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Chemical Constituents and Antimicrobial Properties of Saffron: A Review Article

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ABSTRACT

Saffron is the product of the flower of Crocus sativus L. It is well known not only for its culinary uses but also for a wide range of medicinal benefits. The importance of saffron both in ancient medicine and modern pharmacology has attracted attention owing to the richness of its compounds-terpenes and their derivatives. Recent studies have increasingly focused on pharmacological aspects with antimicrobial and antiparasitic properties. This paper tries to make a synthesis based on existing research evidence concerning the antimicrobial and parasiticidal potential of saffron, noting where there are gaps in information and suggesting avenues for further investigation. Also, this paper shall try to make a synthesis based on existing research evidence on chemical constituents aspects of saffron and its antimicrobial property, giving it potentiality as a natural antimicrobial agent.

KEYWORDS

Crocus sativus, Antimicrobial, Antiparasitic, Saffron

INTRODUCTION

Saffron *(Crocus sativus)* is a high-celebrated plant for culinary and medicinal uses since time immemorial. Literature proves a strong relationship between the chemical composition of saffron and antimicrobial properties. Compounds such as crocin and safranal may increase its efficacy as an alternative natural antimicrobial agent, consistent with evidence reported in studies of other phytochemicals having similar properties (Swamy et al., 2016; Parham et al., 2020). This thus places higher pharmacological importance on this matter of saffron concerning antimicrobial resistance, which is an urgent concern worldwide about health (Naylor et al., 2018).

These revelations notwithstanding, considerable gaps exist in the current knowledge of the antimicrobial efficacy of saffron. For example, some studies have pointed it out to be effective against certain pathogens, comprehensive studies that would determine its effect as an antimicrobial across all spectra and various microbial strains are not available. Another area that has not come under much influence is how extraction methods affect the bioactivity of saffron, which in turn could greatly affect its application in clinical settings.

To close the existing knowledge gaps about the antimicrobial potential of saffron, future studies should take a multi-aspect and systematic approach. The most imperative shall be a thorough antimicrobial profiling under which the efficacy of saffron against a wide variety of microbial strains (including multidrug-resistant bacteria and fungi) is tested; this shall also include clarifying its therapeutic spectrum and possible clinical applications. Simultaneously, mechanistic studies are needed to reveal how at the molecular level— whether through cell wall damage, interference with protein synthesis, or quorum sensing inhibition— the bioactive components of saffron like crocin and safranal exert their effects on microbial cells. Further advances are also needed in extraction and formulation approaches to improve the stability, solubility, and bioavailability of compounds isolated from saffron. For example, novel delivery systems (for instance, nanoparticles or emulsions) holding active ingredients could prolong their activity as well as more actively catalyze their action. To bring real-world relevance, clinical trials should be initiated to evaluate the safety and efficacy of saffron in treating infections in humans, thus paving the way for its use as a complementary or alternative therapeutic agent. Finally, comparative studies benchmarking saffron against other popular natural antimicrobials—garlic, turmeric, or green tea—will help place it appropriately within the phytotherapeutic options' landscape and establish its relative advantages and limitations.

Chemical Structure

Saffron is known as the most complex phytochemical composition. Carotenoids, flavonoids, and picrocrocin seem to divide this spice-based compound in terms of flavor, smell, and medicinal value Islam et al., 2020). Actually active ingredients mainly antioxidant components such as crocin, safranal, and picrocrocin (Islam et al., 2020) .Crocin imparts color to the stigmas of the flowers and antioxidant as well as neuroprotective properties are attributed to it. Safranal gives the aroma to Saffron and is mainly an anticonvulsant as well as antidepressant by nature Amin et al., 2015). Picrocrocin bitter-tasting in Saffron otherwise shows antimicrobial potential. The above-mentioned constituents mostly occur in the stigmas of a flower. Their concentration varies with how they are grown plus processed. These compounds constitute the chemistry of saffron's therapeutic potential, such as anti-inflammatory, anticancer, and antimicrobial activities (Khorasanchi et al., 2018). Knowledge of the composition is a prerequisite for any kind of standardization towards medicinal and clinical use.

Safranal results either from the oxidative or enzymatic degradation of zeaxanthin by Crocus sativus stigmas since it is carotenoid contained within them. This compound is one of the primary volatile contributors to saffron aroma. Picrocrocin undergoes degradation during both drying and storage safranal results from this degradation. Post-harvest processing, such as drying, transforms the carotenoid precursors into safranal (Tarantilis et al., 1995).

Crocin, the principal water-soluble carotenoid pigment of Crocus sativus (saffron) is best known for its antioxidant properties as well as anti-inflammatory and anticancer properties. It should be noted that more studies have brought to light its potential antimicrobial activity but comparatively this area is still emerging against other bioactivities.

Picrocrocin, the main bitter principle of Crocus sativus is mostly known as the constituent responsible for the bitterness of saffron and as a precursor of safranal which imparts fragrance to saffron. While the antimicrobial, antioxidant, and anticancer properties of safranal and crocins have been studied quite extensively, available scientific literature does not seem to document adequately the antimicrobial activity of picrocrocin.

It is these bioactive compounds that not only contribute to the organoleptic properties of saffron but also endow it with pharmacological potential, thus making it eligible for further investigation as a natural product (Choudhari et al., 2020). The main bioactive components of saffron are crocin, picrocrocin, and safranal. According to Hosseinzadeh and Nassiri-Asl (2013) the review concentrates mainly on the neurological and psychological effects of saffron, however, it can be inferred that there exist anti-inflammatory and cytotoxic activities which could establish antimicrobial properties. It sets an initiative towards exploring more applications for therapeutic interventions with this herb particularly in infections due to microbes.

Antimicrobial Properties of Saffron

The antimicrobial properties of saffron have been proved by lots of studies which show its effect against a number of microbial pathogens. The mechanisms for these antimicrobial effects are believed to be firstly the disruption of microbial cell membranes and secondly interference with metabolic activities (Gonelimali et al., 2018). Evidence, Gram-positive and Gram-negative bacteria growth can be inhibited by Saffron extracts which reflects its potential as a general antimicrobial agent (Islam et al., 2020).

Saffron presents an unusual spectrum of activity compared to other plant antimicrobials, which it components. For instance, the antimicrobial efficacy of saffron has been reported in comparison with other extracts from plants such as garlic and rosemary, which are also very potent antimicrobials (Nieto et al., 2018; Batiha et al., 2020). However, the exact antimicrobial mechanisms of action of saffron are not taken; this calls for specific investigations directed at its mode of action. Cerdá-Bernad et al. (2020) just a little helpful in understanding the antibacterial properties of saffron and its immunomodulatory effects. They point out that there should be much more research directed toward mechanisms by which material exerts antimicrobial effects against particular bacterial strains. This points to an important area where valuable future research should be directed in order to establish more concrete evidence regarding the utility of saffron in combating bacterial infections .

Boskabady and Farkhondeh (2016) reported antioxidant and anti-inflammatory effects of the saffron and its compounds which may be used as natural food preservatives. From such perspectives, it could be assumed that their main actions would enhance efficacy against various pathogens. Antioxidant action can prevent oxidative damage resulting from microbial infection; this will further strengthen the antimicrobial activity of saffron. The immunomodulatory potential of the components of saffron has been well documented in studies by Mzabri et al. (2019) and Zeinali et al. (2019). According to these reviews, modulation by saffron on immune responses and inflammatory markers may raise the body's capacity to combat infections, including parasitic diseases. From this perspective, it could be further assumed that its therapeutic potential is going to act above direct antimicrobial actions but through enhancing host defense mechanisms.

A major part of saffron belongs to carotenoids. These are a group of pigments present in a wide variety of plants and displaying different antimicrobial activities. Zhang et al., (2021) discusses mechanisms that antimicrobial peptides use to exert their effects and can be similar to those carotenoids. These include actions like attacking cell membranes of microbes, scavenging free radicals, and regulating immune responses. Carotenoids may also act by inducing permeability in microbial cell membranes such that the normal functioning of microbial cells is disturbed, leading to lysis and death of the cells. Another point of view is offered by Vaou et al., (2021), emphasizing how important it is to understand antimicrobial mechanisms when it comes to plant-based compounds such as carotenoids. According to this review, harmful effects imposed by the carotenoids on microorganisms involve very intricate interactions with microbial cells, however not only that but depending on the microorganism involved as well there lies complexity which stresses the importance for further research specifically related pathways through which carotenoids affect microbial viability. Carotenoids from the microalgal biomass have also been proven to possess antimicrobial activity. As Ksouri et al. (2012) puts it, "carotenoids are very important in promoting the health benefits of functional foods and feeds especially in fighting microbial infections". Owing to their bioactive nature, carotenoids should be strategically placed as active ingredients in formulations combating antibiotic resistance. Besides all these, nutraceutical and pharmaceutical applications resulting from antioxidant and antimicrobial effects were assigned to microalgal carotenoid compounds. However, their actual potential as antimicrobials is still largely unexplored, more especially against resistant strains of pathogens. Futureworks should head towards the extraction and use of microalgal carotenoid compounds in commercial products through industrial applications that are already established for essential oils which are well-known antimicrobial agents due to the presence of carotenoids as active constituents Marchese et al., 2017. The very compound nature of these natural products increases their potency against a wide array of microorganisms, thus making them useful assets in food preservation as well as therapeutic applications. Antioxidant properties of carotenoids are presented in the article by Eghbaliferiz and Iranshahi (2016), therefore validating essential oils' antimicrobial effects. Such synergy may aggregate the total antimicrobial effectiveness of essential oils, i.e., a natural solution for food safety and preservation. More research is needed to determine the actual role played by carotenoids in such formulations and more importantly possible synergistic effects with other plant-based compounds. Indeed, while quite promising about the actual antimicrobial capacity possessed by carotenoids, this remains an emerging field with many challenges left to address. Standardized Balouiri et al., 2015; methods for antimicrobial activity are imperative in assessing and validating such efficacy claimed by carotenoids against microbes. An absence of standardized assay methods tended to frustrate cross-study comparisons toward gaining insight into efficacy. Also, Wang and others (2017) talk about the present condition of nanoparticle tech in fighting microbes and say that mixing carotenoids with it might make them better at this. This overlap gives a thrilling path for upcoming studies which might result in new antimicrobial helpers. Another main spot for future looking into is making better ways to take out carotenoids. As Pandey and others (2017) show, better ways to extract can greatly affect both the amount and cleanness of carotenoids thus making their ability to fight microbes stronger.

While most of the current writings highlight the antibacterial nature of saffron, very little research has emphasized its antiparasitic property. The paper by Abu-Izneid et al. (2020) mentioned the uses of saffron in traditional medicine, which could include antiparasitic uses. But there is not enough empirical data to support such claims. Future studies may be conducted on the efficacy of saffron against common parasites and thus extend its therapeutic applications.

CONCLUSION

Saffron opens a bright path toward the study of natural antimicrobials since it is rich in chemicals and has shown pharmacological actions. This will become even more relevant as the world faces an uptrend in antimicrobial resistance. Thus, further properties of saffron may give new insights into alternative therapeutic strategies. Filling these gaps will harness the use of saffron to the maximum as a natural antimicrobial agent. Proven to be effective against microbes and parasites, *Crocus sativus* should be researched more extensively. Though this has already been established by existing literature, which thus laid a solid base for studying its pharmacological properties, there still exist enormous gaps that when filled would place saffron unequivocally as a desirable therapeutic agent within modern medicine for combating microbial and parasitic infections.

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