

# An Overview on Flavor Extraction, Antimicrobial and Antioxidant Significance, and Production of Herbal Wines

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Cite This: *ACS Omega* 2024, 9, 16893–16903

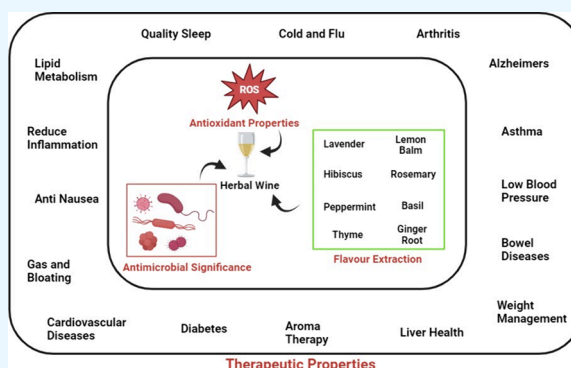
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**ABSTRACT:** Wine has been utilized as a source for medicinal preparations, combined with various herbs, to treat particular ailments and disorders. By utilizing herb extracts, regular but limited consumption of these herbal wines helps to decrease the need for prescription medications to treat a variety of ailments. The diversity and the composition of the yeast micropopulation significantly contribute to the sensory characteristics of wine. A particular metabolic activity characterizes the growth of each wine yeast species, which determines the concentrations of flavor compounds in the final wine. Numerous herbs, such as tulsi, ginger, aloe vera, tea, amla, lemongrass, and peppermint, are used in the preparation of herbal wines, where either the herb or herbal blends are primarily used as the substrate. The variants provided improved accuracy, increased acceptability, and broader uses for the novel product. Herbal wines pave the way to provide nutraceuticals to consumers and protection against pathogenic microorganisms and inflammation through their richness in antioxidants. The existing herbal wines and their health advantages are discussed in this Review, along with some new directions for the herbal wine business.



## 1. INTRODUCTION

Wine is categorized as a fermented food. It is a type of alcoholic beverage that is prepared from fermented grapes. It is thought to be the earliest beverage, also known as one of the ancient fermented commodities. Different grape varieties and yeast strains produced different wine varieties. Fermentation is a relatively efficient, low-energy preservation procedure that improves shelf life and reduces the need for freezing or other technology to preserve food.<sup>1</sup> Wine has been made from grapes right from the ancient era by fermenting the grapes for a particular period and then aging them in barrels of oak followed by placing them in wooden blocks enclosed with leather fabric to increase their flavor profile.<sup>2</sup> The juice of grapes is fermented with different strains of *Saccharomyces cerevisiae* (yeast), also producing alcoholic fruit wine with a subsequent aging process.<sup>1</sup> Different fruits, such as apples, apricot, kiwi, strawberries, etc., are transformed into wine. These wines are made up of different grapes that are partially or entirely fermented. Certain biologically active compounds are released into wine during fermentation. Ethanol production during fermentation allows fragile and bioavailable polyphenols and bioactive components to be accessible during absorption.<sup>3</sup> Wine provides the effects of stimuli required for physiological processes, like digestion and absorption.<sup>4</sup> Fermentation is biotechnology where suitable microorganisms are used in the

production of value-added items that pose various commercial benefits and interests. In warm conditions, aerial yeasts activate and convert sugar into alcohol and carbon dioxide. Alcoholic drinks have been produced in various societies for centuries.<sup>5</sup> Fermentation is a relatively efficient, minimal-energy preservation process that improves shelf life and eliminates the need for cooling and other preservation equipment. The fermentation process eventually feeds sugars and nutrients in a leavening solution, which returns favor through the processing of carbon dioxide gas and alcohol. This process continues until either the sugar is consumed or the yeast cannot tolerate the alcoholic amount of the beverage. Different yeasts yield different effects and have different tolerance rates. Different from other alcoholic drinks, wine shows good health and well-being effects, improving reflection and relaxation when consumed in the correct dosage.<sup>6</sup>

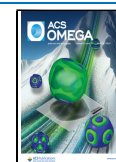
This Review includes the different types of wines that are available and their differences. Herbal wine has more medicinal

Received: December 11, 2023

Revised: March 9, 2024

Accepted: March 15, 2024

Published: April 2, 2024



properties compared with normal wine; the flavors of the herbs used are extracted from different methods, and each one of them has its own advantages and disadvantages. This Review also provides information about the processing of herbal wine and its antimicrobial, antioxidant, and antiaging properties, which increase the therapeutic value of the herbal wine. Different ranges of herbs are used in the processing of herbal wine, and each one of them is rich in a variety of bioactive components.

## 2. DIFFERENT TYPES OF WINES AVAILABLE IN THE MARKET

The sector of the alcoholic beverage industry that specializes in wines infused with different herbs, botanicals, and spices is known as the herbal wine market. These wines, which are made with herbal elements, frequently have distinctive flavors and are said to have health benefits. An explanation of some facets of the market for herbal wines is provided below.

**2.1. Product Variety.** There are many different types of herbal wines, from ancient recipes that have been handed down through the years to contemporary versions created by creative winemakers. They can contain a variety of herbs, each of which gives the wine a unique flavor and aroma, such as hibiscus, ginger, lavender, rosemary, and chamomile.<sup>1</sup>

**2.2. Trends in Health and Wellbeing.** Due to their apparent health benefits, herbal wines have become more and more popular as interest in health and well-being has grown. Numerous herbs employed in these wines have therapeutic qualities linked to them, including the ability to improve digestion, lower stress levels, and induce relaxation. Herbal wines fit into the growing trend of customers looking for natural and useful beverages.<sup>7</sup>

**2.3. Craft and Artisanal Production.** Smaller, artisanal wineries or craft breweries that focus on unusual and experimental concoctions are frequently the producers of herbal wines. The focus on authenticity and craftsmanship appeals to those seeking unique premium goods.<sup>8</sup>

**2.4. Cultural and Historical Significance.** In many parts of the world, herbal wines have a rich cultural and historical background. For instance, European nations like France and Italy have extensive histories of manufacturing herbal liqueurs and aperitifs, and Chinese traditional medicine has long included herbal-infused wines.<sup>9</sup>

**2.5. Marketing and Positioning.** Businesses in the herbal wine industry frequently use the botanical and natural elements of their products in promotional efforts. They might draw attention to the wines' traditional winemaking techniques, as well as the use of organic or locally produced components. Furthermore, the luxury and handmade aspect of these products is communicated through branding and packaging, which is essential.<sup>10</sup>

**2.6. Consumer Demographics.** Although the target market for herbal wines varies, it frequently consists of people who are curious about unusual flavor profiles, adventurous in their culinary endeavors, and health-conscious. Products that offer authenticity, sustainability, and a link to cultural history particularly appeal to millennials and younger generations.<sup>11</sup>

**2.7. Regulatory Considerations.** Depending on the jurisdiction, laws governing alcoholic drinks and food products may apply to the manufacturing and marketing of herbal wines. For enterprises to operate in this market, compliance with alcohol content restrictions, labeling standards, and health claims is crucial.<sup>12</sup>

**2.8. Market Growth and Outlook.** Although they still only make up a small portion of the overall wine business, herbal wines have steadily expanded in recent years. The market for herbal wines is anticipated to grow as customers look for more creative and health-conscious beverage options. This will present chances for product development and innovation.<sup>13</sup>

All things considered, the herbal wine market presents a fascinating fusion of heritage, creativity, and health consciousness, attracting customers seeking out unusual tastes and all-encompassing experiences in their drinks. There are different types of wines, such as natural wines like sweet table wine, specialty wine, champagne, Muscat, dry wine, and burgundy wines and dessert and appetizer wines like cherries, sweet wine, dry wine, port wine, and vermouth port wines.<sup>14</sup> The simple classification is like mainly the classification into grape and nongrape wine, then the nongrape wine is again classified into table wine, fruit wine, fortified wine, medicinal wine, sparkling and still wine, and dessert wine.

**2.9. Grape Wine.** Grape wine comes under the type of wine known as the table wine category and is developed using fermented yeast crops and grapes. It could be made from white grapes or black grapes. Grape wine is classified as table wine (Figure 1) and is developed by yeast and grape varieties using alcoholic fermentation (it may be green or black). There is a variety of red and white wines.<sup>15–17</sup>

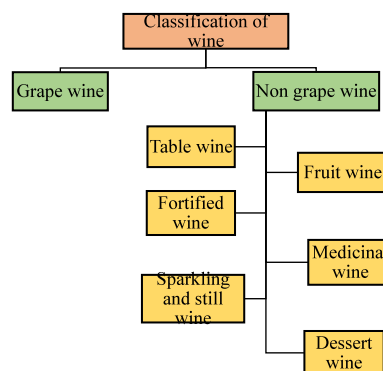


Figure 1. Classification of wine.

**2.10. Nongrape Wine.** Fruits are grown worldwide. Specific fruit depends on the climatic conditions and the environmental capital. They are collected in large quantities and are of great benefit to their respective region. The fruits are consumed widely and exported transnational. Fruit not only contributes to novel winemaking but also increased waste management.<sup>5</sup>

**2.11. Fruit Wine.** Fruit wine is made from various fruits other than grapes, such as apples, peaches, blueberries, black pear berries, plums, grenades, bananas,<sup>2</sup> and oranges. Fruit wines have recently gained popularity as health-promoting functional foods.<sup>18</sup> Several studies have indicated the potential for generating health-enhancing functional fruit wines by combining medicinal herbs with fruit juice.

**2.12. Table Wine.** Table wine includes white wine, red wine, and cider (apple cider, etc.), which are the most popular and best-selling wines. Sparkling champagne with the touch and sound of a soft drink is attractive for consumers. Table wine is a wine of low cost that often does not specify the varieties of grapes used or the region of origin.<sup>19</sup>

**2.13. Fortified Wine.** Fortified wine is classified as special essence aromatized wine and includes vermouth, which is either herb-flavored sparkling aromatized wine or some other aroma and taste flavor, including commodity. Sweet or dry vermouth is present in wine. Port, madeira, sherry, and marsala are the best-known fortified wines.

**2.14. Medicinal Wine.** Medicinal wine has medicinal properties and is typically infused with herbs and medicinal plants. Wine act as medicine; for example, low to moderate intake of red wine with food and virgin olive oil has been documented to prevent cardiometabolic diseases, including CVD, T2DM, MetS, and obesity.<sup>13</sup>

**2.15. Sparkling and Still Wine.** Sparkling wine includes CO<sub>2</sub> that is created naturally by fermentation or later by pressure injection. A substantial yet subsaturated concentration of carbon dioxide (CO<sub>2</sub>) is present in still wine.<sup>14</sup> For this reason, the wine is fermented twice; when in a bottle, the gas is caught and remains in the wine.

**2.16. Dessert Wine.** Desert wine varies slightly from mild (less than 50 g/L sugar) to extremely sweet wines of more than 400 g/L sugar.<sup>2</sup>

### 3. DIFFERENT METHODS OF FLAVOR EXTRACTION FROM HERBS

There are a number of methods by which the flavors can be extracted from herbs, such as the direct extraction method,<sup>15</sup> the concentrate extract method, maceration,<sup>16</sup> ultrasound- or microwave-assisted extraction,<sup>17,18</sup> and infusion and decoction.<sup>19</sup>

**3.1. Direct Extraction.** In this technique, the used herbs are usually pulverized and weighed before being added to the base wine for a determined amount of time while stirring.<sup>20</sup> To improve the flow of aroma from the herbs to the base wine, it is better to employ a fine herbal powder. The base wine may either be heated or kept at room temperature, while spices or herbs are used to aromatize it. Nevertheless, heating the wine usually increases the rate of the flavor's migration to the wine.<sup>21</sup>

**3.2. Concentrate Extract Method.** Concentrated extracts are made by placing the herbal material or mass in a specific vessel and circulating the base wine through it until the flavorants are extracted. The extract is utilized to flavor the bulk of the base wine. During the extraction procedure, the wine is frequently heated.<sup>22</sup>

**3.3. Maceration.** To perform a maceration, base wine and herbal mixtures are put at 60 °C and left to macerate for 3–4 weeks until they become fortified wine. The obtained wine with herbs is decanted and permitted for to stand for 10 days. Other times, herbs and seasonings are placed in solvents like ethanol or any other organic solvent, and the resulting herbal extract is then added to the wine to confer flavor and health benefits.<sup>23</sup>

**3.4. Ultrasound- or Microwave-Assisted Extraction.** These methodologies are innovative technologies that incorporate the use of ultrasound or microwaves in the extraction process. For that, a procedure similar to the maceration protocol described is used, along with the incorporation of ultrasound or microwave waves. This helps the base wine absorb the herbal flavors and also shortens the extraction times. These processes are widely used mostly to extract and produce small quantities of products but can be scaled for incorporation in the wine industry.<sup>23</sup>

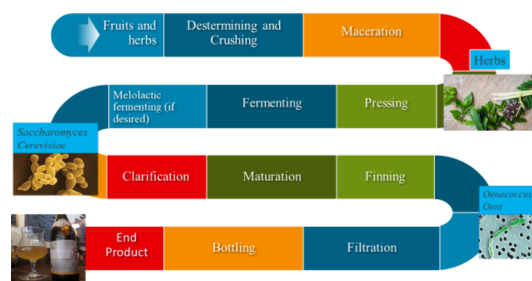
**3.5. Infusion.** The extract is prepared by putting the herbs and spices in a container, and the extract is passed through the base wine in the container until the maximum flavor is obtained or extracted by the base wine.<sup>23,24</sup>

Infusions are a simple extraction method that allows for the extraction of a water-soluble compound from a plant matrix. They are performed by macerating the crude plant with hot or cold water for a fixed amount of time, resulting in a diluted solution of the numerical compounds available in the plant material. One of the standard protocols used is a treatment for 15 min with cold water, followed by treatment with boiling water for 30 min, all under agitation. The main disadvantage of infusions is that due to their high water content they are very prone to bacterial and fungi growth, which does not allow for long shelf life and is the reason why this method is not commonly used by industries.<sup>25</sup>

**3.6. Decoction.** Decoction of herb flavor and aroma can be obtained by keeping herbs in heated water.<sup>23</sup> It is an extraction method similar to infusion used specifically for water-soluble compounds. The process usually takes a longer time but can produce a high yield of hydrophilic compounds. The method is suitable for thermostable compounds, as the high temperature can denature other thermosensitive substances. In decoction, the plant material is added to a fixed volume of boiling water at a predetermined temperature and time. Since the method is usually performed in an open extractor, the solution reduces to 1/4 its initial volume, subsequently concentrating the extract compounds. Finally, the end resulting crude extract is strained, filtered, or centrifuged to eliminate the mark (solid residue) in suspension.<sup>25,26</sup>

The method has been widely reported for the development of remedies containing beneficial compounds in Chinese medicine. Unlike previous methods, which consisted of chewing and swallowing, decoction enables the delivery of higher concentrations of therapeutic compounds more efficiently, translating to its excellent medicinal properties.<sup>27</sup>

**3.7. Production of Herbal Wine.** Herbal wines are alcoholic beverages made primarily of herbs including amla, aloe vera, holy basil, lemongrass, peppermint, cinnamon, elderberry, ginger, and others.<sup>28</sup> There is evidence from the Palaeolithic era of herbal use where herbs for spice extraction were subjected to steeping and straining and maintained for fermentation or the production of alcoholic drinks. Nowadays herbal-infused wine is a novel trend consumed either in the liquid form or in the dried form. Figure 2 shows a schematic outline of a typical nutraceutical herbal wine processing. Homemade wines have a comparatively low alcohol level compared to commercial wine. Unlike commercial wines that require storage preservatives, the therapeutic compounds



**Figure 2.** Schematic overview of nutraceutical-activated herbal wine production.

Table 1. Nutraceutical Properties and Significance of Wines Made Using Different Herbs

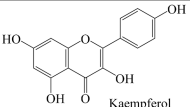
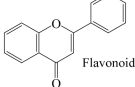
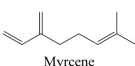
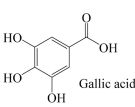
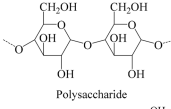
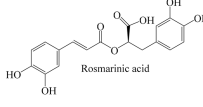
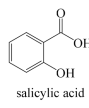
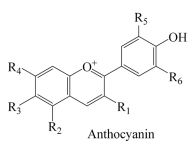
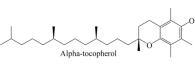
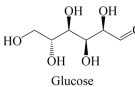

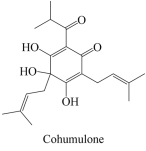
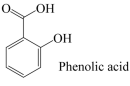
herb name	medicinal use of herb	herb's part	significance or observations	ref
tea ( <i>Camellia sinensis</i> )	tea is known to reduce coronary heart disease risk, type 2 diabetes, atherosclerosis, obesity and cardiovascular disease	tea extract	<i>Combrētum micranthum</i> G. Don may be useful in the treatment of insulin-resistant diabetes	45, 46
aloe vera with juice of cane sugar	aloe vera has many pharmaceutical properties such as antimicrobial, antiaging, laxative, antiulcerative, and healthy dermatological effects to the consumers	leaves	aloe vera infused with cane sugar was found to exhibit antimicrobial, antiaging, laxative, healthy dermatological, and antiulcerative activities	47, 31
lemon grass, peppermint, ginger, and holy basil (supplemented with orange juice)	lemon grass has many pharmaceutical properties such as antioxidant, anticancer, antifungal, antioxidant, active against respiratory obstruction, and increasing conditions such as cough and cold, as well as the capacity to balance glucose and lipid	leaves	lemon grass with other herbs infused with orange juice herbal wine was found good in terms of fragrance and highest in taste quality in all sensory parameters	24
wild berries <i>Pyrus pashia</i> , <i>Actinidia deliciosa</i> , <i>Syzigium jambos</i> , <i>Prunus cerasoides</i> , <i>Rubus ellipticus</i> , <i>Craetagus</i> species	wild berries have the capacity to reduce increased kapha and pitta, and berries used in wine are helpful in pregnancy by uterine preparation and strengthening; they give positive effects when consumed in small amounts, demonstrating antifertility results and wound healing, antidepressant, antioxidant and antidiabetic characteristics	berries	herbal wine infused with wild berries was found to have the highest volume of polyphenols measured as the cumulative count of phenols; <i>Emiblica</i> wine and <i>Prunus cerasoides</i> wine showed the best results	48
blue water lily ( <i>Nymphaea lotus</i> ) used with cassava starch	blue water lily is used for dyspepsia, dysentery, and treating indigestion, and the leaves of lily serve as a refrigerant in skin diseases; it exhibits therapeutic action against hepatic and urinary disorders and menstrual problems	stamen bud	blue water lily-infused wine shows medicinal properties for the treatment of diabetes and inflammation; it tastes bitter and is a good tonic for health and was tested with 14% ethanol	49
hibiscus flower petal ( <i>Hibiscus Rosa-sinensis</i> )	hibiscus flower has antifertility, soothing, antidepressant, antioxidant, and antidiuretic properties	petals of crushed dried flowers	herbal wine infused with hibiscus flower petals was tested with a 11.50% ethanol content, which was powerful among the all herbal wine produced	1, 50
purple sweet potato ( <i>Ipomoea batatas</i> ) used and mixed with 18 different herbs	purple sweet potatoes are rich in anthocyanin, and antioxidants	roots	wine produced by purple sweet potato infused with 18 different herbs was tested with 8.61% ethanol; the aroma and flavor of the wine was appealing, and it had a dark color	51
garlic ( <i>Allium sativum</i> )	garlic has medicinal properties such as activity coronary disease, hyperlipidemia and hypertension, Alzheimer's disease, cancer, and microbial activity and has dermatological applications	bulb	garlic-infused herbal wine exhibited antimicrobial properties	48
hops ( <i>Humulus lupulus</i> )	hops have medicinal properties such as promoting sleep and relaxation, anti-inflammatory effects, antimenopausal effects, anti-HIV-1 activity, antiaacne effects, weight control, and cardiovascular well-being enhancement	the female flowers	used primarily as a bitterness, flavoring, and stability agent in wine; in addition to bitterness, they hey impart floral, fruity, or citrus flavors and aromas	48
aloe vera ( <i>Aloe barbadensis</i> )	aloe vera has many medicinal properties such as antibacterial, antifungal, antiviral, and anti-inflammatory effects, as well as properties of tissue regeneration, gastrointestinal impact, and antiarthritis impact	aloe leaves (gel)	aloe vera-infused herbal wine demonstrated antibacterial, antiviral, and antiseptic properties and was tested with 8.52% ethanol	1, 43
amla, Indian gooseberry ( <i>Emiblica officinalis</i> )	amla has numerous health benefits for hair growth and eyesight and is a good source of vitamin C; it regulates bowel movements and is effective against stomach ache and constipation disorders	whole berry	amla-infused herbal wine was found to be neuro-protective and rich in antioxidants; it tested with 11.4% ethanol	31, 52
ginger ( <i>Zangiber officinale</i> )	ginger has numerous benefits such as controlling the level of glucose and lipid, being rich in antioxidants, demonstrating anticancer and antifungal effects, effectiveness against respiratory obstruction, and reducing illnesses such as cough and cold	roots	ginger infused in herbal wine serves as a potent antioxidant that repels bacteria from the body; it tested with 4.8% ethanol	24
peppermint ( <i>Mentha arvensis</i> )	peppermint has various medicinal uses as an antiviral, antifungal, and antibacterial agent; it is effective against breathlessness and reducing illnesses such as cough and cold	whole herb	peppermint-infused herbal wine was found to contain phytonutrients and antioxidants; it tested with 12% ethanol	24,53
lemon grass ( <i>Cymbopogon citratus</i> )	lemon grass has many medicinal powers against gastrointestinal problems, fever, and cancer	herb	lemon grass-infused wine was found to have a pleasant fragrance, with the max scored	24



present in herbal wine preserve quality and reduce the harmful effects of the product. The evidence of herbal integration into ancient alcoholic beverages was observed from the chemical analysis data of ancient earthenware. The investigation has shown the use of tree resin in wine to prevent pathogen propagation. Evidence of natural fragrance additives in alcoholic formulations of native species such as rice, wheat, and millet has also been reported in China.<sup>29</sup> Different varieties of herbs are crucial for enhancing the wine flavor. Abydos juice, a native rosemary herbal tea, and mint combined with thyme were added to certain fermented drinks (Spain's malted wheat and barley), which is considered to be part of Egyptian winemaking and tradition.<sup>30</sup> Present research that carefully examines the volatile chemicals and metabolites in jujube wine was performed using HS-SPME-GC-MS and UHPLC-MS metabolomics.<sup>31,32</sup> This yields important insights into the fermentation process and the flavor profile of the wine. This thorough study not only improves the comprehension of the sensory characteristics of jujube wine but also helps to optimize its production processes, which may open the door to the creation of premium jujube wine varieties. Furthermore, aloe vera is well-known for its anti-inflammatory, antioxidant, and wound-healing qualities in medicine and has been adopted for its application in the production of herbal wine. The study determines whether it is feasible to use aloe vera in winemaking to produce a unique beverage with possible medicinal benefits.<sup>33</sup> The researchers describe in detail how aloe vera juice is fermented into wine, emphasizing the conditions and characteristics of the fermentation process that are required for the best outcomes. In order to determine the major bioactive components in aloe vera that contribute to the plant's potential health benefits, the researchers also conduct a chemical analysis of the herbal wine. The research also examines the herbal wine's sensory qualities, rating its flavor, aroma, and general appeal. The study also looks at the possible healing benefits of drinking aloe vera wine and makes suggestions for how it may be used to advance wellbeing and health.<sup>34–36</sup>

**3.8. Therapeutic Properties of Herbal Wine.** Before the onset of modern medicines, people were treated with herbal formulations derived from plants. Regular consumption of herbal wine can benefit from these advantageous extracts. Furthermore, limited usage of herbal wines reduces the dependency on prescription drugs to treat various disorders.<sup>31,33</sup> Herbs play an important role in maintaining good health and well-being (Table 1). They are reported to possess antimicrobial and anticancer properties.<sup>37</sup> Currently, infusion of herbs in alcoholic drinks has been demonstrated to lower hypertension and increase overall metabolism.<sup>32,38</sup> Herbal wines are rich in polyphenols and tannins and have lower titratable acidity. The presence of sulfur esters and aldehydes in herbal extracts is responsible for the medicinal and nutritive value of the herbal wines. Additionally, tannins and hydroxyl groups present in herbs possess astringency and also have antioxidants and fragrance intensification properties.<sup>39</sup> Herbal extracts also contain oxygen inhibitors from seeds, bark, and leaves, fruits, stems, and roots. Red wines, being a major source of oxygen inhibitors, have been demonstrated to delay aging and protect against many diseases.<sup>40</sup> They also have been reported to prevent ovarian cancer, prevent heart attacks by maintaining healthy coronary arteries, strengthen bones and the body as a whole, detected cancer cells, and reduce ovarian and lung functions.<sup>41</sup> Secondary compounds such as alkaloids,

**Table 2. Phenolic Compounds and Antioxidant Constituents Present in Winemaking Herbs<sup>5468</sup>**

Herb	Phenols and other chemical compounds	Chemical Structure	References
Tea	Tea leaves mainly contain phenolic compounds such as epigallocatechin gallate (EGCG), epigallocatechin, epicatechin gallate, epicatechin, and flavanols (kaempferol, quercetin, astragalol and myricetin).		50,51
Aloe Vera	Aloe-vera leaves are rich in tannin, phlobatannins, saponin, flavonoids (kaempferol, quercetin and miricetin), steroids, terpenoids and cardiac glycosides anthraquinones used for medicinal purposes.		52,53
Lemon grass	Lemon grass contains flavonoids and phenolic compounds such as gallic acid, flavanol, quercetin, flavone, catechin etc. Monoterpenes, Myrcene, linalool, neral and nerol etc are the main constituents of essential oils.		54
Peppermint	Peppermint contains phenolic compounds like gallic acid, caffeic acid, eugenol chlorogenic acid and rosmarinic acid.		55
Ginger	Ginger contains terpenes, polysaccharides, lipids, organic acids, and raw fibers.		56
Holy basil	Holy basil contains many phenolic compounds and flavonoids like rosmarinic acid, rutin, gallic acid, quercetin, caffeic acid, chlorogenic acid and kaempferol etc.		57
Wild berries	Wild berries contain principal phenolic compounds such as myricetin, ellagic acid, rutin, salicylic acid, ferulic, epicatechin, and chlorogenic acid etc. Flavonoids presenting as aglycone, glycosides and methylated derivatives in wild berries.		58,59
Blue water lily	Blue water lily flowers contain flavonoids such as anthocyanin, flavones, gallic acid, corilagin, astragalol, kaempferol, isokaempferide, and quercetin.		60
Hibiscus	Hibiscus flowers contain phytochemicals with inherent antioxidant properties like $\alpha$ -tocopherol, ascorbic acid, carotenoids and flavonoids (quercetin, myricetin, ellagic acid, rutin and kaempferol 3-O-glucose).		61,62
Purple sweet potato	Main components present in purple sweet potato are carbohydrates 60 to 70%, starch, glucose, amylase etc.		63
Garlic	Garlic contains sulphur containing non-volatile amino acids, thiosulfinate or S-allyl-cysteine sulfoxide (ACSO) comprises most predominant garlic flavors precursors. it has many phenolic compounds (vanillic acid, caffeic acid, ferulic acid, sinapic acid) and anthocyanins.		64
Hops	Principal phenolic compounds present in hops are quercetin 3-hexoside, quercetin 3-acetylhexoside, kaempferol-3-hexoside, xanthohumol, catechin, epicatechin, and multifidol. Hops contain humulone, and cohumulone, which has strong estrogenic properties.		65,66
Amla	Major compounds present in amla are hydrolysable tannins, anthocyanins, flavonoids, and phenolic acids. Few phenolic compounds present in amla are gallic acid, para-caumaric acid, ferulic acid, caffeic acid, rutin hydrate, ellagic acid and catechin hydrate.		67,68

glycosides, phenols, and steroids are metabolically active and can induce varied and profound phenotypic and genotypic changes among consumers.<sup>42</sup> A study conducted to show the interactions of herbs with human cells and enzymes has been demonstrated to promote blood purification, antimicrobial

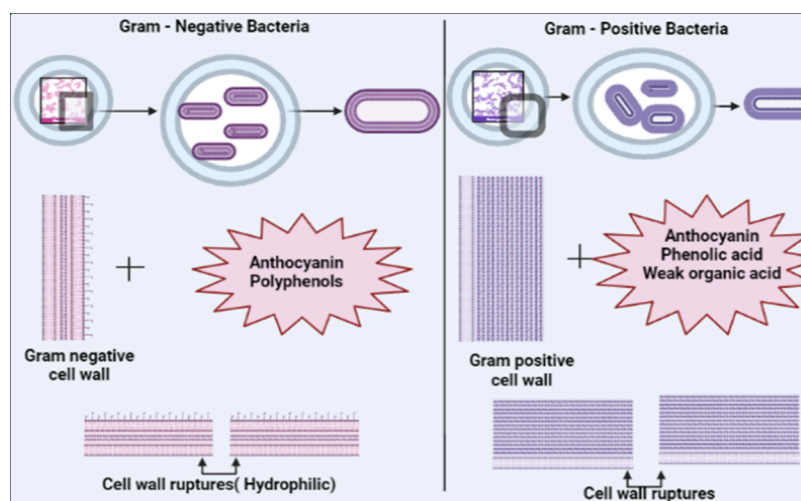


Figure 3. Action mechanism of antimicrobial activity.

activity, optimization of cardiovascular function, and body weight maintenance. India has developed proof of Ayurvedic knowledge in which it has been found that spices, herbal powders, and liquid herbal formulations are effective against mild to fatal diseases.<sup>43</sup> Traditional uses confirm the infusion of coriander with beer or other sweet formulations such as honey and flax seeds for homemade treatment of hemorrhoids. Herbal wines are capable of decreasing the blood sugar level and the amount of glucose in the body. The herbs have also proved effective in regulating enzyme secretion and reversing chromosomal damage by radiation and DNA repair.<sup>38,39,44</sup>

### 3.9. Antimicrobial Significance of Herbal Wines.

Herbal wine has been used as a therapeutic agent against several pathogens. Polyphenols and anthocyanin components of wine are effective against gastrointestinal pathogens such as *Campylobacter jejuni*, *Escherichia coli*, *Salmonella*, *Staphylococcus aureus*, and *Listeria*.<sup>69,70</sup> Wine can be used as an antiseptic agent in wound dressings.<sup>71</sup> It was found that the organic acids in tested wine were responsible for the antibacterial actions against oral streptococci.<sup>71</sup> The major antimicrobial property of wine is due to the synergistic effects of ethanol, organic acids, and low pH. The study shows that the antimicrobial property of six red wines significantly corresponded to the total phenolic and monomeric anthocyanin content.<sup>70,72</sup> The aqueous and ethanol solutions of wine demonstrated negligible activity against *Salmonella enteritidis* when applied independently, while combinations of ethanol and organic acids indicated strong microbial action against *Listeria monocytogenes*, *S. aureus*, *Salmonella typhimurium*, and *E. coli*.<sup>73</sup> Few wine mixtures were found to be active against foodborne pathogens like *Bacillus cereus*, *E. coli*, *Staphylococcus enterica*, and *L. monocytogenes*.<sup>74</sup> The relative antimicrobial property of red wine was found for mutations combining olive and green tea extracts with oregano and lemongrass, respectively, at pH 3.6 and 7.0.<sup>75</sup>

**3.9.1. Mechanism of Action.** Herbal wine blends the medicinal qualities of many different plants and long-standing winemaking traditions. They have a complex mechanism of action against microorganisms. Fundamentally, this strength is derived from the combined effect of the bioactive substances present in the wine and the herbs that are infused into it. First off, the main alcohol in wine, ethanol, is a strong antibacterial agent that works by rupturing the membranes that surround

microbes, damaging their structural integrity and impairing their ability to operate. Furthermore, the inclusion of herbs in the wine yields a multitude of secondary metabolites, including flavonoids, polyphenols, and essential oils, all of which enhance the wine's antimicrobial activity<sup>76</sup> (Figure 3). Rich in both wine and herbs, polyphenols have antibacterial qualities through cellular disruption, oxidative stress induction, and inhibition of microbial enzyme activity. Moreover, flavonoids included in herbs act as antibacterial agents by rupturing the membranes surrounding microbial cells and interfering with essential biological processes. The volatile chemicals found in essential oils, which are derived from herbs, have strong antimicrobial effects. They can damage microbial membranes, stop microbial enzymes, and obstruct microbial cell signaling pathways. Herbal wine is not just a tasty drink but also a powerful weapon against microbes because of the way ethanol and the wide range of bioactive chemicals extracted from herbs work together to create a potent antimicrobial defense mechanism.<sup>77</sup> Gram-negative bacteria are inhibited by herbal extracts rich in polyphenols and anthocyanins, whereas Gram-positive bacteria are not. This is due to the structural variation cell wall structures between Gram-negative and Gram-positive bacteria, with the outer membrane of Gram-negative bacteria acting as a preventive barrier against hydrophobic compounds but not hydrophilic compounds. These antimicrobial activities of polyphenol extracts may be due to the multiple mechanisms and synergistic effects of various phytochemicals in the extract, such as anthocyanins, weak organic acids, phenolic acids, and their mixtures of different chemical forms. Rather than concentrating primarily on anthocyanins, the antibacterial activity of chemically complicated substances should be thoroughly studied. Furthermore, the key bioactives in preventing microbial infection are anthocyanins present in purple, red, and blue fruits, and vegetables.<sup>78</sup>

**3.10. Antioxidant Significance of Herbal Wine.** Red wine, polyphenols, and natural phytochemicals all seem to have great potential for preventing, delaying, or blocking the development of cancer. Wine is a rich source of antioxidants like anthocyanins, oligomeric, polymeric pro-anthocyanidins, and phenolic acids, among others (Table 2). Many of these compounds have been reported to have multiple biological activities, including cardioprotective and anti-inflammatory activity.<sup>79–81</sup> Due to the presence of antioxidants, the

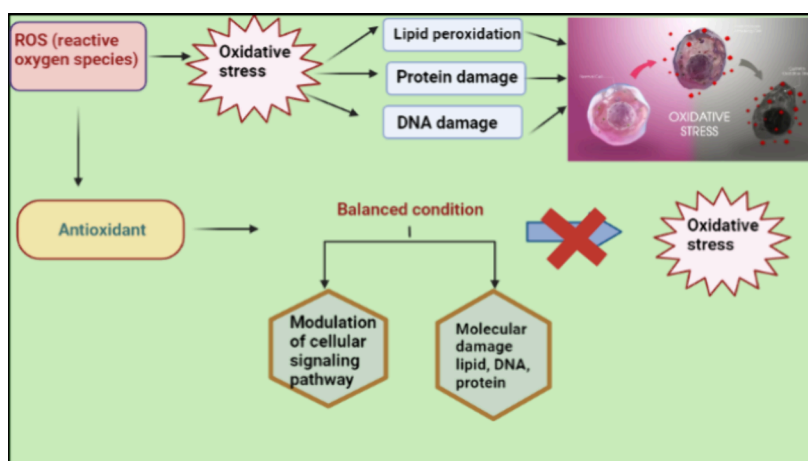


Figure 4. Action mechanism of antioxidant activities.

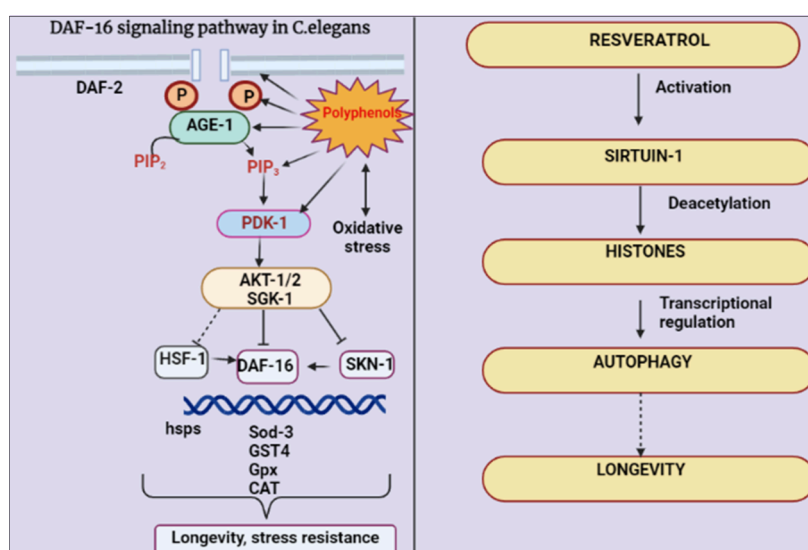


Figure 5. Action mechanism of antiaging.

moderate consumption of red wine has reduced the risk of many diseases such as the risk of coronary heart disease, atherosclerosis, and cancers.<sup>82</sup> Epidemiologists have observed that the presence of antioxidants in wine may have a positive effect. Antioxidants present in wine play a functional role against free radicals and show a physiological role in increasing the antioxidant capacity in the human body after wine consumption. The consumption of wine reduces the risk of platelet aggregation.<sup>1</sup> Khoo et al. stated in their study that consuming wine is associated with a lower risk of mortality from cardiovascular diseases owing to the antioxidant potential of the phenolic compounds from wine. These compounds not only contribute to the color and flavor but also eliminate the formation of free radicals, which can cause disease and aging. Anthocyanins have an antiangiogenic effect, and several berries (bilberry, wild blueberry, cranberry, elderberry, and strawberry) are the good source of it.<sup>83,90</sup>

**3.10.1. Mechanism of Action.** To maintain proper cell signaling, several radical scavenging enzymes maintain a threshold amount of reactive oxygen species (ROS) inside the cell. When the level of ROS reaches this threshold, however, the cell may receive too many messages as well as direct damage to crucial components in signaling pathways.

Oxidative stress occurs when the balance of ROS generation and detoxification favors an increase in ROS levels, disrupting cellular function. ROS can also cause irreparable damage to important macromolecular targets, such as DNA, protein, and lipids, leading to cancer. ROS concentrations must be controlled by a number of defenses systems<sup>84,85</sup> (Figure 4). The mechanisms that antioxidant defense follows are as follows: (1) preventing the production of free radicals by oxidants, (2) the process of converting toxic free radicals into less toxic substances, (3) blocking the production of secondary toxic metabolites and mediators of inflammation, (4) suppressing secondary oxidant chain propagation, (5) restoring the damaged molecules, and (6) activation and enhancement of the endogenous antioxidant defense system. All of these defense mechanisms work together to protect the body from oxidative stress.<sup>86</sup> The neuroprotective and antioxidant effects of polyphenols are also achieved due to the ability of anthocyanins and phenolic to absorb rapidly and cross the blood–brain barrier (BBB). Anthocyanins can exert antioxidant activity as direct scavengers of ROS because they can reach the brain in their native form.<sup>87</sup> The antioxidant mechanism of phenolic compounds can be summarized as a transfer based on hydrogen atoms or a single electron transfer



through protons; nevertheless, catechins and theaflavins may also stimulate the generation of ROS in the body.<sup>83</sup>

**3.11. Antiaging Properties.** Aging is associated with a decline in the function and character of the body's physiological, physical, and cosmetic characteristics.<sup>88</sup> Herbal product employment strategies for the treatment and prevention of aging skin are based on their potential activities as antioxidants, anti-photoaging agents, anti-inflammation agents promoters of skin cell proliferation, modulators of collagen and elastin synthesis, or inhibitors of melanin production. Polyphenol compounds, depending on their structure, can act as antioxidants through radical scavenging or as oxidized pro-oxidants via phenoxy reactive radicals intermediate quinones or quinone methides.<sup>89</sup> Polyphenol antioxidant activities have been reported to be more effective than vitamin E and C commonly used as topical formulations in the production of effective antiaging agents. Flavonoids and phenolic acids can capture free radicals while also acting as chelators for metal ions such as iron and copper, which can initiate the formation of reaction free radicals. Furthermore, flavonoids can inhibit the activity of some redox enzymes, preventing cell damage caused by free radicals.<sup>90–94</sup>

**3.11.1. Mechanism of Action.** The structural properties of the carbocyclic ring of polyphenols found in herbs as well as the number of hydroxyl groups on the ring are solely responsible for extending lifespan.<sup>95</sup> Different chemical classes may activate similar signaling pathways involved in the aging process, as well as act as substrates in multiple pathways.<sup>96</sup> It has been reported that resveratrol can prolong the lifespan of *C. elegans* through the MPK-1/ERK or SIR-2.1/DAF-16 pathways.<sup>97</sup> Sirtuin activation is thought to be an important mechanism of resveratrol-mediated longevity.<sup>98</sup> According to research, resveratrol can activate SIR-2.1 and then extend the life of nematodes by regulating bec-1 to induce autophagy.<sup>99,100</sup> Furthermore, many polyphenols, such as myricetin, blueberry extract echinaco, and others, can modulate longevity via the IIS pathway (Figure 5), particularly through the key transcription factor DAF-16 in the pathway.<sup>101</sup> The main reason for this effect could be that DAF-16 expression improves free radical scavenging and resistance to oxidative stress.<sup>102</sup>

## 4. FUTURE RECOMMENDATIONS

**4.1. Yeast Strain Optimization.** The impact of different yeast strains on the sensory profile and health benefits of herbal wines could be investigated. Yeast strains could be optimized to maximize the production of desirable flavor compounds and enhance the potential therapeutic properties can also be recommended

**4.2. Herbal Combinations.** Novel combinations of herbs could be explored to create unique and potent herbal wine blends. The synergistic effects between herbs to amplify the overall health benefits and sensory appeal of the final product can also be investigated

**4.3. Standardization and Quality Control.** Standardized processes for herbal wine production should be established to ensure consistency in the flavor, antimicrobial efficacy, and antioxidant content. Rigorous quality control measures should be implemented to meet industry standards and consumer expectations.

**4.4. Clinical Studies.** Clinical studies should be validated in order to claim the health advantages of herbal wines. The potential of herbal wines must be explored as nutraceuticals,

providing evidence-based support for their effectiveness in addressing specific health concerns.

**4.5. Innovative Infusions.** More research should be conducted to develop innovative infusion techniques to extract and incorporate herbal properties more efficiently, ensuring optimal retention of flavor and health-promoting compounds in the final wine product.

**4.6. Packaging Solutions.** Sustainable and functional packaging solutions should be developed so as to preserve the integrity of herbal wines and contribute to the overall consumer experience.

## 5. CONCLUSION

Herbal wines are alcoholic beverages that are not distilled and are often produced with herbs like amla, aloe vera, holy basil, lemon grass, peppermint, ginger, or elderberry. The presence of essential aromatic compounds found during the aging process extend the wine's shelf life. These wines are nutritious, aromatic, and mild; therefore, it is predicted that wine quality can be improved by using herbs. Besides, due to globalization, industrialization, and subsequent increase of worldwide exposure, wine consumers are becoming more knowledgeable. They need more choices when buying wines, considering the unique health advantages of each medicinal component used in winemaking. As functional foods, herbal wines provide pharmaceutical properties with positive effect on host. They pose special properties that deliver the advantages of consumer good health and well-being. Herbal wine contains good health benefits that extend beyond regular nutrition to the host.

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The manuscript was written through contributions of all authors. All authors have given approval to the final version of the manuscript.

## Notes

The authors declare no competing financial interest.

## ACKNOWLEDGMENTS

The authors are thankful to Lovely Professional University, India, for the support. The authors extend their appreciation to the Deanship of Scientific Research at King Khalid University, Saudi Arabia, for funding this work through the Large Groups Project under Grant Number RGP2/132/45.

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