Review Article

A Review of Preparation and Validation of Mead through *Saccharomyces cerevisiae*

Ashish Rohan Kujur[1], Avinash Kumar[2], Lokesh Mishra[1], Pratichi Singh[1], Vinod Kumar Gupta[2]
[1]Department of Microbiology, Galgotias University, Greater Noida, Uttar Pradesh, India.
[2]Rapture Biotech International Pvt. Ltd., Noida, Uttar Pradesh, India.
***Corresponding author's E-mail:** research.rapturebio@gmail.com

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ABSTRACT

Alcoholic beverages are drinks that contain over 0.5% ethanol, produced through fermentation where yeast or bacteria converts sugar into alcohol. Beverages are classified into three primary categories: beers, wines, and spirits. Mead is a beverage that comes between beer and wine. Mead is a fermented beverage made from honey and water, often with added ingredients like fruits, spices, or hops. Its alcohol content varies from 3.5% to 20%, depending on the fermentation process and honey quantity. Mead's diverse range enables a wide array of styles and flavors, showcasing its versatility as a drink. Honey contains sugars like fructose and glucose that can be easily broken down by yeast and other microorganisms. Honey has many phenolic and flavors that are a great source of antioxidants therefore consumption of honey or mead in a constant amount has a huge positive health impact. Honey has almost 70% of sugar so fermentation process can be done by dilution of honey by adding appropriate water in it. The quality of honey can be determined by the taste, flavor and alcohol content in it. Raw honey must be prepared. The fermentation process utilized Saccharomyces cerevisiae, a standard culture for alcohol production, with wine yeast and baker's yeast serving as starter cultures. Fermentation continued until total soluble solids stabilized, yielding mead with an alcohol content of 9-12%. The resulting mead exhibited antioxidant activity and possessed acceptable sensory characteristics.

Keywords: Saccharomyces cerevisiae, Fermentation, Antioxidant, Mead.

INTRODUCTION

Mead is an ancient alcoholic beverage with a rich history spanning over 3,000 years, originating in Africa, and has been an integral part of various cultures and traditions worldwide. It was revered for its perceived magical and healing properties, believed to grant strength, virility, fertility, and even knowledge and immortality, and was considered a drink of nobles and gods[1]. Mead is deeply rooted in cultural heritage, representing hospitality, community, and celebration. Its production and consumption are often linked to traditional customs and rituals, holding significant symbolic value and fostering social bonding. Despite the passage of time, mead remains a popular beverage, with many modern meaderies producing a wide range of mead styles, and its unique flavor profile and cultural significance continue to captivate audiences worldwide[2].

Traditional mead fermentation, which relies on indigenous microorganisms in honey, can be unpredictable and prone to contamination, leading to variable outcomes, off- flavors, unpleasant odors, and potentially spoiled mead. This unpredictability can result in delayed or arrested fermentation, low mead quality, and challenges in maintaining consistent quality, ultimately impacting the reputation of mead producers and failing to meet consumer expectations. However, potential solutions such as controlled fermentation with specific yeast strains, good sanitation and hygiene practices, and regular monitoring and testing can help improve the predictability and quality of mead fermentation, enabling producers to deliver high-quality products with consistent flavor and aroma profiles. Spoilage often occurs due to unfavourable growth conditions that stress the yeasts, making it difficult for them to perform optimally[3].

Honey is a complex mixture primarily composed of carbohydrates (90-95% of dry matter) and water, with the latter significantly influencing its shelf life and stability. Environmental factors and storage conditions impact honey's water content, which in turn affects microbial stability and fermentation risk. Honey is typically microbiologically stable when its water activity (aw) value is below 0.60, which usually falls within the 0.55-0.75 range critical for controlling microbial growth. Measuring water content is essential for assessing fermentation risk, and various methods like refractometry and Karl Fischer titration can be used. Understanding water content and activity helps beekeepers and producers ensure the quality and stability of honey products[4].

Mead fermentation is a complex process influenced by factors like nitrogen availability, yeast strain, and honey's unique properties. Limited nitrogen sources can lead to slow fermentation, while traditional fermentation challenges include arrested fermentation due to inaccurate sugar content measurement, risking spoilage[5,6]. To enhance fermentation, inorganic salts like ammonium sulphate and ammonium hydrogen phosphate can be added, providing a readily available nitrogen source for yeast growth[7,8]. *Saccharomyces cerevisiae* (baker's yeast) converts sugars into ethanol and carbon dioxide through fermentation, a process that involves glycolysis and pyruvate conversion. Honey's properties, such as bacteriostatic activity and low pH, inhibit microbial growth, contributing to mead's long fermentation period and natural preservation. Adequate packaging preserves honey's quality, prevents

contamination, and supports high-quality mead production[9].

Saccharomyces cerevisiae , commonly called baker's yeast, is a highly adaptable microorganism with diverse uses in industry. This unicellular, oval-shaped yeast can ferment sugars to produce alcohol and carbon dioxide, and is widely used for ethanol production, single-cell protein production, and in the food and beverage industry for baking, brewing, and wine making. Its advantages include high ethanol yield, robustness, and versatility, making it an ideal microorganism for biofuel production, biotechnology applications, and industrial processes[10]. *S. cerevisiae* plays a crucial role in biofuel production, food and beverage industry, and biotechnology, contributing to the production of various products, Mead production is a complex process influenced by factors like raw material quality, including bread, beer, wine, and bio-fuels[11].

Mead Preparation Technique

Microorganisms, and vinification practices, resulting in a wide alcohol content range of 7-22%. By adjusting the honey-to-water ratio and fermentation duration, mead makers can craft diverse styles, from dry and light to sweet and heavy-bodied, or even sparkling varieties with bottle fermentation. This versatility allows for a broad range of flavor profiles, making mead an exciting beverage for enthusiasts and producers, with endless possibilities for traditional, modern, still, or sparkling variations[12].

Raw Materials Used In Preparation Of Mead

Honey: Honey can be classified as monofloral (from one dominant plant species) or multifloral (from multiple plant species) based on its floral source. Its quality is evaluated by color, aroma, and flavor[13]. Honey color is classified into seven grades - from water white to dark amber - based on optical density measurements at 560nm using colorimetric methods[13,14].

Mead production often favors light-colored honey for its mild flavor, while dark honey can impart strong, unbalanced tastes[15]. Honey's characteristics are influenced by heat treatment and storage, making proper handling crucial. Composed mainly of sugars, honey's moisture content (around 17-18%) affects fermentation and alcohol content, while a small amount of protein impacts its properties[16]. Honey's tendency to crystallize or granulate can be addressed by heating it to 60°C to liquefy, making it easier to work with in mead production. Understanding these characteristics helps mead makers select and handle ingredients effectively, producing high-quality meads with desired flavor profiles[17].

The characteristics of mead can vary significantly depending on the source of the honey used in its production. Research has shown that mixed floral honey can result in mead with a higher final alcohol content compared to honey from specific sources like *Eucalyptus ochrophloia,* particularly when fermented with mead yeast[18]. However, the fermentability of honey can also differ, with light honey from sources like clover being more challenging to ferment and requiring additional nutrients like vitamins, minerals, Interestingly, even honey from the same floral source can exhibit variability between batches, with some allowing slow fermentation and others requiring supplementary growth factors to initiate fermentation[19]. Adding growth factors can allow microbes to ferment different types of honey that wouldn't normally support fermentation. Furthermore, environmental factors such as climate and geography can impact the characteristics of honey, resulting in meads with distinct properties even when produced from the same floral source but from different locations or years[20].

Brewing Process

Mead brewing involves two methods: hot and cold. The hot method, which involves boiling the honey mash, accelerates fermentation and enhances stability, but may sacrifice subtle flavors and create new compounds. The cold method preserves natural flavors and aromas, allows for slower fermentation, but carries a higher risk of contamination. The choice between methods depends on desired flavor profiles, fermentation characteristics, and antioxidant properties, ultimately relying on the brewer's goals and preferences[21].

Researchers use techniques like fining agents, cell immobilization, nutrient addition, yeast inoculation, and pollen addition to improve mead quality and consistency. These methods aim to enhance flavor, aroma, and appearance while optimizing fermentation efficiency. The goal is to develop best practices for producing high-quality mead with consistent characteristics[22].

Yeast Selection

Mead production is a lengthy process due to honey's unique characteristics, including high sugar content and low mineral content, which can hinder fermentation[23]. The yeast's metabolic activity, heavily influenced by the availability of assimilable nitrogen, significantly impacts the final aroma profile of the mead. However, honey's typically low nitrogen content can lead to sluggish or incomplete fermentation, ultimately affecting the consistency and quality of the final product, making it challenging to achieve uniformity in mead production[24].

The selection of yeast is a crucial determinant in mead production, necessitating strains capable of withstanding the high sugar concentrations and osmotic pressures characteristic of honey-based fermentation. Different yeast strains are optimized for specific mead styles, such as *T. delbrueckii* for sweet meads and *S. bayanus* for dry meads, each conferring distinct attributes to the final product[25]. Researchers have made significant strides in isolating yeast strains from honey and its by-products, revealing that these native yeasts can yield high-quality meads with intricate flavor profiles and desirable sensory properties. During fermentation, yeast fulfills a dual function: converting sugars into ethanol and producing a wide range of compounds, including higher alcohols and esters, which

substantially contribute to the nuanced flavor and aroma of mead[26]. Recent studies have explored the utilization of non-distilling yeast strains, with the dual objectives of reducing the alcohol content of mead and enhancing its flavor profile, thereby increasing its appeal to a more extensive consumer demographic. This innovative approach presents opportunities for advancing mead production methodologies and aligning with shifting consumer preferences, potentially broadening the market and fostering greater appreciation for this ancient beverage. By tailoring yeast selection to specific mead styles and consumer preferences, producers can create diverse, high-quality products that cater to various tastes and preferences[27].

Different Composition On The Production Of Mead

The volatile compounds in mead, including ethanol and 3-methyl-1-butanol, are shaped by factors such as honey type, processing technology, and yeast selection[28]. Research has pinpointed key sensory attributes that influence mead's acceptability, notably acidity, sweetness, and alcohol heat. Studies have consistently shown that sweetness plays a pivotal role in determining mead's acceptability, whereas alcohol content has a relatively lesser impact[29]. The analysis of commercial meads has uncovered a diverse array of volatile compounds, which collectively contribute to the complex and unique flavor profiles of these beverages. Furthermore, the specific combination and concentration of these compounds can significantly affect the overall character and quality of the mead[30].

Yeast selection significantly impacts the flavor of mead. Studies have demonstrated that utilizing wild yeast strains can yield meads with distinct characteristics, including lower ethanol levels, higher residual sugar content, and a more pronounced presence of floral and fruity notes. Moreover, employing mixed cultures that combine wild yeasts with non- *Saccharomyces cerevisiae* yeasts can further enhance the complexity and depth of the aroma profile. This approach allows for the creation of meads with rich, nuanced flavor experiences, offering a diverse range of possibilities for mead producers to explore and innovate. By carefully selecting and combining yeast strains, mead makers can craft unique and captivating flavor profiles that showcase the versatility of this traditional beverage[31].

Optimizing process conditions and adding specific ingredients can impact mead's composition and flavor. Research has shown that adding hydrogels during fermentation can influence flavor substances, while incorporating pollen into the fermentation process can increase volatile compounds and enhance mead's organoleptic properties[32]. A study found that adding 30 g/hl of pollen resulted in the highest sensory scores, producing a more palatable mead. These findings suggest that careful control of process conditions and ingredient additions can help create high-quality meads with desirable flavor profiles. Optimizing process conditions and adding specific ingredients can impact mead's composition and flavor. Research has shown that adding hydrogels during fermentation can influence flavor substances, while incorporating pollen into the fermentation process can increase volatile compounds and enhance mead's organoleptic properties[33]. A study found that adding 30 g/hl of pollen resulted in the highest sensory scores, producing a more palatable mead. These findings suggest that careful control of process conditions and ingredient additions can help create high-quality meads with desirable flavor profile. Fig 1 shows, Mead is made by mixing honey with water, adding nutrients and yeast, and allowing it to ferment. After fermentation, the liquid is racked and aged to develop its unique flavor and aroma.

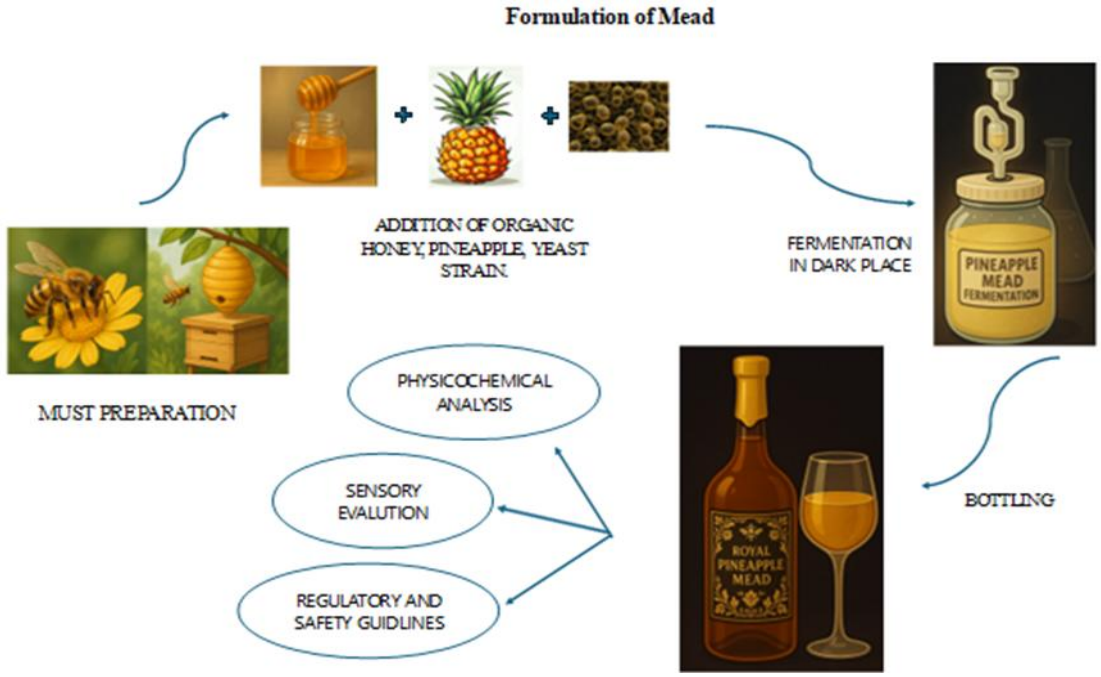

Figure 1: Formulation of Mead.

VALIDATION AND QUALITY ASSISMENT

Physicochemical Analysis of Mead

Assessing physicochemical properties is key to determining mead's quality, stability, and overall acceptability. Common parameters analyzed include pH, titratable acidity, alcohol content, total soluble solids (°Brix), specific gravity, and residual sugars. These characteristics not only reflect the progression and completeness of fermentation but also influence the sensory profile and microbial stability of the final product. For instance, a lower pH and adequate ethanol concentration help inhibit the growth of spoilage microorganisms, ensuring shelf stability. Furthermore, monitoring parameters such as specific gravity and °Brix can guide the fermentation process and indicate when it is complete[34].

Microbiological Safety of Mead

Mead's microbiological safety is vital to protect consumer health and maintain product quality. Although mead's low pH and alcohol content create a relatively inhospitable environment for many microorganisms, contamination can still occur, particularly during production, fermentation, or storage[35].

Common Contaminants: The most frequent microbial contaminants in mead include wild yeasts, lactic acid bacteria (LAB), and acetic acid bacteria (AAB). Wild yeasts such as Brettanomyces can cause off-flavors and undesirable fermentation. LAB, particularly species like Lactobacillus and Pediococcus, may result in increased acidity and haze formation. AAB, such as Acetobacter, can oxidize ethanol to acetic acid, leading to vinegar-like spoilage[36].

Spoilage Indicators: Visual signs of microbial spoilage include turbidity, sediment formation, film development, and gas production. Organoleptic defects such as sourness, bitterness, or medicinal aromas can also indicate microbial activity[37].

Testing Methods: Regular microbiological testing is vital to prevent spoilage and ensure compliance with safety standards. Common methods include:

- Plate count techniques (e.g., pour plate or spread plate) using selective media to quantify total viable bacteria, yeasts, and molds.
- PCR-based molecular techniques for rapid detection and identification of specific spoilage organisms or pathogens.Microscopic observation (e.g., Gram staining) for rapid identification of bacterial groups.ATP bioluminescence assays, which provide quick insights into microbial contamination levels on surfaces or equipment.
- Implementing proper sanitation, using sterilized equipment, and maintaining airtight fermentation conditions are critical practices for minimizing microbial risks. Pasteurization or chemical preservatives (e.g., potassium sorbate or sulfites) may also be used to improve microbial stability, especially in commercial production[38].

Sensory Evaluation

Sensory evaluation is a key component in assessing the overall quality and market potential of mead. It involves the systematic analysis of organoleptic properties such as appearance, aroma, flavor, mouthfeel, and aftertaste, which collectively influence consumer perception and acceptance. The clarity and color of mead can affect visual appeal, while aroma—shaped by volatile compounds from honey, yeast, and fermentation by-products—plays a major role in consumer preference[39]. Flavor balance between sweetness, acidity, alcohol, and any added ingredients (e.g., spices or fruits) contributes to the beverage's complexity. Mouthfeel, including viscosity and warmth from alcohol, also impacts the drinking experience. Sensory panels, often composed of trained assessors or consumer groups, use tools like hedonic scales or descriptive analysis to quantify preferences and detect faults. Such evaluations are vital for product development, quality control, and aligning mead characteristics with target market expectations[40].

TRADITIONAL Vs MODERNITY

Table 1: Traditional vs Modernity

Aspect	Traditional mead	Modern mead
Ingredients	Primarily use raw honey, water and spontaneous or naturally occurring yeast.	Incorporates honey, commercial yeast strains, and often fruits, spices or additives.
Fermentation	Relies on natural fermentation, which can be slow and unpredictable.	Utilized controlled fermentation with added nutrients and temperature control for efficiency.
Flavor Profile	Strong honey character, often with earthy or rustic notes due to wild yeast.	Broader and more controlled flavor profile, often enhanced with fruits and spices,
Technology use	Traditional vessels like earthen pots or wood barrels, minimal instrumentation.	Stainless steel fermenters, airlocks, pH meter and sanitizers used to control variables.
Purpose and context	Typically produced in cultural or household settings with rituals significance.	Commercially produced for the craft beverage market with consumer - driven innovation.
Aging Practices	Requires long term aging (months to years) to mellow and clarify.	Often optimized for shorter aging or even fresh consumption based on additives and style.

REGULATORY AND SAFETY GUIDELINES

The commercial production of mead is governed by a set of legal and safety requirements that vary by country but generally aim to protect consumer health and ensure product quality. Mead producers must obtain the appropriate licenses for alcohol production and adhere to food safety regulations, which often include registering production facilities, complying with alcohol taxation laws, and following standard labeling practices[41]. Mead is typically categorized under wine or fermented beverages, and thus must meet specific criteria for alcohol content, ingredient declarations, and allowable additives. Regulations often mandate the implementation of Good Manufacturing Practices (GMP) and Hazard Analysis and Critical Control Points (HACCP) systems to minimize contamination risks and maintain hygiene during production. Proper labeling—stating the alcohol percentage, ingredients, allergens, volume, producer information, and expiration date—is essential for transparency and legal compliance. These regulations not only help maintain public health standards but also support the credibility and commercial success of mead products in both domestic and international markets[42].

FOOD HYGIENE AND HYGIENE CONSIDERATIONS

Maintaining strict hygiene throughout mead production is essential to prevent microbial contamination and ensure the safety and quality of the final product. This includes thorough cleaning and sanitization of all equipment, fermentation vessels, and storage containers to minimize the risk of spoilage organisms and pathogens. Personnel hygiene, including proper handwashing and use of protective clothing, is equally important to reduce contamination risks. Additionally, controlling the production environment by monitoring temperature and humidity helps inhibit undesirable microbial growth[43]. Adopting internationally recognized hygiene standards such as Good Manufacturing Practices (GMP) and Hazard Analysis and Critical Control Points (HACCP) enables systematic identification and control of potential hazards. These practices collectively contribute to producing a safe, stable, and high-quality mead product that meets regulatory requirements and consumer expectations[44].

HEALTH BENEFITS OF MEAD

Mead's potential health benefits are multifaceted, with its rich honey content and fermentation process offering antioxidant, anti-inflammatory, and cognitive-supporting properties that may enhance cognitive function, reduce inflammation, and improve antioxidant defenses. These benefits may promote overall well-being and support a healthy lifestyle. However, moderation is essential due to mead's alcohol content. Further research is needed to determine optimal consumption levels, investigate potential interactions, and elucidate mead's specific health impacts. By understanding its benefits and risks, individuals can make informed decisions about incorporating mead into their health regimen to support overall health, cognitive function, and balanced wellness[45]. Fig 2 shows the health benefits of mead.

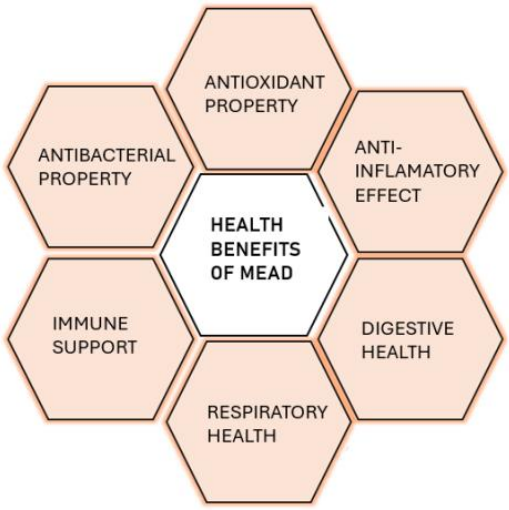

Figure 2: Health benefits of mead.

Antioxidants Properties

Mead, made from raw and unprocessed honey, is a potential rich source of antioxidants, which help protect the body from oxidative stress and damage caused by free radicals. These compounds, including flavonoids, phenolic acids, and ascorbic acid, can neutralize free radicals, reduce inflammation, protect against cell damage, and support overall health. The antioxidant content varies depending on honey type, fermentation methods, and additional ingredients like fruits or herbs. Moderate consumption of mead, as part of a balanced lifestyle, may harness its antioxidant benefits[46].

Anti-Inflammatory Effects

Mead, made from honey, offers a range of potential health benefits due to its anti-inflammatory and antioxidant properties. The polyphenols and other compounds present in honey may help reduce inflammation, alleviating conditions like asthma, allergies, and arthritis. Moderate mead consumption may also promote cardiovascular health by protecting against oxidative stress and inflammation, potentially reducing the risk of heart disease. Additionally, the antioxidant properties of mead may help reduce stress and anxiety, promoting overall well-being. While mead's potential health benefits are promising, it's essential to consume it in moderation due to its sugar and calorie content. To enjoy benefits while reducing risks, drink mead responsibly, just like any other beverage. Mead's unique blend of honey and other ingredients makes it a fascinating option for those looking to explore new flavors and potential health benefits[47].

Immune support: Mead made with raw honey or medicinal herbs (like ginger, elderberry, or cinnamon) may help boost immunity due to their antiviral and anti-inflammatory properties[48].

Antibacterial properties: Mead inherits honey's extraordinary antibacterial properties, which are

remarkably preserved during fermentation, allowing it to retain a substantial amount of these beneficial effects. Moreover, certain meads are rich in probiotics from live yeasts and beneficial bacteria, providing enhanced support for gut health and immune function. This potent combination can unlock a wide array of additional health benefits, establishing mead as a distinctive beverage that not only delights the palate but also offers potential wellness advantages, making it a truly unique drink with a rich history and promising future in the realm of health-conscious consumption[49].

Digestive Health

Mead's potential benefits for digestive health are promising, with its probiotic and prebiotic properties working synergistically to promote a balanced gut microbiome. The beneficial bacteria in mead may aid digestion, boost immunity, and support a balanced gut ecosystem, while honey's prebiotic properties nourish beneficial gut bacteria. This balance is crucial for maintaining overall digestive well-being, potentially alleviating symptoms of digestive disorders and enhancing nutrient absorption. Moderate consumption is key, as excessive alcohol intake can counteract these benefits. Further research is needed to fully understand mead's effects on digestive health and determine optimal consumption levels for maximum benefits. By exploring mead's potential benefits and risks, individuals can make informed decisions about incorporating it into their health regimen. Mead's unique blend of honey and beneficial bacteria makes it an intriguing option for those seeking natural ways to support digestive health[50].

Respiratory Health

Mead's potential benefits for respiratory health are promising, with honey's medicinal properties offering a natural remedy for soothing coughs, sore throats, and other respiratory issues. The soothing and anti-inflammatory properties of honey may calm the throat and respiratory system, reducing discomfort and inflammation. Additionally, honey's antibacterial and antiviral properties may help combat underlying infections, potentially alleviating symptoms of colds and flu. By leveraging these properties, mead may provide a comforting and potentially effective way to support respiratory health, promote relaxation, and enhance overall well-being. As a natural remedy, mead's unique blend of honey and other ingredients may offer a valuable alternative or complement to traditional treatments for respiratory issues, providing a soothing and potentially therapeutic option for those seeking to support their respiratory health[51].

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