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Research Paper

Development of Halal Antimicrobial Agents from Plants: Prospects for a Halal Nutritional Framework

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Abstract

Proper halal nutrition refers to a halal diet that provides every nutrient and ingredient required to sustain regular body function. Muslim consumers are worried about the origin of food antimicrobial agents, such as free fatty acids (FFA), since they can contain ingredients that are forbidden in Islam, such as lards and other animal sources. This study evaluated extracts from ginger, cumin, and Echinophora plants as alternatives to halal food antimicrobial agents such as halal-free fatty acids (HFFA). These extracts were prepared using a solvent extraction method. Then, these extracts were added to the butter production. The butter samples were compared to synthetic sulfonamide and animal-based lactoferrin regarding their antioxidant activity (DPPH) and antimicrobial effects on dairy butter samples for 30 days of storage. The extracts of ginger and Echinophora exhibited greater antimicrobial potential. In contrast, cumin demonstrated the lowest antimicrobial potential at 50 µM and 100 µM solutions of *Staphylococcus* and *E.Coli sps*., but was still significantly higher than those of sulfonamide and lactoferrin. After 30 days of storage for butter preservation, the DPPH activity of *echinophora* (43.5 mmol TEAC/kg) and ginger (39.65 mmol TEAC/kg) was higher than that of cumin (30.52 mmol TEAC/kg), lactoferrin (27.55 mmol TEAC/kg), and sulfonamide (25.56 mmol TEAC/kg). The results showed that these plants had higher antimicrobial and antioxidant activity, but the activity decreased with storage time. Therefore, this research will open the way for new natural sources of HFFA as potential active food ingredients that might boost the halal market and promote the nutritional framework.

Keywords: *Plants; Halal antimicrobial agents; Nutritional framework; Halal food; Authenticity*

INTRODUCTION

Academics have always debated food, because eating is an essential component of human health. Recently, food production has been using the latest developments in science and technology. Various ingredient sources are employed in the manufacturing of culinary items. These components are either forbidden (haram) or allowed (halal). Furthermore, various components are mixed, including synthetic and chemical additives. Additionally, the researchers debate issues related to obtaining the source material, processing, packaging, and transportation. To put it another way, the conversation about the food chain begins with farm management and ends with customers (from farm to fork). Muslim customers worldwide are becoming more concerned about the authenticity of halal cuisine as more delicacies become accessible on the market. This is due to the widespread and challenging-to-identify adulteration of haram or Subhash ingredients in food goods. Muslims are urged to use scientific knowledge to examine the benefits and drawbacks of such bans and their rationality. This essay uses Islamic and contemporary scientific methodologies (Typek et al., 2019).

Halal nutrition is becoming increasingly popular worldwide because it avoids forbidden elements (haram). Ensuring all food ingredients, particularly antimicrobial agents, are halal is a significant concern as the halal food business grows. Because of their antibacterial qualities, free

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fatty acids (FFA) are frequently used in food preservation; nevertheless, the halal market is concerned because they come from animal sources. By assessing plant-based sources of HFFA as viable halal substitutes for traditional animal-based antimicrobial agents, this study aims to close this gap. Traditional animal-derived antimicrobials, like several FAAs, have demonstrated efficacy in preventing the growth of microorganisms. However, their use is restricted because of their toxicity and possible harmful effects on sensory attributes such as taste and odor. There is also a demand for halal-certified substitutes that maintain effectiveness without endangering customer safety or religious observance because non-halal animal-based FFAs violate Islamic dietary regulations (Sahne et al., 2017).

Ancient people employed plants to treat illnesses, which is how the term "medicinal plants" was coined and spread among various ethnic groups and cultures. According to the World Health Organization, Eighty per cent of people worldwide favour using herbal medicines. Medicinal plants are popular because they are inexpensive and typically have fewer adverse effects than chemical medications. Medicinal herbs are used for their flavoring, preservation, aromatising properties, and therapeutic uses. Various extracts, essential oils, and seasonings are produced from medicinal plants' leaves, stems, and roots.

A seven-carbon chain with an -unsaturated -diketone moiety joined to two aromatic rings with ortho-methoxy phenolic-OH groups forms the organized crystal structure of curcumin (Sahne et al., 2017). Temperature, polarity, and solution pH all impact curcumin's molecular structure. The α, β-unsaturated β-diketone moiety functions as a hydrogen donor site at neutral and alkaline pH values, which causes curcumin to hydrolyze and degrade. Depending on the characteristics of the solvent, the β-diketone chain present in the curcumin structure can persist as an ethanol tautomer form. It forms at the basic pH state at which the enolic is formed and at the acidic or neutral pH levels found in bis-keto. The predominant basket form of curcumin, which is yellow and has minimal water solubility, was indicated by the pH solution, which ranged from 1 to 7. Consequently, curcumin stability and solubility rise with alkalinity. Because of the poor delocalization of unpaired electrons, the enolic form works by donating H atoms from C-H bonds from the core carbon atom to nearby oxygen atoms (Typek et al., 2019).

The plant's aerial sections provide various functions. Echinophora is a member of the Umbelliferae family of plants. Four herbaceous, perennial, and aromatic species are found in Iran. Iran is home to two indigenous species: Echinophora platyloba and Echinophora cinerea. It is added to yoghurt, pickles, and buttermilk as a condiment. Traditional medicine also uses *echinophora* to treat gastrointestinal issues. Numerous investigations have been conducted to determine which Echinophora constituents have therapeutic qualities. Of the 8500–9500 vascular plant species in Iran, 2324 are endemic. There is also much plant diversity in Lorestan, west of Iran, where 29 species are native. Iran is home to four aromatic perennial herbaceous species of *Echinophora*, including the endemic species *E. cinerea* and *E. platyloba*, as well as the sibthorpiana and orientalis that are grown in Anatolia, Armenia, Russia, Turkmenistan, Afghanistan, the Balkan Peninsula, Crete, Cyprus, and Syria. At elevations above 1500 meters, *E. cinerea* can be found in Lorestan, particularly in Ashtorankuh, Kuh Kala, Garin Kuh, and Sefid-kuh. The plant is known in Iran by the native names Khoshrizeh, Tigh Toragh, Kashndar, and Toluq Otto. It is used to treat stomach disorders in traditional medicine. Additionally, it is used as a spice in cheese and yoghurt (Kharat et al., 2017).

The essential oil of *Echinophora* is a white or yellowish liquid that exhibits potent antioxidant and antibacterial properties. It works against yeast and both gram-positive and gram-negative bacteria. *E. cinerea* may have an antioxidant role because of α-phel-landrene activity, whereas *E. platyloba* essential oil has been shown to suppress foodborne illnesses and food deterioration in yeasts successfully. Consequently, it can be added to food as a natural preservative. Using 50 and

100 µl/l *Echinophora* essential oil could prevent button mushrooms from becoming bad while they were stored.

Owing to its limited cultivation, Echinophora is not well-known worldwide, and no research has examined its traits (Safari et al., 2018). Antioxidant and antibacterial substances with several functions can be found in essential oils and extracts. They are classified as secondary metabolites of alkaloids, glycosides, flavonols, and phenolic chemicals. Turmeric's primary curcuminoid, curcumin [1, 7-bis (4-hydroxy-3-methoxyphenyl)-1, 6-heptadiene-3, 5-dione], gives it its vivid yellow hue. A carotenoid that changes colour in alkaline or high-pH solutions can be isolated from the rhizomes of the plant Curcuma longa (Oglah et al., 2020). Curcumin's antioxidant qualities are explained by its ability to effectively scavenge various reactive oxygen species (ROS), such as superoxide anions and hydroxyl radicals (Hewlings & Kalman, 2017).

In addition, curcumin exhibits encouraging promise for treating cystic fibrosis. The research demonstrated that curcumin when administered orally, promoted the functional appearance of the AF508 CFTR protein, which is the affected protein in cystic fibrosis, even though the test was only conducted on animal cells, namely the kidney cells of baby hamsters (Egan et al., 2013). Turmeric oleoresin is used as the raw material for the industrial production of curcumin. The by-products of curcumin isolation have antibacterial properties against a variety of spoilage and pathogenic bacteria, such as *Pseudomonas aeruginosa, Bacillus cereus, Bacillus coagulans, Bacillus subtilis, Staphylococcus aureus,* and *Escherichia coli* (Nelson et al., 2017). Because of its sensitizing properties, curcumin may destabilize mixtures of other substances. Curcumin is a low-molecular-weight, nontoxic, hydrophobic diphenol molecule that dissolves in methanol, ethanol, and dimethyl sulfoxide but not in water or ether. Composite film manufacturing is appealing for packaging applications because it provides extra functional benefits, including enhanced mechanical strength, UV protection, antioxidant qualities, and antibacterial activity. Additionally, curcumin exhibited a discernible colour shift that was responsive to pH. Its main structure varied depending on the pH (Ezati et al., 2021).

Animal-origin food antimicrobial agents (FAA) exhibited strong antimicrobial qualities against gram-positive and gram-negative infections, but also exhibited toxicity and organoleptic problems in foods. Therefore, it is necessary to introduce halal FFA so that Muslim customers can accept the use of FAA. This study examines the antibacterial and antioxidant properties of ginger, cumin, and *Echinophora* extracts as halal are examined in this study as halal substitutes for butter preservation. We intend to evaluate the appropriateness of these plant-based extracts as HFFAs in the halal food business by analyzing their effectiveness over 30 days.

LITERATURE REVIEW

Plant Extracts with Different Properties

A potent immunomodulator in both people and animals, curcumin [1,7- bis (4-hydroxy-3-methoxyphenyl)-1,6-heptadiene-3,5-dione] creates an orange-yellow polyphenolic and hydrophobic phytochemical component. The development of halal plant extracts and their green environment as a safe platform for developing a halal nutrition framework is illustrated in Figure 1. It is a curcuminoid that is commonly found in turmeric rhizomes. Traditional Chinese medicine and Indian Ayurveda medicines have long regarded curcumin as a potent natural antioxidant (Aggarwal et al., 2006; Zheng et al., 2018). Curcumin has anti-inflammatory, antibacterial, antioxidant, immunomodulatory, appetite-increasing, and gastro-protective effects on animal health. In addition, its drawbacks were demonstrated, including its hydrophobicity, unstable chemical structure, low absorption in the body (curcumin's bioavailability), which varies depending on the animal species and sex, and quick metabolism (Hewlings & Kalman, 2017). Curcumin's antioxidant qualities are attributed to its ability to scavenge various reactive oxygen

species (ROS) effectively, such as hydroxyl radicals and superoxide anions (Ruby et al., 1995).

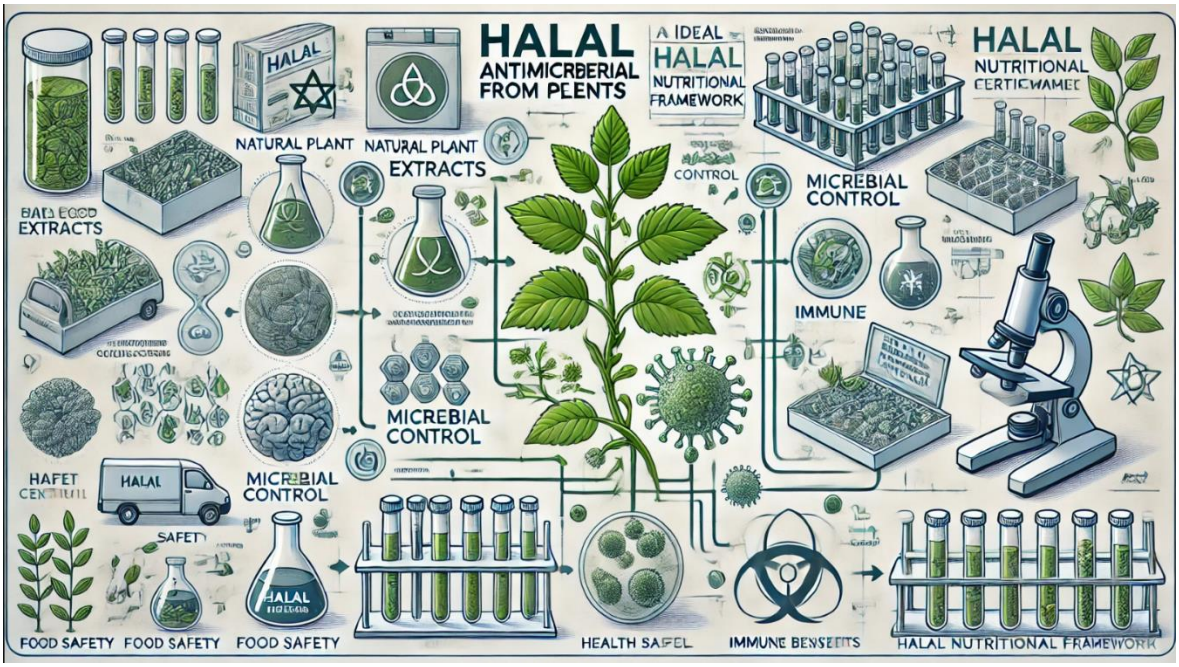

Figure 1. Development Aspects Related to Halal Antimicrobial Agents From Plants

Halal Antimicrobial Activity

Food antimicrobial agents (FAA) offer the first defence against infections in processed food products. They also serve as antioxidants, preventing alterations in food's color and flavor that compromise its safety and quality. Muslim customers are worried about the FAA's source because it can include elements that are forbidden by Islam, such as pigs and sources of unkilled animals. Concerns have also been raised over the potential for the FAA to have an organoleptic effect on food and the growing danger of harm when consumed (Sani et al., 2020). By applying the FAA, food is shielded from microbial contamination and indirectly fights against the emergence of deadly diseases. Halal FAA (HFAA) can help Muslim customers accept the use of the FAA. In general, HFAA is categorized based on the sources of its ingredients, which include synthetic, bacterial, plant, and animal sources.

The halal status of animal-origin FAA is questioned because the source may be a pig, an unslaughtered animal, a human, or a dirty source. In addition to toxicity and organoleptic problems, animal-origin FAA exhibits potent antimicrobial qualities against Gram-positive and Gram-negative pathogens (Abdalla et al., 2023). Thus, the FAA should be used within the allowable range. HFAA has become one of the most studied FAAs due to these issues. Many HFAAs are manufactured in animal farms without fully verifying the halal status. With an anticipated 2.2 billion by 2030, Muslims make up 26.4% of the world's population and are a major commercial force. In addition to being nourishing and hygienic, halal food must be free of biological dangers and contamination from haram materials. Antimicrobial resistance (AMR) is a global health concern that affects various businesses, including the food industry. Halal food items are not exempt from the problems caused by AMR, which include the use of antibiotics in animal husbandry, seafood contamination, and the importation of halal food products from different locations.

To address the issues of AMR in halal food products, some steps can be taken, including following appropriate treatment protocols and withdrawal periods and using antibiotics responsibly in animal agriculture. Programs for surveillance and monitoring must be developed to assess the presence and trends of AMR in halal food products. Increasing public awareness and

education, implementing food safety and hygiene protocols, and enacting regulations are all necessary to promote the proper use of antibiotics. Governments, food manufacturers, researchers, and consumers must work together to reduce the occurrence of AMR in halal food items (Saidin et al., 2021).

According to the earlier study cited by Chen et al. (2010), curcumin has antiviral properties that can counteract the influenza virus. They asserted that at a treatment dose of 30 μM, more than 90% of the substance can aid in lowering the viral population in cell culture. Curcumin has been shown to interfere with viral adhesion to host cells, suggesting its potential to inhibit the spread of the influenza virus. Studies have also shown that curcumin and similar compounds affect the fungus Candida albicans. Compared with demethoxycurcumin, curcumin has a more substantial antifungal impact. It was asserted that curcumin's methoxyl group increases its lipophilicity, allowing it to enter the fungal cell membrane unhindered and perhaps inhibiting its growth. The antibacterial activity of turmeric against over 100 diseases from 19 different species was tested in the earlier work by Adamczak et al. (2020). Along with several Gram-positive and Gram-negative bacteria, moulds are also present. It has been demonstrated that curcumin exhibits a stronger antibacterial propensity against Gram-positive bacteria than Gram-negative ones.

Some plant compounds, such as carvacrol, linalool, p-cymene, α-pinene, and γ-terpinene, are among the hydrocarbon monoterpenes that are primarily responsible for the antibacterial activity of the *Echinophora* plant and its essential oil. *E. platyloba* essential oil's antimicrobial activity against gram-positive and gram-negative bacteria. *Listeria monocytogenes* and *Staphylococcus aureus* were the most susceptible bacteria in their investigation, whereas essential oil did not affect the growth of gram-negative bacteria. Additionally, Fallah et al. (2011) investigated the antibacterial activity of *E. platyloba* against foodborne microbes. According to their findings, gram-positive bacteria were significantly suppressed by the essential oil of E. platyloba, followed by yeasts. The bacteria that were least sensitive to essential oil were gram-negative (Zhang et al., 2012).

Using the disk diffusion method, Zarali et al. (2016) investigated the inhibitory effect of *E. cinerea* essential oil against *Shigella, B. cereus, S. aureus*, and *E. coli* compared to chloramphenicol. *E. cinerea* essential oil exhibited the lowest inhibitory impact against *B. cereus* and the most substantial antagonistic effect against *S. aureus* among gram-positive bacteria. The most resilient species was *S. dysentery*. The study also examined the antibacterial activity of E. cinerea essential oil against foodborne pathogens, including *L. monocytogenes, S. aureus, Escherichia coli, Pseudomonas aeruginosa,* and methicillin-resistant *S. aureus*. The findings demonstrated that Pseudomonas had a high resistance level to the essential oil. Due to their poor drug permeability and chromosomal AmpC enzyme synthesis, these bacteria also exhibit high antibiotic resistance.

Curcumin [(E, E)-1,7-bis(4-hydroxy-3-methoxy-phenyl)-1,6-heptadiene-3,5-ione] is a well-known orange-yellow bioactive compound that was isolated from turmeric (*Curcuma longa* L.) and is approved (E-100) for use in food processing as a color, spice, flavor, and preservative; it has excellent antibacterial and antioxidant properties and is non-toxic. Curcumin has long been a mainstay in daily diets, mainly in Asian and occasionally African countries, and it has been used extensively for its anti-inflammatory, antioxidant, anticancer, and antimicrobial properties in pharmaceuticals. The mechanism of curcumin's antimicrobial activity includes (1) the disruption of the membrane walls of specific bacteria, (2) the damaging effect on bacterial DNA, and (3) membrane leakage of the bacterium, producing a lot of reactive oxygen species, either as singlet oxygen or as hydroxyl radicals.

Additionally, curcumin has antioxidant qualities derived from its structure-based polyphenolic group. A hydrophobic phenol group found in curcumin is quickly broken down and is barely soluble in water. Despite its many beneficial properties, curcumin has a slow dissolution

rate, high intestinal metabolism, low water solubility, and low bioavailability, limiting its use. Consequently, the efficacy of curcumin in food depends on its bioavailability and antioxidant content. In order to create new ingredients with optimal techno-functional and nutritional qualities, an alternative processing technology is needed. Numerous studies have documented various strategies, especially nanotechnology, for boosting curcumin bioavailability and overcoming its limited water solubility. To improve their resilience against the aforementioned circumstances and capitalize on their biological characteristics, curcumin is a promising candidate for creating innovative natural materials such as microparticles and nanoparticles.

Antioxidant Activity

Reactive species called free radicals target essential macromolecules and seriously harm the body, resulting in some illnesses like cancer, heart disease, Alzheimer's disease, and Parkinson's disease. Although the food industry extensively uses synthetic antioxidants, there are concerns about their safety. Phenolic substances, including flavonoids, tannins, and phenolic acids, are found naturally in plants and act as antioxidants. Reactive oxygen species (ROS) scavenging, chelating metal ions to prevent ROS generation, enzyme inhibition, hydrogen atom transfer, single electron transfer, and other processes are some ways phenols exert their antioxidant action. A plant's phenol concentration is closely related to its antioxidant action. Numerous phenolic compounds with significant antioxidant activity are found in echinophora plants (Parimita et al., 2007).

Monoterpene hydrocarbons found in echinophora essential oils have antioxidant properties because of their active methyl groups, particularly in the beta-carotene-linoleic acid system. Another antioxidant found in *Echinophora* species is limonene Fallah et al. (2011) used the β-carotene-linoleic acid bleaching experiment and the DPPH method to investigate the antioxidant activity of *E. platyloba* essential oil. They found that the essential oil of *E. platyloba* has a high antioxidant potency (IC50 = 49.7 µg/ml), which was primarily caused by the activity of limonene and trans-ocimene. Interestingly, the DPPH, FRAP, and ABTS techniques were used to evaluate the chemical composition and antioxidant activity of three plants: *Heracleum lasiopetalum* Boiss, *Kelussia odoratissima* Mozaff, and *E. platyloba*. According to previous studies, the extract from E. platyloba exhibited the maximum antioxidant potency (Hamzeh-Kalkenari et al., 2021). *Ghasemi Pirbalouti* and *Gholipour* used the DPPH method to evaluate the antioxidant activity of butylated hydroxytoluene (BHT) *and E. cinerea* essential oil*. E. cinerea* essential oil had an IC50 of 1.97–2.25 mg/ml in their investigation, whereas BHT had an IC50 of 0.412 mg/ml. Although *E. cinerea* essential oil possesses good antioxidant activity, its ability to control oxidative processes was not as strong as that of BHT.

Halal Nutrition Framework

Lifelong dietary patterns that solidify with age are the subjects of nutrition. Additionally, dietary patterns can vary from person to person based on cultural and regional environmental differences. We must appropriately combine these elements' food sources to guarantee a sufficient supply of vital nutrients. Breastfeeding should begin at birth and continue for 6 months or until the child is two years old. While meat should be consumed in moderation, milk, dates, honey, fruits, and vegetables should also be consumed. This leads to a nutritious and well-rounded diet. To provide proper nutrition guidelines for quality and better consumption of halal food for future generations, the research concluded that the halal nutrition framework is parallels to the food pyramid. While it is a moderate and healthy balanced diet, relevant and appropriate for halal nutrition, the entire regime must be free of the haram elements—blood, pork, carrion, and liquor. This is consistent with Shariah Maqasid (Ahmad et al., 2023).

The food and eating habits of the Prophet are covered by halal nutrition. Muslims do not live

to eat; they eat to live. Repeating the adage "You are what you eat," food is fundamental to our way of life and shapes who we are from the inside out. Proper halal nutrition is obtaining all the elements from a halal diet to maintain the body's regular functions. This is significant because your body needs specific essential molecules to function, which it cannot produce independently. Your body will lack the necessary nutrients if you do not take them from your food. This is crucial because for the body to function correctly, the proper quantity of each necessary molecule is needed (Larsson & Wolk, 2006). How the body works is significantly impacted by the food consumed. Thus, it can be mentioned as follows by the guidelines of Swinburn et al. (2011), which are mentioned as follows:

1. The Immune System: Food with adequate nutrients boosts immunity, helping to prevent chronic illnesses such as HIV, TB, malnutrition, and other infectious diseases.
2. Mind: Halal food promotes both a healthy body and mind, influencing one's thoughts and behavior.
3. Skin, Hair, and Nails: The development of the body's surface, including skin, hair, and nails, depends on the food consumed.
4. The Nervous System: A balanced diet is crucial for maintaining brain health and a properly functioning neurological system.
5. Digestive Health: Making the right dietary choices can facilitate easy digestion and efficient absorption of nutrients, contributing to overall wellness.

The World Health Organization (2017) defines health as the "state of complete physical, mental, and social well-being, and not merely the absence of disease". A person's lifestyle plays a significant role in both short-term and long-term functionality. Therefore, leading a healthy lifestyle is essential for maximizing life quality, helping individuals stay healthy, feel good, and look their best. A healthy, balanced diet should include various foods from the four major food groups: bread, other cereals and potatoes, fruits and vegetables, milk and dairy products, meat, fish, and alternatives. Although they make our diet more enjoyable, foods and beverages with fat or sugar should only be consumed in moderation. This study will be planned to keep in view the following objectives:

1. Development of butter using halal sources
2. We evaluated butter's antimicrobial and antioxidant capacity prepared from different plant extracts.

RESEARCH METHOD

Preparation of Plant Extracts

Ginger, cumin, and *echinophora* were procured, cleaned, and extracted using a solvent to obtain plant-based FFAs. The extracts were then produced and concentrated at two different concentrations (50 µM and 100 µM) for use in butter samples. Using a Clevenger-type device, the dried plant material was hydrodistilled for eight hours (60 g of sample in 500 mL of distilled water) to extract the extract (Rahimi-Nasrabadi et al., 2009). Before examination, the oil was kept in sealed glass vials at 4–5 degrees Celsius after being dried over anhydrous sodium sulfate. The yield was also computed using the sample's dry weight.

Butter Sample Preparation

Five sets of butter samples were created, and each group received either a traditional antibacterial agent (lactoferrin or sulfonamide) or a plant extract (ginger, cumin, or *Echinophora*). In addition, control samples were prepared without any additional antimicrobials. The butter was created by churning cream in a butter churner supplemented with varying amounts of herbs. Samples were then stored in airtight brown jars at the proper temperature and for the necessary

time. The oxidative stability of each therapy was examined at treatment intervals. Three replications of each treatment were conducted (Shanker & Debnath, 2019).

Antimicrobial and Antioxidant Activity Testing

Two strains of Staphylococcus and E. coli were used to assess each sample's antibacterial effectiveness. The DPPH assay was used to assess antioxidant activity, and the results are reported in mmol TEAC/kg. These tests were performed at baseline and following a 30-day storage period at 4°C (Figueiredo et al., 2008). To obtain final concentrations of 250, 125, 50, 25, 10, and 5 mg/mL in ethanol, sample stock solutions (1.0 mg/mL) were diluted. 2.5 mL of sample solutions with varying concentrations were mixed with 1 mL of a 0.3 mM DPPH ethanol solution, and the mixture was left to react at room temperature. The absorbance readings were obtained at 518 nm after 30 minutes, and the following formula was used to translate these into the percentage antioxidant activity (AA):

$$AA\% = \frac{100\left(Abs_{sample} - Abs_{blank}\right).100}{Abs_{Control}}$$

As a blank, 1.0 mL of ethanol and 2.5 mL of plant extract solution were used. As a negative control, 1.0 mL of DPPH solution (0.3 mM) and 2.5 mL of ethanol were used. Standard solutions were used as positive controls. The EC 50 values were determined using linear regression of plots, with the ordinate representing the average percentage of antioxidant activity from three different experiments and the abscissa representing the concentration of the tested plant extracts (Gholivand et al., 2011).

Statistical Analysis

Three duplicate experiments were conducted. The mean standard deviation (SD) of the results is displayed. The student's t-test was employed when comparing two means, and when comparing more than two means, a one-way analysis of variance (ANOVA) was employed. When $p<0.05$, a difference was deemed statistically significant (Montgomery, 2017).

FINDINGS AND DISCUSSION

Antimicrobial Activity

Extracts from ginger and Echinophora showed greater antibacterial potential at the start of the storage period than those from cumin, sulfonamide, and lactoferrin (Table 1). *Staphylococcus* and *E. coli* growth was significantly inhibited by ginger and *Echinophora*, with ginger exhibiting the best overall efficacy. Cumin surpassed lactoferrin and synthetic sulfonamide with lesser antibacterial effectiveness (Rukkumani et al., 2004).

Table 1. Antimicrobial Activity of Different Plant Extracts

Extract/Agent	Concentration	*Staphylococcus* Inhibition	*E. coli* Inhibition
Ginger	100 µM	High	High
Echinophora	100 µM	High	High
Cumin	100 µM	Moderate	Moderate
Sulfonamide	-	Low	Low
Lactoferrin	-	Low	Low

Antioxidant Activity

Echinophora exhibited the highest antioxidant activity at 43.5 mmol TEAC/kg, followed by ginger at 39.65 mmol TEAC/kg, according to the results of the DPPH assay (Table 2). Compared

with lactoferrin and sulfonamide, which had respective activities of 27.55 mmol TEAC/kg and 25.56 mmol TEAC/kg, cumin's activity was lower but still higher (Figure 2).

Many Curcuma species have been traditionally used for their therapeutic properties (Rai et al., 2015). Species such as Curcuma longa, Curcuma zedoaria, Curcuma aromatica, and Curcuma amada have antifungal, antibacterial, and anti-inflammatory properties (Apisariyakul et al., 1995; Mujumdar et al., 2000; Negi et al., 1999; Yoshioka et al., 1998). It has been demonstrated that curcumin extracted with a range of solvents (hexane, ethanol, methanol, etc.) other than alkaline extraction has antibacterial properties against more than 24 pathogenic bacteria, including *Streptococcus, Staphylococcus, Lactobacillus*, and others (Chattopadhyay et al., 2004). According to the current study, rhizomes are used in conventional systemic medicine to treat various microbially induced infectious disorders. Further investigation is necessary to more precisely evaluate the potential effectiveness of the crude extracts as antibacterial agents.

Table 2. DPPH Activity of Plant-Based Butter Samples

Sample	DPPH Activity (mmol TEAC/kg)
Echinophora	43.5
Ginger	39.65
Cumin	30.52
Lactoferrin	27.55
Sulfonamide	25.56

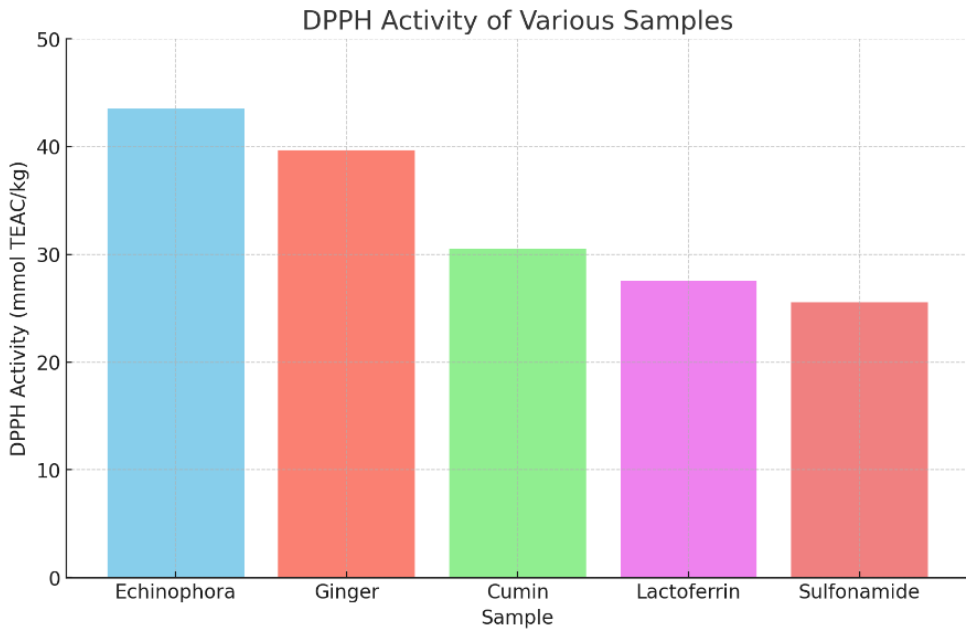

Figure 2. Graphical Representation of The DPPH Activity of Plant Extracts and Comparison With Lactoferrin and Sulfonamide

Storage Stability

All samples exhibited decreased antioxidant and antibacterial activity after 30 days. Echinophora and ginger, on the other hand, continued to exhibit a comparatively high level of efficacy, suggesting their potential use as long-term preservatives in dairy products. According to these findings, plant-derived HFFAs from Echinophora and ginger show promise as halal substitutes for antibacterial agents generated from animals. These extracts offer potent microbial suppression and antioxidant qualities in addition to meeting halal dietary guidelines. More studies

on stabilizing strategies to extend shelf life are needed, as indicated by the gradual decline in efficacy. The DPPH antioxidant results further support the functions of these plant extracts in maintaining food quality. By implementing antimicrobial agents that comply with halal standards, the halal food sector can increase product safety and reach a larger market (Syahariza et al., 2005).

Given the established dangers of synthetic preservatives and antimicrobials and the rising global rate of antibiotic resistance, the use of herbal preservatives and antimicrobials are important. Bioactive substances in *echinophora* essential oil impact the regular operation of microbial cells. The *Echinophora* plant and its essential oils have strong antibacterial, antioxidant, and anticancer qualities, as was covered in depth. The results of this review will provide new avenues for creating functional food, cosmetic, and medicinal goods. However, further clinical and in vivo research is needed (Nabati et al., 2014).

Finally, HPLC analysis of five selected *Zingiberaceae* species using the chemical extraction method showed that the highest amounts of curcumin were found in tem mas. All five *Zingiberaceae* extracts demonstrated strong antibacterial activity against the examined species. More studies are required to evaluate and validate the antibacterial properties of the extracts against a wider variety of human pathogenic pathogens. Temu mas produced inhibitory zones ranging from 3 to 9 (g/L) and showed higher activity than the other extracts at 5 mg/ml. At 5 mg/ml, Temu mas inhibited S. aureus ATCC 25923. Only at 20 mg/ml did any of the four species—Cekur, Lempoyang, Temu Kunci, and Temu Pauh—produce inhibition, with *S. aureus* ATCC 25923 exhibiting inhibitory activity doses as high as 9 g/L (Aali et al., 2017).

Synthetic and natural antioxidants are frequently added to foods to extend their shelf life. The antioxidant and antimicrobial properties of *Echinophora* extract were examined in fish fillets in the Safari et al. (2018) investigation. The authors demonstrated that the shelf life of fish fillets was increased to 30 days by using the extract at a concentration of 1.5 g/l. Additionally, compared with samples without extract, the peroxide value of the samples containing *Echinophora* extract was noticeably lower (Otieno et al., 2015). According to Hamzeh-kalkenari et al. (2021), button mushrooms coated with an edible film made of polyethylene-clay nanocomposites containing 100 µl/l E. cinerea essential oil had an extended shelf life. When *Echinophorra* essential oil and extract were compared for antioxidant activity, it was shown that the essential oil had a greater capacity to control oxidation than the extract. This may be due to the higher concentration of phenolic chemicals in essential oils (Rashidipour et al., 2020). A comprehensive approach to nutrition should be taken when considering the ideas of halal and Tayyiban, which includes adding the FAA to food items while they are being manufactured. More thorough research is required to determine the best preservation methods to increase food safety and quality without sacrificing nutrients. Given the negative impacts on human health and the benefits to food safety and quality, natural FAAs have drawn much attention. In addition, natural FAA encourage appropriate standards for maintaining food quality.

CONCLUSIONS

This study showed the potential of ginger, cumin, and *Echinophora* extracts as halal antibacterial agents, with ginger and *Echinophora* exhibiting the best efficacy. These findings support the development of natural, halal-compliant preservatives in the food sector. To satisfy the rising demand for halal-compliant meals, future studies should focus on enhancing the stability of these extracts over time and broadening their use beyond dairy products. In conclusion, Islam forbids the adulteration of pig origins in culinary products. According to Islamic law, this ban covers every component of pigs, including their flesh, skin, and byproducts (such as lard and enzymes). Consequently, food labels are required to indicate the presence of fat in products clearly. Various strategies, such as PCR, HPLC, and FTIR, have been developed to assist consumers in making

informed food choices. To ensure the protection of Muslim consumers, particularly in avoiding non-halal ingredients, there is a strong need for Muslim researchers to be actively engaged in exploring reliable methods for detecting food adulteration. Consequently, food labels are required to indicate the presence of fat in products clearly. Various strategies, such as PCR, HPLC, and FTIR, have been developed to assist consumers in making informed food choices. To ensure the protection of Muslim consumers, particularly in avoiding non-halal ingredients, there is a strong need for Muslim researchers to be actively engaged in exploring reliable methods for detecting food adulteration. Numerous studies have demonstrated the efficacy of natural compounds, such as essential oils, enzymes, bacteriocins, chitosan, and organic acids, as antimicrobial agents, which are increasingly regarded as legitimate alternatives to synthetic FAA. Finally, it is crucial for the food industry to employ a combination of methods to detect non-halal substances, thereby preserving the integrity of halal products while simultaneously assuring consumers of the safety and hygiene of the food supply. Lastly, food industries must use several techniques to identify non-halal substances to safeguard the authenticity of halal products while informing and reassuring customers about safe and hygienic products.

LIMITATION & FURTHER RESEARCH

This study needs to explore plant extracts and their purification and characterization to explore them as economical and easily available commercial plants for use in foods. This research will support the larger goal of a halal nutritional framework in food science by paving the way for halal-certified, plant-based antimicrobials that guarantee food safety and religious compliance. Comprehensive research is essential to identify additional sources of FAA, with particular emphasis on those derived from animal origins. The nutritional evaluation should integrate the principles of halalan Tayyiban, emphasizing that food must be both safe and halal. Consequently, it is critical to investigate FAA's toxicity and permissible limits to safeguard consumer health and prevent potential adverse effects.

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