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Investigation of Halal Status and Permitted Industrial Utilization of Carmine Dye in Iran

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HIGHLIGHTS

- Carmine is added to Iranian halal foods at low quantities.
- Carmine is not halal but it is permitted for halal foods by concept of Istahala.
- Carmine is a potent alternative for synthetic red dyes with antibacterial potency.

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ABSTRACT

Background: The limited arable land for producing animal and plant-based foods has compelled governments to explore foods and additives from uncommon sources such as insects. In this manuscript, we investigated the carmine certification by Iranian halal authorities and provided a list of the approved food products containing carmine in Iran.

Methods: The Halal Research Center of Iran inquired the halal status of carmine from the office of the supreme leader in Iran. Details of the dye's consumption in food products were explained to the authorities, and their final decision, or "fatwa" was followed regarding the possible use of carmine in the products. A list of food products with permitted levels of carmine, deemed safe in Iran, is also provided.

Results: Our investigation revealed that carmine, due to its insect origin, is not inherently halal. However, its usage as a food additive in small quantities is permitted under the term of Istahala. Despite the ongoing debates about the halal status and allergenicity of carmine, it is currently used as a food additive in Europe and the United States. In this regard, a permitted level of 50-500 mg/kg is allowed for carmine and its derivatives in food products. In Iran, carmine is permitted in various foods such as fruit beverages, jellies, chocolate dragees, chewing gums, breakfast cereals, candies, and toffees, dairy desserts, sport, and caffeinated drinks, up to the required level, except for margarine, which has a maximum permitted level of 500 mg/kg.

Conclusion: Carmine use should be listed as an ingredient on product labels to help consumers select appropriate foods, especially for vegans.

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Introduction

Halal is a well-known word among Islamic countries. Due to the high level of safety in halal products, this topic has attracted non-Muslim populations in recent decades. Halal-certified foods are recognized globally as high-quality, hygienic products approved by Islamic standards, and commodities with halal logos are widely traded worldwide (Ab Talib, 2017). Nonetheless, trading halal foods may present challenges to non-Islamic countries due to the lack of knowledge (Tieman, 2017). It is globally accepted that halal foods do not originate from non-halal sources or include non-halal ingredients such as alcohol. Additionally, animals must be slaughtered according to the Islamic rule known as Dhabihah or Zabiha (Alzeer and Hadeed, 2021). Halal commitment is a global concern, especially in food systems. For example, the production of a flavor enhancer by a Japanese company, which had received a halal certificate from Indonesia, was banned in 2001. This was due to the use of non-halal enzymes in the preparation of a culture medium to produce the flavor enhancer (Fischer, 2011).

Halal certification in food systems involves either evaluating the site to ensure the supplier meets requirements or assessing the final products (Hanzaee and Ramezani, 2011). Despite the rapid advancements in related scientific fields, halal-certifying bodies have developed slowly due to a lack of consensus on certain halal concepts (Halim and Salleh, 2012). Therefore, it is a challenge to use carmine as an edible dye in foods and beverages. The first investigation into the structure of carmine dates back to 1920, with further studies conducted over the last six decades (Rather et al., 2020). Besides its chromogenic potency, carmine has been identified as a potent antiradical and antioxidant agent, comparable to ascorbic acid in suppressing free radicals (González et al., 2010). Other researchers have reported the antioxidant activity of carmine in beef patties (Aragon-Martinez et al., 2023). Carmine originates from insects, which are prohibited for eating purposes according to the Islamic rules (Rahim, 2018). However, only a small quantity of carmine is required in products due to its high chromogenic potency. This has led to differing opinions among Islamic countries. Additionally, there is evidence of its pathogenicity in consumers. Due to the significant demand for natural colorants and the widespread market for carmine, we studied the usage guidelines and halal status of carmine dye as a natural edible color. For this purpose, we investigated the opinions of the Iranian religious authorities regarding the edible intake of carmine.

Methods

This is a qualitative research done by researchers at the Halal Research Center of Iran, which belongs to the Iran Food and Drug Administration. The center is responsible for halal investigation and issuing halal certificates for foods and beverages in the country. The halal status of carmine was asked from the office of the supreme leader in Iran by the Halal Research Center of Iran. Detailed of the dye usage and the manufacturing conditions were explained to the authorities. Then, the authorities' final decision or their "fatwa" on carmine was followed for its potential use as a food additive in foods and beverages. In addition, the halal status of carmine in other Islamic countries was investigated by studying the official pages of national authorities in those countries.

Results and Discussion

Evaluation of the halal concept in Iran and other countries

The halal status of materials that are not inherently halal is determined by the term “Istahala”. There are different opinions about Istahala among countries. This term refers to the structural changes in a material, and converting it into a new form during processing. Essentially, the material transforms into a new substance with different characteristics. Examples include the fabrication of synthetic genes from pork or the production of vinegar from alcohol, which might be questionable.

Generally, halal certification considers various aspects including the source of materials, the hygienic procedure in production units, the by-products, and the processing aids. However, there are some exceptions in the food industry; for instance, alcohol residue up to 0.5% is acceptable in products (Riaz and Chaudry, 2018). Besides halal uncertainties, the use of some additives derived from animal sources such as carmine, is restricted in products formulated for vegans (Müller-Maatsch et al., 2018; Nugraha et al., 2015). However, plant-derived additives are acceptable for both Muslims and vegan consumers (Khattak et al., 2011).

A major challenge in halal assurance systems is the absence of a requirement for producers to list the additives on labels (Alhariri, 2020). It is believed that some additives such as protein-based chemicals have a labile structure and may degrade during processing leaving no residue in the final product. Additionally, there is concern about the sale of products due to the consumers’ misconception about potential health risks from uncommon additives (Uzogara, 2000).

Halal concepts and food additives

According to the definition of Codex Alimentarius, “food additive is any substance not normally consumed as a food by itself and not normally used as a typical ingredient of

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the food, whether or not it has nutritive value, the intentional addition of which to food for a technological (including organoleptic) purpose in the manufacture, processing, preparation, treatment, packing, packaging, transport or holding of such food results, or may be reasonably expected to result (directly or indirectly), in it or its by-products becoming a component of or otherwise affecting the characteristics of such foods" (Codex Alimentarius, 2007). Food additives are commonly used in the food industry for purposes such as color enhancement, acidity regulation, antioxidant preservation, stabilization, emulsification, bulking, foaming, gelling, thickening, antifoaming, preservation, glazing, flavoring, flavor enhancement, sweetening, and anticaking (European Commission, 2024). The source and the manufacturing process of food additives are of concern for Muslims due to their religious beliefs. According to Islamic rules, food additives are halal if they are not harmful to humans, originate from plant sources, do not contain non-halal ingredients, and do not come from non-halal sources such as pork (Alzeer and Hadeed, 2021). Generally, halal food additives must be free of the prohibited materials mentioned in the Quran. In the modern era, genetically modified food additives should be evaluated based on their origin and processing aids (Altun and Aydemir, 2021). Among the animal sources used to produce food additives, insects pose a dilemma in the food industry. Given the rapid population growth and shortage of food due to famine and limited arable lands, using alternative food sources is unavoidable. Consequently, insect-based foods have been adopted in various countries. The halal status of insects and their products is uncertain. The use of some animal-derived materials, such as honey, royal jelly, and beeswax, is accepted in Islam, and people are advised to consume bee-derived products due to their functional properties. Nonetheless, there is no consensus on other animal-based chemicals such as carmine (Müller-Maatsch et al., 2018).

Carmine in the food industry

The body and eggs of cochineal insect are the source of carmine. Carmine (E 120) differs from the azo pigment of cochineal red A (E 124), which is a synthetic dye. This natural dye is known for its red color, but it ranges from orange to red depending on the pH of the medium. It is extracted from the female *Dactylopius coccus* insect (Borges et al., 2012). Approximately 450 g of cochineal extract or carmine is obtained from 70,000 insects (Japar and Aghwan, 2021). Carmine dye is currently used in the formulation of cosmetics, drugs, foods, and feeds (Altun and Aydemir, 2021; Arriagada et al., 2020; EFSA ANS Panel, 2015; FEEDAP et al., 2022; Silva et al., 2021; Vega et al., 2023). Chemically, carminic acid is the active component responsible for the cochineal color. It complexes with aluminum to form carmine at a molar ratio of 2:1 (carminic acid: aluminum) (INSO, 2019) (Figure 1).

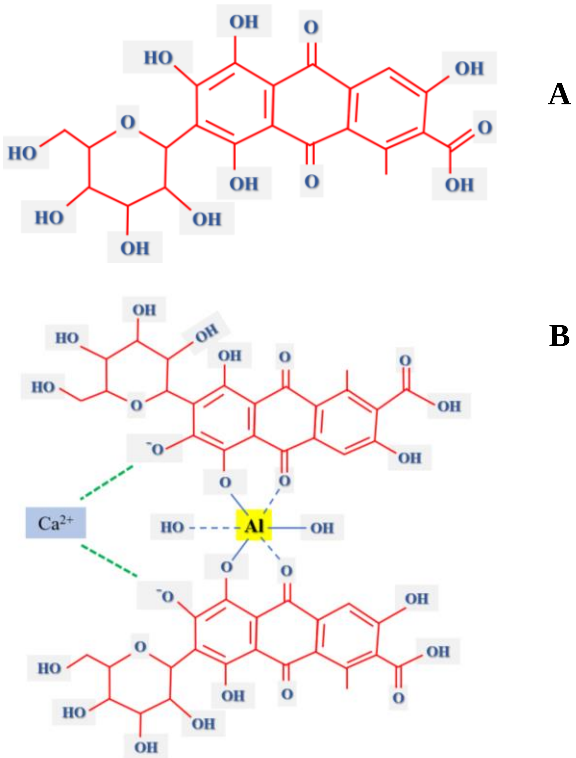

Figure 1: Chemical structure of A) carminic acid; B) aluminum lake of carmine combined with calcium (Ca^{2+})

Commercial carmine is usually a chelate of aluminum complexed with ammonium (Al^{3+}), calcium (Ca^{2+}), potassium (K^{+}), and sodium (Na^{+}) (Silva et al., 2022). Specifically, the Al^{3+} lake combined with Ca^{2+}m is the most common structure. The chromophore is present in the anthracycline and its coloring properties are determined by the number and position of OH groups (Liu et al., 2021). Carmine is soluble in water and other polar solvents (Liu et al., 2023) and is resistant to light and oxidation (E Silva et al., 2020). This color is more stable than many synthetic colors used in the food industry (Kendrick, 2012). These features make carmine popular in various industrial fields.

The EU-approved food colors by are listed from E100 to E199, and carmine has been designated as E120 (European Commission, 2018). Table 1 shows the synthetic and natural red colors currently used in the food industry excluding carmine. It is important to note that it has been approved for use by the Codex Alimentarius (2023) and United States FDA (2023a, b). Moreover, the Food and Agriculture Organization (FAO) and the World Health Organization (WHO) have approved carmine as a food colorant (Liu et al., 2021). However, its halal status is of concern among Islamic countries. According to the

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Standards and Metrology Institute for Islamic Countries (SMIIC), carmine is not halal for edible use. Some countries, including Iran and Malaysia, also regard carmine as non-halal (Rahim, 2018).

Table 1: The approved red dyes by the European Union for use in food industries (European Commission, 2024)

E-number	Name	Source	Chemical structure
E 120	Cochineal, Carminic acid, Carmines	Natural	Anthraquinone
E 122	Azorubine, Carmoisine	Synthetic	Azo dye consisting of two naphthalene subunits
E 123	Amaranth	Synthetic	Azo
E 124	Ponceau 4R, Cochineal Red A	Synthetic	Azo
E 127	Erythrosine	Synthetic	Organoiodine compound
E 129	Allura Red AC	Synthetic	Naphthalenesulfonic acid.
E 160a	Carotenes	Natural	Isoprene units
E 160b(i)	Annatto bixin	Natural	Apocarotenoid
E 160b(ii)	Annatto norbixin	Natural	Apocarotenoid
E 160c	Paprika extract, capsanthin, capsorubin	Natural	Xanthophyll class of carotenoids
E 160d	Lycopene	Natural	Tetraterpene
E 160e	Beta-apo-8′-carotenal (C 30)	Natural	Carotenoid
E 162	Beetroot Red, betanin	Natural	Glycoside
E 163	Anthocyanins	Natural	3-glucosides of anthocyanidins
E 172	Iron oxides and hydroxides	Synthetic	

As per the Halal Malaysia website, carmine is generally considered questionable and specifically non-halal, according to Hanafi Fiqqah (Altun and Aydemir, 2021; Malaysian Halal Consultation and Training Agency, 2017). This dye is used in some Islamic countries such as Iran and Turkey as food colorant. Although Iranian authorities believe that carmine is not allowed for Muslims to be used due to its non-halal animal origin, its use in small quantities in foods is considered legal based on the definition of "Istahala". However, some other countries such as Indonesia and Singapore, consider carmine a halal additive. There is an agreement among these countries on the definition of haram: the foods or additives are derived from poisonous and/or repulsive animals (Rahim, 2018).

Beneficial effects of carmine

Some scientists have reported carmine's biological activities in suppressing clinical disorders (Abu-Hussien et al., 2021; Seabrooks and Hu, 2017). The antioxidant activity of carmine has also been documented (González et al., 2010). Carmine has been proposed for the treatment of non-alcoholic fatty liver developed under metabolic stress (Ferreyra-Suarez et al., 2024). Furthermore, carmine's antimicrobial activity has been attributed to the anthraquinone compound in its structure which can interfere with cell integrity and DNA synthesis (Malmir et al., 2017; Nollet and Gutierrez-Uribe, 2018). Regarding the antimicrobial potency, a mixture of carmine and cumin essential oil was used in the formulation of red meat sausage as a nitrite substitute at concentration of 600 mg/kg in our previous work (Nateghi et al., 2024). In the study, we evaluated the formulation by considering the average daily intake of carmine through sausage consumption in the Iranian population. The risk assessment study was based on consuming 15 g/day of sausage and average body weight of 50 and 75 kg for the two age groups of younger and older than eighteen. Accordingly, the daily intake of carmine was 0.18 mg/kg body weight/day for individuals younger than eighteen and 0.12 mg/kg body weight/day for those older than eighteen. The daily intake varies among countries based on the average daily consumption. However, the total daily intake seems to be well below the maximum permitted limit of 0-5 mg/kg body weight/day (JECFA, 2006) for doses at which carmine is added to the foods. Therefore, it seems that there is no safety concern at the regular doses used to achieve the functional properties of carmine.

Commercial usage of carmine

To extract carmine, the female cochineal insect is dried, and the red dye containing about 20% carminic acid, is extracted using water, alcohol, or a water/alcohol mixture (INSO, 2019). In the EU, 50 to 500 mg/kg of carmine is permitted in food products (Codex Alimentarius, 2023). According to the US FDA, carmine is a color additive exempt from certification and can be used in foods under good manufacturing practices (FDA, 2023a, b). As mentioned above, the halal status of carmine is particularly challenging among Islamic countries (Rahim, 2018). Even though carmine is not considered halal in Iran, its use in low quantities in products is exempt from halal restrictions. The food products permitted to use carmine in Iran are presented in Table 2. However, it is prohibited in some other countries (Al-Teinaz, 2020). Given its beneficial

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functional properties, favorable biological activities, and verification by several health agencies, carmine can be used as a safe alternative to harmful additives such as nitrite (Nateghi et al., 2024).

Table 2: List of the food products permitted for carmine use in Iran

Food products	Permitted level
Margarine	Up to 500 mg/kg
Sauce, chewing gum, potato-, bean-, and cereal-based fried foods, breakfast cereals, colored sugar, puffed cereals, candy and toffee, jelly, dragee chocolate, flavored cream, milk dessert, probiotic ice-cream, fruity ice-cream, milky ice-cream, drinkable dairy dessert, non-carbonated fruit drink, herbal extract beverage, iced tea drink, instant beverage powder, carbonated soft drink, edible ice products, fruit juice, syrup of plant distillates, sport, and caffeinated drink	*Quantum satis

* Quantum satis: up to needed amount

Carminic acid and its derivatives have a long history of use in foods and other industries including, textiles, cosmetics, and drugs (Müller-Maatsch and Gras, 2016). Carmine has an intense red color making it a potent candidate for adulteration in natural expensive colorants (Ordoudi et al., 2018). However, its uncertain status limits its widespread use in some countries. Carmine can be used as alternatives for synthetic red colors of erythrosine (E127), allura red (E129), azorubine, carmoisine (E122), ponceau 4R, cochineal red A (E124), amaranth (E123), and iron oxides (E172) (Table 1). Due to individuals' tendency to consume natural additives, the EU has approved and introduced several plant-based red colorants. They include carotenoids (E160) and anthocyanins (E163) derived from various plants, and betalains (E162) mainly derived from red beet. The natural colors lycopene and capsanthin, derived from tomato and paprika, respectively, are red dyes with greater desirability and functionality than carmine (Mariyam et al., 2022).

Possible concerns about carmine

As mentioned earlier, carmine is an aluminum lake complexed with metal ions such as calcium. Therefore, besides its questionable halal status, it is a source of aluminum intake, which is of great concern to consumers (Ordoudi et al., 2018). The allergenicity of carmine is a controversial issue in scientific societies. Carmine is not toxic or carcinogenic and is currently used in foods and beverages in the EU. However, it has caused anaphylactic shock in some people. It was estimated that the shock was due to the impurities, not the dye. The natural colors are small molecules and have non-protein structure. Therefore, it is unlikely to induce immunoglobulin E (IgE)-mediated or cell-mediated allergies. However, natural dyes such as carmine are extracted from biological sources, which may also extract allergenic proteins along with the dye (Greig, 2012). Some adverse effects, including acute allergic reactions, urticaria, rhinitis, nausea, vomiting, asthma, chills, angioedema (localized swelling), and diarrhea have been reported after consuming carmine-containing foods and beverages such as fruit yogurt, alcoholic beverages, orange beverages, strawberry milk, red-colored cocktails, and popsicles (Caro et al., 2012). Undoubtedly, the adverse effects were attributed to the protein molecules in the dye matrix, which can be mitigated by providing a purer dye during extraction. Nonetheless, the addition of carmine to foods and beverages should be mentioned on labels to inform consumers following religious authorities who do not consider carmine as a halal additive.

Conclusion

Food additives are popular in the food industry. They include synthetic, nature-identical, and natural additives. Although synthetic additives are more readily available and cost-effective than their natural counterparts, consumers prefer natural additives because of their low health concerns. Due to the increasing population growth and the limited arable land resources, the development of natural foods and additives is a challenge for the industry. Therefore, the use of potent alternative sources is unavoidable. Carmine is an insect-derived additive available in the Iranian market and other countries. It is widely used as a food colorant, but its halal status is of concern. According to the Iranian religious authorities, the addition of carmine to foods in low quantities does not change the halal status of foods and beverages. The potential of carmine to cause allergenic reactions in people can be mitigated by removing protein impurities during its extraction from the insect. However, the addition of carmine to the edible products should be mentioned on product labels to allow consumers to make informed choices.

Author contributions

M.M. designed the study, and wrote the manuscript; H.R. supervised the work; L.K. conducted the research and collaborated with the religious authorities; N.S. wrote the initial draft and A.A. edited the final draft. All authors read and approved the final manuscript.

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Conflicts of interest

The authors declare that they have no conflict of interest with respect to the content of this paper.

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Ethical consideration

The current work is a qualitative study about halal status of carmine. It does not include any animal and/or human investigation. Therefore, ethical consideration is not applicable for this paper.

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