

Systematic Review

Do We Know Who Drinks Kombucha and Why? A Systematic Scoping Review of Sensory Research, Consumer Choice and Market Adoption

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Highlights

What are the main findings?

- Kombucha studies increasingly measure chemistry and sensory response, but direct integration between them remains rare.
- Evidence declined sharply along the adoption chain: 85 studies assessed liking or acceptance, but only three examined choice or willingness to pay, and none measured observed purchase or retention.

What are the implications of the main findings?

- Kombucha research should move beyond product optimisation towards integrated designs linking composition, sensory response, consumer choice and repeated market behaviour.
- Producers should not assume that a functional or naturalness halo will offset excessive acidity, unfamiliar flavours, adverse nutritional labelling or premium prices without real-world consumer testing.

Abstract

The kombucha sensory and consumer evidence base has diversified substantially since the methodological concerns raised by Kim and Adhikari in 2020. This systematic scoping review and maturity audit examines how the field has evolved from sensory product testing towards evidence on consumer choice and market adoption. Searches in Web of Science and Scopus identified 372 unique records, and the substantive synthesis was based on full-text reports from 130 core studies. The literature shows clear progress in beverage formulation and sensory methodology, including trained panels, descriptive methods, temporal techniques, emotion measurement and consumer testing. However, most studies still focus on how fermentation conditions, substrates and ingredients affect acidity, sweetness, aroma, flavour and liking. Chemical and sensory outcomes are commonly measured together, but direct links between composition and human perception remain rare. Functional improvements also do not automatically increase acceptance: in some studies, bioactive or antioxidant endpoints improved with longer fermentation while sensory acceptance peaked earlier. Consumer and market studies indicate that health and



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naturalness may encourage initial interest, but flavour, sugar content, price, familiarity, labelling and regulation shape product choice. Evidence on observed purchasing, repeat consumption and retention is virtually absent. Kombucha research has therefore advanced further in optimising beverages than in explaining how consumers value, choose and continue to purchase them.

Keywords: kombucha; sensory evaluation; consumer acceptance; willingness to pay; functional beverages; market adoption; PRISMA-ScR

1. Introduction

Kombucha has moved from a predominantly home-brewed fermented tea to a diversified commercial beverage category associated with naturalness, live cultures and functional value [1–4]. Its appeal rests partly on a health-oriented promise: consumers encounter kombucha as an alternative to conventional soft drinks, as a fermented product associated with digestive or gut-health benefits, and as a vehicle for plant-derived bioactive compounds. Consumption, however, is mediated by a demanding and highly variable sensory experience. Fermentation produces acidity, carbonation and complex volatile profiles, but it may also generate vinegar-like notes, harsh sourness, bitterness, astringency and off-flavours. Kombucha is therefore a revealing case in which to examine whether functional promise can be converted into sensory acceptance and, ultimately, durable market adoption.

Scientific activity has expanded alongside product innovation. Research now covers conventional tea kombucha and beverages based on coffee by-products, herbs, fruits, cereals, roots, seaweeds and other alternative substrates. Processing studies have clarified how fermentation time and temperature, sugar concentration, starter composition, secondary fermentation and flavouring influence chemical, microbiological and sensory outcomes [5–8]. At the flavour-chemistry level, yeasts and acetic acid bacteria transform sugars into ethanol, organic acids and carbon dioxide, while fermentation also reshapes volatile compounds that contribute to aroma and mouthfeel [5,6]. The resulting sensory profile depends not only on fermentation intensity but also on the starting matrix, because tea type and processing affect the initial balance of polyphenols, pigments and volatile precursors [5,6]. Consequently, acidity should be interpreted as part of a broader sensory balance involving sweetness, bitterness, astringency, carbonation and aroma rather than as an isolated driver of acceptance. Human evaluation has also diversified beyond basic hedonic scales to include trained descriptive analysis, check-all-that-apply (CATA), rate-all-that-apply (RATA), just-about-right (JAR) scales, temporal methods, emotion measurement, conjoint analysis and willingness-to-pay (WTP) designs [9–17]. Yet growth in the number and sophistication of product studies does not necessarily imply equivalent progress in consumer science. Sensory description, liking, purchase intention, market choice and repeat consumption represent distinct evidential stages, but they are frequently treated as interchangeable.

The closest antecedent is the review by Kim and Adhikari, published in *Beverages* in 2020 [1]. Their review, which covered the literature available through 2019, identified only 20 publications containing sensory or consumer data and documented substantial weaknesses in sample size, participant description, panel training, scale selection, test classification, replication and interpretation. In the present corpus, 150 of the 163 adjudicated core records (92.0%) were published during 2021–2026, showing that the eligible sensory and consumer evidence base examined here has expanded substantially since that methodological benchmark. An updated synthesis is therefore timely, but the contribution

of the present review goes beyond documenting the expansion of the eligible evidence base. Rather than repeating a sensory-method inventory, it uses the 2020 assessment to examine whether earlier methodological weaknesses have been addressed, whether chemical and functional measurements are now linked more convincingly to human perception and acceptance, and whether research has progressed from product testing towards consumer choice, purchasing and sustained adoption.

Other reviews define adjacent but incomplete parts of the problem. Tran et al. connected technological parameters and chemical composition with sensory quality [5], and Bishop et al. examined biochemical and microbiological determinants of chemical and flavour profiles [6]. Liu et al. [7] and Barakat et al. [8] synthesised functional and sensory properties of kombucha analogues and alternative substrates. Batista et al. [2], de Miranda et al. [3] and Nyhan et al. [4] addressed broader questions of perceived benefits, regulation, safety, production and market prospects. At a broader category level, García-Barón et al. classified intrinsic, extrinsic, psychological, situational and sociocultural drivers of perception and preference across fermented foods and beverages [18]. However, none of these reviews systematically maps how far kombucha evidence advances from sensory product testing towards consumer choice, market constraints and sustained use.

Therefore, four gaps remain. First, the extent to which post-2020 studies improved the reporting and design weaknesses identified in 2020 has not been quantified. Second, chemistry and sensory response are often measured in the same experiment, but the relationship between them is rarely distinguished as a direct statistical link, a treatment-mediated association or a descriptive interpretation. Third, functional metrics and acceptance scores are routinely reported together, yet coexistence is frequently labelled as synergy even when no relationship has been tested and no joint optimisation has been performed. Fourth, the consumer literature appears concentrated on liking and stated intentions, with much less attention to price sensitivity, label effects, branding, cultural context, actual purchasing, repeat consumption, discontinuation or loyalty.

The present review addresses these gaps by treating the literature as an evidence chain: product and process characteristics → chemical and sensory experience → liking and acceptance → product choice and WTP → purchase, repeat use and sustained consumption. Its contribution is evaluative rather than encyclopaedic. Table 1 positions the present review against the closest antecedents and clarifies how it extends previous syntheses of sensory methodology, chemical and flavour composition, alternative substrates, and consumer drivers.

Table 1. Positioning of the present review against the closest antecedents.

Review	Primary Focus	Overlap	Residual Gap Addressed Here
[1]	Market status and early sensory/consumer studies	Participants, scales, test classification and reporting weaknesses	Systematic post-2020 maturity audit; extension to choice and adoption
[5,6]	Production, chemistry and sensory/flavour quality	Chemical basis of sweetness, acidity, aroma and mouthfeel	Evidence hierarchy distinguishing direct statistical links from treatment-mediated or narrative interpretation
[7,8]	Alternative substrates and kombucha analogues	Functional and sensory properties of non-traditional formulations	Classification of joint measurement, trade-off and coincidence of functional and sensory optima

Table 1. Cont.

Review	Primary Focus	Overlap	Residual Gap Addressed Here
[18]	Consumer drivers across fermented foods and beverages	Broader taxonomy of intrinsic, extrinsic and consumer factors	Kombucha-specific synthesis extending to WTP, labels, market constraints and retention
Present review	Maturity of sensory, consumer and market evidence	Integrates sensory, chemical, functional, consumer and market evidence	Identifies where the chain from product testing to repeated behaviour becomes underdeveloped

Figure 1 translates this positioning into the conceptual chain used to distinguish product characterisation, affective response, market choice and sustained adoption. Progress along the chain requires more than the parallel measurement of product and consumer outcomes; it requires explicit links between successive evidential stages.

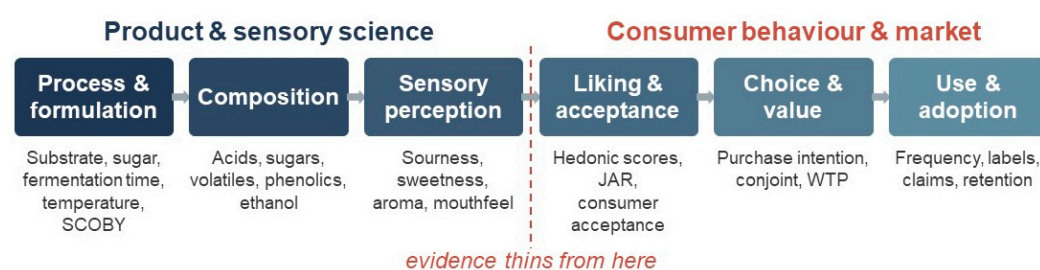


Figure 1. Conceptual framework used to distinguish product characterisation, affective response, market choice and sustained adoption.

The primary contribution is to use literature evidence to identify where kombucha research has progressed and where the evidence chain remains weak, from product composition and sensory response to consumer choice and sustained adoption. A second contribution is to assess methodological maturation since 2020, using the deficiencies identified by Kim and Adhikari as an explicit benchmark. The central proposition is that product optimisation has advanced faster than consumer understanding. Practically, this distinction indicates where product-development evidence is sufficient for formulation decisions and where consumer-choice or real-world market validation is still required.

On the basis of this positioning, the review addresses five research questions:

- RQ1. How has kombucha sensory and consumer research evolved since the methodological assessment published in 2020?
- RQ2. To what extent have post-2020 studies addressed earlier weaknesses in participant selection, panel training, sensory methodology, experimental control and reporting, and how discoverable are these safeguards in searchable metadata?
- RQ3. How are product, processing and chemical characteristics linked to human sensory perception, liking and acceptance, and how strong is the evidence supporting those links?
- RQ4. Under which conditions do functional improvements and consumer acceptance display synergy, trade-offs or merely parallel outcomes?
- RQ5. How far has the literature progressed beyond liking towards product choice, WTP, reported consumption, actual purchase and sustained adoption?

2. Materials and Methods

The study was designed as a systematic scoping review and maturity audit combining record-level evidence mapping, full-text data extraction and a separate searchable-record

discoverability audit. In this review, maturity refers to four dimensions: methodological diversification, reporting transparency, integration between evidence domains and proximity of the measured outcome to observed market behaviour. It does not represent a formal risk-of-bias score. A scoping design was selected because the eligible literature spans heterogeneous products, populations and methods, including descriptive sensory analysis, affective testing, temporal methods, surveys, conjoint experiments, WTP studies and market audits. Reporting was structured with reference to PRISMA-ScR [19]. The bibliographic record—title, abstract, keywords and metadata—was the unit used for initial screening, whereas the full-text report was the evidentiary unit for substantive extraction and evidence-strength classification.

Web of Science Core Collection and Scopus were searched on 18 June 2026 using two complementary strategies combined with OR. The sensory strategy targeted kombucha records containing structured human sensory terminology. The consumer-market strategy targeted kombucha-specific perception, preference, motivation, barriers, purchase intention, WTP, price, labels, claims, trust, consumption, adoption and repeat-purchase terminology. In Web of Science, kombucha was required in the title, abstract or author keywords, and the thematic terms were searched in Topic. The equivalent Scopus strategy used TITLE-ABS-KEY and the W/5 proximity operator. Complete executable search strings for both databases are provided in the Supplementary Information (Search_Strategies sheet).

No restriction was applied by language, document type or publication year. The 372-record unique corpus contained 355 English-language records and 17 records in nine other languages. It included 300 articles, 36 reviews, 24 conference papers, five book chapters, three conference reviews, two editorials, one book and one erratum. Document type was therefore used during eligibility assessment rather than as a search filter.

The Web of Science export contained 277 records and the Scopus export 280, producing 557 records before deduplication. Records were matched first by normalised DOI and then by normalised exact title when DOI was absent. This procedure identified 184 DOI duplicates and one additional title duplicate, leaving 372 unique records. Of these, 185 were present in both databases, 92 were unique to Web of Science and 95 were unique to Scopus. A total of 359 unique records had a DOI and 13 did not. Each record was assigned a stable identifier (K001–K372), and all screening decisions were retained in a master audit file. Table 2 summarises the numerical outcome of the search, deduplication, screening and synthesis stages. The corresponding record flow and the separation of unresolved records from the substantive synthesis are presented in Figure 2.

Table 2. Search, deduplication, screening and synthesis outcome.

Stage	<i>n</i>	% or Note
Web of Science records	277	Search date: 18 June 2026
Scopus records	280	Search date: 18 June 2026
Gross records	557	Before deduplication
Duplicates removed	185	184 DOI matches + 1 exact-title match
Unique records	372	185 in both databases; 92 WoS-only; 95 Scopus-only
Core records	163	43.8% of unique records
Full-text substantive synthesis	130	124 Route S; 11 Route C; 5 overlaps
Unresolved screening records	33	Retained in record-level map only
Adjacent beverage records	9	2.4%
Contextual record	1	0.3%
Excluded records	199	53.5%

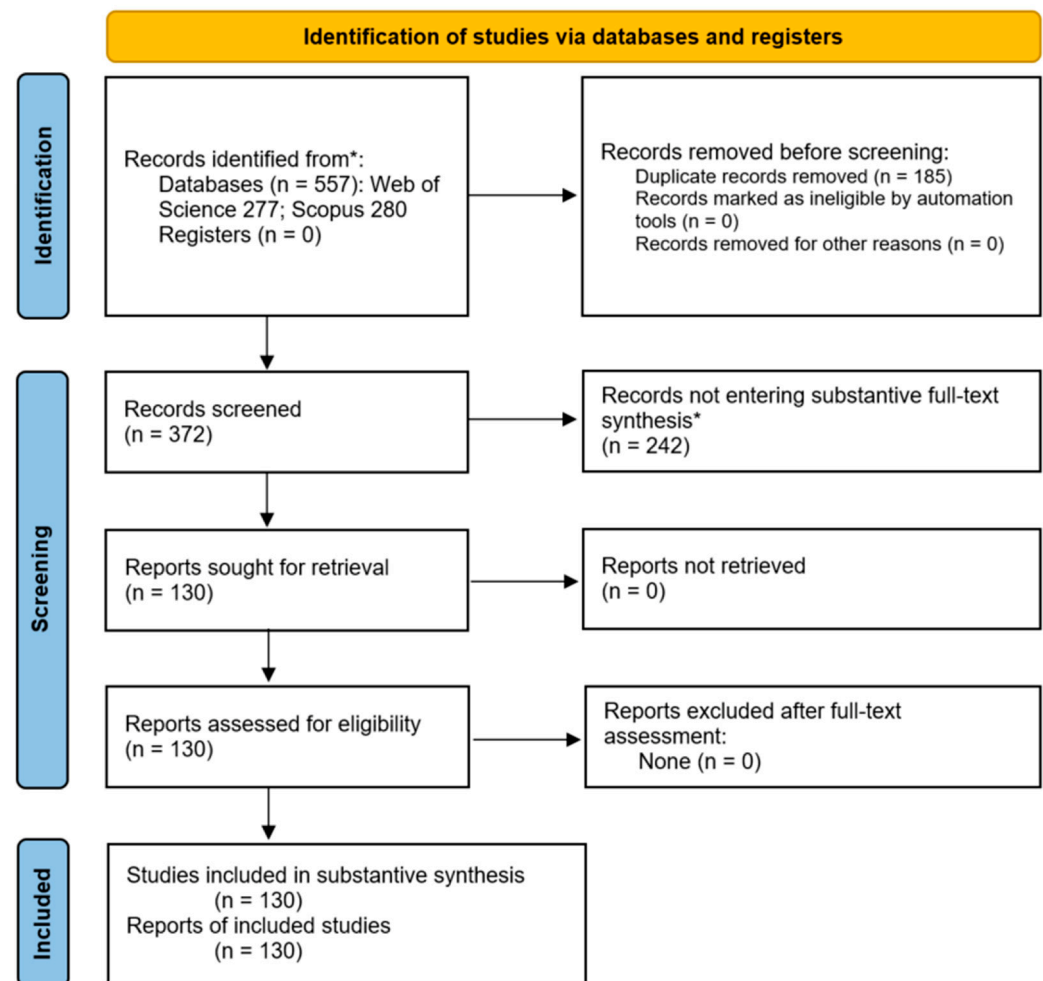


Figure 2. PRISMA-ScR flow diagram for record identification, screening, independent validation and substantive synthesis. Prisma checklist, as well as record-level exclusion decisions, reason codes and corresponding justifications are provided in the Supplementary Information (Excluded_Adjacent_Contextual sheet and PRISMA 2020 Expanded Checklist sheet). * Of the 242 records not entering the substantive full-text synthesis, 199 were excluded, 9 were classified as adjacent beverage evidence, 1 as contextual evidence, and 33 remained Route S uncertain and were retained only in the record-level map/discoverability audit.

Studies were eligible through either of two independent routes. Route S included primary empirical records reporting structured human sensory or acceptance evaluation of a beverage explicitly presented as kombucha. Eligible participants included trained or semi-trained panels and consumers. Eligible methods included descriptive analysis, hedonic tests, CATA, RATA, JAR, sorting, ranking, temporal methods and other structured human procedures. Instrumental-only assessments using electronic nose, electronic tongue, colour or volatile analysis were excluded unless accompanied by human evaluation. When the indexed record referred to sensory quality or organoleptic properties but did not establish that structured human evaluation occurred, Route S was coded as uncertain rather than forced into inclusion or exclusion.

Route C included primary empirical records reporting kombucha-specific consumer-behaviour or market outcomes, including reported consumption, motivations, barriers, product choice, purchase intention, WTP, price sensitivity, label or claim use, trust, adoption, repeat purchase, loyalty, discontinuation, market availability or positioning. Sensory liking alone did not qualify a record for Route C because liking is an affective response to a product, not a purchasing or market outcome.

The core product category comprised beverages explicitly presented as kombucha, including traditional tea kombucha and products made from alternative plant, fruit, coffee, cereal, herbal or algal substrates. This inclusive definition followed how beverages were presented in the source literature and was used for evidence mapping; it does not imply chemical or sensory equivalence across substrates. Beverages fermented with kombucha microorganisms but presented as mead, beer, smoothies, fermentation broths or milk drinks were retained separately as adjacent evidence. Non-beverage foods, edible SCOBY products, biomaterials and industrial applications were excluded. Reviews and other non-primary documents were excluded from the empirical synthesis but retained for the novelty audit.

Title-and-abstract screening followed a conservative retrieval rule. Records were retained whenever the searchable information confirmed one route or strongly suggested structured sensory evidence without providing enough detail to resolve it. Two human reviewers participated in screening. The first reviewer screened all 372 unique records. The second reviewer independently screened a blinded, randomly ordered set of 67 records comprising all 32 records initially coded as Route S uncertain, the single Route C-uncertain record and a stratified random sample of 34 remaining decisions. The second reviewer had no access to the first reviewer's classifications, the manuscript or the supplementary synthesis.

Agreement was 77.6% for Route S ($\kappa = 0.659$), 95.5% for Route C ($\kappa = 0.608$), 91.0% for product class and final decision ($\kappa = 0.778$), and 92.5% for binary inclusion or exclusion ($\kappa = 0.792$). Eighteen records differed on at least one field, six differed in final class and five differed in binary inclusion. All disagreements were resolved through discussion between the two reviewers using the prespecified codebook, and the final adjudicated classifications were jointly agreed. Because every initially uncertain record was deliberately included in the validation set, these statistics describe an uncertainty-enriched sample rather than a simple random sample of the full corpus.

Full texts were used for the substantive synthesis. The 130 distinct core studies with confirmed Route S or Route C evidence were examined to extract study design, participant characteristics, sensory and consumer methods, chemical and functional outcomes, market outcomes, evidence-strength categories and the furthest stage reached in the adoption chain. Rayyan, Consensus, and NotebookLM were used as document-navigation and extraction-assistance tools to locate relevant passages and organise preliminary notes. The original publication remained the evidentiary source: every study-level datum used in the synthesis was traced to the underlying full text and checked against the source document. The 33 records that remained Route S uncertain after screening were retained in the record-level map and discoverability analysis, thus adding 163 core records [9–17,20–173], but they did not enter the substantive sensory denominators.

A separate discoverability audit assessed information visible in searchable titles, abstracts and keywords: participant type, numerical human sample size, specific sensory method, panel training or calibration, sample coding, serving-order control, blinding, palate cleansing, replication and named statistical analysis. A field coded as not reported therefore means absent from the searchable record, not absent from the underlying study. This analysis evaluates retrievability and machine-readable reporting rather than methodological quality or risk of bias. Method names such as CATA, RATA, JAR and TDS were tabulated when explicitly visible in searchable metadata; full-text interpretation was used for the substantive classification of sensory, emotional and behavioural outcomes.

Chemistry-sensory relationships were classified from the full text as a direct statistical link when a correlation, regression or integrated multivariate analysis connected chemical variables with human sensory outcomes. Within this category, attribute- or score-level associations were distinguished from broader integrated or product-level associations so that direct links operating at different measurement scales were not treated as methodolog-

ically equivalent. Studies in which chemical and sensory outcomes changed under the same experimental treatment without a direct variable-to-variable test were interpreted as treatment-mediated evidence. Parallel measurement without formal linkage was treated as co-occurrence, not demonstrated mechanism.

Functional-acceptance evidence was mapped in two steps. First, the review identified studies that jointly measured a functional endpoint and human liking, acceptance, purchase intention or WTP. Second, it assessed whether the study used an explicit optimisation procedure. The term multi-objective optimisation was reserved for a formal procedure combining functional and acceptance objectives; simply selecting the formulation that appeared favourable across several endpoints did not qualify.

For the adoption chain, each core study was assigned to the furthest outcome it established: sensory characterisation; liking or acceptance; purchase intention; stated choice or WTP; self-reported consumption or label behaviour; market audit; or observed purchase and retention. The 33 unresolved screening records were displayed separately. Each study was counted once in the mutually exclusive chain, although it could contribute to multiple thematic syntheses. Table 3 consolidates the analytical hierarchy applied throughout the review to distinguish direct statistical relationships from treatment-mediated associations, parallel measurement and progressively stronger behavioural outcomes. These rules governed both study-level coding and the terminology used in the synthesis.

Table 3. Analytical hierarchy distinguishing measurement from demonstrated relationships.

Domain	Category	Operational Meaning	Interpretive Rule
Chemistry-sensory	Direct statistical link	Correlation, regression or integrated multivariate analysis connects chemical and human sensory variables	May support a relationship claim, but the measurement scale should be reported
Chemistry-sensory	Treatment-mediated association	Chemical and sensory outcomes change under the same experimental treatment	Do not describe as a direct chemical-to-perception estimate
Chemistry-sensory	Parallel/descriptive evidence	Both domains are measured but their relationship is not formally tested	Report as co-occurrence or author interpretation only
Functionality-acceptance	Joint measurement	A functional endpoint and human acceptance are both reported	Do not infer synergy from two favourable endpoints
Optimisation	Formal vs. empirical selection	Explicit multi-objective procedure versus selection after inspecting several outcomes	Do not call empirical selection multi-objective optimisation
Adoption	Liking → choice → purchase → retention	Increasing proximity to market behaviour	Do not treat liking or intention as observed adoption

The synthesis used exact counts and percentages, with the denominator stated for each analysis. No inferential comparison between publication periods and no meta-analysis were undertaken because the corpus is not a random sample of publications and the outcomes are heterogeneous in design, population, product, unit and measurement method. The review combines evidence mapping with narrative interpretation of representative studies. Adjacent and contextual records were not pooled with the core corpus.

3. Results

3.1. Search Outcome and Corpus Composition

The two searches generated 557 records and 372 unique records after deduplication. Following independent validation and adjudication, 163 records were classified as core, nine as adjacent beverage evidence and one as contextual, while 199 were excluded. The retained core represented 43.8% of the unique corpus. Four records moved from exclusion to the

core map during adjudication: three because organoleptic or sensory language warranted conservative retention and one because commercial labelling and producer-practice data met Route C. The substantive synthesis comprised 130 distinct core studies: 124 Route S studies and 11 Route C studies, with five contributing to both routes, while 33 additional records remained unresolved at screening and were retained only in the record-level map.

The core corpus was overwhelmingly recent. Only six records (3.7%) were published by 2019, seven (4.3%) in 2020 and 150 (92.0%) during 2021–2026. The number of core records was highest in 2023–2025, with 30, 30 and 43 core records, respectively. This temporal concentration shows that the sensory and consumer evidence available since the 2020 review by Kim and Adhikari [1] has expanded substantially. The more important issue is what type of evidence expanded.

3.2. Sensory and Behavioural Routes

Human sensory or acceptance evidence was found in 124 of the 163 core records (76.1%). An additional 33 records (20.2%) remained possible Route S studies because searchable metadata used sensory or organoleptic terminology without establishing the human method; these records were retained in the screening map but excluded from the substantive Route S denominator. Consumer-behaviour or market evidence was confirmed in 11 records (6.7%) [9,10,12,14,33,44,56,68,118,139,147]; no Route C classification remained uncertain after adjudication. The final route combinations are shown in Table 4.

Table 4. Adjudicated Route S and Route C combinations among the 163 core records.

Route S	Route C	n	% of Core	Interpretation
Yes	No	119	73.0%	Confirmed sensory/acceptance evidence only
Uncertain	No	33	20.2%	Retained in record-level map; excluded from substantive full-text synthesis
Yes	Yes	5	3.1%	Combined sensory and consumer-behaviour/market evidence
No	Yes	6	3.7%	Consumer-behaviour or market evidence without confirmed tasting
Total		163	100.0%	

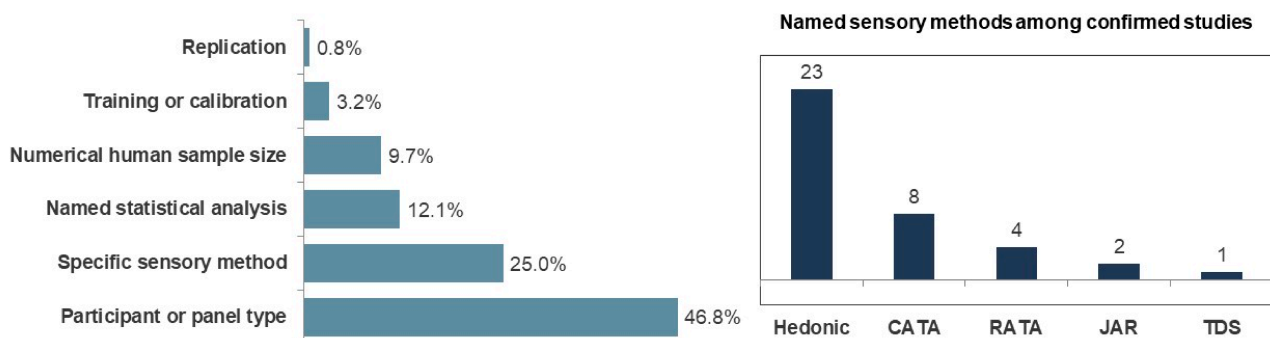
Route C was confirmed in 11 records: five combined sensory and behavioural-market evidence [9,12,44,56,68], while six contributed consumer or market evidence without a confirmed sensory test [10,14,33,118,139,147]. Within the core corpus, the expansion was therefore concentrated mainly in product formulation, sensory characterisation and acceptance testing, rather than consumer behaviour or market research.

3.3. Methodological Maturation and Searchable-Record Discoverability

The literature synthesis confirms genuine methodological diversification. The post-2020 literature includes trained descriptive panels, larger consumer tests, free sorting, CATA, RATA, JAR, TDS, emotion measurement, conjoint designs and WTP experiments [9–17]. Searchable metadata, however, often failed to expose those methods. Among the 124 confirmed sensory studies, only 58 documents (46.8%) identified the participant or panel type, 12 (9.7%) reported a numerical human sample size and 31 (25.0%) named a specific sensory method. Training or calibration appeared in four documents (3.2%), a named statistical analysis in 15 (12.1%) and replication in one (0.8%). None described sample coding, serving-order control, blinding or palate cleansing. Table 5 summarises the item-level results of the searchable-record discoverability audit and clarifies how each reporting indicator was operationalised, while Figure 3 visualises this reporting profile and the frequency of sensory methods explicitly named in searchable records, highlighting the marked contrast between the occasional identification of participants or sensory methods and the near-total absence of experimental safeguards from searchable abstracts.

Table 5. Searchable-record discoverability among 124 confirmed Route S studies.

Searchable-Record Item	<i>n</i>	%	Interpretation
Participant or panel type	58	46.8%	Explicitly stated in the searchable abstract
Numerical human sample size	12	9.7%	A number linked to consumers, participants or panellists
Specific sensory method	31	25.0%	Beyond a generic statement that sensory evaluation occurred
Training or calibration	4	3.2%	Explicit reference to trained or calibrated assessors
Named statistical analysis	15	12.1%	ANOVA, correlation, PCA/PLS or another named method
Replication	1	0.8%	Explicitly stated in the searchable abstract
Sample coding	0	0.0%	Not reported in the searchable abstract
Serving-order control	0	0.0%	Not reported in the searchable abstract
Blinding	0	0.0%	Not reported in the searchable abstract
Palate cleansing	0	0.0%	Not reported in the searchable abstract

**Figure 3.** Searchable-record reporting indicators and explicitly named sensory methods among the 124 confirmed Route S studies.

Method names in searchable records provide a conservative indicator of post-2020 diversification. Hedonic testing was explicitly named in 23 records; CATA appeared in eight, RATA in four, JAR in two and TDS in one, with overlap between methods. Thirteen distinct searchable records named at least one of CATA, RATA, JAR or TDS, and all were published after 2020 [9,11–13,22,28,34,48,49,53,54,103,126]. The full texts showed a richer range of designs than abstracts alone revealed, reinforcing the need to treat the abstract analysis as a discoverability audit rather than a substitute for methodological appraisal.

Fibrianto et al. illustrate both sides of this development [11]. The study combined RATA with 82 untrained Generation Z participants, TDS with 11 trained panellists and facial-expression analysis. The full text reports an overall facial-emotion classification accuracy of 92% from 161 photographs of the 11 trained panellists. However, the basis of that estimate was incompletely documented: participants were trained to reproduce target expressions, the image set was acknowledged as non-representative and no independent validation set, confusion matrix or class-specific performance metrics were reported. The technique is innovative, but its external validity as a measure of spontaneous consumer emotion is limited.

Dartora et al. used CATA to evaluate sensory attributes and evoked emotions in 105 consumers [13]. The document describes an informed-only design: consumers knew whether the beverage was made from green tea, black tea or yerba mate, and no blind baseline or blind-versus-informed comparison was performed. Yerba-mate kombucha was associated with positive emotion terms including tender, loving and peaceful, whereas black-tea kombucha produced a more ambivalent profile that included aggressive and worried. Because the substrate was disclosed, these associations cannot be attributed exclusively to intrinsic sensory properties; familiarity and cultural meaning may also have shaped the responses.

3.4. From Composition to Human Perception

Chemical, physicochemical or functional measurements were reported alongside confirmed human sensory evidence in 121 of the 124 Route S studies (97.6%). The literature is therefore not short of parallel measurement. It is short of direct integration. The analysis identified only five studies—4.0% of confirmed Route S and 3.1% of the core corpus—that directly connected chemical variables with human sensory outcomes through correlation or comparable integrated analysis [16,34,66,95,141]. However, these links operated at different measurement scales: three reported explicit attribute- or score-level relationships, one integrated chemical variables with a broader sensory balance, and one reported physicochemical–sensory correlations across a mixed set of fermented beverages that included kombucha.

Sales et al. [34] used Pearson correlations to connect titratable acidity with sourness and other sensory attributes in tea- and coffee-by-product kombuchas. Andreson et al. [16] integrated acid concentrations with the broader sweet–sour sensory balance of commercial kombuchas. Li et al. [141] found that the gluconic-acid proportion correlated positively with taste score ($r = 0.986$, $p < 0.05$), whereas the acetic-acid proportion correlated negatively ($r = -0.986$, $p < 0.05$). Moccia et al. [95] reported direct relationships between physicochemical composition and trained-panel sensory attributes, including titratable acidity with vinegary taste ($R^2 = 0.931$), residual sugars with fruity and sweet tastes, and ethanol with bitterness. Petrova et al. [66] reported correlation analysis connecting acidity with sensory characteristics in fermented plant-based beverages that included kombucha-based formulations; the mixed-beverage design means that not every relationship can be attributed exclusively to kombucha. These studies justify a direct-link classification; most of the remaining corpus supports only treatment-mediated or parallel interpretation.

Most other studies occupied weaker levels of the hierarchy. They measured volatiles, acids, sugars, phenolics or antioxidant activity and discussed these results alongside sensory scores, but did not formally test a direct statistical bridge. This distinction is important for interpreting the evidence. Previous research has identified compounds and physicochemical changes likely to contribute to flavour [5,6], but the evidence map shows that individual studies rarely demonstrate a direct link to human sensory perception.

3.5. Functional Promise Versus Sensory Reality

Sixty-seven of the 124 confirmed sensory studies (54.0%) jointly measured at least one functional endpoint, such as antioxidant activity, phenolics, flavonoids, antimicrobial activity, enzyme inhibition or probiotic viability and a human acceptance, liking, preference or valuation outcome (see Supplementary Information, Core_Evidence_Map sheet). Joint measurement, however, is not evidence that the endpoints were statistically related or jointly optimised.

Twenty-seven confirmed sensory studies used optimisation, optimal or optimum language, but none used a formal multi-objective framework combining functional and acceptance objectives (see Supplementary Information, Core_Evidence_Map sheet). The dominant approach was empirical selection after comparing several endpoints. That approach can identify a useful formulation, but it should not be described as demonstrated functional-sensory synergy or formal multi-objective optimisation.

Across the available studies, functional enhancement and sensory acceptance were sometimes compatible but not consistently aligned. Compatibility is reported when functional enhancement derives from substrate selection, blended formulation, probiotic or starter design or microbial-community engineering [22,28,39,43,61,124]. Trade-offs are clearest when longer fermentation improves bioactive or antioxidant endpoints while reducing sensory acceptance [60,87]. Lestari et al. [60] provide a clear example: antioxidant activity

measured by DPPH and FRAP and total phenolic content were maximal after 12 days, whereas the consumer sensory optimum occurred after four days. The eight-day separation is descriptive rather than a statistical test of competing optima, but it demonstrates that the functionally maximal and preferred conditions did not coincide.

3.6. From Liking to Adoption: The Evidence Chain

Assigning the 130 core studies to their furthest outcome makes the asymmetry visible, as shown in Table 6. Thirty-four stopped at sensory characterisation and 85 at liking or acceptance. Only two reached purchase intention [44,68], three stated choice or WTP [9,10,14], four self-reported consumption, familiarity, segmentation or label behaviour [12,56,118,139], and two were market audits [33,147]. No study measured observed purchase, repeat purchase, loyalty, switching or discontinuation. The 33 records that remained unresolved during screening are displayed separately in Table 6 rather than treated as substantive sensory evidence.

Table 6. Evidence-chain distribution across the 163 core records, separating 130 confirmed studies from 33 unresolved screening records.

Furthest Stage	Operational Outcome	<i>n</i>	% of Core
Sensory route unresolved	Sensory/organoleptic wording unresolved during screening; retained only in record-level map	33	20.2%
Sensory characterisation	Attribute profile, intensity or structured sensory description without a higher affective/market outcome	34	20.9%
Liking and acceptance	Hedonic rating, acceptability, preference or consumer taste-test outcome	85	52.1%
Purchase intention	Stated intention or likelihood to buy	2	1.2%
Choice and WTP	Conjoint choice, stated valuation or willingness to pay	3	1.8%
Reported consumption/label behaviour	Prior use, consumption patterns, segmentation, familiarity or label-information use	4	2.5%
Market audit	Availability, observed price, nutrition, alcohol content, producer practices and on-pack claims	2	1.2%
Observed purchase and retention	Transaction, repeat purchase, loyalty, switching or discontinuation	0	0.0%
Total		163	100.0%

The trial-to-adoption gap is therefore an evidence gap rather than a measured consumer failure rate. The review demonstrates that the transition is largely unobserved; it does not demonstrate that consumers routinely try kombucha and then abandon it. Self-reported consumption in cross-sectional surveys also differs from verified repeated purchasing and is classified separately.

3.7. What the Small Behavioural-Market Literature Shows

The 11 confirmed Route C records [9,10,12,14,33,44,56,68,118,139,147] illustrate the diversity and limitations of the behavioural evidence. Five combined sensory and behavioural-market outcomes, including Adiegwu et al., who combined tasting, CATA and a direct WTP question in 97 untrained participants [9]. Black-tea kombucha was preferred to the 100% white-hibiscus and 50:50 formulations, suggesting that lower white-hibiscus proportions warrant further testing. Ndiaye et al. evaluated hibiscus beverage concepts rather than tasted products in a choice-based conjoint web survey (*n* = 147) [14]. A'yuni et al. used conjoint-based ratings from 241 Thai and Indonesian participants who evaluated 27 concepts [10]. Reduced sugar was the most important attribute in both coun-

tries. Indonesian respondents favoured original flavour, regular price and antioxidant benefits, whereas Thai respondents favoured natural fruity flavours, more affordable prices and gut-health benefits. These are stated concept preferences, not observed market shares or purchases.

Cross-sectional consumer evidence provides information on consumption, familiarity, segmentation and label use but remains cross-sectional [12,56,118,139]. Góis et al. compared Portuguese and Brazilian perceptions of probiotic and kombucha consumption [118]. Kim et al. found that U.S. kombucha drinkers paid particular attention to sugar, calories and natural or organic ingredients [139]. Two market audits were retained: the UK audit systematically recorded availability, cost, ingredients, nutritional composition and on-pack claims across fermented-food categories, including 41 kombucha products [147]. Nordstrom et al. audited alcohol concentrations, nutritional labelling and production practices in New Zealand commercial kombucha [33]; 22% of the nine analytically tested samples exceeded the national 1.15% ABV threshold. These records add market and regulatory context, but neither measures consumer response to labels nor follows consumers from first trial to verified repeat purchase.

3.8. Regulation, Product Composition and Valuation

Table 7 brings together the principal post-2020 studies discussed across the preceding sections, highlighting both the methodological or substantive advance represented by each study and the boundary of inference supported by its design.

Table 7. Illustrative post-2020 studies showing where evidence has advanced and where inference stops.

Study	Advance	Key Finding	Boundary of Inference
[112]	Controlled 3 × 2 consumer sensory design	Higher temperature had the stronger sensory effect, increasing titratable acidity/astringency and reducing sweetness/liking; lower-temperature samples were preferred	Treatment-mediated evidence, not a direct chemical-to-liking model
[95]	Commercial profiling, direct correlations and regulation	Direct physicochemical–sensory relationships included titratable acidity with vinegary taste and residual sugars with fruity and sweet tastes; 9/10 products exceeded the applied sugar criterion and only 20% met the ethanol limit.	Warning-label effects and purchasing were not tested
[11]	RATA, TDS and facial-expression analysis	Authors reported 92% emotion-classification accuracy from 161 images	Only 11 trained panellists contributed images; validation reporting and external validity were limited
[13]	Sensory and emotion CATA	Yerba-mate kombucha evoked tender, loving and peaceful in an informed tasting; black tea produced a more ambivalent profile	No blind condition; intrinsic sensory and culturally shaped expectation effects cannot be separated
[60]	Joint functional and acceptance assessment	Functional maxima occurred at 12 days, whereas consumer sensory preference was highest at 4 days	Descriptive eight-day separation; empirical trade-off rather than formal multi-objective optimisation
[10]	Cross-cultural conjoint analysis	Reduced sugar was most important in both countries, with different flavour, price and health-benefit preferences	Concept-based stated choice, not tasting or observed purchase
[14]	Health-information conjoint/WTP experiment	Mean WTP was USD 3.23 before and USD 2.84 after health information; no significant increase	Web-based concept evaluation; confidence intervals are not individual WTP ranges
[9]	Tasting, CATA and direct WTP question	Black-tea kombucha was preferred to white-hibiscus formulations	Preliminary tasted-product valuation; no repeat-purchase evidence

Moccia et al. provide a particularly useful example of why product optimisation and market positioning should not be studied separately [95]. Among ten commercial Argentinian kombuchas, only 20% complied with the applicable ethanol limit and nine exceeded the sugar criterion applied under Argentina's front-of-pack framework. These findings place product composition directly within a regulatory positioning context; consumer response to the resulting warning labels was not measured.

Ndiaye et al. found no evidence that health information increased stated WTP for the hibiscus kombucha concept [14]. Mean WTP for the hibiscus kombucha concept was USD 3.23 before health information (95% CI: USD 2.91–3.60) and USD 2.84 afterwards (95% CI: USD 2.59–3.10), with no statistically significant increase. As a web-based concept evaluation, the study estimates stated rather than observed valuation. Health information alone therefore did not increase WTP in this setting.

4. Discussion

4.1. Growth and Methodological Maturation Since 2020 (RQ1–RQ2)

RQ1 and RQ2 indicate substantial but uneven maturation. The sensory and consumer evidence base examined here has expanded substantially since 2020 and now uses a broader methodological repertoire, including trained descriptive panels, CATA, RATA, JAR, temporal methods, emotion measurement, conjoint analysis and WTP designs [9–17]. This represents clear progress beyond the predominantly small and weakly documented evidence base described by Kim and Adhikari [1] in 2020. However, methodological diversification has not been accompanied by equally consistent reporting or experimental integration. Participant characteristics, panel preparation and presentation safeguards remain poorly visible in searchable records, while advanced methods are concentrated in a limited subset of studies. The evidence base has therefore expanded and diversified methodologically, but not uniformly in transparency, comparability or inferential strength.

4.2. Linking Composition with Sensory Response (RQ3)

The answer to RQ3 is that direct composition–sensory evidence remains narrow. The five direct-link studies operate at different measurement scales and are not methodologically equivalent. Across them, higher acidity or acetic character is generally associated with sour, vinegar-like or less favourable sensory outcomes, whereas residual sweetness, fruity attributes and, in one study, a higher proportion of gluconic acid are associated with more favourable sensory responses. These findings are directionally coherent, but they arise from only five studies using heterogeneous products and analytical designs [16,34,66,95,141]. Most of the literature changes fermentation time, temperature, substrate or formulation and observes corresponding chemical and sensory changes without testing the variables directly. The field can therefore identify plausible sensory mechanisms, but it cannot yet offer a general predictive model connecting composition with human sensory response or liking.

Interpretation is further complicated by substantial starting-matrix heterogeneity. Conventional black- and green-tea kombuchas, other tea types and alternative plant substrates differ in their initial polyphenol, pigment, sugar and volatile profiles, so chemically similar fermentation changes need not produce equivalent sensory effects across products. Tea type, cultivar, geographical origin, harvest season, processing history, infusion strength and the use of unfermented controls therefore matter when attributing sensory changes specifically to fermentation. Acidity should likewise be interpreted within the overall sensory balance, including sweetness, bitterness, astringency, carbonation and aroma, rather than as an isolated determinant of response. Future composition–sensory models should also incorporate tea-specific constituents, including catechins, caffeine, pigments,

amino acids and tea-derived volatiles, and, where appropriate, pair volatile profiling with aroma-activity metrics.

4.3. Functional Value and Consumer Acceptance (RQ4)

RQ4 does not support a general conclusion of functional–sensory synergy. Functional endpoints and acceptance are frequently measured in the same experiment, but no study applied formal multi-objective optimisation (see Supplementary Information, Core_Evidence_Map sheet). Across the available studies, compatibility was reported when functional enhancement arose from substrate selection, blending, starter or probiotic design, or microbial-community engineering [22,28,39,43,61,124]. Clearer trade-offs appeared in studies of fermentation duration, where bioactive or antioxidant endpoints improved under longer fermentation while sensory acceptance peaked earlier [60,87]. These patterns are descriptive rather than formal tests of joint functional and sensory optima. Nevertheless, the available evidence is insufficient to determine systematically which production conditions generate synergy and which generate trade-offs. The principal finding is therefore not that functionality and acceptance are generally incompatible, but that their relationship has rarely been tested.

4.4. From Liking to Market Adoption (RQ5)

RQ5 reveals the sharpest weakness in the evidence base. The small behavioural literature suggests that health perceptions can encourage interest in kombucha, but stated choice also depends on flavour, sweetness, sugar content, price, familiarity and product information [10,12,14,118,139]. Health-related positioning does not automatically translate into economic value: Ndiaye et al. found no significant increase in WTP after providing health information, while A'yuni et al. showed that attribute priorities differed between Thai and Indonesian consumers despite a common preference for reduced sugar [10,14]. Cross-cultural evidence remains sparse, and branding itself has rarely been tested directly. Regulatory and labelling studies likewise describe the product environment more often than consumer response to it.

However, the published literature scarcely observes what happens after initial evaluation. Purchase intention, conjoint choice and WTP are uncommon [9,10,14,44,68], and no included study followed verified transactions, repeat purchase, switching or discontinuation. This gap may partly reflect the greater cost and logistical complexity of longitudinal or real-world consumer studies, together with limited access to scanner, loyalty-card and brand-level purchase data. The predominance of controlled sensory and product-development research also means that revealed purchasing behaviour lies outside the main methodological tradition represented in the corpus. This imbalance is not unique to kombucha: sustainability-oriented beer research also relies heavily on choice experiments and WTP estimation, while longitudinal evidence on behavioural change remains scarce [174]. The evidence chain should therefore be interpreted as an evidential hierarchy rather than as a deterministic consumer journey: the review demonstrates that sustained adoption is largely unmeasured, not that consumers necessarily try kombucha and subsequently abandon it.

4.5. Integrative Diagnosis

Taken together, the kombucha evidence base has diversified horizontally across substrates, formulations, analytical endpoints and sensory techniques, but it has developed much less vertically across the evidence chain. The field is rich in measurements made within the product-testing stage but poor in explicit links from composition to perception, from perception to economic value and from choice to repeated behaviour. Its maturity is therefore domain-specific rather than general: product optimisation is comparatively

advanced, whereas consumer explanation and market validation remain underdeveloped. A next-generation evidence framework should therefore model these links within the same design, connecting chemical composition to sensory perception, perception to valuation and valuation to observed repeated behaviour.

5. Limitations

Two human reviewers participated in screening, but independent duplication covered an uncertainty-enriched set of 67 records rather than all 372 unique records. Agreement on final class and binary inclusion was strong, while Route S agreement was lower because reviewers differed in the threshold between Yes and Uncertain. All discrepancies were resolved through discussion, and final classifications were agreed jointly. Thirty-three records remained unresolved at the screening level and were retained in the broad map but excluded from substantive denominators. The search was restricted to Web of Science and Scopus, although no language, year or document-type filter was used within those databases. Grey literature outside indexed sources was not systematically searched.

The review did not have access to proprietary scanner, loyalty-card, retail-panel or brand-level consumer datasets. Accordingly, the absence of observed purchase and retention studies refers to the peer-reviewed evidence base examined here and should not be interpreted as evidence that such behavioural data do not exist commercially. The corpus is heterogeneous, and no meta-analysis or inferential pre/post comparison was attempted. This heterogeneity also extends to conventional tea kombucha, different tea types and alternative substrates, with substantial variation in starting matrices and processing conditions that was not amenable to formal quantitative stratification. The conclusions concern the architecture and maturity of the evidence base, not pooled effect sizes or a causal estimate of market adoption.

No formal risk-of-bias instrument was applied because the corpus combined heterogeneous sensory experiments, consumer tests, surveys, conjoint studies and market audits. The analytical hierarchy evaluates the type of relationship established and the proximity of outcomes to observed behaviour, rather than assigning a global internal-validity score to each study.

Full-text extraction and evidence classification were not independently duplicated for all included studies, although study-level data were checked against the original reports and key classifications were audited through the prespecified hierarchy.

6. Conclusions

The five research questions converge on a common diagnosis: the kombucha sensory and consumer evidence base has diversified substantially since 2020, but integration across the pathway from product composition to sustained consumer behaviour remains limited. Kim and Adhikari [1] documented a small and methodologically weak sensory literature through 2019. The subsequent evidence base is broader in products, formulations and methods, but its maturation has been uneven.

Methodological development is most evident in sensory and product evaluation, with increasing use of trained panels, CATA, RATA, temporal methods, emotion measurement and structured consumer-choice designs. However, direct integration remains uncommon. Only five studies established direct composition–sensory relationships, and although functional endpoints and acceptance were frequently measured together, no study formally optimised them jointly. Starting-matrix heterogeneity further limits generalisation across tea types and alternative substrates. Product development has therefore advanced further than the ability to predict how chemical or functional changes translate into human perception and acceptance.

The largest gap appears beyond liking. Consumer-behaviour and market studies remain scarce, and none of the included peer-reviewed studies observed verified purchasing, repeat purchase, loyalty, switching or discontinuation. This identifies a trial-to-adoption evidence gap, rather than evidence that consumers routinely abandon kombucha after initial trial. Health positioning, naturalness or functional claims should likewise not be assumed to translate automatically into valuation or purchase: available evidence indicates that flavour, sweetness, acidity, sugar content, price, familiarity, cultural context and product information can all influence stated preferences.

Future research should therefore move beyond parallel measurement towards linked designs: direct chemical–sensory modelling, blind-versus-informed testing, integrated evaluation of formulation, claims and price, representative and cross-cultural consumer samples, incentive-compatible choice and longitudinal or transaction-based measures of repeated behaviour. For product developers, sensory optimisation should be accompanied by realistic valuation and post-launch behavioural evidence rather than inferred from functional composition alone.

The central conclusion is that kombucha research has become increasingly capable of optimising the beverage, but remains much less capable of explaining how consumers value it, choose it and continue to purchase it.

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Abbreviations

The following abbreviations are used in this manuscript:

ABV	Alcohol by volume
AI	Artificial intelligence
ANOVA	Analysis of variance
CATA	Check-all-that-apply
CI	Confidence interval
DOI	Digital object identifier
DPPH	2,2-Diphenyl-1-picrylhydrazyl
FRAP	Ferric reducing antioxidant power
JAR	Just-about-right
PCA	Principal component analysis
PLS	Partial least squares
RATA	Rate-all-that-apply
RQ	Research question
SCOBY	Symbiotic culture of bacteria and yeast
TDS	Temporal dominance of sensations

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