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Production, antimicrobial, antioxidant, sensory, and therapeutic properties of herbal wine – A comprehensive review

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Summary

Wine is a fermented beverage. Herbal-infused wine is beneficial to health due to its antimicrobial and anticancer properties. The constituents of these plants, including flowers, fruits, stems, roots, bark, and leaves, contain antioxidant activity. The herbs can be extracted through various methods such as maceration, decoction, infusion, crushing, grinding, and blending. *Saccharomyces cerevisiae* is the primary organism responsible for fermentation, converting glucose into metabolic energy.

This review analyses the potential medicinal value of herbal wine in treating human diseases. Herbal wine is a recent development in culinary technology, as herbs possess antioxidant and antimicrobial properties that make them effective against cancer and diabetes. Polyphenols found in wine have been reported to be effective in treating human ailments such as coronary heart disease, diabetes, microbial infections, neurodegenerative diseases, and aging. Therefore, fortifying alcoholic beverages may increase health benefits and clinical applications.

The qualities of these herbal extracts are comparable to those of fortified wines, making drinking fortified wines a healthier option than consuming conventional wines. However, the production of herbal wine from certain extracts may require the addition of taste enhancers.

Our focus is on the fermentative production of wine from various herbal extracts, including physicochemical, antioxidant, antimicrobial, and sensory evaluation. We compare and describe the health benefits and harmful effects of fruit wine and herbal wine.

Keywords: Herbs, wine, therapeutics, polyphenols, antioxidant activity, antimicrobial activity

Introduction

Wine is one of the oldest and most popular alcoholic beverages. It improves contentment and aids in relaxation both of which are necessary for optimal digestion and food absorption (Gutiérrez-Escobar et al., 2021). Historically, the use of herbs and botanicals in alcoholic beverages dates back centuries, with cultures around the world incorporating local flora into their traditional beverages (Martínez-Francés et al., 2021). Before the invention of modern medications and the medical revolution, people were treated using herbal formulations produced from herbs (Dias et al., 2020). Wine is a popular alcoholic drink that is widely recognized, used, and favored by many people due to its nutritive and healthful properties. Wine can be blended with additives that help to improve the wellness of consumers by strengthening its basic and medicinal properties. Herbal wine paves a great way to extract many of the beneficial medicinal qualities of plants (Dias et al., 2020). Extracts from several herbs with significant medicinal qualities are employed for fortification (Shiradhonkar et al., 2014). The top wine-producing countries are Italy, France, Spain, Argentina, Germany, South Africa, Portugal, and the United States (Rathi, 2018). India is ranked 77th in the world in terms of wine consumption. The country produces 0.8 % of the wine consumed by Asia. Consumption of wine in India is particularly high in large cities such as Delhi (23%), Bengaluru (9%), Mumbai (39%), and Goa (9%) and the rest of India (20%).

Herbal infusions in wine are currently very popular (Gujariya and Tarpara, 2023). Herbal foods, whose phytochemical ingredients provide medical benefits, have sparked a lot of attention in the last decade (Butnariu and Butu, 2020). Herbal wine is used as a core ingredient for medicinal preparations to alleviate the symptoms of ailments (Wurz, 2019). Herbal wine produced from *Tinospora cordifolia* was known to possess probiotic properties (Kamboj et al., 2023). The ingredients of herbal wine have a pleasant scent and are beneficial to human health. Bioactive compounds found in herbs and other plants have antioxidant, anticarcinogenic, anti-hypertensive, and antimutagenic activities, which may exert health advantages. When these herbal wines are taken regularly, prescription of drugs for various health conditions tend to be less necessary. It fulfills the criteria for functional food. As the yeast releases amino acids and other elements during the fermentation of herbal wine, the product has more nutritional value. Herbs are frequently used to enhance flavor, but they also have strong bioactive qualities that aid in the prevention of many chronic illnesses (Opara, 2019). Wine is an effective nutraceutical (Nambiar et al., 2016) and herbs infused in wine significantly improve its shelf life due to their antioxidant and bacteriostatic or bactericidal characteristics (Sandhu and Morya, 2022). These herbs are available in powdered or dry form. Herbal wine has a wide range of health and well-being benefits for humans. They also provide phytonutrients, vitamins, and essential minerals to foods, (Panda et al., 2013) and many of these compounds have antimicrobial and anticancer properties (Rathi, 2018). Based on flavor, fragrance, bouquet, and color, tropical wines are judged as being of lower quality (Carvalho et al., 2020). The addition of herbal extracts produces properties similar to fortification, and thus consumption of such herbal wine could provide significantly greater health benefits than regular wines (Shiradhonkar et al., 2014).

Herbal wine has a lot of advantages over the standard wines given. Due to the infusion of different herbs and botanicals, herbal wines have a wide range of distinctive and complex flavors (Rana and Singh, 2013). A unique and captivating flavor sensation can arise from this approach. The whole sensory experience is enhanced by the inclusion of herbs and spices, which add to the fragrant complexity of the wine (Rana and Singh, 2013). Certain herbs that are used to

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make herbal wines have been reported to have therapeutic qualities. Wine lovers have a plethora of possibilities to choose from because of the adaptability of herbal wines (Rana and Singh, 2013), which enable experimentation with various herbal combinations. Apart from the advantages, herbal wine does have certain drawbacks. Herbal wines have distinctive flavors that not everyone might like (Lee and Lee, 2008). Controlling the infusion process can be difficult, which might cause differences in the finished product (Liang et al., 2021). When compared to traditional wines, achieving consistency in flavor and quality might be more challenging. Certain botanicals and herbs might not mature well in wine, which could cause flavor and quality to vary over time (Chaudhary and Kumari, 2022). To preserve the integrity of the herbal infusion, proper storage conditions become essential (Chaudhary and Kumari, 2022). Whether herbal wines are appealing ultimately comes down to personal taste. While some may love the distinctive and varied flavors, others might prefer the more conventional taste of regular wines.

This review article critically examines the production, physicochemical analysis, antioxidant analysis, antimicrobial analysis, and sensory evaluation of wines made from different herbal formulations. It then draws a comparison between fruit wines and herbal wines.

Tab. 1: List of herbs and yeast used in the wine-making process.

Name of the herbs	Yeast used	References
Aloe barbadensis	*S. cerevisiae*	(Patil, 2022; Trivedi et al., 2015b)
Phyllanthus niruri	*S. cerevisiae*	(Sarkar and Singhal, 2018)
Hibiscus rosa sinensis	*S. cerevisiae MTCC 178, MTCC 180, MTCC 786*	(Tiwari et al., 2017)
Camellia sinensis	*S. cerevisiae*	(Thakur, 2020)
Nymphaea lotus	*S. cerevisiae*	(Yuwa-Amornpitak et al., 2012)
Amomum biflorum	*S. cerevisiae*	(Yuwa-Amornpitak et al., 2012)
Clitoria ternatea	*S. cerevisiae*	(Yuwa-Amornpitak et al., 2012)
Zingiber officinale	*S. cerevisiae* var. *ellipsoideus*	(Sharma et al., 2021)
Lippia javanica	*S. cerevisiae*	(Chawafambira, 2021)
Emblica officinalis	*S. cerevisiae*	(Rana and Singh, 2013)
Oscimum sanctum	*S. cerevisiae*	(Shiradhonkar et al., 2014)

Preparation of herbal wine

Microbiology of wine

Yeasts are crucial microorganisms in the winemaking process. *Saccharomyces* species are significant to winemakers because they are involved in the process of alcoholic fermentation (Fig. 1). *S. cerevisiae* and *S. cerevisiae* var. *ellipsideus* are the main species to produce wine (Tab. 1) and the list includes *Saccharomyces fermentati*, *Saccharomyces pyriformis*, and *Saccharomyces bayanus* as well. Yeasts have an elevated tolerance to alcohol, meaning they can continue to ferment even as the alcohol concentration rises, resulting in stronger, drier wines with up to 16% (v/v) or 18% (v/v) alcohol when the yeast is supplied regularly with a small amount of sugar. As yeasts have the inherent capacity to be stable and have a high fermentation capacity, they produce higher-quality wines than when fermentation falters after a volatile start. Yeasts have a high degree of agglutination, which means they tend to flocculate into little lumps that form a cohesive sediment after fermentation ends, making racking easy. Yeasts can withstand strong osmotic pressures, which are caused by a high sugar concentration in the must. The use of specific yeast starters improves control of the process and influences the sensory and sanitary qualities of the wine (Karki, 2019).

Herbs used to produce wine

Herbs with immunomodulatory, anti-inflammatory, antidiabetic, anti-infective, and antiallergic qualities have been employed in traditional medicine for thousands of years and span a wide variety of therapeutic areas. Herbs and spices are employed as enhancers, preservatives, and antioxidant sources in the beverage industry (Bhattacharya et al., 2022). Fermentation improves the biological qualities of herbs (Hussain et al., 2016). As these herbal extracts have characteristics

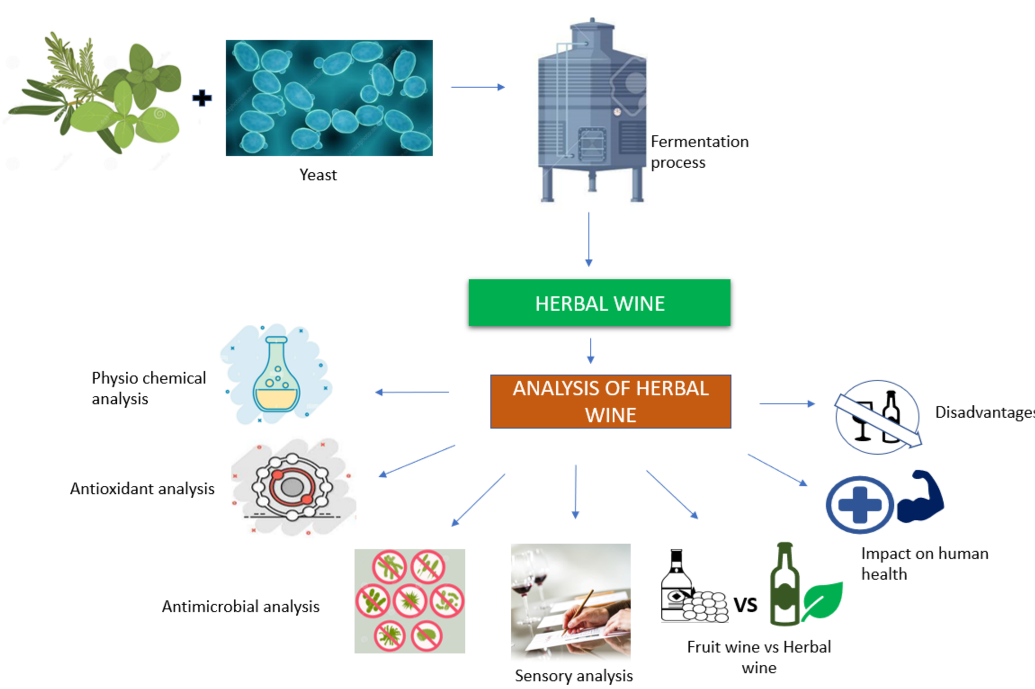

Fig. 1: Diagrammatic representation of herbal wine preparation.

that are similar to those of fortified wines, drinking such wines would be far healthier than drinking ordinary wine. Herbs are used to enhance the flavor of wines and also act as a preservative. Antioxidants present in the herbs protect low-density lipoprotein (LDL) from getting oxidized (MORYA et al., 2016). Herb wines contain more tannins and polyphenols, and less titratable acidity (THAKUR, 2020). Since yeast releases amino acids and other nutrients during fermentation, herbal wine has more nutritional value. Though their high bioactive content makes them useful for preventing a number of chronic diseases, herbs are also commonly used to enhance flavor (OPARA, 2019). An abundant availability of bioactive substances with a broad spectrum of nutraceutical qualities can be found in herbs and derived products.

Herbal extractions from plant materials

Herbs can be extracted through processes like crushing, blending, maceration, infusion, and decoction. Direct extraction entails weighing the herbs first, cleaning and rinsing them, and then adding the required amounts of herbs to the core wine and allowing it to rest for several hours to allow the herb's full flavor to pervade the core wine. To maximize the flavor passage from herbs into the base wine, winemakers prepare a fine powder of herbs. In the meantime, the core wine with spices or herbs can be processed or kept at room temperature. Heating wine is frequently suggested to improve flavor blending between the herbs and the base wine (RATHI, 2018).

Researchers have reported how herbs are prepared. In one study, ginger and amla were chopped into small pieces, and the pulp from aloe vera was removed. Tulsi, peppermint, and tea leaf extracts were prepared in distilled water. In each beaker, 200 mL of distilled water is boiled. These leaves were immersed in the water and allowed to boil for 15 min and then steeped for 30 min. Then the boiled extracts were sent in two batches for fermentation with yeast, one batch containing the herbs with peels in 2500 mL of distilled water and another batch with the leftover pulp of herbs in 2000 mL of distilled water (THAKUR, 2020). In another study on the preparation of herbal wine from cassava starch, the authors extracted 1% dried herbs (w/v) in boiling water. After the herb for 1-2 min in a membrane filter, they filtered the supernatant through a sieve. The herb extract was used as a solvent in the preparation of a 13% gelatinized starch slurry. The extracted herbal preparation was then subjected to fermentation with powder yeast *Saccharomyces cerevisiae*. This research successfully proved that herbal wine can be prepared from low-cost cassava starch, and the resultant wine has been shown to have better aroma and antioxidant properties (YUWA-AMORNPITAK et al., 2012).

In a study investigating the minimum inhibitory concentration (MIC) of the *Hibiscus rosa-sinensis* wine, the authors prepared an extract by sorting the *H. rosasinensis* petals and washing them in cold water. They heated 80g of powdered *H. rosasinensis* petals for 10 min in 1000 mL of water starting at 80 °C. The extracted petals were allowed for fermentation with three different yeast strains. The wine prepared from *H. rosasinensis* had high antimicrobial activity against food-borne pathogens, with a growth inhibitory effect in the range of 11-16 mm (YAZDI et al., 2014; TIWARI et al., 2017).

In another study, the authors added *Humulus lupulus*, *Mentha arvensis*, *Emblica officinalis*, *Zingiber officinale*, and *Allium sativum* extracts to the must at a concentration of 5% each to provide flavor and medicinal benefits. The garlic extract was prepared by peeling and cleaning the garlic cloves, crushing them in a blender, and then centrifuging them. The supernatant was transferred to a fresh container. The authors used a similar approach that was used for ginger. For the aonla extract, they removed undesirable elements by soaking the material water for 4 h; then, they extracted the juice. This juice was then fed into the fermentation broth. The authors showed that the addition of the extract had no negative effects on the physicochemical properties of apple wine before and after 6 months of aging (JOSHI et al., 2013).

In a study focusing on the production of wine from *Emblica officinalis* and *Phyllanthus niruri*, the authors used the following extraction procedure. Fresh green herb leaves were picked and cleaned to remove any contaminants. A total of 5 g of leaves were weighed and crushed. Water was used to evenly smash the leaves. After that, it was heated in 100 mL of distilled water and then filtered using filter paper. The extract was freshly prepared before adding it to the wine. Fermentation was then carried out on the prepared extracts with *Saccharomyces cerevisiae*. The prepared herbal wine was comparable to commercially available wines in terms of the antioxidant profile, alcohol content, total suspended solids (ºBrix), pH, and titratable acidity (SARKAR and SINGHAL, 2018).

To reduce the loss of volatile compounds, an extraction is usually done in one or two sealed jars (RATHI, 2018). Researchers found that making herb wines with a variety of flavors can be done quickly and simply by steeping dried herbs or boiling fresh herbs, then adding essential herbs or herb fragrances extracted into the water for manufacturing the wine.

Special attention should be paid to ensure that the tastes and properties of herbs are extracted. Certain herbs with strong aromatic characteristics can be suspended in a linen bag in the liquor for a few days. The extraction procedure might influence the content of an herbal product (KARKI, 2019).

The fermentation process

Fermentation involves microorganism-induced gradual breakdown of organic compounds. Fermentation can be managed to produce positive outcomes. Many side effects, such as gas and bloating, are eliminated by using complex anaerobic fermentation. Fermentation aggressively ruptures the cells of plant materials, subjecting them to more menstruum, and bacteria have enzymes that break down cell walls, further aiding the leaching process. *S. cerevisiae* is widely utilized because it can develop quickly and tolerate high sugar concentrations while still producing the required levels of alcohol (MULAY and KHALE, 2011). The biochemical process of producing high-quality wines is complex and involves the sequential appearance of several microbial species, such as *S. cerevisiae*, lactic acid, and acetic acid bacteria, the development of which is influenced by several external as well as internal variables. The substrate being fermented must provide the microbes with the nutrients they need to flourish in order for the fermentation of wine to be successful (LASIK, 2013).

The sugar content should be between 10% and 18%. The pH of the medium is adjusted to between 4.8 and 5. The amount of yeast used is 1%-3% of the extract's volume. In most cases, total alcoholic fermentation takes 14 days. The fermentation process is divided into three stages. Yeast proliferation is an extremely active stage characterized by bubbling and a significant temperature increase (KARKI, 2019).

In the case of aloe wines, using sugar as substrate, the yeast strain grows well and ferments to generate ethanol with a fermentation efficiency of over 90%. producing an alcoholic beverage that is yellowish orange in color. The fermentation begins after around 12 h, as evidenced by the beginning of CO_2 bubbles escaping from the medium, which picked up after 24 h and persisted for 7 days. After one day of incubation, total soluble solids and sugar levels steadily dropped, and this trend persisted for 7 days. The fermentation's kinetics showed that, during the final 24 h of fermentation, the rate of sugar utilization decreases to its starting point after increasing to a certain point and then being constant. When fermentation proceeded, the medium's pH gradually decreased (NEETIKA et al., 2012).

In one study, researchers prepared herbal wine from holy basil/tulsi (*Oscimum sanctum*), peppermint (*Menthe arvensis*), ginger (*Zinziber *officinale*), Indian gooseberry/amla (*E. officinalis*), aloe vera (*Aloe barbadensis*), and tea leaves (*Camellia sinensis*) in fermentation bottles. They added activated yeast to both jars at room temperature (about 27 °C) and tightly covered the bottles with a CO_2 outlet to stimulate anaerobic fermentation. For 10 days, the fermentation was carried out at room temperature (Thakur, 2020).

To prepare ginger wine, researchers sliced ginger into pieces and added 1 kg of sugar, 3 g of citric acid, and 15 g of activated yeast (*S. cerevisiae*). Before adding 1 kg of sugar, everything was combined and left to ferment for 10 days. The fermentation continued for another 21 days, stirring every other day until the bubbling stopped (Bhattacharya et al., 2022).

To prepare apple wine with aonla extract, fermentation was carried out at a temperature of 22 ± 1 °C. The process was started by adding 5% active *S. cerevisiae* culture (Joshi et al., 2013). The fermentation was considered complete when there was no additional loss of total soluble solids (TSS).

For the preparation of wine from amla (*Emblica officinalis*), batch fermentation was used to process the amla-containing medium, which had a TSS of 20% and a pH of 4.5 after being prepared as a hot water extract. The medium containing intact amla berries was transferred to a 5-liter Erlenmeyer flask, supplemented with 100 parts per million sodium meta-bisulphite, and incubated in a stationary condition in a Biochemical Oxygen Demand (BOD) incubator at 37 °C after being plugged with cotton wool. The batch with 10% sugar had the highest fermentation efficiency of 90% across different sugar concentrations in several batches used to produce wine, followed by 88% in the batch with 15% initial sugar concentration. An increase in the initial sugar concentration resulted in a decrease in the efficiency of alcohol generation, most likely because of an increase in the medium's osmotic pressure or cell overload from the high substrate concentration. High substrate concentrations inhibit the growth of yeast cells as a result of high osmotic pressure and low water activity leading to the dehydration of the yeast cells. After two rounds of fed-batch fermentation, which involved constant sugar administration, the wine's alcohol concentration was 16.1% (Soni et al., 2009).

With a total sugar level of 19%-24%, alcoholic fermentation progresses quickly and is completed with alcohol-tolerant yeast strains, yielding roughly 10%-12.5% alcohol (Thakur, 2020). Standardization of conditions is necessary for the fermentation of herbal medicines, including the type of microbial culture medium, the fermentation temperature, medium pH, solvent type, the types of fermenting bacteria, the loading of the microbes, and the incubation period.

A recent study examined the quality and antioxidant activity of ginseng seeds fermented separately by *Lactobacillus gasseri* KCTC 3162, *Pediococcus pentosaceus* LY011, *Bacillus subtilis* KFRI 1124, and *B. subtilis* KFRI 1127. The extracts fermented with *B. subtilis* KFRI 1127 had the highest levels of total sugar, acidic polysaccharides, and phenolic compounds, including *p*-coumaric acid. These findings show that *B. subtilis* had a higher fermentation capacity to create sugars by degrading carbohydrates than the other studied bacteria, and the overall phenolic compound content varied depending on the fermentation strains utilized. Additionally, ginseng seeds fermented by *B. subtilis* had stronger ABTS radical scavenging activity than those fermented by *L. gasseri* KCTC 3162 and *P. pentosaceus* LY011. Ginseng seeds fermented by *L. gasseri* KCTC 3162 and *P. pentosaceus* LY011 had higher superoxide dismutase (SOD) activity than seeds fermented by *B. subtilis* (Hussain et al., 2016).

A 2015 study looked at the impact of temperature during the production of apple wine on both the main smell components and the sensory qualities of the beverage. According to sensory testing, apple wine fermented at 20 °C had the highest level of customer acceptability. As a result, the authors determined that employing the chosen yeast strain (*S. cerevisiae* AP05) for apple wine production and fermenting at 20 °C is the best scenario (Peng et al., 2015).

In another study, wine titratable acidity was decreased and pH and 420 were enhanced via pomace interaction. In the pomace contact treatments, fermentations at 15 °C produced a fruitier scent than fermentations at 30 °C, a less yellow color, and a more herbaceous aroma (Reynolds et al., 2003).

Analysis of herbal wines

Many wines are created from herbs that are thought to have medicinal properties, and these wines have numerous health benefits. Alkaloids, tannins, flavonoids, saponins, and phenolic compounds are the major bioactive elements of herbs found in wine. Wine includes polyphenols and other elements such as bioactive molecules (bioactive peptides) that help consumers maintain their health (Dias et al., 2020). The DPPH (2,2-diphenyl-1-picrylhydrazyl) free radical scavenging capacity of wine and the FRAP (ferric reducing/antioxidant power) assay is used for antioxidant analysis (Jurca et al., 2021; Benzie and Strain, 1996). The flavonoid content can be measured with colorimetric methods (Chang et al., 2002). The total phenol content can be estimated by the Folin-Ciocalteu reagent (Singleton et al., 1999). Techniques such as High-performance liquid chromatography (HPLC), Gas Chromatography (GC), Fourier Transform Infra – Red (FTIR), spectrophotometry, and colorimetry are used to analyze wine.

Physicochemical analysis

Analysis of aloe vera wine

Liquid Chromatography with Quadrupole Time-of-Flight Mass Spectrometry (LC/Q-TOF-MS) was utilized to validate the presence of polyphenols and anthocyanins in aloe-mint wine. The type of polyphenolic compounds present in aloe-mint wine was determined by using LCMS with Time of Flight- Electrospray Ionization (TOF-ESI) in the positive ionization mode. Aloemint fermentation produced a translucent pale yellowish-colored wine with an ethanol concentration of 8.5% ± 0.05 (v/v), a final pH of 3.67 ± 0.02, and a total phenolic content of 1785 ± 10.28 mg Gallic Acid Equivalents (GAE)/L (Chauhan et al., 2015).

Changes in physicochemical parameters were evaluated for six months. The process I (P-I) contains Aloe vera-10%, honey-30%, and water-50%; Process II (P-II) contains Aloe vera-10%, sugar-15%, honey-15%, and water-50%; and Process III (P-III) contains Aloe vera-10%, sugar-30%, and water-50%. In P-I, P-II, and P-III, TSS content was reduced to 15.8. At 0 h, the pH in P-I was 4.3, 4.5 in P-II, and 5.2 in P-III. After the wine was distilled, the alcohol content was determined using an alcoholmeter, and the result showed that P-III had 12.5%, P-II had 11.4%, and P-I had 10.5% (Myint and Htun, 2019).

Analysis of amla wine

According to early phytochemical studies, amla contains carbohydrates, glycosides, steroids, alkaloids, flavonoids, vitamin C, tannins, and phenolic compounds. In one study, the authors prepared two types of alma wine: one with flowers and the other with yeast. They adjusted the initial pH to 4. After fermentation, the pH was reduced to 3.4 and 3, respectively, and the ethanol content was 1.64% and 2.40%, respectively. The total phenol and flavonoid contents were 0.9 and 0.85, respectively (Argade and Pande, 2016).

In amla wine mixed with *P. niruri*, the tannin concentration was 21.9 mg/100 mL. The amla wine with 20 mL of the herbal extract had the highest tannin level (49.32 mg/100 mL). As the amount of herbal extract increased, the tannin concentration increased. *P. niruri* has a tannin content of 381.6 ± 77.64 mg/100 g, which comprises ellagic acid, gallic acid, corilagin, and other compounds. The amla wine created with 20 mL of the herbal extract and 347.6 mg GAE/100 mL had the highest phenolic concentration. The phenolic compounds phyllanthin, rutin, and quercetin are abundant in *P. niruri* (44.17 ± 0.21). The alcohol content was 9.79% (SARKAR and SINGHAL, 2018).

Analysis of herbal wine made from cassava starch with Thai herb
Ten formulations of Thai herbal wine were made from cassava starch. The herbs *Aneilemabiflorum*, *Clitoria ternatea*, *Nymphea lotus*, and *Carthamus tinctorious* were dried and used as antioxidant sources and flavoring agents for the wine. The wine's original pH was 5.18, which is higher than the ideal pH for yeast growth (pH-4.5). However, the pH of the starch slurry containing herbs extracted before fermentation did not need to be adjusted. The sugar content of the glucose wines was about 238-520 µg/mL. The total phenolic content of herbal wines made with *N. lotus* (bud) and *C. tinctorious* were higher than other the mixture of herbal wines. The highest total phenol content was present in lotus bud wine. *A. biflorum* herbal wine has the lowest total phenol content. The ethanol content of the ten formulations of Thai herbal wine was 49.8%, 52.14%, 49%, 47.4%, 48.2%, 49%, 51.4%, 49.8%, 50.7%, and 51.4% (YUWA-AMORNPITAK et al., 2012).

Analysis of Hibiscus sabdariffa calyx extract wine
The calyx extract of the roselle (*H. sabdariffa*) was used to prepare wine. The roselle calyx wine had a pH of 3.43, 0.75% titratable acidity, and 10.8% (w/v) alcohol. The wine had a total anthocyanin content of 22.26 abs/mL and a total color density of 25.20 abs/mL, respectively (ALOBO and OFFONRY, 2009).

Analysis of apple wine maturation with herbs
Apple cider had a pH of 3.22, medium titratable acidity (0.382% MA), TSS (14.17 °Brix), sugars (13.40%), and reducing sugars (8.63%). The total aldehyde, ester, phenol, and alcohol levels of apple wine formulated with herbs were 41.20, 76.80, 124.50, 197.70, and 10.50, respectively (JOSHI et al., 2013).
The total phenolic content, brightness, and free amino acid content were all increased in apple-herb wine. The ethanol concentration was 15.9%, with a pH of 3.87. The total amino acid content was 22.90 after aging for 40 days (LEE et al., 2013).

Analysis of H. rosasinesis-based wine
In *H. rosasinesis*-based wine, *S. cerevisiae* MTCC 178 produced the highest (16.64%) concentration of phenolic compounds based on absorbance of 765 nm, followed by *S. cerevisiae* MTCC 180 (15.78%), and *S. cerevisiae* MTCC 786 had the lowest (15.73%) total phenolic content. The tannin content was almost the same in the *S. cerevisiae* MTCC 180 and *S. cerevisiae* MTCC 786 wines when assessed using the vanillin-HCl method based on absorbance at 500 nm. Apple cider had a pH of 3.22. The wine made from *S. cerevisiae* MTCC 178 had the greatest tannin content (83.54%) and the total flavonoid content was between 9.15% and 10.48% (TIWARI et al., 2017).
The physicochemical characteristics of *H. rosasinesis* wines made with different yeast strains revealed that they all had a fermentation rate of more than 1.6; *S. cerevisiae* MTCC 178 had the highest rate. This strain has produced more alcohol (11.50%) compared with the other *S. cerevisiae* strains. The titratable acidity ranged from 0.50% to 0.78%, which is a significant feature. On the other hand, the protein content of the designed wine ranges between 1.70%-1.90%. Wine with *S. cerevisiae* MTCC 786 had a reducing sugar content of 0.050%, whereas wine with *S. cerevisiae* MTCC 178 had a higher content (0.090%). This implies that in all the wines, *S. cerevisiae* MTCC 178 ingested more sugar (TIWARI et al., 2017).

Analysis of herbal wine produced from agricultural wastes
In a notable experiment, the authors divided the fermentation process into two groups: A and B. The herbs used in the process *E. officinalis*, *O. sanctum*, *A. barbadensis*, *M. arvensis*, *Z. officinale*, and *C. sinensis* were under group A and the leftover pulp of pineapple and beetroot were under group B. The alcohol content was 15.75% for group A and 10.5% for group B, whereas the pH was 5.5 for group A and 5.3 for group B (THAKUR, 2020).

Analysis of Smallanthus sonchifolius wine
The pH of yacon pulp wine (3.73) was higher than that of yacon syrup wine (3.53), but it was similar to that of yacon juice wine (3.67). The pH observed in yacon wines was slightly higher than what was found in rose (3.0) and white wines (3.33). Yacon syrup wine had the highest total phenolic content (mg GAE/100 mL), although the values for yacon juice and yacon pulp wines were not significantly different. Wine should have an alcohol content of 80-540 mg/L, with higher alcohol concentrations below 300 mg/L contributing to the desired aroma. In the three wines, the methanol concentration ranged from 0.0014% to 0.0017% (KARKI, 2019).

Analysis of ginger wine
Alkaloids, terpenoids, flavonoids, carbohydrates, and proteins were found in ginger wine after a qualitative examination of its phytochemicals. Ginger wine had a pH of 3.45 a yellow colour and a 16.0% alcohol content (BHATTACHARYA et al., 2022).

Analysis of aloe vera and Ocimum tenuiflorum wine
Aloe and basil wines had a pH of 3.77 and 3.71, respectively. Aloe vera wine was light yellow and contained 10.0% alcohol. Both aloe and basil wine included flavonoids, which are key antioxidants that protect cells from free radical damage. Only basil wine had phenols, and neither of the wines had tannins. Although alkaloids and terpenoids were not identified in the aloe extract or wine, they were identified in the basil extract and wine (DIAS et al., 2020).

Analysis of apple tea wine
In one study, the authors used different volumes of tea to make wine. The alcohol content ranged from 8.3% to 8.8% (v/v), indicating that fermentation was practically complete. There were higher alcohol levels as the tea concentration increased; wine was created from 5 g of tea/100 mL, whereas apple juice contained 159 mg/L of higher alcohols. The authors stated that the discrepancy in the alcohol content between the various amounts of tea is most likely due to variations in the fermentability of the must (KUMAR et al., 2016).

Analysis of ginger-amla wine
In one study, the titratable acidity of ginger-alma wine began to change as it aged. The pH of Batch 1 amla changed from 3.79 to 3.56 on day 24, with an increase in specific gravity from 1.09 to 1.17 on day 24 and a 10.5% alcohol content. Batch 2 amla had an overall pH change from 3.81 to 3.30 on day 22, a specific gravity increases from 1.09 to 1.167 on day 22, and an alcohol content of 10.35%. The alcohol level of Batch 3 amla was 8.64%, with a pH change from 3.83 to 3.34 after 21 days, and a specific gravity change of 1.0 to 1.10 after 21 days. Batch 1 ginger had a decrease in pH from 3.77 to 3.59 on day 14, an increase in specific gravity from 1.119 to 1.178 on day 14, and a 7.94% alcohol content. Batch 2 ginger had a pH decrease from 3.89 to 3.94 on day 18 and a 6.81% alcohol level. Finally, Batch 3 ginger had a decrease in pH from 4.42 to 4.01 on day 13 and an increase in specific gravity from 1.144 to 1.188 on day 13 (NANDAGOPAL and NAIR, 2013).

Analysis of Lippia javanica wine
The total acidity of 0.12 ± 0.10 in *L. javanica* extracts was 0.2, but it increased to 0.31 ± 0.01 in the produced wine. The wine that contained *L. javanica* extract had a decreased total titratable acidity of 5.9 g/L. The TSS content of the produced wine was just 4.8 ± 0.1%. The wine was 10.2% alcohol by volume (CHAWAFAMBIRA, 2021).

Antioxidant analysis of herbal wine

Antioxidants have the ability to scavenge reactive chemical species such as singlet oxygen, triplet photochemical sensitizers, and free radicals that would otherwise damage DNA inside cells, cause cancer and disrupt immunological processes (Weissenberg et al., 1997). DPPH has been widely used to assess the antioxidant activity of foods (Panda et al., 2014a). This assay is based on spectrophotometric studies of antioxidants' ability to scavenge DPPH radicals. Thus, the total amount of reductants in the solution in plant extracts can be estimated using the DPPH test (Gulcin and Alwasel, 2023). The total antioxidant activity of reductive (electron-donating) antioxidants in a test sample can be measured directly, quickly, and affordably using the Ferric Reducing Antioxidant Power (FRAP) assay (Benzie and Strain, 1999). The assay's indicator is the reduction of ferric ions (Fe_3^+) to ferrous ions (Fe_2^+), which is linked to a colour change. This test is frequently used to assess the antioxidant potential of foods, beverages, and dietary supplements that include polyphenols (Benzie and Devaki, 2018). There is another common assay called the ABTS assay, that also provides light on the antioxidant properties. The interaction of an antioxidant with the pre-generated ABTS•+ radical cation forms the basis of the ABTS assay (Ilyasov et al., 2020).

Antioxidant activity of cassava starch

Ten formulations of Thai herbal wine were made from cassava starch. The herbs *A. biflorum*, *C. ternatea*, *N. lotus*, and *C. tinctorious* were dried and used as antioxidant sources and flavoring agents for the wine. The wines made from herbal extracts showed increased DPPH activity. Overall, the wine with herb isolated from *N. lotus* (bud) extract had the highest DPPH activity -2 times higher than the other herbal extracts (Yuwa-Amornpitak et al., 2012).

Antioxidant activity of E. officinalis and P. niruri

The percentage inhibition of free radicals was measured in the homemade wine prepared from *E. officinalis and P. niruri*. After storage for 4 months, the suppression of free radicals by amla wine was modified by varying concentrations of *P. niruri* extract. There were substantial differences across the treatments. When the herbal extract concentration was increased, the percent inhibition increased (89.76%); it was significantly higher in amla wine with 20 mL of the herbal extract. *P. niruri* extract has a higher concentration of phenols and thus a greater ability to scavenge free radicals (Sarkar and Singhal, 2018).

Antioxidant analysis of H. rosasinesis wine

The antioxidant activity of *H. rosa-sinensis* was investigated by evaluating DPPH scavenging and performing the FRAP assay. All of the examined wines showed significant antioxidant activity in terms of their phenolic, tannin, and flavonoid contents and the DPPH radical scavenging and FRAP assay results. The antioxidant capacity evaluated by the FRAP assay varied from 30.18% to 35.34% mol FRAP/mL wine, and the DPPH method indicated a maximum inhibition of about 97.43% (Tiwari et al., 2017).

Wine prepared from *S. cerevisiae* MTCC 178 had outstanding DPPH radical scavenging activity, with a maximum inhibition of about 97.43%, which was similar to the control. The ability of a chemical to reduce ferric oxide may be a good indicator of its antioxidant capability. The transformation of Fe_3^+ to Fe_2^+ was explored to estimate the reductive ability. Wine prepared from *S. cerevisiae* MTCC 178 had a good reducing capacity, with a maximum inhibition of around 35.34%, which was equivalent to the control. There was a significant absorption band at 700 nm (Tiwari et al., 2017).

Antioxidant analysis of apple wine

Three different apple wines were tested by utilizing an HPLC system with two pumps/detectors and one column for online antioxidant analysis. A sample of apple wines provided by the first compressor was separated by an analyzing column, and the first detector detected phenolic components in the sample. The separated sample was then mixed with the ABTS (2,2'-azino-bis 3-ethylbenzothiazoline-6-sulfonic acid) free radical from the second pump, and the degree of ABTS radical scavenging was detected at 734 nm using the second detector. The total polyphenolic and total flavonoid contents of 26-year-old hwanggi extracts were 44.7-46.7 mg/g and 5.3-6.0 mg/g, respectively, while ABTS radical scavenging activity was 30%-36%. Furthermore, the antioxidant activity of mistletoe extract was 17.6% (Lee et al., 2013).

Antioxidant analysis of yacon wine

The antioxidant activity of yacon wine was investigated by using the DPPH radical scavenging method. The wine was filtered briefly using Whatman No. 41 filter paper. Filtered wine was diluted to 10 mL with distilled water and 4 mL of 0.004% methanolic DPPH solution was added to the diluted wine. The antioxidant activity of wines varied greatly, with yacon syrup wine having the highest value (89.83%) and yacon pulp wine having the lowest (42.88%) (Karki, 2019).

Antioxidant analysis of aloe wine

In a notable *in vivo* experiment, the administration of *Aloe vera* wine increased the levels of reduced glutathione by 29.9% in the afflicted fed group compared with the untreated control group, demonstrating that it has antioxidant ability. Aloe vera wine possesses substantial antioxidant properties *in vitro* and *in vivo*, which may have helped to battle the oxidative stress generated by *Salmonella* infection. Furthermore, the FRAP values in each group increased by an average of 30.0% compared with the control group, indicating that the wine-fed mice had better antioxidant status (Trivedi et al., 2015a).

Antioxidant analysis of L. javanica wine

Antioxidant activity was 72.1 ± 0.1 and 46.3 ± 0.2 in wine added with *L. javanica* extract and the control wine, respectively (Chawafambira, 2021). *L. javanica* leaf infusions showed antioxidant activity, with an EC50 of 358 g/mL and a total phenolic content of 14.8 mg GEA/mL dry weight (Shikanga et al., 2010). More specifically, the considerable antioxidant activity discovered in the *L. javanica* leaf extract could be linked to the high levels of verbascoside (1.5 mg/g dry weight) (Chawafambira, 2021).

Antimicrobial activity of herbal wine

Researchers have recently reported the antibacterial activity of various plant extracts against specific diseases. Plant polyphenols have antioxidant, anticarcinogenic, anti-inflammatory, and antimicrobial characteristics. Some harmful microorganisms are inhibited by resveratrol, hydroxytyrosol, quercetin, and various phenolic acids (Daglia et al., 2007). Wines and wine extracts have antibacterial capabilities against a range of microorganisms (Yazdi et al., 2014).

Antimicrobial activity of aloe vera wine

Researchers examined the antibacterial activity of herbal wines against *Staphylococcus typhimurium*, *Staphylococcus aureus*, and *Escherichia coli* based on the zone of inhibition (by good diffusion), minimum inhibitory concentration (MIC), minimum bactericidal concentration (MBC) values, and time-dependent bactericidal assays (Deans and Ritchie, 1987). The antibacterial activity against *S. typhimurium*, *S. aureus*, and *E. coli* was assessed by using a good diffusion technique. Both wines had a much greater inhibitory efficacy than the controls, which consisted of 10% ethanol and herbal extracts. Aloe-amla and aloe-ginger wine had average zone sizes of 12.3 and 11.0 mm against the three species, respectively, making aloe-amla wine marginally more effective than aloe-ginger in terms of antibacterial activity. Aloe-amla wine showed the best antibacterial activity against *S. typhimurium* and *E. coli*, while antibacterial activity against *S. aureus*. Other ingredients, such as aloe-amla and aloe-ginger extract, produced average zone diameters of 3.7 and 3.3 mm, respectively, whereas 10% ethanol alone had a zone size of 2.7 mm (Lawrence et al., 2009).

Antimicrobial analysis of H. rosasinesis wine

Researchers used the agar diffusion method to determine the bactericidal capabilities of *H. rosasinesis* wine produced by *S. cerevisiae* MTCC 178, *S. cerevisiae* MTCC 180, and *S. cerevisiae* MTCC 786. At the concentrations of 2, 4, and 8 mg/mL, *H. rosasinesis* wine produced by *S. cerevisiae* MTCC 178 demonstrated less antibacterial action against *S. typhimurium*, *S. aureus*, *B. subtilis*, and *E. coli*. In addition, it failed to prevent the bacterium from developing on cultured material. *S. typhimurium*, *S. aureus*, *B. subtilis,* and *E. coli* were all eliminated by *H. rosasinesis* wine produced by *S. cerevisiae* MTCC 178 at doses of 16, 32, and 64 mg/mL. At doses of 2, 4, and 8 mg/mL, *H. rosasinesis* wine produced by *S. cerevisiae* MTCC 180 exerted less antibacterial action against *S. typhimurium*, *S. aureus*, *B. subtilis*, and *E. coli* (Yazdi et al., 2014). All pathogens were reduced by varying concentrations of wine, although the bactericidal activity of the herb differed for each organism. Overall, the zone of growth suppression produced by the wines was 11.00 ± 0.17-16.00 ± 0.10 mm (Yazdi et al., 2014).

Antimicrobial analysis of ginger wine

Ethanol, ginger extract, and ginger wine have antibacterial activity against *E. coli*, *S. aureus*, and *Salmonella typhi* (Bhattacharya et al., 2022). Compared with ethanol and ginger extract, ginger wine was the most effective against all three types of bacteria. It had the broadest zone of inhibition in *S. aureus* (14.6 mm), followed by *E. coli* (14.0 mm), and *S. typhi* (13.6 mm). The active components of ginger, such as zingerone, gingerol, and shogaol, are responsible for its antimicrobial activity. The ethanol in ginger wine dissolves organic compounds and liberates the active components (Azu et al., 2012). A combination of organic acids, ethanol, and a low pH had a significantly better antibacterial effect against a variety of foodborne infections than any of these components alone (Møretrø and Daeschel, 2004).

Antimicrobial analysis of aloe vera and O. tenuiflorum

The usefulness of wine against foodborne pathogens has been proven in previous studies (Neetika et al., 2012). Aloe wine produced the largest zone of inhibition for *S. aureus* (14.6 mm), followed by *E. coli* (13.3 mm), and *S. typhi* (12.6 mm). Ethanol produced the smallest zone of inhibition. Basil wine produced the largest zone of inhibition for *S. typhi* (14.0 mm), followed by *S. aure*us (11.6 mm) and *E. coli* (11.0 mm). As a result, compared with ethanol, aloe extract, and basil extract alone, the aloe and basil wines produced a wider zone of inhibition (Dias et al., 2020).

Antimicrobial analysis of apple tea wine

The antimicrobial activity of the different components of apple tea wine (polyphenolics, alcohol, and citric acid) produced revealed that increasing the tea concentration (from 2% to 5%) slightly increased the antimicrobial activity against all tested microorganisms, possibly due to increasing phenol concentration (Vaquero et al., 2007). All wines showed antibacterial action against each of the tested pathogenic microorganisms–*Bacillus cereus, S. aureus, Enterococcusfaecalis,* and *E. coli* - zone of inhibition > 7 mm (Kumar et al., 2016).

Sensory evaluation of wine

Numerous studies involve the sensory evaluation of wine. In general, a team of wine tasters 22 (Rana and Singh, 2013) evaluates the sensory quality of wine by using specific scales. An example is a 9-point hedonic scale, where 9 means extremely like and 1 means strongly detest (Ihekoronye and Ngoddy, 1985). The sensory evaluation of wine is primarily based on taste, aroma, color, and flavor.

Sensory analysis of H. rosasinesis wine

The roselle wine sensory evaluation scores were 7.6, 7.0, 6.9, 7.2, 6.4, and 7.0 for color, clarity, flavor, aroma, taste, and overall acceptability, respectively. The roselle wine obtained higher color and clarity scores than the control sample (Alobo and Offonry, 2009).

Color, taste, flavor, and overall acceptability were all higher in wine produced by *S. cerevisiae* MTCC 178 according to the sensory evaluation scores. All the wines were commercially viable. The use of the proper yeast strain for the creation of *H. rosasinesis* wine, as well as other vinification procedures, is highly significant, as it influences the sensory quality of the wine (Tiwari et al., 2017).

Sensory analysis of apple-herb wine

A panel of 29 students assessed the colors, taste, and flavors of three apple wines. They preferred the flavor of apple-herb wine over apple-pine wine. In terms of taste, color, and flavor, the apple-herb wine earned scores of 2.83, 1.79, 5.79, 1.70, 4.69, and 1.98, respectively, but the apple-pine wine had a lower sensory preference than regular apple wine (Lee et al., 2013).

Sensory analysis of aloe wine

After fermentation, five hedonic scales were used to assess the acceptability of aloe vera wine in terms of color, flavor, and taste. Yeast created many metabolites in the media during fermentation, which gave the beverage its flavor. Ten volunteer tasters between the ages of 20 and 35 years evaluated the look, flavor, and scent of the wine. The color, flavor, and taste preferences for the P-II fermentation method were 3.7, 3.8, and 4.3, respectively, compared to other processes, but not significantly different from P-I. The tasters preferred P-II, which included an equal amount of honey and sugar.

A panel of five judges assessed aloe and basil wine based on appearance, color, fragrance, bouquet, vinegar, acidity, sweetness, body, taste, astringency, and overall quality. They utilized a scoring method (Amerine, 1980). Aloe wine obtained a total score of 16.4 after organoleptic evaluation and was classified as standard wine (13-16), with neither an excellent character nor a defect. The basil wine was assigned a rating of 17.3 and was categorized as a wine (17-20) with excellent attributes and no flaws (Dias et al., 2020).

Sensory analysis of fortified wine

A semi-trained panel of four judges evaluated three major attributes of wine: look, smell, and taste. The 20-point scoring scale (Allen and Germov, 2011), which is best suited for semi-trained panels, was inspired by the one used in New Zealand and Australian wine contests. Each of the four fortified wines displayed acceptable qualities and met expectations. The addition of the extracts produced wines with remarkably stable and comparable qualities to the original wines. The wine fortified with tulsi extract had a high level of taste satisfaction and received an average score of 15 out of 20. The wine with lemon grass extract had a beautiful scent and bouquet, which was its most distinguishing attribute. Out of the four fortified wines, the lemongrass wine obtained the highest score of 16/20. The peppermint-fortified variant, which received a score of 13/20, had acceptable attributes but a refreshing texture. The wine that was fortified with ginger extract had a light refreshing flavor and a soothing aroma, earning it a score of 14/20 (Shiradhonkar et al., 2014).

Sensory analysis of ginger wine

Ginger wine was judged on appearance, color, fragrance, aroma, vinegar, acidity, sweetness, body, flavor, astringency, and general quality by a panel of five judges using a 20-point scale (AMERINE, 1980). The wine received an average total score of 16.8, placing it in the category of wines (17-20) with exceptional quality and no significant flaws (BHATTACHARYA et al., 2022).

Sensory analysis of L. javanica

Thirty semi-trained panelists were chosen to analyze the sensory qualities of the prepared wine samples. The panelists were divided into several age groups: 20-29, 30-39, 40-49, and ≥ 50 years. The group consisted of six women and nine men. The panelists were randomly assigned 30 mL of wine samples in 150 mL wine glasses. Compared with the control wine, the flavor, and color of the wine with added *L. javanica* extracts were deemed outstanding by most of the panelists (IHEKORONYE and NGODDY, 1985).

The activity of polyphenol oxidase during the production process has an impact on the wine's flavor (GUERRERO and CANTOS-VILLAR, 2015). As a result, the action of sulfur dioxide (SO_2) regulates both favorable and negative spontaneous fermentation processes (RIBÉREAU-GAYON et al., 2006). In one study, the authors restricted the addition of potassium thiosulfate (70 mg/L), a source of SO_2, because the wine with more *L. javanica* extracts was assessed as 'average'. The flavor and color of the control wine were given an 'average' rating. The sensory quality of the wine created with extra *L. javanica* extracts and control wine averaged 4.5 ± 0.1 on a scale from 1 to 5 (CHAWAFAMBIRA, 2021).

Fruit wine versus herbal wine

Fruit wines are alcoholic beverages made from grapes or other fruits such as peaches, plums, apricots, bananas, elderberries, or black currants. They have a pleasant and stimulating nature and are of moderate nutritional value. Because wine is a fermented and undistilled beverage derived from fruit, it retains most of the nutrients included in the original juice (SWAMI et al., 2014).

Fruit is high in sugars, antioxidants, minerals, and vitamins, and has a wide range of industrial and therapeutic applications. Sapota (*Achras sapota Linn*.) is a popular tropical fruit. It contains a lot of bio-iron, which is required for the production of hemoglobin and vitamin A (NAMBIAR et al., 2016). In one study, 250 g/mL sapota wine scavenged 46% of DPPH. Alcohols, phenols, anhydrides, amides, esters, and alkenes in sapota wine have been identified using infrared spectroscopy. The 10 original analytical and proximate variables (total soluble solids, total sugar, pH, phenol, β-carotene, ascorbic acid, lactic acid, ethanol, and DPPH-scavenging activity) were reduced to four independent components by principal component analysis (PCA), which accounted for 87.55% of the variance (PANDA et al., 2014b).

Jackfruit is abundant in phenolic compounds and flavonoids, both of which are powerful antioxidants (JAGTAP et al., 2010). Researchers examined the ability of jackfruit wine to scavenge free radicals by using the DPPH assay, the FRAP assay, N, N-dimethyl-p-phenylenediamine (DMPD), and gas scavenging experiments (NO). It effectively scavenged DPPH radicals (69.44 ± 0.34%), FRAP (0.358 optical density value), DMPD (78.45 ± 0.05%), and NO (62.46 ± 0.45%) (JAGTAP et al., 2011).

Researchers compared several fruit wines and found that bilberry, blackberry, and black mulberry wines had the highest antioxidant potential and phenolic content (61.80%, 1161 mg/L GAE; 60.00%, 1232 mg/L GAE; and 58.10%, 1081 mg/L GAE, respectively). Bilberry fruit wine had the highest absorbance a 420, 520, and 620 nm (YILDIRIM, 2006) (Fig. 2).

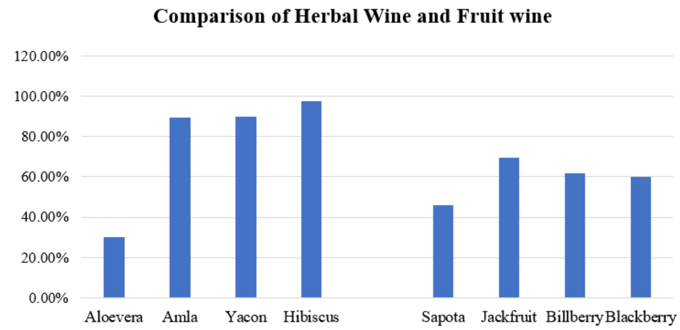

Fig. 2: Comparison of the antioxidant properties of herbal wine and fruit wine. Herbal wine has antioxidants such as Aloe vera - 29.9%, Amla - 89.83%, Yacon - 89.83%, and Hibiscus - 97.43%. Fruit wines such as sapota - 46%, Jackfruit - 69.44%, Bilberry - 61.80%, and Blackberry - 60.10% have antioxidant activity. From this graph, we conclude that herbal wine has more antioxidant properties.

The health benefits of herbal wine

Wine contains a diverse blend of components that contribute to its character after fermentation. The levels of sugars, alcohol, and phenolic compounds vary among wines. Tannins, resveratrol, and quercetin are the most studied phenolic compounds in wine (MARKOSKI et al., 2016). There are also polysaccharides or other trace elements, acids in various forms, and volatile chemicals. The key bioactive polyphenols include flavonols, anthocyanins, and resveratrol (AMIOT et al., 2016). Catechin, epicatechin, proanthocyanidins, flavones, and anthocyanin are all flavonoids (QUIDEAU et al., 2011). Since the turn of the century, wine has been used as a medium for herbal medicines including various herbs to treat specific ailments and illnesses (LIU et al., 2015). Herbs including amla, aloe vera, holy basil, lemongrass, peppermint, cinnamon, elderberry, and others are widely used to produce herbal wines. Frequent but limited use of these herbal wines reduces the need for prescription medications to treat a variety of conditions. The health benefits of herbal wines and their formulation are numerous. It fulfills the purpose of functional food. The release of amino acids and other nutrients from yeast during fermentation enhances the nutritional value of herbal wine (OPARA, 2019).

The impact of herbal wine on human health

Herbs are commonly used as flavor enhancers, but they also have bioactive qualities that could aid in the prevention of chronic human-related diseases (OPARA, 2019) (Tab. 2). In addition to these unique features, these plants contain anticancer, anti-tumour, and antiproliferation compounds that are less harmful than traditional therapies (PHAN et al., 2019). Chemical and natural medications are utilized to treat diseases (CAVALLINI et al., 2016). Wine polyphenols lower the risk of cardiovascular disease and have a beneficial effect on certain human organs (CAVALLINI et al., 2016). Polyphenols have been shown to improve the cardiovascular system, cardiovascular disease, arteriosclerosis, and heart failure, as well as lower the risk of hypertension and diabetes (SCHINI-KERTH et al., 2010).

Consuming wine helps you live longer and diminishes your chances of having a heart attack. Moderate drinkers with high blood pressure are 30% less likely than non-drinkers to have a heart attack. It also slows brain aging and lowers the risk of type 2 diabetes, stroke, cataract, and colon cancer. Wine is also an important part of the human diet because it helps with the digestion and absorption of nutrients (GUTIÉRREZ-ESCOBAR et al., 2021). Moderate wine drinking has been associated with the prevention of cancer, and a reduced risk of coronary heart disease (RENAUD et al., 1998). Numerous polyphenols present in wine are also helpful in the treatment of human disorders such as coronary, cancer, diabetes, microbial inflammation, neurological, and kidney diseases, and aging (SEO et al., 2009).

Tab. 2: The health benefits of wine produced from various herbs.

Herbs used	Microorganism used	Metabolites identified	Health benefits	References
Aloe vera (*A. barbadensis*)	*S. cerevisiae* and *S. cerevisiae* MTCC 786	Acemannan, aloe-emodin, aloesaponarin I and II, aloesin, aloin, chrysophanol, esculetin, polyphenols, umbelliferone, and vitamin C	Anti-inflammatory, antioxidant, and immune-modulatory properties, reduce burn and wound-healing activities	(DIAS et al., 2020; MAJUMDER et al., 2019)
Garlic (*Allium sativum*)	*S. cerevisiae*	Ajoene, allicin, alliin, diallyldisulfide, diallylsulfide, diallyltrisulfide, and S-allyl-cysteine	Antibacterial, anticancer, anti-diabetic, antifungal, anti-inflammatory, anti-obesity, antioxidant, cardiovascular, hepatoprotective, immune-modulator, neuroprotective, renal protective, and digestive system protective activities	SHIRADHONKAR et al., 2014; SHANG et al., 2019; BHISE and MORYA, 2021
Amla (*Phyllanthus niruri*)	*S. cerevisiae*	Rich in phenols, tannins, and free radical scavenging activity	Help to prevent cardiovascular disease, ulcers, cancer, and tumors	SARKAR and SINGHAL, 2018
Hibiscus (*Hibiscus rosasinensis*)	*S. cerevisiae* and *S. cerevisiae* MTCC 178	Cyanidin-3,5-diglucoside, cyanidin-3-sophoroside, luteolin-8-C-glucoside, quercetin, quercetin-3-diglucoside, and ß-sitosterol	abortifacient, anti-bacterial, anti-cancer, anti-diabetic, anti-inflammatory, antioxidant, antipyretic, Hypotensive, and wound healing. In addition, Low-Density Lipoproteins (LDL) found in Hibiscus help to prevent cancer cells.	MISSOUM, 2018; TIWARI et al., 2016; TIWARI et al., 2017a; TIWARI et al., 2017b
Holy basil (*Ocimum tenuiflorum*)	*S. cerevisiae*	Caffeic acid, carvacrol, chlorogenic acid, eugenol, germacrene, kaempferol, linalool, oleanolic acid, quercetin, rosamarinic acid, rosmarinic acid, rutin, gallic acid, ursolic acid, β-caryophyllene, and β-elemene	Analgesic, anticancer, antifertility, antifungal, antimicrobial infection, antispasmodic, arthritis, chronic fever, eye disease, hepato-protective, used to cure ulcers, inflammation, wounds fever, and syphilis	DIAS et al., 2020; PANCHAL and PARVEZ, 2019
Peppermint (*Menthe arvensis*)	*S. cerevisiae* and *S. cerevisiae* MTCC 786	Menthol, menthone, and menthyl acetate	Antioxidant and antiviral activities, cure indigestion and gastrointestinal problem, reduce cholesterol, and treat chest pains and stomachache	SHIRADHONKAR et al., 2014; CHAUHAN et al., 2015; BRAHMI et al., 2017
Tea (*Camellia sinensis*)	*S. cerevisiae* and *S. cerevisiae* 71B	Caffeine, catechins, epicatechins, flavonol glycosides, linalool, L-theanine, theaflavins, theobromine, and volatile organic substances	Cure cancer, cardiovascular illnesses, digestive problems, help to defend against cough, colds, and fever, metabolic disorders such as obesity and diabetes	SHIRADHONKAR et al., 2014; SAMANTA 2020; WANG et al., 2020
L. javanica	*S. cerevisiae* N96	Good source of iron, potassium, calcium, carbohydrates, vitamins, flavonoid, and phenolic compounds	Antioxidant activity and helps to reduce postharvest losses while also improving nutrition and health	CHAWAFAMBIRA, 2021
Ginger wine (*Z. officinale*)	*S. cerevisiae*	Gingerols, paradols, and shogaols	Anticancer, antidiabetic, antiemetic anti-inflammatory, antimicrobial, antinausea, antiobesity, antioxidant, cardiovascular, respiratory, and neuroprotective properties	BHATTACHARYA et al., 2022; SHANG et al., 2019; BHISE and MORYA, 2021
Apple-Herb wine	*S. cerevisiae* and *S. cerevisiae* CTCCM201022	Catechin, chlorogenic acid, coumaric acid, cyanidin-3-galactoside, epicatechin, gallic acid, p-coumaroylquinic acid, phloridzin, procyanidin, quercetin-3 galac-toside, and quercetin-3-rhamnoside	Antibacterial, antioxidant effect, erythema (acne-causing erythema), greasiness, increase blood clotting, lowered melanin level, strengthening the gums and heart muscle, and useful in reducing sebum production	JOSHI et al., 2013; PATOCKA et al., 2020; MAKSIMOVI and MAKSIMOVI, 2017; JAGTAP and BAPAT, 2015
Cassava starch-Thai herbs	*S. cerevisiae*	High total phenolic content and DPPH radical scavenging activity	Antioxidant properties	YUWA-AMORNPITAK et al., 2012

Karanda (*Carissa carandas*)	*S. cerevisiae*	High total phenolic content, DPPH, ABTS, and reducing power assay	Antidiabetic, antimicrobial, cytotoxicity, hepatoprotective, and anti-inflammatory properties.	RUMJUANKIAT et al., 2018
Tendu (*Diospyros melanoxylon*)	*S. cerevisiae* var. *ellipsoideus*	Ascorbic acid, lactic acid, β-carotene, DPPH activity	Antioxidant properties	SAHU et al., 2012
Black Rice (*Oryza sativa*)	*Monascus purpureus* NBRC 5965	High total phenolic content, DPPH scavenging activity, lipid peroxidation activity	Antioxidant property with an attractive red color	TAKESHITA et al., 2016
Purple Sweet Potato roots (*Ipomoea batatas*)	*S. cerevisiae* and dry yeast *S. cerevisiae*	Alatanin C, diosgenin, and discorin	Anti-diabetic, antioxidant, attenuates liver dysfunction, decreases blood sugar, enhances memory function, hypoglycemic activity, inhibits cancer cell growth, lower insulin resistance, and scavenges free radicles	PANDA et al., 2013; KANU et al., 2018; ZHONG-HUA and JIE, 2015
Pumpkin (*Cucurbita moschata*)	*Saccharomyces cerevisiae* var. *ellipsoideus*	Rich in phenolic content, DPPH, and FRAP activity	Antioxidant properties and prevent worms and intestinal parasites.	SHARMA et al., 2021
Lycium barbarum and *Polygonatum cyrtonema*	*S. cerevisiae* RW and *Debaryomyces hansenii*	Oxalic acid, citric acid, tartaric acid, quinic acid, lactic acid, malic acid, succinic acid, caffeic acid, vanillic acid, ferulic acid, quercetin, catechins, rutin, catechins class, chlorogenic acid, and kaempferol	Exerts antioxidant and anti-aging effects	WANG et al., 2023
Raspberry Wine (*Rubus coreanus* miq and *Raubus idaeus*)	*S. cerevisiae* CY3079	Caffeic acid, cyanidin-3-glucoside, ellagic acid, ferulic acid, gallic acid, malvinidin-3-glucoside, p-coumaric acid, pectins, provitamin A, salicylic acid, and vitamins C, B1, B2 and B6	Anticancer, anti-inflammatory, antimutagenic, and antioxidant properties	JUNG et al., 2009; FENG et al., 2015; SEGANTINI et al., 2015
Holy basil/tulsi (*Oscimum sanctum*)	*S. cerevisiae* and dry yeast *S. cerevisiae*	Carvacrol, eugenol, germacrene, linalool, oleanolic acid, rosmarinic acid, ursolic acid, β-caryophyllene, and β-elemene	Analgesic, anticancer, antifertility, antifungal, antimicrobial, antioxidant, antispasmodic, arthritis, chronic fever, eye disease, hepato-protective activity, and used to cure ulcers, inflammation, wounds fever, and syphilis	DIAS et al., 2020; PANCHAL and PARVEZ, 2019; DESHMUKH et al., 2021
Wild Berries (*Berberis lycium*)	*S. cerevisiae*	Abundant source of total polyphenol, total flavonoid content, and antioxidant activity	Antioxidant activity	RANA and SINGH, 2013
Bael (*Aegle marmelos*)	Wine yeast *S. cerevisiae*	Ascorbic acid, lactic acid, β-carotene, DPPH activity, and phenolic compounds	Antidiarrheic, antibacterial, and anti-inflammatory activity	
Hops (*Humulus lupulus*)	*S. cerevisiae* var. *ellipsoideus*	Isoquercitrin and quercetin	Antibacterial, antifungal, anti-inflammatory, antioxidant, antiviral, and cancer-fighting activity	ASTRAY et al., 2020; ALMEIDA et al., 2020; JOSHI et al., 2014
Blue water lilly (*Nymphaea lotus*)	*S. cerevisiae*	Apigenin and their glycosides, ellagic acid, gallic acid, isokaempferide, kaempferol, and quercetin	Anti-inflammatory, Antioxidant, and hepato-protective activity	YUWA-AMORNPITAK et al., 2012 BAKR et al., 2017
Indian gooseberry (*Emblica officinalis*)	*S. cerevisiae*	Apigenin, ascorbic acid, catechol, chebulinic acid, corilagin, ellagic acid, gallic acid, isostrictiniin, luteolin, methyl gallate, quercetin, and rutin	Anti-atherogenic, antibacterial, antidepressant, antifungal, anti-hyperlipidemic, antioxidant, immune-modulatory activity, cytotoxic, and hypolipidemic effects	CHAHAL et al., 2020; HASAN et al., 2016; AMALEY et al., 2016
Lemon grass (*Cymbopogon flexuosus*)	*S. cerevisiae*	E-citral and Z-citral	Antibacterial, anticarcinogenic, antifungal, anti-inflammatory, antioxidant, antiprotozoal, anti-rheumatic, antiseptic, antitussive, and cardio-protective activities	BHISE and MORYA, 2021; HAQUE et al., 2018

Harmful effects of wine

There are other detrimental effects of wine consumption besides those caused by misuse or high intake. Even just a modest amount of wine can cause allergies and side effects. SO_2 is thought to be the principal cause of wine allergies (Weissenberg et al., 1997). The symptoms of ethanol poisoning, including hypoglycemia, unconsciousness, and hyperthermia, can occur when blood ethanol levels exceed 50-100 mg/dl. In people with inadequate glycogen stores, these problems can also occur at lower ethanol dosages (Vonghia et al., 2008). Despite the fact that daily low-to-moderate alcohol use is inversely connected to cardiovascular disease, the hormetic behavior of alcohol indicates that increasing alcohol consumption raises the risk of some cancers, cirrhosis, and fatal accidents (Castelnuovo et al., 2010). Drinking three or more drinks per day increases the risk of heart disease, stroke, obesity, hypertriglyceridemia, breast cancer, neurodegeneration, depressive disorders, bone thinning, suicide, and injury (Saremi And Arora, 2008). Heavy irregular drinking appears to offset the cardiovascular-protective benefits of moderate alcohol consumption by raising the risk of stroke (Reynolds et al., 2003). Finally, methanol, a neurotoxin can contaminate alcoholic beverages (Zhang et al., 2012).

Conclusions

Herbal wine can be made by using methods such as herb extraction and yeast fermentation. Plant extracts have a long history of usage in the prevention and treatment of a wide range of illnesses. Wines made with herbal extracts have higher levels of polyphenols, esters, and aldehydes and altered physicochemical and sensory qualities. The advancement of biotechnology has led to well-developed yeast strains that are employed to produce wine. Herbal wine provides consumers with health benefits that go beyond conventional nutrition. Numerous studies have indicated that the inclusion of specific herbs in the winemaking process results in wines with elevated levels of antioxidants, polyphenols, and other bioactive molecules known for their health-promoting properties. The antioxidant-rich nature of herbal wines has been associated with a potential reduction in oxidative stress, which plays a pivotal role in various chronic diseases. In summary, the scientific evidence surrounding herbal wine health benefits underscores the potential for these beverages to contribute positively to human health. The sensorial properties of herbal wine are significantly affected by the extraction procedure and fermentation conditions which should be carefully optimized to attract consumers. Herbal wine production will likely continue to boom. In the future, consumers will become aware of the use of herbs and their flavours. The herbal wine industry has a bright future ahead of it, and it can be embraced by all consumers throughout the world.

Future perspectives

Wines made from herbal sources are a promising research topic with a bright future. Research-wise, herbal wine has a bright future ahead of it as experts and researchers work to better comprehend the intricacies of these wines. The potential health benefits of the herbs used in winemaking may be revealed by identifying and measuring particular phytochemicals, antioxidants, polyphenols, and other bioactive compounds. Research could focus on how different herbs influence fermentation, yeast activity, and the overall chemical composition of the final product. This knowledge could lead to optimized fermentation strategies and the development of herbal wine varieties with distinct characteristics. The prevalence of several diseases continues to rise, and conventional therapy is expensive and can have severe side effects. Herbal wines have gained increased consumer interest as a way to improve health through the diet. Understanding the physiological responses to herbal wine consumption can contribute to evidence-based recommendations for consumers. Extensive research should be carried out to analyze, identify, and improve the factors that affect the sensorial and qualitative properties of herbal wines. It would be interesting to investigate the ability of herbal wines to age. For researchers as well as enthusiasts, there may be fresh insights to be gained from examining how herbal constituents change with age and how aging affects the flavors and health benefits of herbal wines. These findings could allow herbal wines to replace conventional wines, making them a great option for wine-consumers throughout the world.

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Conflict of interest

No potential conflict of interest was reported by the authors.

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