 12.4 μgL^{-1} ethyl acetate, 1.86 μgL^{-1} ethyl lactate, 0.65 μgL^{-1} 2,3-butanedione, etc.	[25]
Electronic nose (e-nose)	Nondestructive analysis method	Ethanol was detected from 13 soy sauce samples in the concentration range of 0.0004 to 1.7% by weight using e-nose coupled with MS	[36]
	Fast analysis, smaller and more reproducible	The environment, particularly temperature and humidity, affects this machine, causing sensor drift. A limited number of sensors to volatiles	[33]
Biosensor	Rapid response	The colored solution binds to the surface of the biosensor, becoming an interference LOD: 0.001% ethanol in fermented drinks	[40]
	Good reproducibility	High interference in the presence of catalase	
	Can be stored for up to 7 weeks at 4°C High selectivity and behavior under moderate experimental conditions A wide range of molecular methods A large number of sources		[38]
	High selectivity	Microbial and cell-based biosensors have low selectivity and high response time. The shelf life is an issue since changes in temperature and	[39]

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	Reduce analysis time Improve analysis quality Identify and quantify biological components in food and biological fluids in the environment	moisture content typically compromise the stability	[37]
Specific gravimetry		Requires pre-treatment	
Colorimetry based sensors		Low selectivity and long assay times	[29] [39]

LOD: Limit of detection

Electronic noses

Electronic noses simulate the sense of smell and their interaction with the human brain [15,33]. The samples are evaluated using a range of gas sensors and pattern recognition algorithms, which requires exposing the system to smells and then flushing the system for sensor recovery, as well as a controlled environment chamber for temperature and humidity [34]. It can be beneficial, allowing for qualitative and quantitative identification of compounds in fermented foods and beverages [35]. This method has been used in analyzing samples like soy sauce [36], fruit juices [15], fruits, beverages, grain, and dairy products [33]. This method may also benefit quality and consistency control [33]. In a study by Ordukaya and Karlik (2016) [15], a technique was devised to determine the analysis of mixed beverages using an electronic nose and a machine learning algorithm. The study also discovered the best machine-learning algorithms for each mixed fruit juice set. Electronic noses were also paired with mass spectrometry (MS) to detect the ethanol concentration of soy sauce; ethanol was detected from 13 soy sauce samples in the concentration range of 0.0004-1.7wt%. [36].

Biosensor

The development of susceptible and selective, but also expressive analysis techniques, has been receiving more attention lately [37]. A biosensor is an analytical device that consists of two fundamental components and converts a biological signal to an electrical signal when it comes in touch with a transducer [38]. Enzymes are frequently used in biorecognition because of their excellent selectivity and activity under mild experimental settings and their widespread availability and ability to tune substrate specificity using molecular methods. Alcohol biosensors based on microbial cells have also been reported [39]. An innovative and straightforward visual ethanol biosensor based on alcohol oxidase (AOX) immobilized onto polyaniline (PANI) film, which changes conductivity and color with changes in pH or redox reactions, has been developed. This biosensor exhibits a linear response within an ethanol concentration range of 0.01% to 0.8% with a correlation coefficient (r) 0.996. The detection limit of the biosensor was 0.001%, with a reproducibility (RSD) of 1.6% and a useful life of up to 7 weeks when stored at 4 °C [40].

PROGRESS AND CHALLENGES

Although the advent of new, quick techniques for dealing with complicated sample matrixes sounds promising, the analytical procedures themselves have their challenge. Analytical testing alone is complex and dependent on processed food and supply chain management [41]. Given the wide range of concentrations of volatile metabolites in different products, developing analytical pipelines that allow

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simultaneous quantification of them in a single run with a relatively small sample and minimal sample preparation is always tricky [8]. In some cases, because of the lack of specific markers, several analytical methods could not identify some haram compounds [30].

Halal cuisine has a worldwide market potential not restricted to Muslims; other customers may be interested in halal food. As a result, several businesses are proposing halal as a viable target market in global trade [30]. Nations such as Japan and South Korea have already begun to promote *halal* tourism in order to attract more Muslim tourists [42]. With the growing influence of non-Muslims on the food sector, the status of halal food is in jeopardy [43]. Some manufacturers and suppliers need to learn the uniqueness of halal food processing. *Halal* food manufacturing requires a thorough understanding of the supply chain to maintain the integrity of *halal* products [44]. Although the main ingredient is considered a subject of concern, manufacturers must also consider any other elements that may be added to standardize or stabilize the primary ingredient [45]. Most food products are now obtained from all over the world, not only because of the distance and the number of food handlers but also the validity of the *halal* certification [3]. The nation of origin of food items impacted consumer trust and confidence in the *halal* supply chain. Consumer choice and trust in the *halal* supply chain are influenced by the place of origin of *halal* products, which is harmful to imports from Muslim minority countries and favorable for imports from Muslim majority countries [46]. In addition, many firms have been discovered to use ambiguous claims and *halal* logos in their product and service marketing [47]. Goods and procedures must be observable or measurable to ensure the products are halal. Detection and quantification of *haram* substances such as alcohol concentration or pork are often done through auditing and accreditation. In contrast, raw material traceability, slaughtering techniques, storage, and distribution procedures are observed [2]. Therefore, a set of guidelines must be created and followed that follow the Islamic dietary code needs to be created and followed. Standardization is the most pressing topic in the *halal* food business, where agreement and acceptance on worldwide *halal* food certification, production, and distribution standards are difficult to establish [46]. Industrial *Halal* food products need certificates from accredited authorities, which may only be readily available in some nations seeking to enter the market [42]. To ensure the integrity of the pristine *halal* food supply chain, each participant in the supply chain must be monitored, from the supplier to the end user, so that consumers can be confident in the authenticity of *halal* products [48]. The implementation of traceability systems was shown to have a strong link with the integrity of the *halal* food supply chain [47].

Furthermore, easy access to inaccurate online information leads to misunderstanding and disinformation among Muslims, resulting in a wave of suspicion and uneasy feelings and views of the country's *halal* system as a whole. As a result, consumers are skeptical of every food product [4,43]. A study of perceived understanding and actual knowledge of alcohol conducted on food technology undergraduates has shown that there is a high discrepancy between perceived and actual knowledge. The continuous unsure replies found throughout the poll might be due to various factors [45]. When it comes to *halal* goods, the zero-tolerance policy is carefully followed to eliminate unwanted ingredients and their derivatives.

CONCLUSION

Progress in the food industry has raised concerns among religious consumers, especially Muslims. Alcohol, commonly used as a solvent in flavors, colors, and preservatives, is being questioned on its *halal* status. Alcohol that is not permitted to be consumed by Muslims is called *khamr,* which intoxicates the mind. According to a fatwa of Muslim scholars, *khamr* is *haram* and prohibited for consumption by Muslim believers. Ethanol is a compound found in *khamr* and is present naturally in fermented food, fruits, and some beverages. In this case, the source of ethanol determines the permissibility of its use in food and beverage products, as scholars in respective countries discussed. In authenticating alcohol in food and beverage products, various analysis methods can be conducted, such as GC-MS, electronic noses, and biosensors. Each method has its benefits and constraints and depends on the intended usage. Criteria like sample types, time required for analysis, or costs should also be considered when selecting the analysis.

https://doi.org/10.24191/sl.v18i1.24338

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There are also challenges in practicing halal conduct where the analytical method cannot detect certain compounds due to the complex assembly of interactions between compounds in food. As the *halal* market rises globally, interest in the traceability chain of halal produce should be developed for consumers' confidence in its integrity. Similarly, consumers must fundamentally understand *halal* to avoid misinformation and confusion.

ACKNOWLEDGMENTS

The authors would like to acknowledge the support of the Faculty of Science and Technology, Universiti Sains Islam Malaysia (USIM) and the International Institute for Halal Research and Training (INHART), International Islamic University Malaysia (IIUM) for facilities and instruction in completing this project. I would like to express my sincere gratitude to my supervisor for providing invaluable guidance, comments, and suggestions throughout the writing process. Also, I would like to thank fellow associates who helped directly and indirectly in the process.

AUTHOR’S CONTRIBUTION

Nur Hanisah Mohamad Ikhiwan carried out the research, wrote, and revised the article. Nur Azira Tukiran anchored the review, made revisions, and approved the article submission.

CONFLICT OF INTEREST STATEMENT

The authors agree that this research was conducted without any self-benefits or commercial or financial conflicts and declare the absence of conflicting interests with the funders.

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