Scientific Papers. Series B, Horticulture. Vol. LXIX, No. 1, 2025
Print ISSN 2285-5653, CD-ROM ISSN 2285-5661, Online ISSN 2286-1580, ISSN-L 2285-5653

CRAFTED BARREL - AGED BEER: TRADITION AND INNOVATION IN FLAVOR EVOLUTION - REVIEW

Mihai FRÎNCU[1], Corina DUMITRACHE[5], Diana-Iuliana BĂRBULESCU[2], Mihaela BEGEA[3, 4], Carmen-Rodica VRÎNCEANU[5], Răzvan-Ionuț TEODORESCU[5]

[1]Research Center for Studies of Food Quality and Agricultural Products, University of Agronomic Sciences and Veterinary Medicine of Bucharest, 59 Mărăști Blvd, District 1, 011464, Bucharest, Romania
[2]Faculty of Biotechnologies, University of Agronomic Sciences and Veterinary Medicine of Bucharest, 59 Mărăști Blvd, District 1, 011464, Bucharest, Romania
[3]National University of Science and Technology Politehnica Bucharest, 313 Splaiul Independentei, District 6, Bucharest, Romania
[4]Faculty of Biotechnical Systems Engineering, National University of Sciences and Technology Politehnica Bucharest, 060042, Bucharest, Romania
[5]Faculty of Land Reclamation and Environmental Engineering, University of Agronomic Sciences and Veterinary Medicine of Bucharest, 59 Mărăști Blvd, District 1, 011464, Bucharest, Romania

Corresponding author email: corina_dumitrache17@yahoo.com

Abstract

Barrel-aging beer is a practice that dates back to the early days of brewing, when wooden barrels served as essential tools for storage and transportation. Over time, brewers observed that barrels could enhance the flavor of beer, transforming a practical necessity into a valued tradition. This process has been revitalized in the modern brewing industry to craft beverages with unique and complex sensory profiles. Barrel-aging involves storing beer in barrels made from various types of wood, often previously used to age spirits such as whiskey or rum. The interaction between beer and wood releases aromatic compounds like vanillin, γ-nonalactone, and volatile phenols, which contribute to the beer's enhanced flavor and character. This paper investigates the key factors influencing the sensory characteristics of barrel-aged beer, focusing on oxidation, wood compound extraction, and biochemical transformations during aging. It also highlights the beer styles best suited for barrel-aging, such as stouts, porters, and strong ales, which benefit most from the process. Finally, this paper underscores how barrel-aging merges tradition and innovation, offering brewers new ways to diversify and refine the sensory profile of modern beers.

Key words*: barrel-aged beer, aromatic compounds, yeast, flavor, craft beer.*

INTRODUCTION

Beer has significantly influenced cultural, economic, and technological advancements in human societies, with its origins tracing back to ancient civilizations such as Mesopotamia, where evidence suggests beer production dates back over 13,000 years (Paulette, 2024; Pilcher, 2025). Initially, brewing techniques were rudimentary, but they evolved through technological advancements, as seen in the ancient Hymn to Ninkasi, which outlines the brewing process (Paulette, 2024). The introduction of hops in the thirteenth century revolutionized beer preservation and trade, leading to the commercialization of beer and the emergence of distinct styles, reflecting social distinctions among consumers (Pilcher, 2025; Withers, 2017). Recent research highlights the importance of sustainability in beer production, emphasizing the environmental impacts of brewing processes and advocating for improved technologies and practices, such as Life Cycle Assessment (LCA) to evaluate ecological footprints (D'Ascanio et al., 2024). Nowadays, barrel aging exemplifies the fusion of traditional brewing practices with modern scientific insights, enhancing the sensory complexity of beer through complex interactions between the beverage and wood (Noviello et al., 2024; Paulette, 2024; Seo, 2024; Winstel et al., 2024; Paulette, 2024).

The transition from necessity to craft beer technique marks a profound shift in brewing practices and cultural significance over millennia. Originally, beer production served as a means of grain preservation and nutrition, playing a key role in the shift from nomadic to agrarian societies around 14,000 BP (Cabras et al., 2023). Over time, brewing evolved beyond its practical origins, becoming a dynamic cultural expression shaped by tradition, innovation, and advancements in technology (Mastanjević et al., 2019; Valentoni et al., 2022; Villacreces et al., 2022). This ongoing evolution underscores beer's role as a dynamic cultural artifact, shaped by both historical context and contemporary innovation (Billingsley, 2024; Kimberley, 2018).

Advances in chemometrics provide insights into aging compounds, aiding brewers in quality control (Coelho et al., 2019; Mutz et al., 2020). Additionally, craft beer's role in tourism underscores its cultural and economic significance, reinforcing the need for strategic approaches to enhance consumer experience (Tham et al., 2024; Withers, 2017). These aspects highlight aging as a key factor in sustaining the integrity and market value of craft beer.

MATERIALS AND METHODS

This review was based on an extensive selection of scientific publications, web pages data and relevant academic books covering the chemistry, microbiology, and sensory aspects of barrel-aged beer. Literature was retrieved from databases such as ScienceDirect, Google Scholar, Web of Science, and SpringerLink, focusing on works published between 2015 and 2025 (approximately 80% of all references), with the remaining citations representing historical or foundational sources that consolidate the theoretical background and contextualize traditional practices. Search terms included: barrel-aged beer, oak wood compounds, beer maturation in spirit barrels, volatile aroma compounds, yeast metabolism during aging, and flavor development in craft beer. Both recent experimental studies and historical references on wood aging and fermentation processes were included. Priority was given to sources discussing the influence of wood, the residual compounds from previously stored beverages, and the role of yeast in shaping the final sensory profile. Emphasis was placed on identifying how barrel-aging contributes to the transformation of beer aroma and flavor, with particular attention to beer styles most suitable for this maturation technique, such as stouts, porters, and strong ales.

Barrel composition and types of wood used

The barrel-aging process significantly shapes the chemical composition and aromatic complexity of beer through its interactions with wood, with factors such as the wood type and barrel charring playing a pivotal role. In addition to the compounds derived directly from the wood, the impact of the previously stored beverage must also be considered (in the case of using recycled barrels from the spirits or wine industry). Essentially, the barrel walls act as a reservoir of aromas: bourbon, whiskey, or wine barrels will release residual components into the beer, such as aldehydes, esters, and alcohols specific to those beverages (Bhowmik, 2023). Different oak species, such as American and French oak, introduce distinct phenolic compounds that enhance both flavor and aroma. For example, American oak can increase certain phenolic acid concentrations by up to tenfold compared to French oak (Carpena et al., 2020; Machado, 2019). The extraction of wood-derived compounds, including pyrazines and pyrroles, further contributes to the sensory profile of matured beers, influencing aroma, taste, and color (Picard et al., 2021; Silva et al., 2022; Tarko et al., 2023). Additionally, the aging process fosters the development of complex flavors, particularly in sour beers, where microbial activity adds an additional depth to the profile (Bossaert et al., 2021; Bossaert, Kocijan, et al., 2022). Ultimately, the interplay between wood characteristics and beer composition is fundamental to achieving the desired sensory attributes (Castro & Ross, 2018; Karathanos et al., 2024; Machado, 2019; Winstel et al., 2024). In order to highlight the influence of barrel maturation on the aromatic profile of beer, it's essential to examine the impact of different types of barrels used. The specific characteristics of each type of wood, as well as previous maturation processes, significantly contribute to the chemical composition and sensory complexity of the beer.

Maturation in whiskey barrel

The maturation of whiskey in oak barrels leads to a diverse and intricate aromatic profile, shaped by a range of chemical processes. The interaction between the spirit and the barrel releases a variety of volatile compounds that define its sensory attributes. For instance, key components found in American Bourbon, such as (E)-β-damascenone and vanillin, originate both from the oak barrel and the spirit absorbed in the wood, impart distinctive caramel and smoky notes (Sterckx, 2012; Tarko et al., 2023). The structural changes in oak during toasting and charring facilitate the formation of roasted aroma compounds, including pyrazines and pyrroles, which deepen the overall complexity of the whiskey (Picard et al., 2021; Goullet et al., 2023). Additionally, terpenoids extracted from the wood contribute subtle floral and minty undertones, further refining the whiskey's sensory character (Picard et al., 2023). The Maillard reaction, occurring as a result of barrel heating, generates maltol and furaneol - compounds essential for the development of a rich, toasted caramel aroma (Tamanna & Mahmood, 2015; Starowicz & Zieliński, 2019). As the beer matures, residual whiskey compounds previously absorbed by the oak, such as lactones, furfurals, and ethanol derivatives, gradually dissolve into the beer, contributing to a richer and more layered flavor profile.

Maturation in rum barrel

Oak barrels previously used for rum aging can significantly influence the sensory profile of barrel-aged beer, imparting rich notes of molasses, brown sugar, and tropical fruits. The interaction between beer and the residual compounds absorbed by the wood during rum maturation enhances both sweetness and complexity. Key aroma compounds such as vanillin and phenolic derivatives extracted from the oak contribute to the beer's overall depth and balance. Additionally, the presence of ethyl esters, which increase during both fermentation and aging (some originating from the beer itself and others extracted from the residual spirit) further intensifies fruity and caramel-like notes, complementing the malt backbone of the beer (Franitza et al., 2016). The porous structure of the barrel allows controlled oxygen exchange, promoting the slow oxidation of phenolic and aromatic compounds, which can enhance the perception of vanilla, caramel, and dried fruit notes. The residual impact of molasses-based fermentation, a defining element of rum production, also influences the final character of barrel-aged beer by introducing subtle yet distinct layers of dried fruit and spice. Ultimately, the combination of raw material origins, brewing techniques, and barrel-aging conditions creates a complex and evolving flavor profile unique to beer matured in rum barrels (Mangwanda et al., 2021; Maza Gomez, 2002; Yi, 2013).

Maturation in wine barrel

The sensory characteristics of wine, including its aroma, taste, and color, are primarily influenced by its composition, which is shaped by various factors throughout fruit cultivation and wine production (Barbulescu et al., 2022; Frincu et al., 2023; Frîncu et al., 2024). Key components such as sugars, organic acids, polyphenols (including anthocyanins), and yeasts activity play a critical role in determining the wine's quality and sensory attributes (Martínez-Gil et al., 2022; Recamales et al., 2006; Styger et al., 2011; Viviani et al., 2007). Beer aged in wine barrels gains complexity from the wood and residual wine compounds, enriching its aroma and flavor profile (Bossaert, Winne, et al., 2022). Oak barrels previously used for wine maturation contribute lactones, tannins, and phenolic compounds, enhancing sensory attributes like vanilla, coconut, dried fruits, and spices (Oliver & Colicchio, 2011). The porous structure of oak barrels facilitates micro-oxygenation, promoting controlled oxidation and stabilizing polyphenols. This reaction softens astringency, deepens color, and refines overall sensory perception (Gomez-Cordoves & Gonzalez-SanJose, 2002; Ribéreau-Gayon, 2006). The degree of wood toasting significantly influences aromatic profiles: lightly toasted barrels release more ellagitannins, stabilizing color and enhancing subtle fruity notes, whereas medium to heavy toasting favors smoky and spicy phenolic compounds (Díaz-Maroto et al., 2008; Poisson & Schieberle, 2008). Red wine barrels particularly introduce complex, tannic, and fruity characteristics due to residual anthocyanins and tannins interacting with beer compounds (Del Fresno et al., 2020; Maga, 1989). White wine barrels, however, provide more subtle fruity, floral, and vanilla nuances (González-Centeno et al., 2020; Stegăruș et al., 2021). However, the maturation in wine barrels carries risks, such as excessive oxidation, potentially leading to undesired off-flavors or color deterioration, necessitating careful control of the aging process to maximize beneficial impacts while minimizing negative effects (Del Fresno et al., 2020; Ortega-Heras et al., 2007; Picard et al., 2021).

Cognac and brandy barrel maturation

Cognac and brandy barrels play a significant role in shaping the sensory complexity of barrel-aged beer, imparting layered notes of dried fruit, nuts, and caramel (Caldeira et al., 2010; Tarko et al., 2023). The toasting process applied to oak used for cognac and brandy production is particularly important, as it modifies the chemical composition of the wood, facilitating the extraction of key aromatic compounds during beer maturation. In this context, the interaction enhances the flavor complexity, contributes to a smoother mouthfeel, and intensifies the aromatic profile of the final product (Gadrat et al., 2022; Tsakiris et al., 2014). When beer is aged in barrels previously used for grape distillates, residual compounds from cognac or brandy, along with wood-derived elements, slowly infuse the beer, imparting nutty, and caramelized notes, enriching its complexity (Butrón-Benítez et al., 2024). Furthermore, volatile compounds released during aging amplify these sensory characteristics, reinforcing the perception of fruit-forward and oaky flavors (Uselmann & Schieberle, 2015). As with whiskey and rum barrels, the residual spirit absorbed into the wood also contributes to the beer's complexity, introducing ethanol derivatives and esterified compounds unique to each barrel's previous contents. Ultimately, the intricate exchange between beer and cognac or brandy barrels plays a crucial role in developing sophisticated flavor profiles unique to this aging method.

Table 1. Summary of key aroma compounds and sensory notes contributed by different barrel wood species and previous beverages

Barrel wood species	Previous beverage	Key aroma compounds	Dominant sensory notes
American oak	Bourbon whiskey	Vanillin, (E)-β-damascenone, pyrazines, pyrroles, furfurals, terpenoids	Caramel, vanilla, smoke, roasted nuts, minty, toffee
American/French oak	Molasses-based rum	Vanillin, phenolic derivatives, ethyl esters, lactones	Brown sugar, molasses, tropical fruits, dried fruits, spice, vanilla, caramel
French oak	Red wine	Tannins, anthocyanins, organic acids, phenolic compounds, lactones	Plum, fig, vanilla, oak, spice, dried fruits, coconut
French oak	White wine	Volatile esters, ellagitannins, phenolic aldehydes, lactones	Fruity, floral, vanilla, creamy, slightly oxidized
American/French oak	Grape distillates	Ethanol derivatives, esters, nutty aldehydes	Dried fruits, nuts, caramel, soft oak, sherry-like notes

Types of beer suitable for barrel aging

Maturation is a key stage in the beer production process, particularly when it comes to craft beers. During this phase, the beer naturally clarifies, and its flavors blend and develop harmoniously. Historically, beer maturation was carried out in wooden barrels, whose essences enriched the beer's aromatic profile, imparting distinctive taste nuances and a unique character. Nowadays, maturation takes place in stainless steel vessels, which allow for strict quality control by minimizing oxidation and the risk of microbiological contamination. However, this modern solution comes with a trade-off: a subtle loss of the flavor complexity once imparted by wooden aging. The suitability of a particular beer style for barrel aging is influenced by several factors, including the

style of the beer, the type of wood used, and the desired flavor profile. Certain beer styles are better suited to this process due to their robust aromatic character and their ability to withstand the complex interactions resulting from contact with wood.
Ale beers are particularly well-suited for barrel maturation due to their malt-forward profile, low bitterness, and inherent caramelized sweetness, which are enhanced through aging in oak barrels (Sterckx, 2012). The interaction between the beer and the wood during maturation leads to the development of complex flavor profiles, including notes of vanilla, toffee, and mild smokiness (Wyler et al., 2015).
Stout and Porter beers are among the most popular styles for barrel aging, as their roasted, coffee-like flavors complement the vanilla, oak, and caramel notes imparted by the barrel (Schneider, 2023). Additionally, their high alcohol content and rich mouthfeel make them particularly well-suited for extended maturation periods, allowing the development of complex and harmonious flavor profiles (Nilsen, 2024).
Barley wine beers, both English and American styles, are well-suited for barrel aging due to their high alcohol content, residual sweetness, and robust malt character (Craft Beer & Brewing, 2010). These attributes provide a stable base that interacts favorably with the barrel, developing flavors of dried fruits, sherry, oak, and caramel over time (Bjergso & Pang, 2015). The aging process enhances their complexity, making them ideal candidates for long-term maturation in wood barrels previously used for wine, bourbon, or other spirits.
Belgian Dark Strong Ales and Quadrupels are particularly well-suited for barrel aging due to their complex malt profiles and phenolic yeast characteristics, which harmonize with the flavors imparted by wood. The process of aging these beers in barrels, especially those previously used for red wine or brandy, enhances their sensory attributes by intensifying notes of fig, plum, vanilla, and subtle spices, while also smoothing the perception of alcohol (Sanna & Pretti, 2015). Also, wood aging significantly influences the flavor profile of beverages, as seen in the increased woody, vanilla-like, and spicy notes in beers aged with oak chips (Sterckx, 2012).
Sour ales (Vrînceanu,et al, 2022), including Lambic, Gueuze, Flanders Red, and Oud Bruin, are characterized by their unique fermentation processes that occur in wooden barrels, which harbor diverse microbiota such as *Brettanomyces*, *Lactobacillus*, and *Pediococcus*. These microorganisms contribute significantly to the beers' acidity and complex flavor profiles, which often feature tart fruit notes, earthy undertones, and a vinous character (De Roos et al., 2019). The fermentation process is influenced by various factors, including the barrel's microbial community, which can vary based on cleaning procedures and barrel type, as well as environmental conditions during fermentation (Bongaerts et al., 2021). Traditional sour ales rely on spontaneous inoculation rather than pure cultures (Nasuti et al., 2023a), allowing for a rich interplay of microorganisms that evolve over time, leading to distinctive taste variations and enhancing the overall quality of the final product (De Roos And & De Vuyst, 2022; Spitaels et al., 2017).
Saison and other farmhouse ales can be successfully aged in barrels, particularly when aiming for rustic or mixed-fermentation profiles. Their dry body, spicy phenolics, and moderate ester content offer a clean base that allows wood and secondary fermentation to shine (McCarthy & Ewing-Mulligan, 2006). Barrel aging introduces layers of hay, leather, white wine, and soft oak tannins, especially when using barrels previously containing white wine or cider (Alexander & Valliere, 2019).

The Role of Yeasts in Barrel-Aging

Yeasts play a crucial role in the barrel-aging process of beer, contributing significantly to the flavor and aroma profiles of the final product. During barrel aging, various yeast strains, including *Saccharomyces cerevisiae*, *Brettanomyces*, and *Pichia*, dominate the microbiome, each imparting unique sensorial attributes to the beer (Iorizzo et al., 2021; Nasuti et al., 2023b; Shayevitz et al., 2020; Vrînceanu et al., 2025). The metabolic activity of yeasts varies considerably depending on the species and the environment from which they were isolated, influencing their contribution to the beer's sensory characteristics (Bărbulescu et al., 2021; Dumitrache et al., 2020). The presence of these yeasts in wooden barrels can significantly alter microbiome profiles, affecting beer consistency and quality, not only through their role in fermentation but also by reducing undesirable aged aroma compounds such as aldehydes, responsible for off-flavors like cardboard (Saison et al., 2010; Shayevitz et al., 2020). Yeasts play a critical role not only in fermentation but also in reducing undesirable aged aroma compounds, such as aldehydes, responsible for off-flavors like cardboard and ribes (blackcurrant-like notes), by metabolically converting these aldehydes into corresponding alcohols, thus enhancing beer flavor stability (Maicas, 2020; Saison, 2011). The chronological lifespan of yeast cells is crucial, as it affects their reductive metabolism capacity, essential for enhancing beer shelf life by removing staling compounds, while the selection of yeast strains, including non-*Saccharomyces* yeasts, has gained importance among brewers aiming to innovate and develop specialty beers with unique organoleptic profiles (Wauters et al., 2021). Moreover, optimization processes targeting yeast performance are equally important, as they can significantly enhance the aroma complexity and overall quality of fermented beverages (Barbulescu et al., 2024; Dumitrache et al., 2024). Furthermore, selecting yeast strains, particularly non-*Saccharomyces* species, is increasingly important for brewers aiming to innovate and create specialty beers with unique sensory profiles, as these yeasts possess specific enzymatic activities that distinctly influence beer taste and aroma, offering valuable biotechnological potential to the brewing industry (Iorizzo et al., 2021; Marongiu et al., 2015; Mascia et al., 2016)). Overall, yeasts have a multifaceted role in barrel-aged beer production, encompassing fermentation, flavor enhancement, and opportunities for innovation.

CONCLUSIONS

Barrel-aging is a traditional yet increasingly innovative practice in craft brewing, offering a unique avenue for flavor development through the complex interaction between beer, wood, and microorganisms. This review highlights the multifactorial nature of the maturation process, where variables such as wood species, toasting levels, the previous contents of the barrel (whiskey, rum, wine, or cognac), and the metabolic activity of yeasts play critical roles in shaping the final sensory profile.

American oak contributes intense flavors such as vanilla, coconut, and sweet spice, while European oaks offer more subtle, tannin-rich notes. The reuse of barrels previously containing spirits or wines allows for the transfer of residual compounds that enhance complexity and depth. Yeasts, particularly *Brettanomyces* and certain non-*Saccharomyces* strains, not only survive barrel conditions but also actively contribute to aroma stabilization by reducing oxidative off-flavors and producing distinctive esters and phenols.

The aging process is especially suited to high-alcohol, full-bodied styles such as imperial stouts, porters, and strong ales, which can better integrate and express the compounds extracted during maturation. While barrel-aging can significantly elevate a beer's aromatic profile, it also poses challenges related to oxidation, microbial variability, and process reproducibility.

Future directions in this field may include the exploration of novel wood types, greater control of micro-oxygenation, and tailored microbial inoculations to standardize and optimize flavor outcomes. Barrel-aging thus represents a compelling convergence of tradition, biochemistry, and craftsmanship within the evolving landscape of specialty beer production.

REFERENCES

Alexander, T. R., & Valliere, B. L. E. (2019). *The Professional Handbook of Cider Tasting*. CABI.

Barbulescu, I. D., Ciric, A. I., Begea, M., Matei, P. M., Moisac, A., Nita, A., Frincu, M., Banita, C.-D., Teodorescu, R. I., Tudor, V., & Dumitrache, C. (2022). Tamaioasa Romaneasca and Busuioaca De Bohotin Grapes- Valuable Sources for Wine Production. *SCIENTIFIC PAPERS-SERIES B-HORTICULTURE*, *66*(2), 171–176.

Bărbulescu, I. D., Ghica, M. V., Begea, M., Albu Kaya, M. G., Teodorescu, R. I., Popa, L., Mărculescu, S. I., Cîrîc, A. I., Dumitrache, C., Lupuliasa, D., Matei, F., & Dinu-Pîrvu, C.-E. (2021). Optimization of the Fermentation Conditions for Brewing Yeast Biomass Production Using the Response Surface Methodology and Taguchi Technique. *Agriculture*, *11*(12), 1237. https://doi.org/10.3390/agriculture11121237

Barbulescu, I. D., Radoi-Encea, R. S., Dumitrache, C., Ghica, M. V., Frincu, M., Begea, M., Tudor, V., Boroiu, E.-M., & Teodorescu, R. I. (2024). Optimisation of Culture Media Factors for Active Wine Yeast Biomass Production. *SCIENTIFIC PAPERS-SERIES E-LAND RECLAMATION EARTH OBSERVATION & SURVEYING ENVIRONMENTAL ENGINEERING*, *13*, 866–875.

Bjergso, M. B., & Pang, P. (2015). *Mikkeller's Book of Beer*. Jacqui Small.

Bongaerts, D., De Roos, J., & De Vuyst, L. (2021). Technological and Environmental Features Determine the Uniqueness of the Lambic Beer Microbiota and Production Process. *Applied and Environmental Microbiology*, *87*(18), e00612-21. https://doi.org/10.1128/AEM.00612-21

Bossaert, S., Kocijan, T., Winne, V., Van Opstaele, F., Schlich, J., Herrera-Malaver, B., Verstrepen, K. J., De Rouck, G., Lievens, B., & Crauwels, S. (2022). *Development of a tractable model system to mimic wood-ageing of beer on a lab scale*. https://doi.org/10.1101/2022.03.11.483928

Bossaert, S., Winne, V., Van Opstaele, F., Buyse, J., Verreth, C., Herrera-Malaver, B., Van Geel, M., Verstrepen, K. J., Crauwels, S., De Rouck, G., & Lievens, B. (2021). Description of the temporal dynamics in microbial community composition and beer chemistry in sour beer production via barrel ageing of finished beers. *International Journal of Food Microbiology*, *339*, 109030. https://doi.org/10.1016/j.ijfoodmicro.2020.109030

Bossaert, S., Winne, V., Van Opstaele, F., Buyse, J., Verreth, C., Herrera-Malaver, B., Verstrepen, K. J., De Rouck, G., Crauwels, S., & Lievens, B. (2022). Impact of wood species on microbial community composition, beer chemistry and sensory characteristics during barrel-ageing of beer. *International Journal of Food Science & Technology*, *57*(2), 1122–1136. https://doi.org/10.1111/ijfs.15479

Butrón-Benítez, D., Valcárcel-Muñoz, M. J., García-Moreno, M. V., Rodríguez-Dodero, M. C., & Guillén-Sánchez, D. A. (2024). Chemical and Sensory Profile of Grape Distillates Aged in Quercus alba Casks Previously Used for Sherry Wine or Brandy. *Molecules*, *29*(22), Article 22. https://doi.org/10.3390/molecules29225303

Cabras, I., Kogler, D. F., Davies, R. B., & Higgins, D. (2023). Beer, brewing, and regional studies. *Regional Studies*, *57*(10), 1905–1908. https://doi.org/10.1080/00343404.2023.2216066

Caldeira, I., Anjos, O., Portal, V., Belchior, A. P., & Canas, S. (2010). Sensory and chemical modifications of wine-brandy aged with chestnut and oak wood fragments in comparison to wooden barrel. *Analytica Chimica Acta*, *660*, 43–52. https://doi.org/10.1016/j.aca.2009.10.059

Carpena, M., Pereira, A. G., Prieto, M. A., & Simal-Gandara, J. (2020). Wine Aging Technology: Fundamental Role of Wood Barrels. *Foods*, *9*(9), Article 9. https://doi.org/10.3390/foods9091160

Castro, L., & Ross, C. (2018). Correlation Between Sensory Descriptive Analysis and Volatile Composition of Beer Using Multivariate Analysis: The Effect of the Nonvolatile Matrix on the Sensory Perception and Volatile Fraction Behavior. *Journal of the American Society of Brewing Chemists*, *76*, 86–95. https://doi.org/10.1080/03610470.2018.1433943

Coelho, E., Magalhães, J., Pereira, F. B., Macieira, F., Domingues, L., & Oliveira, J. M. (2019). Volatile fingerprinting differentiates diverse-aged craft beers. *LWT*, *108*, 129–136. https://doi.org/10.1016/j.lwt.2019.03.044

D'Ascanio, V., Greco, D., Abbasciano, M., & Avantaggiato, G. (2024). Optimization and in-house validation of the analytical procedure for official control of bentonites as aflatoxin inactivators. *Food Chemistry*, *432*, 137198. https://doi.org/10.1016/j.foodchem.2023.137198

De Roos And, J., & De Vuyst, L. (2022). Lambic Beer, A Unique Blend of Tradition and Good Microorganisms. In F. J. De Bruijn, H. Smidt, L. S. Cocolin, M. Sauer, D. Dowling, & L. Thomashow (Eds.), *Good Microbes in Medicine, Food Production, Biotechnology, Bioremediation, and Agriculture* (1st ed., pp. 225–235). Wiley. https://doi.org/10.1002/9781119762621.ch18

De Roos, J., Van Der Veken, D., & De Vuyst, L. (2019). The Interior Surfaces of Wooden Barrels Are an Additional Microbial Inoculation Source for Lambic Beer Production. *Applied and Environmental Microbiology*, *85*(1), e02226-18. https://doi.org/10.1128/AEM.02226-18

Del Fresno, J. M., Morata, A., Loira, I., Escott, C., & Suárez Lepe, J. A. (2020). Evolution of the Phenolic Fraction and Aromatic Profile of Red Wines Aged in Oak Barrels. *ACS Omega*, *5*(13), 7235–7243. https://doi.org/10.1021/acsomega.9b03854

Díaz-Maroto, M. C., Guchu, E., Castro-Vázquez, L., De Torres, C., & Pérez-Coello, M. S. (2008). Aroma-active compounds of American, French, Hungarian and Russian oak woods, studied by GC–MS and GC–O. *Flavour and Fragrance Journal*, *23*(2), 93–98. https://doi.org/10.1002/ffj.1859

Dumitrache, C., Frîncu, M., Alexandru, T., Diana, I., Tudor, V., & Ionuţ, R. (2020). Identification by PCR ITS-RFLP technique of new yeast isolates from Pietroasa vineyard. *Scientific Papers. Series B, Horticulture*, *LXIV*(1), 287–293. https://horticulturejournal.usamv.ro/pdf/2020/issue_1/Art43.pdf

Dumitrache, C., Ghica, M. V., Frîncu, M., Bărbulescu, I. D., Begea, M., Diguță, C. F., Baniță, C., Cotea, V. V., Israel-Roming, F., & Teodorescu, R. I. (2024). Bioprocess Optimization by Taguchi Design and Response Surface Analysis for Obtaining Active Yeast Used in Vinification. *Fermentation*, *10*(8), 413. https://doi.org/10.3390/fermentation10080413

Franitza, L., Granvogl, M., & Schieberle, P. (2016). Influence of the Production Process on the Key Aroma Compounds of Rum: From Molasses to the Spirit. *Journal of Agricultural and Food Chemistry*, *64*(47), 9041–9053. https://doi.org/10.1021/acs.jafc.6b04046

Frîncu, M., Dumitrache, C., & Ionuț, R. (2024). *PHYSICO-CHEMICAL COMPOSITION OF*

DIFFERENT GRAPE VARIETIES FROM PIETROASA VINEYARD.

Frincu, M., Dumitrache, C., Petre, A.-C., Mot, A., Teodorescu, R. I., Barbulescu, D. I., Tudor, V., & Matei, F. (2023). Physico-Chemical Characterization of Some Sources of Grape Marc from Pietroasa Vineyard. *AGROLIFE SCIENTIFIC JOURNAL*, *12*(1), 81–86.

Gadrat, M., Lavergne, J., Emo, C., Teissedre, P. L., & Chira, K. (2022). Sensory characterisation of Cognac eaux-de-vie aged in barrels subjected to different toasting processes. *OENO One*, *56*(1), Article 1. https://doi.org/10.20870/oeno-one.2022.56.1.4853

Gomez-Cordoves, C., & Gonzalez-SanJose, M. L. (2002, May 1). *Interpretation of Color Variables during the Aging of Red Wines: Relationship with Families of Phenolic Compounds* (world). ACS Publications; American Chemical Society. https://doi.org/10.1021/jf00051a001

González-Centeno, M. R., Teissedre, P.-L., Thibon, C., & Chira, K. (2020). Does barrel size influence white wine aging quality? *IVES Technical Reviews, Vine and Wine*. https://doi.org/10.20870/IVES-TR.2020.3305

Goullet, A., Hanaei, F., Vallet, N., Nonier, M.-F., Vivas, N., Vivas, N., & Picard, M. (2023). A sensory characterization of some N-heterocycles in model spirit matrix: Influence of ethanol and several chemical features on aroma perception. *Flavour and Fragrance Journal*, *38*(2), 108–120. https://doi.org/10.1002/ffj.3729

Iorizzo, M., Coppola, F., Letizia, F., Testa, B., & Sorrentino, E. (2021). Role of Yeasts in the Brewing Process: Tradition and Innovation. *Processes*, *9*(5), 839. https://doi.org/10.3390/pr9050839

Karathanos, A., Soultani, G., Kontoudakis, N., & Kotseridis, Y. (2024). Impact of Different Wood Types on the Chemical Composition and Sensory Profile of Aged Tsipouro: A Comparative Study. *Beverages*, *10*(3), Article 3. https://doi.org/10.3390/beverages10030076

Machado, S. (2019). *Craft beer in Portugal: A study about consumers, perceptions, drivers and barriers of consumption*. repositorio.ucp.pt. https://repositorio.ucp.pt/handle/10400.14/29285

Maga, J. A. (1989). The contribution of wood to the flavor of alcoholic beverages. *Food Reviews International*, *5*(1), 39–99. https://doi.org/10.1080/87559128909540844

Maicas, S. (2020). The Role of Yeasts in Fermentation Processes. *Microorganisms*, *8*(8), 1142. https://doi.org/10.3390/microorganisms8081142

Mangwanda, T., Johnson, J., Mani, J., Jackson, S., Chandra, S., Mckeown, T., White, S., & Naiker, M. (2021). Processes, Challenges and Optimisation of Rum Production from Molasses-A Contemporary Review. *Fermentation*, *7*, 21. https://doi.org/10.3390/fermentation7010021

Marongiu, A., Zara, G., Legras, J. L., & ... (2015). Novel starters for old processes: Use of Saccharomyces cerevisiae strains isolated from artisanal sourdough for craft beer production at a brewery scale. *Journal of Industrial …*. https://doi.org/10.1007/s10295-014-1525-1

Martínez-Gil, A. M., Del Alamo-Sanza, M., Del Barrio-Galán, R., & Nevares, I. (2022). Alternative Woods in Oenology: Volatile Compounds Characterisation of Woods with Respect to Traditional Oak and Effect on Aroma in Wine, a Review. *Applied Sciences*, *12*(4), 2101. https://doi.org/10.3390/app12042101

Mascia, I., Fadda, C., Karabín, M., Dostálek, P., & Del Caro, A. (2016). Aging of craft durum wheat beer fermented with sourdough yeasts. *LWT*, *65*, 487–494. https://doi.org/10.1016/j.lwt.2015.08.026

Mastanjević, K., Krstanović, V., Lukinac, J., Jukić, M., Lučan, M., & Mastanjević, K. (2019). Craft brewing – is it really about the sensory revolution? *KVASNY PRUMYSL*, *65*(1), 13–16. https://doi.org/10.18832/kp2019.65.13

Maza Gomez, S. (2002). Rum aroma descriptive analysis. *LSU Master's Theses*. https://doi.org/10.31390/gradschool_theses.2770

McCarthy, E., & Ewing-Mulligan, M. (2006). *Wine for dummies* (4th ed). Wiley Pub.

Mutz, Y. S., Rosario, D. K. A., & Conte-Junior, C. A. (2020). Insights into chemical and sensorial aspects to understand and manage beer aging using chemometrics. *Comprehensive Reviews in Food Science and Food Safety*, *19*(6), 3774–3801. https://doi.org/10.1111/1541-4337.12642

Nasuti, C., Ruffini, J., Sola, L., Di Bacco, M., Raimondi, S., Candeliere, F., & Solieri, L. (2023a). *Sour Beer as Bioreservoir of Novel Craft Ale Yeast Cultures*. https://doi.org/10.20944/preprints202307.0964.v1

Nasuti, C., Ruffini, J., Sola, L., Di Bacco, M., Raimondi, S., Candeliere, F., & Solieri, L. (2023b). Sour Beer as Bioreservoir of Novel Craft Ale Yeast Cultures. *Microorganisms*, *11*(9), 2138. https://doi.org/10.3390/microorganisms11092138

Nilsen, D. (2024). *How To Pair Bourbon Barrel-Aged Beers with Craft Chocolate*. Www.Beantobarstool.Com. https://www.beantobarstool.com/blog/pairing-bba

Noviello, M., Paradiso, V. M., Natrella, G., Gambacorta, G., Faccia, M., & Caponio, F. (2024). Application of toasted vine-shoot chips and ultrasound treatment in the ageing of Primitivo wine. *Ultrasonics Sonochemistry*, *104*, 106826. https://doi.org/10.1016/j.ultsonch.2024.106826

Oliver, G., & Colicchio, T. (2011). *The Oxford Companion to Beer*. Oxford University Press. https://books.google.ro/books?id=oWQdjnVo2B0C

Ortega-Heras, M., González-Sanjosé, M. L., & González-Huerta, C. (2007). Consideration of the influence of aging process, type of wine and oenological classic parameters on the levels of wood volatile compounds present in red wines. *Food Chemistry*, *103*(4), 1434–1448. https://doi.org/10.1016/j.foodchem.2006.10.060

Paulette, T. (2024). Beer in world history. In T. Paulette, *In the Land of Ninkasi* (1st ed., pp. 1–16). Oxford University PressNew York. https://doi.org/10.1093/oso/9780197682449.003.0001

Picard, M., Nonier, M.-F., Vivas, N., & Vivas, N. (2021). The dynamic of roasted aroma compounds release from oak wood: Investigation of the heating barrel process and some spirit maturation parameters. *Wood Science and Technology*, *55*(6), 1821–1839. https://doi.org/10.1007/s00226-021-01330-5

Picard, M., Oulieu, C., Nonier, M.-F., Vivas, N., & Vivas, N. (2023). The role of oak wood in the mint and floral notes of whisky: Identification of common terpenoids by aromatic fractionation. *Journal of the Institute of Brewing*, *129*(1), 62–79. https://doi.org/10.58430/jib.v129i1.8

Pilcher, J. M. (2025). Before Hops. In J. M. Pilcher, *Hopped Up* (1st ed., pp. 17–41). Oxford University PressNew York. https://doi.org/10.1093/oso/9780197676042.003.0002

Poisson, L., & Schieberle, P. (2008). Characterization of the Most Odor-Active Compounds in an American Bourbon Whisky by Application of the Aroma Extract Dilution Analysis. *Journal of Agricultural and Food Chemistry*, *56*(14), 5813–5819. https://doi.org/10.1021/jf800382m

Recamales, Á. F., Sayago, A., González-Miret, M. L., & Hernanz, D. (2006). The effect of time and storage conditions on the phenolic composition and colour of white wine. *Food Research International*, *39*(2), 220–229. https://doi.org/10.1016/j.foodres.2005.07.009

Ribéreau-Gayon, P. (2006). *Handbook of enology: Volume 2: The chemistry of wine stabilization and treatments* (2nd ed). John Wiley.

Saison, D. (2011). Improved Flavor Stability by Aging Beer in the Presence of Yeast. *Journal of the American Society of Brewing Chemists*, *69*. https://doi.org/10.1094/ASBCJ-2011-0127-01

Saison, D., De Schutter, D. P., Vanbeneden, N., Daenen, L., Delvaux, F., & Delvaux, F. R. (2010). Decrease of Aged Beer Aroma by the Reducing Activity of Brewing Yeast. *Journal of Agricultural and Food Chemistry*, *58*(5), 3107–3115. https://doi.org/10.1021/jf9037387

Sanna, V., & Pretti, L. (2015). Effect of wine barrel ageing or sapa addition on total polyphenol content and antioxidant activities of some Italian craft beers. *International Journal of Food Science & Technology*, *50*(3), 700–707. https://doi.org/10.1111/ijfs.12666

Schneider, B. M. (2023). Flavor Compounds Found in Barrel Aged Beers. In *Chemistry of Alcoholic Beverages* (Vol. 1455, pp. 159–172). American Chemical Society. https://doi.org/10.1021/bk-2023-1455.ch008

Seo, M.-J. (2024). Fermented Foods and Food Microorganisms: Antioxidant Benefits and Biotechnological Advancements. *Antioxidants*, *13*(9), 1120. https://doi.org/10.3390/antiox13091120

Shayevitz, A., Harrison, K., & Curtin, C. D. (2020). *Barrel-Induced Variation in the Microbiome and Mycobiome of Aged Sour Ale and Imperial Porter Beer* (p. 299343 Bytes) [Dataset]. Taylor & Francis. https://doi.org/10.6084/M9.FIGSHARE.12848766

Silva, H. G. da, Silva, H. G. da, Souza, P. G. de, & Pinheiro, C. L. (2022). Avaliação físico-química e sensorial da cerveja artesanal estilo Wood e Barrel Aged adicionada de chip de jatobá (Hymenaea courbaril L.). *Brazilian Journal of Science*, *1*(3), Article 3. https://doi.org/10.14295/bjs.v1i3.39

Spitaels, F., Wieme, A. D., Snauwaert, I., Vuyst, L. D., & Vandamme, P. (2017). Microbial Ecology of Traditional Beer Fermentations. In *Brewing Microbiology: Current Research, Omics and Microbial Ecology*. Caister Academic Press. https://doi.org/10.21775/9781910190616.07

Starowicz, M., & Zieliński, H. (2019). How Maillard Reaction Influences Sensorial Properties (Color, Flavor and Texture) of Food Products? *Food Reviews International*, *35*, 1–19. https://doi.org/10.1080/87559129.2019.1600538

Stegăruș, D. I., Călugăr, A., Tanase, C., Muscă, A., Botoran, O. R., Manolache, M., Babeș, A. C., Bunea, C., Gál, E., Bunea, A., & Coldea, T. E. (2021). Influence of Oak Chips and Oak Barrel Ageing on Volatile Profile in Chardonnay Wine of Romania. *Applied Sciences*, *11*(8), Article 8. https://doi.org/10.3390/app11083691

Sterckx. (2012). Wood Aging of Beer. Part II: Influence of Wood Aging Parameters on Monophenol Concentrations. *Journal of the American Society of Brewing Chemists*, *70*. https://doi.org/10.1094/ASBCJ-2011-1201-02

Styger, G., Prior, B., & Bauer, F. F. (2011). Wine flavor and aroma. *Journal of Industrial Microbiology and Biotechnology*, *38*(9), 1145. https://doi.org/10.1007/s10295-011-1018-4

Tamanna, N., & Mahmood, N. (2015). Food Processing and Maillard Reaction Products: Effect on Human Health and Nutrition. *International Journal of Food Science*, *2015*, 526762. https://doi.org/10.1155/2015/526762

Tarko, T., Krankowski, F., & Duda-Chodak, A. (2023). The Impact of Compounds Extracted from Wood on the Quality of Alcoholic Beverages. *Molecules*, *28*(2), Article 2. https://doi.org/10.3390/molecules28020620

Tham, A., Campton, J., & Cooper-McKenzie, B. (2024). Tapping into flavourful journeys: A systematic review and application of craft beer tourism frameworks. *International Journal of Wine Business Research*, *36*(2), 184–206. https://doi.org/10.1108/IJWBR-03-2023-0013

Tsakiris, A., Kallithraka, S., & Kourkoutas, Y. (2014). Grape brandy production, composition and sensory evaluation: Grape brandy production, composition and evaluation. *Journal of the Science of Food and Agriculture*, *94*(3), 404–414. https://doi.org/10.1002/jsfa.6377

Uselmann, V., & Schieberle, P. (2015). Decoding the Combinatorial Aroma Code of a Commercial Cognac by Application of the Sensomics Concept and First Insights into Differences from a German Brandy. *Journal of Agricultural and Food Chemistry*, *63*(7), 1948–1956. https://doi.org/10.1021/jf506307x

Valentoni, A., Santoru, A., Sanna, M., Fanari, M., Porcu, M. C., Fadda, A., Sanna, D., & Pretti, L. (2022). Evolution of sensory analysis attributes and volatile aging markers in bottle fermented craft beers during storage at different temperatures. *Food Chemistry Advances*, *1*, 100151. https://doi.org/10.1016/j.focha.2022.100151

Villacreces, S., Blanco, C. A., & Caballero, I. (2022). Developments and characteristics of craft beer production processes. In *Food bioscience*. Elsevier. https://www.sciencedirect.com/science/article/pii/S2212429221006209

Viviani, A., Moreno, J., & Peinado, R. A. (2007). Differentiation of young red wines obtained in a warm climate region. *International Journal of Food Science and Technology*, *42*(5), 523–527. https://doi.org/10.1111/j.1365-2621.2006.01240.x

Vrînceanu, C.-R., Diguță, F. C., Cudalbeanu, M. D., Ortan, A., Mihai, C., Bărbulescu, I. D., Frîncu, M., Begea, M., Matei, F., & Teodorescu, R. I. (2025). Exploring the Potential of Torulaspora delbrueckii, Starmerella bacillaris, and Saccharomyces cerevisiae as a Probiotic Starter for Craft Beer Production. *Foods*, *14*(9), Article 9. https://doi.org/10.3390/foods14091608

Vrînceanu, C.R.; Bărbulescu, I.D.; Matei, F.; Begea, M.; Tudor, V.; Frîncu, M.; Teodorescu R.I. Review: Actual approaches for the craft beer fermentations. Sci Pap-Ser B-Hortic, 2022, LXVI(1), 944-949

Wauters, R., Britton, S. J., & Verstrepen, K. J. (2021). Old yeasts, young beer—The industrial relevance of yeast chronological life span. *Yeast*, *38*(6), 339–351. https://doi.org/10.1002/yea.3650

Winstel, D., Gammacurta, M., Waffo-Téguo, P., & Marchal, A. (2024). Identification of Two New Taste-Active Compounds in Oak Wood: Structural Elucidation of Potential β-Methyl-γ-octalactone Precursors and Quantification in Spirits. *Journal of Agricultural and Food Chemistry*, *72*(37), 20592–20602. https://doi.org/10.1021/acs.jafc.4c04799

Withers, E. T. (2017). The impact and implications of craft beer research: An interdisciplinary literature review. *Craft Beverages and Tourism, Volume 1: The Rise of …*. https://doi.org/10.1007/978-3-319-49852-2_2

Yi, Z. (2013). *Method for producing compound rum from sugarcane juice and sugarcane molasses* (China Patent CN101760378B). https://patents.google.com/patent/CN101760378B/en