Journal of Food and Nutrition Research (ISSN 1336-8672) Published online 17 April 2026

DOI: https://doi.org/10.64122/AGQM8724

Young adult perception of botanical beers: Hedonic response to hops, chamomile, sage and nettle infused beers

DESPINA KOSTADINOVA JANKOVSKI – DONKA DONEVA-SHAPCHESKA

Summary

Herbs are increasingly explored in brewing as alternatives or complements to hops, offering new flavour profiles that may appeal to young consumers. This study evaluated the sensory characteristics and consumer acceptance of four beers (hops, chamomile, sage, nettle) among young adults (21–25 years). Beers were assessed using a nine-point hedonic scale and a check-all-that-apply (CATA) questionnaire, with multivariate analysis of the resulting data. Significant differences emerged across appearance, taste, mouthfeel and overall liking, with nettle and hops receiving the highest scores, chamomile showing moderate acceptance and sage the lowest. CATA and principal component analysis (PCA) indicated that better-liked beers were associated with sweet, citrus, honey like and clean attributes, whereas bitterness, earthy and mouldy notes characterised less accepted samples. Drivers of liking confirmed these attributes as positive or negative contributors to acceptance, and gender analyses showed that women tended to prefer sweet–aromatic profiles while men displayed greater tolerance for bitter characteristics. These findings identify key sensory directions for designing botanical beers that are better accepted by young adult consumers.

Keywords

botanical beer; sensory evaluation; check all that apply; gender differences

Beer is one of the world's oldest and most widely consumed alcoholic beverages [1]. It is traditionally brewed from malted cereals, water, yeast and hops, but before hops became the dominant bittering agent, a wide range of botanicals were used to shape aroma, flavour and preservation [1, 2]. Gruit beers, historically produced with herb mixtures instead of hops, illustrate this long-standing botanical tradition, which has recently re-emerged as consumers show greater interest in more aromatic, less bitter and distinctive beers, particularly young adults and women [3–6]. Modern brewers increasingly experiment with herbs, fruits and spices alongside or instead of hops, contributing to the growth of special beer styles, including non-alcoholic, low-alcohol and functional products that offer differentiated sensory profiles [6, 7]

Chamomile (*Matricaria recutita*), sage (*Salvia officinalis*) and nettle (*Urtica dioica*) are promising botanicals for brewing because of their distinct aromatic and phenolic profiles. They have already been investigated in various food and beverage matrices, including experimental beers [8–11]. Studies show that chamomile typically contributes floral and mildly bitter notes, sage imparts herbal and spicy characteristics and nettle provides grassy, earthy and mineral nuances [3, 9–11]. The successful incorporation of these botanicals into commercial formulations, however, requires a detailed understanding of how consumers perceive the sensory changes they introduce and which specific attributes act as drivers of acceptance or rejection.

Consumer responses to beer are further shaped by demographic factors such as age and gender. Women typically prefer less bitter, more balanced and aromatically complex beers, whereas men often show higher tolerance for bitterness or rely more on familiarity and social influence

Despina Kostadinova Jankovski, Donka Doneva-Shapcheska, Organic Technology, Faculty for Technology and Metallurgy, University of Ss. „Cyril and Methodius" in Skopje, Ruđer Bošković 16, 1000 Skopje, North Macedonia.

Correspondence author:
Despina Kostadinova Jankovski, e-mail: despina@tmf.ukim.edu.mk

© 2026 The authors. Published by National Agricultural and Food Centre (Slovakia) under a Creative Commons Attribution 4.0 International License (CC BY 4.0)

[12, 13]. Sensory methods that capture both liking and descriptive information are therefore essential for characterising novel botanical beers. The nine-point hedonic scale and the check-all-that-apply (CATA) method are widely used, consumer-friendly approaches that have shown good performance for profiling and segmenting beers, especially when combined with multivariate analysis to identify drivers of liking [12, 14]. This pattern aligns with literature describing *Salvia* extracts as rich in thujone, camphor and related volatile compounds that often impart sharp, resinous or medicinal flavours, which can negatively impact acceptability [3].

Despite growing interest in botanical beers, relatively few studies have examined how young adults perceive specific herbal additions such as chamomile, sage and nettle or which sensory cues govern their acceptance. Therefore, this study aimed to evaluate the sensory acceptability, descriptive profiles and gender-related differences in the perception of beers formulated with chamomile, sage and nettle, compared with a hops control, using hedonic ratings and CATA data supported by multivariate analysis.

MATERIALS AND METHODS

Beer production

Four beer variants were produced on a laboratory scale from barley malt wort, standardised to 12 °Plato. *Saccharomyces pastorianus* (SafLager W-34/70, Fermentis, Marcq-en-Baroeul, France) lager yeast was used for all fermentations. A traditional hops-infused beer served as the control. The remaining three beers were brewed with dried leaves of sage (*Salvia officinalis*), chamomile (*Matricaria chamomilla*) and nettle (*Urtica dioica*), hand-harvested from a local forest in Kruševo, North Macedonia, during the summer season.

Sage and nettle leaves and chamomile flower heads were used. The plant material was air-dried at ambient temperature (20–25 °C) in a shaded, well-ventilated area for 5–7 days and stored in sealed containers protected from light. Prior to brewing, the materials were manually fragmented into pieces of approximately 0.5–1 cm to ensure uniform extraction during boiling.

The control beer was brewed using Hallertauer Tradition hop pellets (type 90; α-acids 3.1%, Eisemann, Vaihingen an der Enz, Germany), a noble hop variety characterised by moderate bitterness and a mild aroma profile with citrus and light fruity notes.

Each wort underwent a 30-min boil, with botanicals added at 6.4 $g \cdot l^{-1}$ in two equal portions (half at boil start, half after 15 min). Post-boil, worts were filtered, cooled rapidly to 18 °C and pitched with yeast at 10 $g \cdot l^{-1}$. Primary fermentation proceeded at 18–20 °C for 7 days, followed by bottling and secondary fermentation/maturation at 4 °C for 10 days. Fermentation was completed when the specific gravity stabilised. All trials were conducted in triplicate.

The selected botanical concentration (6.4 $g \cdot l^{-1}$) was based on preliminary trials to achieve a clearly perceptible yet balanced herbal intensity. This level aligns with brewing practices where relatively high dosages are used to ensure flavour expression [15]. Compared to lower concentrations reported in previous studies (~1.3 $g \cdot l^{-1}$), a higher dosage was applied to enhance sensory differentiation [3]. A uniform concentration was used across all botanicals to enable direct comparison, although differences in intrinsic aromatic intensity remain a limitation.

Basic physicochemical parameters (pH, apparent extract, and alcohol content) were monitored during fermentation. pH was measured using a calibrated pH meter (Sartorius PB-11, Sartorius, Göttingen, Germany). Apparent extract (expressed as degrees Plato) and alcohol content were determined using a FermentoFlash analyser (Funke Gerber, Berlin, Germany).

Consumer panel and sensory evaluation

A total of 188 untrained consumers (ages 21–25) participated in the study. Each evaluator received 100 ml of beer served at 4 °C and coded with a random three-digit number. The questionnaire collected demographic data, beer consumption habits and sensory responses. The design of the questionnaire was informed by a comprehensive review [4]. Sensory parameters including appearance, taste, mouthfeel and overall liking were evaluated using a horizontal nine-point hedonic scale. The scale ranged from 1 (dislike extremely to 9 (like extremely). Participants evaluated samples using 17 CATA descriptors adapted from previous beer studies [4, 16]. The CATA responses were used to characterise the samples and identify sensory attributes associated with consumer acceptance.

Data analysis

Hedonic data were analysed by one-way ANOVA with Tukey's honestly significant difference (HSD) test; gender effects were assessed by two-way ANOVA. CATA data were analysed with Cochran's Q, principal component analysis (PCA) and drivers of liking (DOL); gender differences

in CATA selection used chi-square tests. Analyses were performed in Microsoft Excel 365 (Microsoft, Redmond, Washington, USA) and R software version 4.3.1 (R Foundation for statistical computing, Vienna, Austria).

RESULTS AND DISCUSSION

Physicochemical characteristics of beers

The measured physicochemical parameters (Tab. 1) were consistent with values reported for conventional lager beers, including alcohol content (4.3–4.6 % v/v), pH (3.87–4.32), and apparent extract (~3.4 °Plato) [15, 17]. The similar alcohol content and extract values across samples indicate comparable fermentation performance, suggesting that the addition of botanicals did not adversely affect yeast activity. In addition, previous studies have shown that botanical additions can introduce bioactive compounds, including phenolics and other extractives, which may influence flavour perception without affecting fermentation performance [3, 6, 8]. Slight variations in pH among the beers may reflect the influence of different plant materials on acidification. Overall, these results confirm that the beers were technologically consistent, allowing sensory differences to be primarily attributed to the type of botanical addition.

Tab. 1. Basic physicochemical properties of the botanical beers.

Beer	Final pH	Alcohol [%]	Apparent extract [°Plato]
Hops	3.87 ± 0.02	4.3 ± 0.1	3.42 ± 0.08
Nettle	4.32 ± 0.12	4.6 ± 0.2	3.42 ± 0.16
Sage	3.97 ± 0.01	4.5 ± 0.2	3.43 ± 0.03
Chamomile	4.04 ± 0.13	4.4 ± 0.0	3.43 ± 0.21

Values are expressed as mean ± standard deviation (n = 3).

Hedonic differentiation of botanical beer samples

Across all sensory modalities (appearance, taste, mouthfeel and overall liking), the botanical beers differed significantly ($p < 0.05$; Tab. 2). Taste and mouthfeel were the most discriminating attributes, indicating that the botanical additions influenced flavour and in-mouth perception more than visual attributes, in line with previous reports that mouthfeel is a major driver of beer choice [18]. The nettle sample, followed by hops received the highest scores for mouthfeel and taste. Chamomile did not show any difference in appearance compared to the other beers, but in the other attributes, it was moderately liked, after nettle and hops. At controlled levels, chamomile can improve sweetness, aroma, and mouthfeel in beverages [10]. In contrast, sage exhibited depressed scores across all measured modalities.

Sensory characterisation

CATA citation proportions showed clear sensory separation among the botanical beers. Nettle and chamomile were mainly associated with sweet, honey, grassy and woody notes, indicating a mild sweet–aromatic profile consistent with their higher hedonic scores. These attributes align with sweet–aromatic profiles that typically elicit higher liking, whereas formulations dominated by bitterness, earthy or mouldy notes and strong herbal intensity are generally less accepted by consumers. Sage, in contrast, showed dominant bitter, spicy, earthy, mouldy, and ginger citations, indicating a more intense herbal sensory profile that was associated with lower acceptance in the present study and has also been reported in previous work [5, 6, 19]. Hops exhibited moderate bitterness, wheat-cereal notes, and citrus brightness, attributes consistent with traditional hop-forward profiles. It has been reported that citrus-like and herbaceous freshness attributes showed positive regression coefficients in their preference model, suggesting a beneficial role in consumer acceptance [16].

These differences were summarised effectively by PCA (PC1 = 53.1 %; PC2 = 34.2 %; Fig. 1). PC1 captured the main sensory contrast,

Tab. 2. Hedonic scores of botanical beers.

Beer	Appearance	Taste	Mouthfeel	Overall liking
Chamomile	7.34 ± 1.25 [a]	6.71 ± 1.24 [a]	6.79 ± 1.23 [a]	6.96 ± 1.25 [a]
Hops	7.12 ± 1.15 [a]	7.04 ± 1.23 [b]	7.42 ± 1.19 [b]	7.38 ± 1.14 [b]
Nettle	7.09 ± 1.23 [a]	7.59 ± 1.35 [c]	7.79 ± 1.18 [c]	7.53 ± 1.26 [b]
Sage	6.92 ± 1.31 [b]	4.79 ± 1.28 [d]	4.79 ± 1.32 [d]	5.40 ± 1.27 [c]

Values are expressed as mean ± standard deviation (n = 188).
Different superscript letters within the same column indicate statistically significant differences ($p < 0.05$) according to Tukey's honestly significant difference (HSD) test.

ranging from sweet-aromatic descriptors (sweet, honey, caramel), where nettle and chamomile were positioned, to bitter–harsh attributes (bitter, mouldy, earthy, ginger), which characterised sage. This sensory pattern may be related to the presence of volatile and phenolic compounds typically reported in sage species, which are often associated with sharp, resinous or medicinal flavour impressions [3]. However, as no chemical analyses were performed in the present study, these associations should be interpreted as indicative rather than definitive. Additionally, the positioning of chamomile toward sweet and aromatic descriptors is consistent with previous studies reporting enhanced sweetness and aroma perception in chamomile-enriched beverages [10]. Hops occupied an intermediate position, reflecting balanced cereal-citrus attributes. PC2 accounted for secondary differences, separating samples and attributes associated with higher scores on watery and some grain notes from those positioned closer to sweet and chamomile, without a strong additional flavour-quality gradient. Overall, the two-dimensional configuration mirrors previous botanical beer studies, where beers separate primarily along a sweet–aromatic versus bitter-herbal axis, and more accepted samples tend to cluster with sweet and aromatic attributes [6, 19].

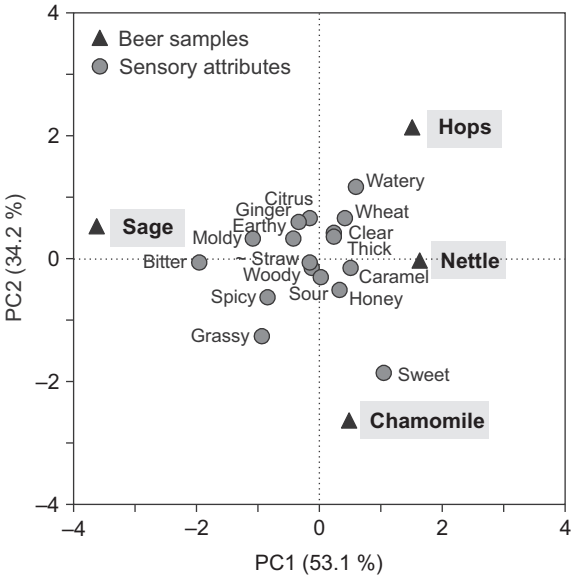

Fig. 1. Biplot of botanical beer samples and sensory attributes on the first two principal components.

Scores and loadings were rescaled for visual clarity while preserving relative relationships.

Drivers of liking

The DOL analysis clarified how specific sensory attributes contributed to acceptance or rejection (Tab. 3). Positive drivers included sweet, citrus, honey, clear and earthy notes, all of which increased liking for the moderately and highly accepted beers. These results are consistent with findings of Ivanova et al. [20], who reported that sweetness and malty flavours increased consumer liking, while bitterness, astringency and intense hop aroma exerted negative effects. It has also been reported that consumers preferred non-alcoholic beers with a sweet taste and light fruity odour [21]. Negative drivers in the present study, particularly bitter, mouldy, and spicy, were most pronounced in sage, mirroring its placement in the bitter-harsh region of the PCA and aligning with earlier reports that bitter, grassy, spicy, and mouldy attributes undermine the acceptance of herbal beers [6, 19]. Light body descriptors such as “watery” and “clear” were weak positive drivers for some beers, indicating that, when bitterness is moderate, a perceived lightness can enhance drinkability [20]. Another atypical finding was that “mouldy” acted as a mild positive driver for chamomile, despite being a negative driver elsewhere. This suggests that low-intensity fermentative or herbal notes may be interpreted as added aromatic complexity rather than as defects.

Tab. 3. Key positive and negative drivers of liking for each botanical beer sample.

Beer	Top positive drivers		Top negative drivers	
	Descriptor	Δ	Descriptor	Δ
Hops	Caramel	+0.34	Bitter	–0.78
	Watery	+0.33	Mouldy	–0.63
	Earthly	+0.05	Spicy	–0.42
Nettle	Watery	+0.74	Bitter	–0.46
	Clear	+0.70	Mouldy	–0.44
	Earthly	+0.59	Spicy	–0.33
Sage	Earthly	+0.53	Bitter	–0.68
	Ginger	+0.52	Mouldy	–0.56
	Clear	+0.44	Spicy	–0.41
Chamomile	Citrus	+0.34	Bitter	–0.61
	Mouldy	+0.25	Spicy	–0.36
	Sweet	+0.19	Grassy	–0.19

Only the strongest positive and negative drivers per beer are shown.
Δ – difference in mean overall liking scores when the attribute was selected versus not selected.

Gender-based sensory and hedonic differences

The attitudinal data (Tab. 4) showed that female participants expressed significantly greater interest in visiting breweries and reading about beer, and placed stronger emphasis on healthy

Tab. 4. Gender differences in botanical beer-related attitudes.

Statement	Female	Male	$F(1,186)$	p
Beer is my favourite alcoholic drink	3.32 ± 1.12	3.00 ± 0.95	3.60	0.060
I like to try new beers	4.30 ± 0.86	4.09 ± 0.79	2.23	0.140
Buying local beer supports the local economy	4.63 ± 0.85	4.55 ± 0.63	0.49	0.480
When I travel, I try local beers	3.66 ± 1.07	3.27 ± 1.08	6.84	0.010**
I like visiting breweries	3.70 ± 0.87	2.73 ± 0.96	52.17	< 0.001***
I like reading about beer	3.16 ± 1.02	1.55 ± 0.78	143.53	< 0.001***
I drink beer on special occasions	2.84 ± 0.98	2.36 ± 0.94	11.67	< 0.001***
I usually buy the same beer	3.16 ± 1.12	2.55 ± 0.95	15.79	< 0.001***
A healthy lifestyle is important to me	4.84 ± 0.44	4.36 ± 0.85	24.87	< 0.001***

Values are expressed as mean ± standard deviation (n = 188).
Responses were collected using a 5-point Likert scale (1 = strongly disagree, 5 = strongly agree). Differences between female and male respondents were evaluated using one-way ANOVA.
$F(1,186)$ – F-statistic from ANOVA, p – statistical significance (** – $p < 0.01$, *** – $p < 0.001$).

living. These trends align with reports that women increasingly engage with beer through exploration and information seeking, whereas men more often rely on social influences when making beverage choices [7, 13]. The heightened lifestyle orientation among women is also consistent with broader evidence that they tend to adopt healthier dietary behaviours [22]. Despite these differences, no significant gender effect was found for identifying beer as a favourite alcoholic beverage, contrasting with findings that wine is typically preferred by many women, while beer liking is more common among young men [4, 22].

These attitudinal differences were reflected in hedonic evaluations. Female participants showed significantly higher liking scores for hops, nettle and sage beers, with the largest gender gap observed for nettle, whereas chamomile showed no significant difference (Tab. 5). This pattern supports earlier findings that women generally perceive bitter stimuli more intensely and therefore tend to prefer less bitter or more balanced flavour profiles [4, 12]. Although detailed modality-wise ANOVA results are not shown, women also rated appearance higher across all samples and gave significantly higher taste and mouthfeel scores for nettle and sage, consistent with reports that visual and in-mouth cues strongly influence consumer expectations and acceptance [23].

Gender differences in basic taste perception were further examined with CATA. A significant effect emerged only for the bitter descriptor in the hops sample: males frequently selected "bitter," whereas females did not, indicating that gender divergence in bitterness perception is product-specific. This aligns with previous evidence that women often treat bitterness as a negative driver of liking, whereas young men more readily identify or tolerate bitter and intense flavour profiles [4, 5, 12, 19].

Despite attitudinal differences seen between females and males, both gender-specific PCA biplots (Fig. 2A, 2B) organised the beers along a dominant sweet–aromatic to bitter-herbal axis on PC1, consistent with botanical beer separations reported previously [6]. In both biplots, chamomile was located toward sweet and caramel attributes, sage toward bitter, mouldy and spicy notes, and hops and nettle occupied intermediate positions associated with cereal, citrus, watery and earthy cues. PC2 separated samples and attributes primarily by intensity and fullness, distinguishing

Tab. 5. Gender differences in overall liking of botanical beers.

Beer	Female	Male	$F(1,186)$	p
Chamomile	7.08 ± 1.19	6.81 ± 1.31	2.11	0.149
Hops	7.70 ± 1.07	7.00 ± 1.11	19.15	< 0.001***
Nettle	8.20 ± 0.87	6.73 ± 1.19	94.39	< 0.001***
Sage	5.66 ± 1.25	5.09 ± 1.24	9.57	0.002**

Values are expressed as mean ± standard deviation (n = 188).
Overall liking was evaluated using a 9-point hedonic scale (1 = dislike extremely, 9 = like extremely).
$F(1,186)$ – F-statistic from ANOVA, p – statistical significance (** – $p < 0.01$, *** – $p < 0.001$).

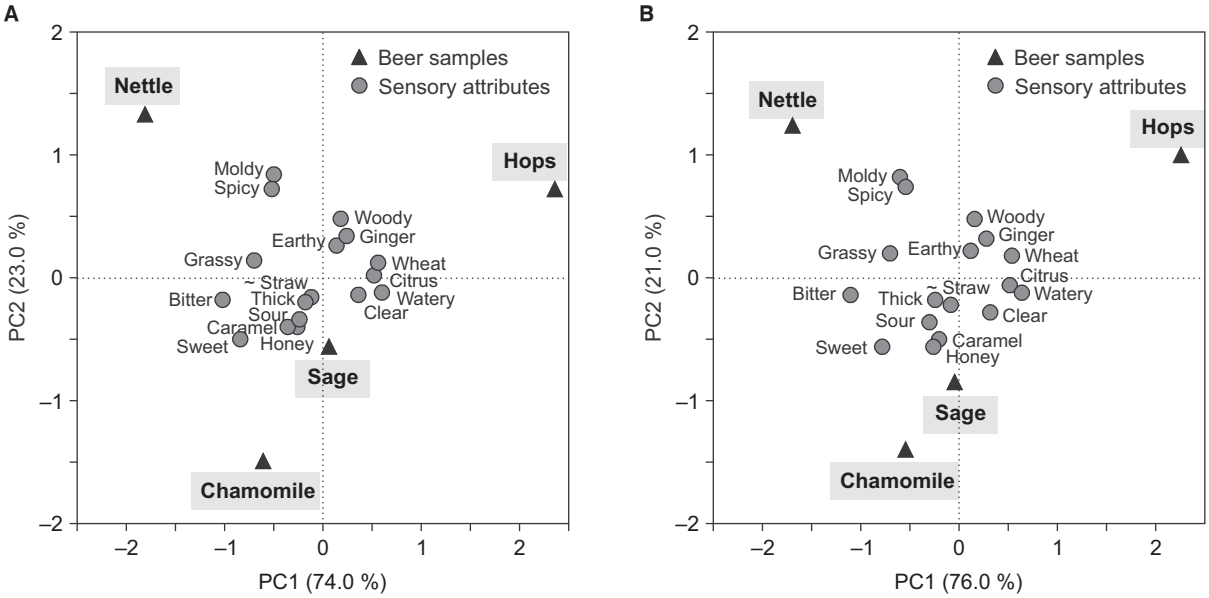

Fig. 2. Principal component biplots of botanical beer samples by gender.

A – female consumers; B – male consumers.
Scores and loadings were rescaled for visual clarity while preserving relative relationships.

lighter or clearer descriptors (e.g. clear, watery) from thicker or more intense notes (e.g. thick, sour, spicy). The overall sensory structure was very similar for women and men, indicating that, despite clear gender differences in liking scores and in the explicit use of the "bitter" descriptor, both groups organised the beers along comparable sweetness-bitterness and light-fullness dimensions, with gender effects emerging mainly in the strength of preference rather than in the basic sensory map.

Such stable sensory configurations across consumer segments provide a robust basis for advanced data-driven modelling approaches, which have demonstrated that complex beer flavour profiles can be predicted and optimised using multivariate and machine-learning models integrating sensory and compositional data [24].

CONCLUSION

This study shows that adding chamomile, sage and nettle reshapes how young adults perceive and like beer, with nettle and hops receiving the highest acceptance, chamomile moderate acceptance and sage clearly the lowest. Sensory mapping and drivers of liking analyses indicated that beers associated with sweet, citrus, honey-like and clear notes were favoured, whereas those dominated by bitter, spicy, earthy and mouldy impressions were rejected. Men and women organised the beers within a similar sensory space, but women tended to prefer the less bitter, sweeter profiles and men showed greater tolerance for bitter and herbal intensity, suggesting that gender differences arise mainly from preference strength rather than fundamentally different sensory perceptions. Overall, botanical beers aimed at young adults appear most promising when bitterness and herbal intensity are moderated and when sweetness, aromatics and a pleasant mouthfeel are carefully balanced. A limitation of the present study is the absence of chemical characterisation of the botanical beers, which restricts mechanistic interpretation of the observed sensory differences. Future work should integrate sensory evaluation with chemical analyses to better elucidate the relationship between composition and consumer perception.

REFERENCES

1. Verberg, S.: From herbal to hopped beer: The displacement of regional herbal beer traditions by commercial export brewing in medieval Europe. Brewery History, *183*, 2020, pp. 9–23. ISSN: 0267-6753. <https://www.breweryhistory.com/journal/archive/183/HerbalToHops.pdf>
2. Solgajová, M. – Dráb, Š. – Straka, D. – Mendelová, A. – Kolesárová, A. – Mareček, J.: Effect of the addition of selected herbs on the technological and sensory quality of beer. Journal of Microbiology, Biotechnology and Food Sciences, *13*, 2024, article e11012. DOI: 10.55251/jmbfs.11012.

3. Pluháčková, H. – Gregor, T. – Boško, R. – Běláková, S. – Svoboda, Z. – Benešová, K.: Fortification of beer with extracts of selected Czech medicinal herbs and plants. Kvasný Průmysl, *66*, 2020, pp. 314–319. DOI: 10.18832/kp2019.66.314.
4. Betancur, M. I. – Motoki, K. – Spence, C. – Velasco, C.: Factors influencing the choice of beer: A review. Food Research International, *137*, 2020, article 109367. DOI: 10.1016/j.foodres.2020.109367.
5. Jimborean, M. A. – Salantă, L. C. – Trusek, A. – Pop, C. R. – Tofană, M. – Mudura, E. – Coldea, T. E. – Farcas, A. – Ilies, M. – Pasca, S. – Uifălean, A.: Drinking behavior, taste preferences and special beer perception among Romanian university students: A qualitative assessment research. International Journal of Environmental Research and Public Health, *18*, 2021, article 3307. DOI: 10.3390/ijerph18063307.
6. Borsa, A. – Muntean, M. V. – Salantă, L. C. – Tofană, M. – Socaci, S. A. – Mudura, E. – Pop, A. – Pop, C. R.: Effects of botanical ingredients addition on the bioactive compounds and quality of non-alcoholic and craft beer. Plants, *11*, 2022, article 1958. DOI: 10.3390/plants11151958.
7. Donadini, G. – Porretta, S.: Uncovering patterns of consumers' interest for beer: A case study with craft beers. Food Research International, *91*, 2017, pp. 183–198. DOI: 10.1016/j.foodres.2016.11.043.
8. Đorđević, S. – Popović, D. – Despotović, S. – Veljović, M. – Atanacković, M. – Cvejić, J. – Nedović, V. – Leskošek-Čukalović, I.: Extracts of medicinal plants as functional beer additives. Chemical Industry & Chemical Engineering Quarterly, *22*, 2016, pp. 301–308. DOI: 10.2298/CICEQ150501044D.
9. Flanjak, I. – Kenjerić, D. – Strelec, I. – Bilić Rajs, B. – Primorac, Lj.: Effect of processing and storage on sage (*Salvia officinalis* L.) honey quality. Journal of Microbiology, Biotechnology and Food Sciences, *11*, 2022, article e3375. DOI: 10.55251/jmbfs.3375.
10. Aamir, M. – Abid, A. – Azam, I. – Ikram, A. – Saeed, F. – Afzaal, M. – Ateeq, H. – Akram, N. – Hussain, S. – Khan, M. R.: Characterization of carbonated beverage fortified with chamomile herbal extract. Food Science & Nutrition, *12*, 2024, pp. 4353–4361. DOI: 10.1002/fsn3.4101.
11. Singh, A. – Chandel, V. – Velmurugan, A. – Bhtoya, R. – Lukram, M. – Roy, S. – Biswas, D.: Development of ice cream nutritionally enriched with *Urtica dioica* extract. Food Materials Research, *5*, 2025, article e003. DOI: 10.48130/fmr-0025-0002.
12. Muggah, E. M. – McSweeney, M. B.: Using preferred attribute elicitation to determine how males and females evaluate beer. Journal of Food Science, *82*, 2017, pp. 1916–1923. DOI: 10.1111/1750-3841.13799.
13. Lazzari, A. – Barbosa, H. D. – Filho, E. R. M. – Dada, A. P. – Saraiva, B. R. – Matumoto-Pintro, P. T.: Gender behavior and influence in acceptability of beers produced with Rubim and Mastruz. Journal of Sensory Studies, *37*, 2022, article e12731. DOI: 10.1111/joss.12731.
14. Vidal, L. – Antúnez, L. – Ares, G. – Cuffia, F. – Lee, P.-Y. – Le Blond, M. – Jaeger, S. R.: Sensory product characterisations based on check-all-that-apply questions: Further insights on how the static (CATA) and dynamic (TCATA) approaches perform. Food Research International, *121*, 2019, article 108510. DOI: 10.1016/j.foodres.2019.108510.
15. Briggs, D. E. – Brookes, P. A. – Stevens, R. – Boulton, C. A.: Brewing: science and practice. Cambridge : Woodhead Publishing, 2004. ISBN: 978-1-85573-490-6.
16. Barry, S. – Muggah, E. M. – McSweeney, M. B. – Walker, S.: A preliminary investigation into differences in hops' aroma attributes. International Journal of Food Science and Technology, *53*, 2018, pp. 804–811. DOI: 10.1111/ijfs.13656.
17. Pires, E. J. – Brányik, T.: Biochemistry of beer fermentation. Cham : Springer, 2015. ISBN: 978-3-319-15188-5. DOI: 10.1007/978-3-319-15189-2.
18. Chen, Y. – Yin, R. – Guo, L. – Zhao, D. – Sun, B.: Development and validation of a consumer-oriented sensory evaluation scale for pale lager beer. Foods, *14*, 2025, article 2834. DOI: 10.3390/foods14162834.
19. Hayward, L. – Wedel, A. – McSweeney, M. B.: Acceptability of beer produced with dandelion, nettle, and sage. International Journal of Gastronomy and Food Science, *18*, 2019, article 100180. DOI: 10.1016/j.ijgfs.2019.100180.
20. Ivanova, N. – Yang, Q. – Bastian, S. E. P. – Wilkinson, K. L. – Johnson, T. E. – Ford, R.: The impact of varying key sensory attributes on consumer perception of beer body. Food Quality and Preference, *112*, 2023, article 105004. DOI: 10.1016/j.foodqual.2023.105004.
21. Schmelzle, A. – Lindemann, B. – Methner, F.-J.: Sensory descriptive analysis and consumer acceptance of non-alcoholic beer. BrewingScience, *66*, 2013, pp. 144–153. ISSN: 1866-5195. <https://brewingscience.de/index.php/brewingscience/article/view/362/263>
22. Feraco, A. – Armani, A. – Amoah, I. – Guseva, E. – Camajani, E. – Gorini, S. – Strollo, R. – Padua, E. – Caprio, M. – Lombardo, M.: Assessing gender differences in food preferences and physical activity: A population-based survey. Frontiers in Nutrition, *11*, 2024, article 1348456. DOI: 10.3389/fnut.2024.1348456.
23. Donadini, G. – Fumi, M. D. – Kordialik-Bogacka, E. – Maggi, L. – Lambri, M. – Sckokai, P.: Consumer interest in specialty beers in three European markets. Food Research International, *85*, 2016, pp. 301–314. DOI: 10.1016/j.foodres.2016.04.029.
24. Schreurs, M. – Piampongsant, S. – Roncoroni, M. – Cool, L. – Herrera-Malaver, B. – Vanderaa, C. – Theßeling, F. A. – Kreft, Ł. – Botzki, A. – Malcorps, P. – Daenen, L. – Wenseleers, T. – Verstrepen, K. J.: Predicting and improving complex beer flavour through machine learning. Nature Communications, *15*, 2024, article 2368. DOI: 10.1038/s41467-024-46346-0.

Received 6 February 2026; 1st revised 27 March 2026; accepted 9 April 2026; published online 17 April 2026.