Sensory evaluation of alternative proteins

A best practices guide

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Suggested citation: Nolden, A., C. Bomkamp, J. Kirchner, and N.M. Kogar. *Sensory evaluation of alternative proteins: A best practices guide*. Washington, D.C.: Good Food Institute. 2025. https://doi.org/10.62468/novg4853

Graphic design: Kristen Fava, Kelli Cromsigt

Acknowledgements

We are grateful to **Caroline Cotto**, *Director of NECTAR*, *Food System Innovations*, for her guidance as a technical advisor throughout this project. We also thank the many experts who generously shared their time and insights during interviews, as well as the respondents to our survey. Their input significantly strengthened the depth and accuracy of this resource and provided valuable perspectives that informed the development of this white paper.

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Executive summary

Sensory science is essential for the success of alternative proteins. While health, environmental, and ethical considerations may influence consumer interest, taste remains a primary driver of food choice.

The alternative protein industry is evolving quickly, driven by advances in science and technology. Yet consumer acceptance hinges first and foremost on taste, followed by factors such as price and accessibility. Sensory science provides the tools to evaluate and optimize taste and the overall eating experience, enabling the industry to deliver products that meet or exceed consumer expectations. While many groups recognize the importance of sensory evaluation, current practices remain inconsistent. This white paper addresses that gap by introducing the basics of sensory science, including traditional and modern methods, and how they can be strategically applied throughout the strategically applied throughout the product lifecycle. It also outlines best practices for participant selection, testing protocols, data analysis, and reporting, providing a roadmap to integrate sensory science more effectively into innovation pipelines.

The overarching recommendations of this resource are to:

- Integrate sensory science and sensory scientists early and often. Even basic or rapid evaluations in informal settings can streamline development toward consumer needs or preferences.
- Choose methods that match the question or goal. Discrimination, descriptive, and affective testing each answer distinct questions—whether differences can be detected, what those differences are, and how much consumers like the product. Temporal methods add further depth by tracking how eating experiences evolve over time.
- Use relevant benchmarks. Comparisons are most meaningful when anchored to well-liked products within the target market. Weak or poorly chosen benchmarks can lead to misleading conclusions.
- Rely on target consumers, not employees. Internal feedback is not a reliable substitute for testing with actual consumers, though employees can provide useful feedback in some scenarios.
- Collaborate across disciplines. Aligning sensory science with ingredient and product development, data science, marketing, and business development de-risks decision-making and supports faster innovation.

These recommendations highlight the central role of sensory science in bridging technical innovation with consumer acceptance. Ultimately, sensory science is not simply a testing step—it is a strategic discipline that, when applied consistently, enables alternative proteins to compete on taste, earn consumer trust, and accelerate adoption in the marketplace.

This guide brings together foundational concepts, practical guidance, and emerging innovations in sensory science for alternative proteins. It is designed to serve a wide range of readers—from those new to sensory science to technical specialists looking for detailed guidance. The table below outlines the focus of each section to help readers navigate the guide.

Section	What it covers	Read this section if you are...
Introduction	Why sensory science matters for alternative proteins, common challenges, and foundational concepts.	...new to sensory science or on a cross-functional team that includes sensory expertise.
Getting started with sensory evaluation	How to define objectives, set standard protocols, and build sensory literacy.	...a product or people manager, R&D lead, or anyone setting up sensory studies.
Traditional and modern sensory methods	Core sensory methods that are field standards or emerging.	...curious about different methods, or choosing which approach best fits a question.
Aligning sensory methods with development objectives	How sensory evaluation supports each stage of the product development process, from concept development through post-launch.	...on or connected to a product development team or using sensory data to guide go/no-go decisions.
Best practices for sensory testing setup, protocol, and presentation	Practical guidance for study setup, participant recruitment, sample preparation, and controls.	...running, overseeing, or commissioning sensory studies.
Data management, analysis, and reporting	Guidance on interpreting data, assessing sensory parity, considering segmentation, and avoiding pitfalls.	...responsible for analyzing results, reporting findings, or guiding strategy.
Innovations and future directions	New approaches, technologies, and opportunities that are shaping the future of sensory evaluation.	...a forward-looking researcher or strategist.
Common questions, pain points, and red flags: A sensory scientist's perspective	FAQ-style insights into frequent challenges and misconceptions.	...looking for quick expert perspectives on navigating common hurdles.
Conclusion, Resources	Key takeaways, research gaps, and further learning opportunities.	...looking for a summary of insights and next steps.

To complement the full report, a quick-start guide is available at gfi.org that distills the main recommendations into a concise overview and illustrates them through brief case studies.

Introduction

What is sensory science, and why does it matter for consumer adoption of alternative proteins?

Alternative protein technologies hold immense potential to improve the environmental, public health, and social impacts of protein production in the global food system. However, despite rapid scientific and commercial progress, many alternative protein products have failed to meet consumers' sensory expectations, particularly in terms of flavor, taste, and texture.[1,2] Consumers who have never tried plant-based meat or who have tried but stopped eating it cite taste, texture, and preference for conventional meat among the top reasons they don't eat it. This sensory gap has slowed widespread adoption and, in turn, the realization of the environmental and public health benefits these innovations can deliver. As NECTAR's Taste of the Industry 2025 report shows, products that deliver better taste outperform their plant-based competitors in the marketplace, underscoring that taste is not just a consumer preference but a commercial imperative.

Closing this gap requires more than scientific breakthroughs. It depends on rigorous methods for assessing sensory quality.[3,4] Without consistent, reliable methods of measuring the efficacy of technological advances, researchers and product developers cannot accurately measure progress to produce inferences and insights about the products being tested.

Sensory analysis, also known as sensory evaluation, is the science of using the human senses to analyze products. It applies principles of experimental design and statistical analysis to produce inferences and insights about the products being tested. Investment in sensory studies is essential to ensure a thorough understanding of consumer interactions with products. Yet, despite its critical role in delivering desirable taste and quality, sensory science remains an often underappreciated element of product development.

The importance of sensory literacy

Sensory education is foundational to alternative protein innovation and the building of effective product development pipelines and teams. Developing sensory literacy within teams provides several advantages:

- Improves decision-making: Teams with sensory knowledge can better interpret data and make informed product choices.
- Reduces reliance on tradition: Many companies follow outdated practices without understanding their purpose.
- Builds internal capability: Even small companies can benefit from basic sensory literacy, reducing dependence on external consultants.
- Enhances cross-functional collaboration: Educated teams can communicate more effectively across R&D, marketing, and sensory functions.
- Supports innovation: Understanding consumer perceptions and variability improves understanding of consumer segments.

The experts we surveyed and interviewed reinforced these points, grounding this report in real-world practice. This white paper serves as a resource for strengthening sensory literacy across teams, beginning with an overview of the core science, challenges, and methods that underpin effective practice.

Overview of sensory science

Sensory is a science. Sensory science is often misunderstood as subjective or informal, but in reality, it is a rigorous and complex scientific discipline. Although sensory evaluation draws on everyday human experiences such as tasting and smelling, the discipline is fundamentally distinct from casual perception. It relies on standardized procedures, controlled environments, and statistical analysis to produce valid, actionable

results. Without these controls, data become unreliable, results cannot be compared across studies, and decision-making is compromised.

Importantly, sensory science is distinct from, yet closely related to, consumer science. Sensory science focuses on product characteristics, also referred to as attributes, under controlled conditions, while consumer science investigates how those attributes drive liking, preference, and behavior in real-world contexts. The two disciplines are complementary and sometimes overlap. However, the focus here is on sensory science, as it provides the diagnostic insight needed to connect formulation decisions with consumer experience.

Sensory science plays a critical role in guiding product development decisions across the food industry and particularly in the alternative protein sector.[5,6] It helps teams translate technical product attributes—like ingredient functionality or processing effects—into human experiences of taste, flavor, and texture that determine purchase intent, satisfaction, and repeat consumption. Sensory science is an essential bridge between formulation and consumer acceptance, with consumer science confirming whether products ultimately succeed in the marketplace.

How we perceive flavor: The chemosensory systems. Flavor is evoked through a complex interplay of multiple chemosensory systems: taste, olfaction, and chemesthesis, each contributing distinct yet interrelated signals that inform perception, preference, and behavior.

- **Taste**, or gustation, occurs when molecules interact with taste receptor cells located on the tongue and throughout the oral cavity. The five taste sensations—sweet, salty, sour, bitter, and umami—are each transduced through specific receptor mechanisms. It is important to distinguish between the technical and everyday use of the word taste, as consumers often use it to refer to flavor. Clarifying this distinction is key to understanding consumers' perceptions.
- **Olfaction**, or smell, involves the detection of volatile compounds by olfactory receptor neurons located in the nasal epithelium, with strong links to the formation of emotional and memory-related associations. Orthonasal olfaction (through the nostrils) and retronasal olfaction (through the back of the throat during eating) both contribute significantly to flavor perception. When working with consumers, odors perceived during consumption are best referred to as flavors, while aroma is commonly used to denote the smell of a product before consumption.
- **Chemesthesis** refers to chemically induced sensations such as burning (capsaicin in chili peppers), cooling (menthol), heat, or tingling (carbonation), which are mediated by trigeminal nerve fibers rather than through taste or odor receptors.

Together, these chemosensory systems create a multidimensional perception of flavor. They often interact in complex ways. Some compounds can trigger multiple pathways or suppress one another, making predictions difficult within a complex food matrix. Sensory science serves as a diagnostic tool and a strategic driver of innovation, helping developers optimize flavor, texture, aroma, and appearance, which are key to replicating the sensory experience of animal-based products.

For a comprehensive, textbook-level overview of the field, there are highly regarded references that serve as standard works.[7,8] This report, by contrast, offers an applied guide to sensory methods aligned with product development needs in the alternative protein industry.

Sensory challenges in alternative proteins

Unlike conventional food products, alternative proteins often face the dual challenge of creating familiar sensory profiles while managing the inherent limitations of novel ingredients (e.g., plant-based proteins, cultivated meat).

Overview of sensory-specific challenges

Flavor remains among the most complex and persistent challenges in alternative protein development. Replicating the nuanced profiles of traditional animal-based foods, particularly the balance of savory, meaty, and species-specific flavor notes, is difficult when working with plant-based, fermented, or cultivated ingredients. Additionally, traditional meat products deliver a complex sensory experience shaped by Maillard reactions, lipid oxidation, and species-specific compounds that are difficult to mimic. As a result, products often lack the savory depth, umami richness, and subtle roasted notes of conventional meat, leading to consumer perceptions of blandness or artificiality.

Off-notes often emerge during formulation and processing, posing significant barriers to consumer acceptance. Off-notes encompass both taste- and flavor-related sensations, such as beany, grassy, metallic, or sulfurous.[9] These often originate from plant-protein ingredients, such as soy, pea, or other legumes,[10] which can undergo changes during and following processing.[11] Well-designed sensory studies are key for identifying problematic sensations and formulation or processing strategies that effectively mitigate them.

Instrumental methods like gas chromatography and mass spectrometry are routinely used to identify and quantify volatile compounds, offering early indicators of flavor performance. While these tools are valuable for screening and troubleshooting, they are limited in their ability to predict the full human experience. Chemical flavor profiles alone often fail to predict flavor perception, as it is a multisensory experience shaped by how components interact within the context of the whole eating experience. Individual factors, such as expectations, prior experiences, and variability, also play a critical role.

Texture is another core hurdle, particularly in products that aim to replicate the fibrous or gel-like structure of meat. Although instrumental methods provide early indicators of performance, they do not replace human sensory evaluation. Several studies have demonstrated that textural and rheological properties (e.g., viscosity) may fail to correlate with consumer mouthfeel and are unable to predict acceptance.[1,12,13]

Visual cues affect how consumers assess the acceptability and quality of alternative protein, even before tasting. This becomes especially important when products are marketed as direct analogs to conventional products, as consumers make direct comparisons between them. Designing visual appearance with these expectations in mind is essential, as appearance can directly influence overall sensory ratings and acceptance.

Together, these sensory challenges underscore the importance of multidimensional sensory design, which integrates a comprehensive assessment of appearance, texture, taste, flavor, and aroma to evaluate acceptance and quality.

Overview of consumer-specific challenges

In addition to overcoming sensory hurdles, a range of consumer-specific challenges has been linked to willingness to try, acceptance, and adoption. Research has shown that factors external to the product itself, including demographics, emotional and cognitive factors, and underlying psychological reactions to unfamiliar ingredients or production methods, can strongly influence sensory evaluations. These insights are especially important when designing sensory consumer studies and recruiting appropriate participants.

The majority of this work has focused on plant-based alternatives intended to mimic the sensory attributes of conventional animal products, as a general product category.[14–17] Some studies have considered specific categories, such as meat or dairy,[18–20] with fewer studies specifically focused on cultivated meat[21–24] or blended products (i.e., a blend of animal and plant ingredients).[25–27] For more reviews on this topic, see Onwezen et al. 2021.[24]

- **Age and generation:** Greater interest in sustainable food choices, including alternative proteins, is expected to grow among younger generations as products become more familiar.[28,29] In contrast, older consumers are often more skeptical and unwilling to alter their accustomed diet.[30]

- **Geography**: Urban consumers are generally more accepting than rural, particularly those who consume a more traditional meat-based diet.[30]
- **Education:** Higher education is often linked to increased awareness of environmental and health-related food issues, though not necessarily to higher sensory acceptance of alternative protein products.[24]

While many reports assert that consumer interest and demand for sustainable alternatives are growing, studies and consumer data suggest that sustainability is a secondary consideration behind taste, cost, availability, and health.[31] Further, there is limited understanding of how much consumers actually know about the environmental impact of food choices, highlighting a gap between stated values and real-world decision-making.

Cognitive and emotional influences: Beyond demographic characteristics, many consumers face emotional and cognitive barriers to the acceptance of alternative proteins. These include perceived unnaturalness, concerns about processing and ingredient familiarity, and lack of trust in the technology behind new protein sources (e.g., fermentation-derived or cultivated meat).[15,17] Though initial research suggested food neophobia, or the reluctance to try new or unfamiliar foods, contributed to reduced acceptance of plant-based foods,[14,32,33] there is growing evidence that fear of food technology may better assess consumers' fear of trying new foods in regards to alternative products.[15,17,34] In some markets, consumers show the opposite trend, viewing new foods as premium and exciting. Consumer beliefs are often shaped more by cultural or societal perceptions than by actual knowledge or understanding of the product composition (e.g., ingredient lists, nutrition facts). Additionally, some consumers have deeply held emotional and cultural connections with conventional animal products that lead them to reject alternatives.[35–37] Efforts to address these barriers through policies, education, and product information have produced inconsistent results.[38–42] For more on consumers' emotional and cultural views of conventional and plant-based products, see GFI US's plant-based meat consumer segmentation and GFI APAC's decoding demand.

Implications for sensory studies and further research: These person-level factors should be proactively researched and considered when designing sensory evaluations. Prior to recruitment, determine whether consumer segmentation is needed, and if so, identify the most relevant factors and target audience. A more detailed discussion of screening and segmentation strategies is provided in the section "Best practices for sensory testing setup, protocol, and presentation."

Ultimately, consumer-specific challenges must be addressed in parallel with technical product improvements. As the field evolves, further research is needed to better understand the complex drivers of perception and acceptance. These insights will be critical not only for improving products but also for refining how sensory studies are designed, who participates in them, and how findings are reported.

Getting started with sensory evaluation

Sensory evaluation is a cornerstone of product development in the alternative protein industry, enabling developers to assess key attributes such as flavor, texture, aroma, and appearance. However, the translation of sensory data into decision-making depends heavily on alignment between the research question, the selected method, and the overall study design. Choosing an inappropriate method or failing to control for experimental variables can lead to misleading or inconclusive data, undermining leadership decisions and delaying innovation.

Interview insights

Companies that integrate sensory evaluation into all steps of the product development cycle and rely on sensory data to drive business decisions have competitive advantages, as taste is often cited as the biggest factor driving consumer purchases, ahead of cost and sustainability.

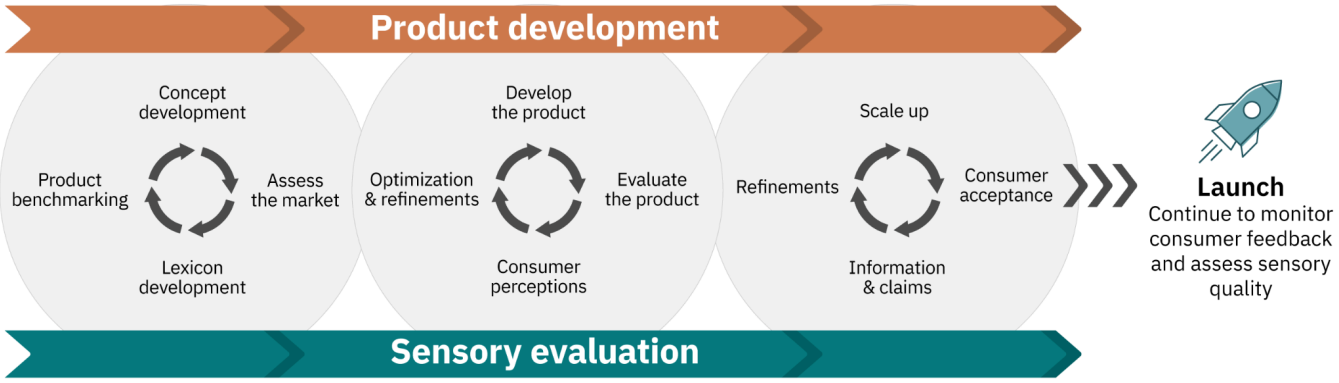


Figure 1. Sensory evaluation is most useful when integrated throughout product development. Considering sensory and consumer feedback at each stage helps the product meet expectations for taste, flavor, and texture—the main drivers of purchase and repeat purchase. Well-designed studies reduce risk by providing clear insights to guide decision-making.

Understanding the objective — a collaborative process

Early partnerships between product developers and sensory scientists help ensure the study design and plan align with the development goal. Sensory studies are complex, requiring many design protocols that depend on the situation and objective. Incorporating sensory data from the first phase of development allows for the effective use of sensory data.

Best practice

Always begin sensory studies with a clear objective, including predefined criteria for moving to the next steps. A shared understanding of background knowledge and goals allows sensory scientists to design studies appropriately, including the selection of methods and participants. Treating sensory testing as a transactional "check box" step rather than a strategic partner often leads to misaligned data and missed opportunities for insight.

Bringing sensory scientists meaningfully into the product development process helps teams choose the most efficient and impactful approaches. Instead of expending resources on methods that may not serve the project's immediate goals, cross-team collaboration enables sensory experts to guide the selection of right-sized methods that deliver actionable insights. In this way, companies don't have to choose between rigor and efficiency. Integrating sensory input early creates genuine resource savings while ensuring product decisions are grounded in accurate consumer and sensory data.

Setting standard protocols

For groups without an established sensory program, hiring a consultant to establish standard testing protocols can provide high value. This process also communicates the value and importance of sensory studies. However, there is no need to invent new processes. Validated and well-designed protocols are readily available from the American Society for Testing and Materials (ASTM) and the International Organization for Standardization (ISO). These methods offer guidance on sensory testing design and execution, including best practices for sample tasting procedures and minimizing biases.

Best practice

Experts emphasized a need to conduct sensory trials that align with industry standards to ensure reliable, decision-ready feedback. Review and adopt ASTM or ISO standards for benchtop sensory testing. Interviewees found that setting standard protocols allows teams to review and track data meaningfully over time.

Educating your team

Building internal sensory literacy establishes a shared language for describing products, improves decision-making, and fosters collaboration between R&D, marketing, and product teams, regardless of company size. Sensory literacy enables teams to discuss products more effectively, align on expectations, and ultimately achieve both product and long-term success, particularly when sensory foundations are established early. Though many experts emphasize the importance of hiring an expert or consultant, even when a team member has prior experience, the following recommendations and action steps introduce foundational sensory education.

Six steps to build sensory literacy

Step 1: Build awareness

- Host a short internal seminar or lunch-and-learn on "What is Sensory Science?" (see Resources).
- Share examples of how sensory literacy impacts product success (see Resources).

Step 2: Identify internal champions

- Identify team members with training in sensory science or individuals who understand the value of sensory insights to serve as internal champions.
- Assign a "sensory lead" to coordinate efforts and liaise with external experts, if needed.

Step 3: Start small with hands-on learning

- Run blind taste tests internally and document results using survey software or electronic ballots. Position these as a means to educate teams on the rigor and value of sensory science or identify target areas for concept development, but not to generate strategic data.
- Conduct a flash profile with commercially available products (see Best practice – Flash profiling).
- Consider using sensory software tools for additional support of sensory evaluation, including advanced data collection, balanced randomized ordering of samples, basic analysis and reporting, and more. However, free programs like Google Forms can be sufficient.
- Discuss findings as a team to build intuition around sensory variation and consumer perception.

Step 4: Train for sensory

- Avoid using company employees or partners as trained panelists. If unavoidable, understand and account for the limitations, and seek individuals who are not involved in product development or business decision-making.
- Avoid jumping into a formal testing methodology like descriptive analysis until panelists are qualified.
- Focus on repeatability and self-consistency rather than conformity.
- Ensure participants can distinguish specific target attributes only if there is a specific predefined concern or focus point (e.g., beany, creamy, juicy). This is distinct from taste sensitivity testing, where panelists are screened for their ability to taste specific compounds (e.g., "super-tasters"). This is not needed nor recommended when screening for panelists.

Step 5: Integrate sensory into product development

- Include sensory checkpoints in your product development timeline.
- Establish processes to use sensory data to guide reformulation, branding, and marketing decisions.
- Encourage collaboration between sensory, R&D, and marketing teams.

Step 6: Invest in continued learning

- Encourage continued education by recommending and supporting online courses (e.g., UC Davis Continuing Education, PSU World Campus).
- Invite external consultants for targeted training (see GFI's industry consultants list – sensory and consumer science consultants).
- Attend key industry conferences (e.g., Pangborn Sensory Science Symposium, Society of Sensory Professionals) or webinars (IFT, Society of Sensory Professionals) to stay up to date on new methods and assessments.

Traditional sensory methods

This section outlines the three primary sensory methods—discrimination, descriptive, and affective—each offering unique insights to drive decision-making. Each test method aligns with key questions they can help answer:

1. Discrimination testing: “Are the products different?”
2. Descriptive testing: “How are the products different?”
3. Affective testing: “Are the products liked?” AND “How much are the products liked?”

Experts revealed that discrimination testing, though valuable for identifying whether perceptible differences exist between products, remains the least used in the alternative protein industry today. In contrast, descriptive analysis is the most used approach. This method, typically conducted with trained internal panels, generates detailed sensory profiles that help teams compare and contrast with benchmarks. Affective testing, which captures consumer preferences and emotional responses, was identified as the largest gap in current industry practices, highlighting a critical area for improvement. Understanding and strategically applying these methods will enable companies to align product development with consumer expectations and accelerate market success. The following sections provide detailed guidance on each method, including the types of questions they are best suited to answer.

Method(s)	Triangle Tetrad	Descriptive Analysis (QDA, Spectrum)	Temporal Methods Sorting, Flash Profile	9-point hedonic scale, Just-About-Right (JAR)
Who	Consumers (30-50)	Trained panel (8-12)	Consumers (30-50)	Target consumers (80-100+)
Best used for	• Assessing parity • Ingredient changes • Shelf-life testing • Quality assurance	• Developing lexicon • Ingredient changes • Shelf-life testing • Quality assurance	• Characterizing dynamic profiles • Quick feedback	• Confirming commercialization • Assessing parity • Identifying top prototypes • Ingredient changes
Notes	Does not tell you what the difference is between products	Requires a target Never ask for liking	Does not require a benchmark & can ask liking	Consider target market and cosumer segementation

Figure 2. Overview of sensory science methods.

Discrimination testing: Are these products perceptually different?

Discrimination testing is a category of sensory method that asks, "Are these products perceptually different?" It is especially valuable when evaluating whether an intentional or unintentional change has altered a product's sensory profile compared to a control.

Examples of when to use discrimination testing:

- Confirm that there is no difference in products prepared at two different locations.
- Assess whether a new formulation with a cost-saving ingredient changes perception.
- Validate consistency across batches or suppliers of a key ingredient.
- Assess how long the product can be stored in the planned packaging before the sensory attributes no longer meet the predetermined quality standards, also known as the shelf life of a product.
- Determine if a new version is different in a specific attribute (e.g., overall bitterness).
- Directly compare an alternative protein product with an animal-based benchmark.

Key nuance:

- A statistically significant result means the products are different.
- A nonsignificant result does not prove products are the same; it means no difference was detected.
- To prove similarity, a different study design and much greater statistical power are required, which is achieved using more participants. Where difference testing typically requires 30 to 50 participants, similarity testing usually requires around 300 to confidently conclude that samples are the same.
- Discrimination tests can be directional or nondirectional. Nondirectional tests simply detect whether products are different, while directional tests indicate whether a product is different for a specific attribute. Directional tests are only practical when a target attribute is known.

Common nondirectional discrimination methods include:

- Triangle test: Participants receive three samples—two identical, one different—and are asked to select the sample that is different. At least 30 participants are typically recommended, 15 of whom would need to select the odd sample to conclude the samples are different. It is important to note that this does not prove the samples are the same, as demonstrating similarity requires greater statistical power and a different study design.
- Tetrad test (standard): Participants receive two pairs of samples. In a standard tetrad, participants are instructed to match the two samples that are the same, with a guessing probability similar to the triangle test.
- ABX: References (A and B) are compared to an unknown (X). Participants are asked to select whether product X is more like reference A or reference B. This method also has to account for the chance of guessing, which is 50%.

Common directional discrimination methods include:

- 3-alternative forced choice (3-AFC): Similar to the triangle test, participants receive three samples but with slightly different instructions. Participants are asked to select the sample that is higher or lower in a specific attribute (e.g., "Select the sample that is more meaty").
- Tetrad test (directional): Participants receive two pairs of samples. In a directional tetrad test, participants are asked to select the samples that are higher or lower in a specific attribute (e.g., meaty flavor), which reduces the chances of guessing and increases sensitivity. Because the task is simpler and imposes less cognitive load than a triangle test, the tetrad often requires fewer participants.
- Paired comparison test: Participants compare two products and are asked which is stronger on a specific attribute. The chance of guessing for this method is 50%.

Discrimination testing best practices and tips

- Sample size matters. Too few participants risk missing small differences and drawing inaccurate conclusions due to the inability to capture variability. If the number of participants is limited, have each participant complete the discrimination task 2-3 times (i.e., replicates).
- Conduct a precheck to confirm that there are no obvious sensory or visual differences. If differences are obvious, discrimination testing is not recommended. Instead, consider what type of information is most relevant for the current stage of product development.
- Control presentation order to reduce the impact of how the prior sample and the first sample influence the perception of the following samples. Randomize order in a balanced way so each sample appears in the first, second, and third positions an equal number of times.
- Interpret with caution. Discrimination tests do not identify where differences lie or how different two samples are, nor do they measure liking or acceptance.
- Note that employees may be more sensitive and invested than typical consumers. If employees fail to detect differences, it can suggest that consumers likely won't either. But if employees do detect differences, consumer testing is recommended before drawing conclusions, including whether the differences impact liking or acceptance.

Tips on statistics

In discrimination testing, participants are effectively guessing if they cannot detect a difference. Each method has a known probability of a "correct" answer by chance (e.g., 1 in 3 for a triangle test). Results are analyzed using binomial statistics to determine whether the number of correct responses is greater than chance, indicating a difference. A significant result shows that a difference was detected, not the size or liking of the difference.

Interview insights

Discrimination testing was reportedly used by about 62 percent of survey respondents, though it was still the least common sensory method in the alternative protein industry. Many interviewees noted that trained descriptive panels are used to detect differences—a question traditionally suited to discrimination testing. Interestingly, when asked which method is best for confirming sensory parity with animal products, the majority pointed to a triangle test, a form of discrimination testing. However, most did not recommend conducting a discrimination test for alternative protein products, since these products are nearly always perceptibly different, making them a poor investment of time and resources.

Similarity testing uses the same methods as discrimination testing, but asks a fundamentally different question. Demonstrating similarity is more demanding because it requires proving the absence of a difference, which in turn requires larger sample sizes and more rigorous statistical thresholds. In difference testing, products are assumed to be the same unless participants correctly identify the odd sample. In similarity testing, products are assumed to be different unless testing determines they are similar. This requires a sufficient number of participants to demonstrate with confidence that any observed differences are not meaningful and could be due to chance or insufficient sample size.

The most common methods for similarity testing are the paired comparison and the tetrad. Paired comparison is easier for participants (lower cognitive load) but less sensitive, while the tetrad is more powerful but mentally demanding. In both cases, sample size is the critical factor. For example, a study with 50–100 participants might only detect medium or large differences, but could miss smaller ones. To be confident that two products are truly similar, the best practice is to test with around 300 participants. Using too few participants risks drawing the wrong conclusion, i.e., declaring products to be the same when the study was simply underpowered to detect subtle differences.

Analogy: Why proving similarity is harder

Imagine flipping a coin:

- If you flip it five times and get heads every time, you might suspect it's not fair.
- But to prove it is fair, you'd need hundreds of flips showing that the results are balanced.

It's the same with sensory testing:

- To detect a difference, a few correct identifications might be enough.
- Proving similarity requires far more data showing that panelists can't tell the difference, and that this result is statistically reliable.

Descriptive sensory analysis: How are the products different?

Descriptive analysis is a category of sensory methods that asks the question, "How are these products different, and in what ways?" This type of test goes beyond determining if a difference exists and provides detailed quantitative information about the specific sensory attributes. This makes it valuable for building and comparing sensory profiles and collecting and measuring attribute intensities. In the alternative protein industry, where products often aim to replicate animal-based benchmarks, descriptive analysis is especially important for guiding R&D. Interviewees indicated that this method was the most used in the industry.

Examples of when to use descriptive analysis:

- Characterize the full sensory profile of a new prototype compared to an original formulation, a leading commercial competitor, or a conventional benchmark.
- Identify and quantify specific off-notes, such as beany, grassy, or metallic sensations, or quantify improvements in these attributes.
- Compare the mouthfeel attributes across formulations using different texturizing agents to determine which more closely replicates animal meat.
- Track sensory attributes across different product manufacturers or across shelf-life conditions.
- Profile commercial products in the target market, often to identify benchmarks or establish reference points for key attributes and their intensities.

Key nuance:

- Descriptive analysis identifies where and how products differ but does not measure liking. Consumer testing is still required for market insights. Combining descriptive data with consumer testing helps connect technical sensory profiles to real-world consumer perceptions.[43]
- Descriptive panels are smaller than consumer or discrimination panels: typically, 8–12 well-trained panelists are sufficient.
- Panelist training is intensive, often requiring at least 100 hours of practice, including developing lexicons, rating standards, and calibration sessions. Panelists should not provide preference or liking judgments, as their role is to generate objective sensory data.

Common descriptive methods include:

- Quantitative Descriptive Analysis (QDA®): Trained panelists identify and select attributes to describe the product and systematically rate them on defined intensity scales. A panel leader sources standards and references for sampling.
- Spectrum™: Panelists use predefined attributes, reference standards, and anchored scales. A panel leader provides specific attributes, references, and predefined scales.
- Free Choice Profiling: Panelists use their own descriptors and scales, making it less resource-intensive but harder to compare across studies.

In both QDA and Spectrum, trained panelists work with a shared lexicon of relevant terms (e.g., "soy beany," "umami," "fibrous," "juicy," "astringent") and undergo regular calibration sessions with known standards and references to ensure consistency across individuals and sessions. This includes ensuring the specific attributes and references are rated consistently within a range. For example, a 0.5 M sucrose solution should be rated within the 3-5 range on a 7-point intensity scale for sweetness. This type of calibration should be performed using relevant standards and references, and any individual who conducts it inadequately should be retrained or removed from the panel.

Establishing an appropriate lexicon is particularly important for the alternative protein industry, as novel ingredients and processing methods can introduce unfamiliar attributes not captured by traditional meat or dairy descriptors. Special attention should be given to off-notes, texture breakdown, aftertaste, and masking effects from added flavors or processing aids. An example sensory lexicon for beef is shown in Figure 3.

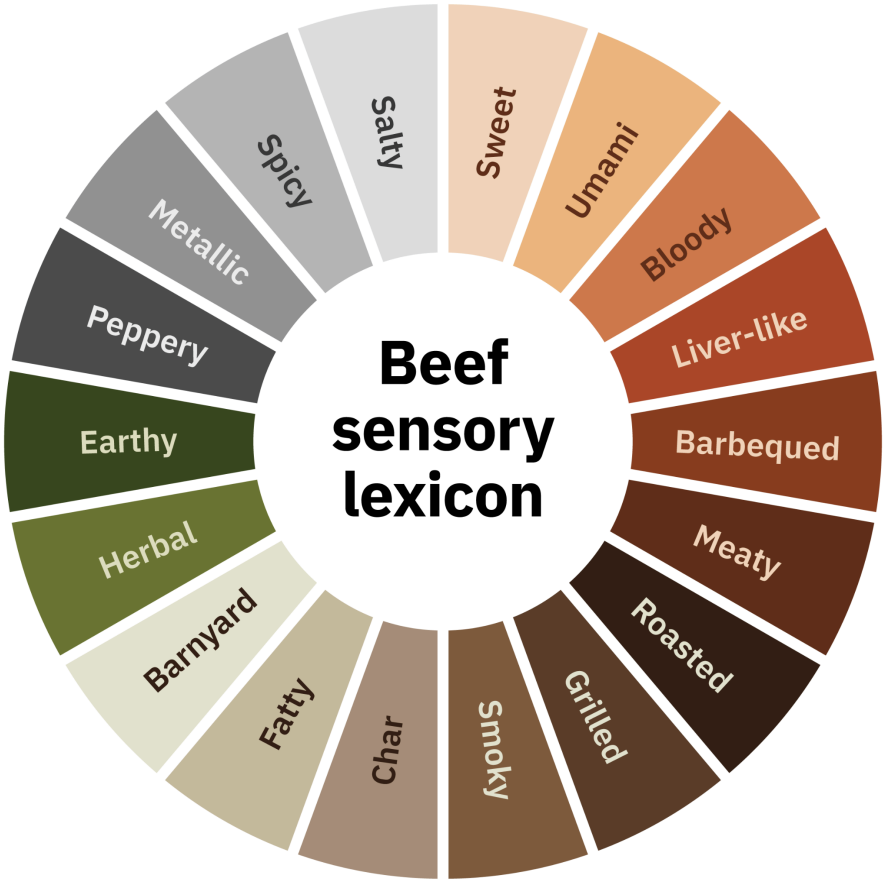


Figure 3. Example sensory lexicon for beef.

Descriptive testing best practices and tips

- Control conditions carefully: standardized preparation, randomized serving order, and consistent environments are essential.
- Descriptive data are most valuable when products are compared to a benchmark. Without one, they are mainly useful when changes are being assessed over time, such as in shelf-life studies.
- Employee panels carry the risk of bias. Internal staff often possess deep experience and familiarity with products and are invested in their success. While employee panels are common, objectivity is better maintained with external participants.
- If internal employees are used for descriptive analysis, rigorous training and ongoing calibration are essential to reduce bias. Panelists' ability to objectively and consistently evaluate products should be reviewed regularly, and once trained, they should never be asked about liking or acceptance.
- If a trained panel is not feasible due to budget or time constraints, refer to the section on Rapid Methods.

Tips on statistics

Descriptive analysis data are typically analyzed with t-tests to compare exactly two products, or analysis of variance (ANOVA) test to compare three or more products. These tests determine if products differ on each sensory attribute, with results commonly considered statistically significant with a p-value (p) < 0.05. If differences are detected, post hoc comparisons such as Tukey's HSD identify where the differences are. For a big-picture view or exploratory analysis, consider principal component analysis (PCA) to examine how products compare across all measured attributes.

Affective testing: Do consumers like this product, and how much?

Consumer hedonic sensory testing asks the fundamental question, "Do consumers like this product and how much?" Hedonic testing directly engages with untrained target consumer groups to measure overall liking and product preferences. These tests must be conducted without the involvement of trained consumers or expert panelists, including company employees, for proper interpretation.

Examples of when to use affective testing:

- Determine if a new alternative is liked as much as a leading animal-based competitor.
- Identify which prototype should advance in development.
- Pinpoint attributes that drive consumer liking or disliking (e.g., penalty lift analysis).
- Assess readiness for launch by testing the likelihood of market success.
- Evaluate the acceptability of specific attributes (e.g., not savory enough vs. too savory).

Key nuance:

- Affective testing requires larger sample sizes than descriptive or discrimination studies to account for consumer variability. Typical studies include 75–100 participants per product, while more robust studies can include 150–200 participants or more to account for demographic and psychographic diversity (e.g., age, education, familiarity, health values). With too few participants, important differences may be missed.
- Liking data provide minimal feedback on specific attributes, making it challenging to identify areas for improvement. For example, a "dislike" rating for meaty taste signals an issue but does not provide direction on how to adjust it to enhance liking.
- Affective testing typically pairs a measurement scale with an evaluation context or location. While the scales and contexts below are most common, experts highlighted the value of complementary approaches, often run by third-party consultants to match study design with business objectives.

Common affective measurement scales and methods include:

- 9-point hedonic scale: participants rate liking from 1 (dislike extremely) to 9 (like extremely), with 5 as a neutral midpoint (neither like nor dislike). This scale can be used to capture overall liking or liking of specific attributes (e.g., appearance, color, flavor, mouthfeel). The resulting data are ordinal categorical, that is, whole-number ratings without values between. These types of quantitative data can indicate rank, reported in integers, with values between integers or categories being undefined. For example, in a race, there are 1st, 2nd, and 3rd places, with 2.5 not a possible outcome.
- Just-about-right (JAR) scale: Combines liking with diagnostic insights by asking whether specific attributes are "too little," "just about right," or "too much." JAR data show both the direction and impact of attributes on overall liking, helping identify how to adjust formulations.
- Ranking tests: Participants order a set of products from most to least preferred or according to another attribute of interest. The data provide relative preferences but not the magnitude of difference between products. However, it is important to avoid overinterpreting ranking data and inferring acceptance or liking.

Common evaluation contexts and locations:

- Central location tests (CLTs): Consumers are brought to a controlled setting such as a sensory lab or testing facility, allowing for standardized preparation, presentation, and assessment.
- Home-use tests (HUTs): Consumers evaluate products in their own kitchens, providing insights into real-life use and application. For example, plant-based cheese might be tested for melting performance in sandwiches or pizza. HUTs are time-consuming and resource-intensive, but provide unique insights into purchase intent and consumer perceptions based on qualitative and quantitative data.
- Chef evaluations: Products are tested with chefs, often with restaurant partners or recruited experts, to assess suitability in foodservice contexts. These studies target restaurant and culinary professionals rather than retail consumers, highlighting the importance of aligning test design with the intended market channel.

Figure 4. 9-point hedonic scale.

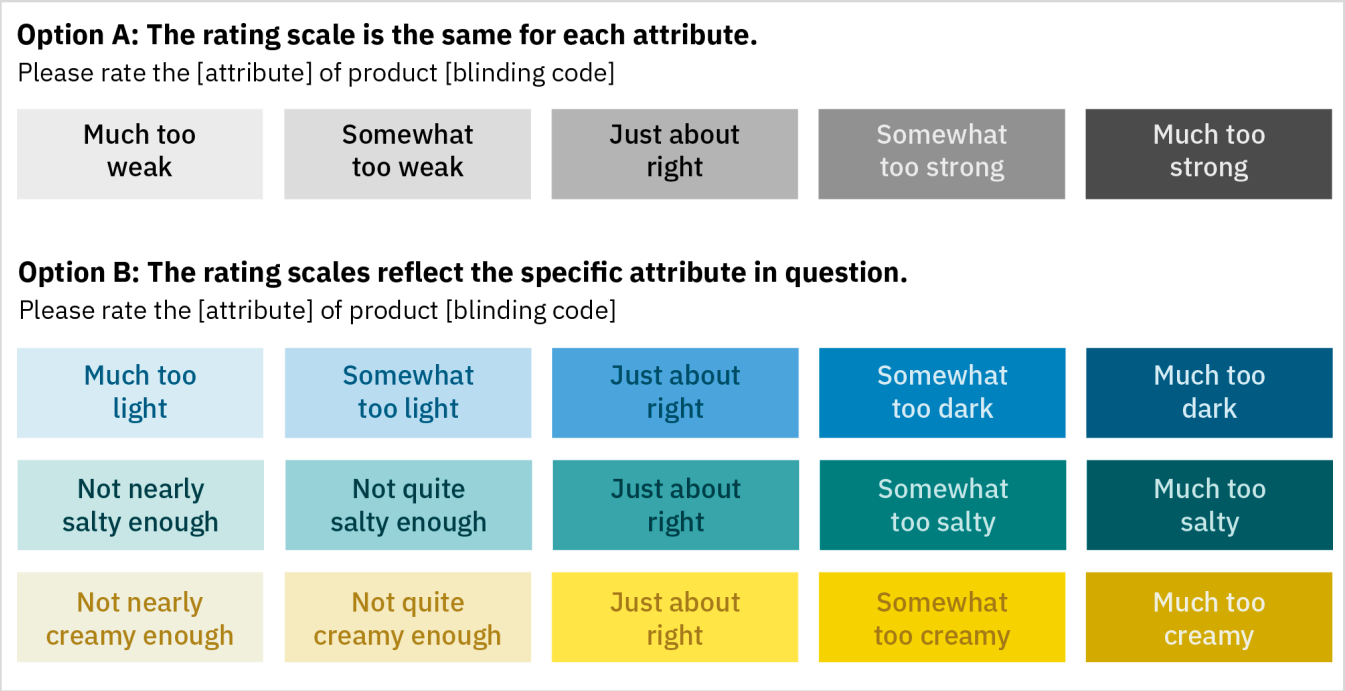


Figure 5. These are examples of the JAR scale, which can be put into more general phrases (option A) where the same options are provided for specific attributes. Option B provides more specific phrasing tailored to each attribute. This approach can provide more specific guides for participants; however, ensure that the ends are true opposites, avoiding the mixing of terminology. Color coding shown here is for visual contrast within this guide and is not recommended in practice when using JAR scales for sensory evaluation.

Affective testing best practices and tips

- Do not use trained panelists or company employees, as bias and expertise distort results.
- Follow up initial consumer studies with real-world testing (e.g., HUT or restaurant settings) for stronger market insights, including performance and purchase intent.
- Distinct from affective testing, revealing the product brand to participants shifts the focus from sensory-specific attributes to marketing questions such as, “Will consumers buy it?”

Interview insights

- Interviewees reported that the 9-point hedonic scale was more commonly used than the JAR method.
- Segmentation studies (e.g., by age, familiarity, or other factors) often require 300+ participants to capture meaningful differences across groups.

Tips on statistics

The goal of affective testing is to identify differences in liking. The measurement scale determines the type of data, which drives the choice of statistical test. Here are some examples of the method and statistical test:

- 9-point hedonic scale: Data are ordinal, so nonparametric tests such as a Kruskal-Wallis or Friedman are most appropriate. In practice, however, these data are regularly treated as continuous and analyzed using t-tests or ANOVA (for comparing two or more than two products, respectively).
- JAR scale: Analyze the frequency or proportion of consumers selecting each option and link that to overall liking to see how “too little” or “too much” of an attribute impacts acceptance. This determines how each attribute drives the overall liking, otherwise known as penalty lift analysis. Penalty lift analyses show whether each attribute reduces, enhances, or has no impact on liking.
    - Note: Drivers of liking for conventional animal products are distinct from alternative protein products. Therefore, alternative protein and animal-derived products should not be merged into a single statistical analysis model.

Modern sensory methods

While conventional and standard practices within sensory science form the foundation of the field, alternative methods can provide similar information in less time and with fewer resources. This section reviews modern methods mentioned by experts or frequently used in the peer-reviewed literature, focusing on rapid methods and temporal methods. These methods are particularly valuable when there are tight turnarounds or limited budgets. They can replace conventional descriptive analysis methods by quickly identifying product differences. In early development, these methods enable quick screening of prototypes and formulations, helping identify top performers without extensive panel training.

Best practice

Rapid methods, which may involve employees or consumers, are typically used in place of descriptive studies to understand how products are similar or different. While faster and less resource-intensive than traditional approaches, experts cautioned that these methods should be applied by those with a solid grounding in sensory science.

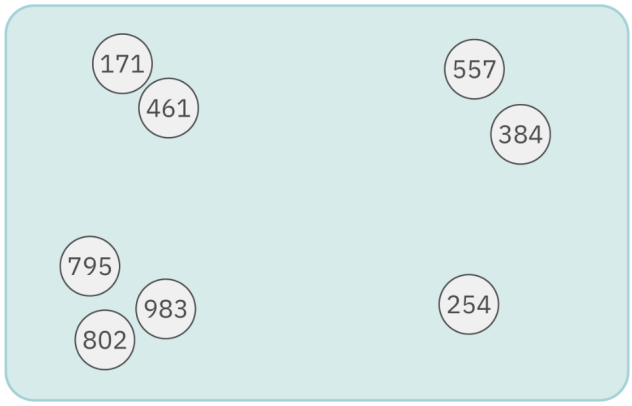
Rapid methods

- Flash and free-choice profiling are alternative approaches to descriptive analysis that characterize sensory attributes and capture perceptual differences, without the need for a trained panel. Though these methods are quicker and more cost-effective, specific data analysis is needed to interpret pooled results across individuals. Free-choice profiling uses 10 to 20 untrained individuals who generate their own attributes. Flash profiling uses 10 to 15 panelists who use a shared lexicon developed by the panel. For both methods, participants describe the product(s) independently and then assign an intensity rank for each attribute term.
- Napping®, sometimes referred to as projective mapping, asks participants to arrange samples in a physical or virtual space based on perceived similarity or difference, without needing to use specific terms. However, after being grouped, participants can be invited to provide attributes or labels to the formed groups. This method is useful for quickly visualizing how multiple prototypes cluster.[44]
- Check-All-That-Apply (CATA) is suitable for consumers (50 to 100+, with more consumers required for additional attributes). Participants select as many items as they perceive to be relevant from a predefined list of terms. The frequency of selection is associated with the intensity of the attribute.[45]
- Rate-All-That-Apply (RATA): Participants select relevant terms from a predefined list and then rate the perceived intensity of each selected attribute, providing richer data than CATA by capturing both frequency and strength of perception.

Example of a Napping sorting task

Objective: To understand how consumers perceive similarities and differences among various commercial and/or prototype samples

- Each participant is given the full set of samples, labeled with random 3-digit codes.
- Participants taste all samples and are instructed to sort them into groups based on overall similarity in sensory profile (no specific criteria are imposed).
- In this example, participants can make no fewer than 2 groups and no more than 7 groups.
- After sorting, participants may be asked to describe what characteristics influenced their grouping (e.g., "softer texture," "strong smoky flavor").



Tip:

- It is recommended to include duplicates to ensure these samples are grouped together.

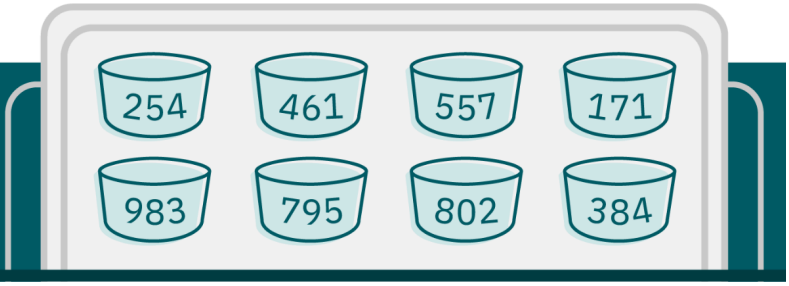


Figure 6: Example of a Napping sorting task. Participants are asked to sort eight samples based on their similarities and differences. They are required to make no fewer than two groups and no more than seven groups. This test is suited to gathering information on attributes that may be too complex for participants (e.g., mouthfeel). Participants can sort based on overall experience, without having prior knowledge or terms to describe specific characteristics. For untrained consumers, it is recommended to have 30-40 participants. At least one duplicate can help in assessing participants' ability to complete the task, where duplicate samples are placed near each other. For an example, see Ong and Delarue, 2025.[44]

Tips on statistics

The data collected from these methods require specific statistical analysis approaches, distinct from conventional descriptive methods. This includes multidimensional scaling, correspondence analysis, principal component analysis, and hierarchical clustering. These methods help to visualize the relationships between products based on similarity. For more detailed guidance, see "Sensory Evaluation of Food: Principles and Practices" (Lawless and Heymann 2010) or similar advanced texts. Unless trained in advanced statistics, it is advisable to work with a statistician or consultant to ensure results are analyzed and interpreted correctly.

Temporal methods

Temporal methods are valuable for the alternative protein industry, as these products have an eating experience or sensory profile that is dynamic, or that changes during cooking or consumption. For example, some plant-based meats release key volatiles already present in the formulation as a rapid "smell burst" once heated, whereas aroma forms progressively in animal products from precursors during cooking. Temporal methods can be used to understand these sensory profiles that evolve over time. They can be used throughout the development lifecycle to benchmark products and to assess how prototypes perform against defined benchmarks. For example, these methods are helpful when:

- testing how an alternative sausage produces mouthfeel and flavors at first bite, but may develop unwanted sensations after swallowing.
- evaluating how well an alternative cheese breaks down in the mouth during chewing.
- understanding how the gel structure of an alternative yogurt changes from the first bite to swallowing.
- assessing changes in flavor intensity or juiciness throughout chewing for alternative chicken meat compared to conventional chicken.

Methods for capturing the temporal profile include Temporal Dominance of Sensation (TDS) and Temporal Check-All-That-Apply (TCATA). These methods measure time-related attributes, offering advantages for investigating flavor release during chewing, lingering aftertaste after swallowing, and mouthfeel attributes. They are especially relevant when investigating changes from the initial to the final bite of a product.

For both TDS and TCATA, attributes are selected in advance. Providing a comprehensive and clearly defined list of attributes is critical, as missing items can lead to the dumping effect, where participants substitute a different, less accurate term. For specific attributes, it can be helpful to provide a description or definition with examples before tasting:

- TDS: participants select a single attribute from a pre-selected list that is dominant at each moment during consumption. This produces a time-intensity curve that shows how perceptions, such as "juicy," "grainy," "fibrous," "beany," or "bitter," change during chewing.
- TCATA: participants check all sensory attributes that apply throughout consumption and update their selections continuously as sensations shift. TCATA provides richer information than TDS when multiple sensations may overlap, rather than strictly the dominant sensation, though TDS is the easier cognitive task.

Both TDS and TCATA provide temporal curves that show how sensations change over time. The proportion of citations is generally related to the perceived intensity: the more participants select an attribute, the stronger it is perceived. Recent studies on alternative proteins have used TDS and TCATA to capture the evolving sensory profiles of plant-based yogurt and chicken.[12,46,47]

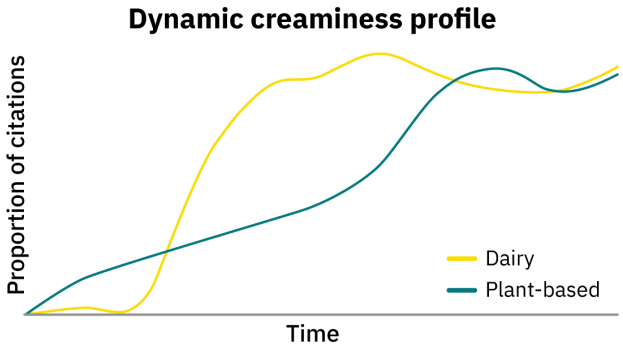


Figure 7. Example of dynamic sensory evaluation results of plant-based versus dairy yogurt. Figure adapted from Greis et al. 2020, licensed under CC BY 4.0.

Hedonic assessments, such as overall liking, can be integrated with temporal methods. These combined methods uncover how specific attributes at specific time points during consumption positively or negatively impact overall liking. For example, penalty lift analysis helps uncover how perceived attributes are either positively or negatively associated with liking ratings. Alternative proteins often face consumer resistance due to unfamiliar or undesirable sensory traits (e.g., beany flavor, rubbery texture). Penalty lift analysis helps identify which attributes most negatively affect acceptance. Instead of general feedback, penalty lift analysis gives quantified insights into how much improving a specific attribute could increase overall liking. It can reveal differences in perception across consumer groups (e.g., flexitarians vs. meat-eaters), helping tailor products to specific markets. Lastly, penalty lift can compare alternative proteins to traditional animal products, showing where sensory gaps exist and how they affect consumer preference.

Studies have demonstrated distinct findings in the temporal profile of conventional animal products and alternative products.[12,48] Attributes that drive liking or disliking of a conventional meat product are distinct from those that drive liking or disliking of alternative protein products. For example, desirable attributes like creamy are shown to differentially influence hedonic ratings between alternative proteins and conventional animal products. For these studies, 50 to 100 unbiased consumers from the target consumer group are typically recommended.

Tips on statistics

Temporal methods provide frequency data, specifically the proportion of citations across time. Analyses may include penalty lift analysis (when paired with hedonic data), area under the curve, or time until maximum citations. For more reading on these methods, consider reviewing Rovai et al. 2025 or Castura et al. 2022.[49,50]

Relationships between instrumental and sensory data

Integrating sensory and instrumental data involves combining human perception (e.g., taste, texture, aroma) with objective measurements (e.g., texture analysis, volatile compound profiling) to gain a more complete understanding of product characteristics. This allows researchers to identify relationships between sensory attributes and measurable physical or chemical properties, supporting predictive modeling, product optimization, and quality control.

Instrumental analysis is generally considered more accessible and faster, while typically requiring smaller sample sizes than sensory testing. Instrumental analysis, such as texture profile analysis, rheological properties, water activity, moisture content, pH, or other measures, may inform early development stages where targets are defined, and later in production for confirming quality throughout production and storage.

However, instrumental assessments alone cannot directly predict consumer acceptance. For example, a plant-based yogurt may match the rheological properties of dairy yogurt, yet fail to produce the same mouthfeel characteristics or correspond with consumer liking.[12,51] Overreliance on instrumental measures without confirmation from sensory or consumer studies is a common pitfall. Establishing a framework that integrates instrumental benchmarks with sensory and consumer data ensures that physical parameters translate into the desired sensory profile and positive consumer response.

To explore these relationships, multivariate statistical methods like principal component analysis (PCA), multiple regression, or correlation matrices are commonly used to validate that instrumental data reflect consumer-relevant sensory outcomes.

Interview insights

There is an overwhelming consensus within the field that instrumental data cannot replace, nor is there a good demonstration of it predicting, sensory experiences or liking (see Role of AI/ML in predicting sensory outcomes).

Aligning sensory methods with development objectives

A clear understanding of the business question should guide sensory evaluation objectives. Developing objectives should be a collaborative effort across R&D, product, ingredient, and business development teams to ensure data support decision-making throughout the product development lifecycle. This collaboration helps teams prioritize the most relevant sensory insights, ensuring that sensory feedback directly informs formulation, optimization, and positioning. This in turn improves efficiency and increases the likelihood that products will meet consumer expectations and succeed in the marketplace.

Product development cycle and integration of sensory evaluation

The product development cycle for alternative proteins typically follows stages of ideation, formulation, prototyping, optimization, and commercialization. Each stage presents unique challenges, including ingredient functionality, cost, and replicating the sensory cues of animal-based counterparts, while also ensuring nutritional quality and consumer appeal.

Sensory evaluation is most effective when integrated throughout the entire cycle, rather than reserved for the final stages. In early development, experts recommend rapid methods and descriptive testing to guide decisions around product type and goals for attributes. These sensory tests can provide valuable insights into target attributes such as texture, flavor, or off-notes. As products progress, consumer hedonic testing provides critical insight into liking, purchase intent, and target demographics. During optimization and scale-up, sensory testing ensures product alignment with consumer expectations.

Embedding sensory science from concept to launch reduces innovation risk, adds rigor to decision making, and ensures products deliver on taste, texture, and overall eating experience, which are the key drivers of acceptance in the alternative protein marketplace.

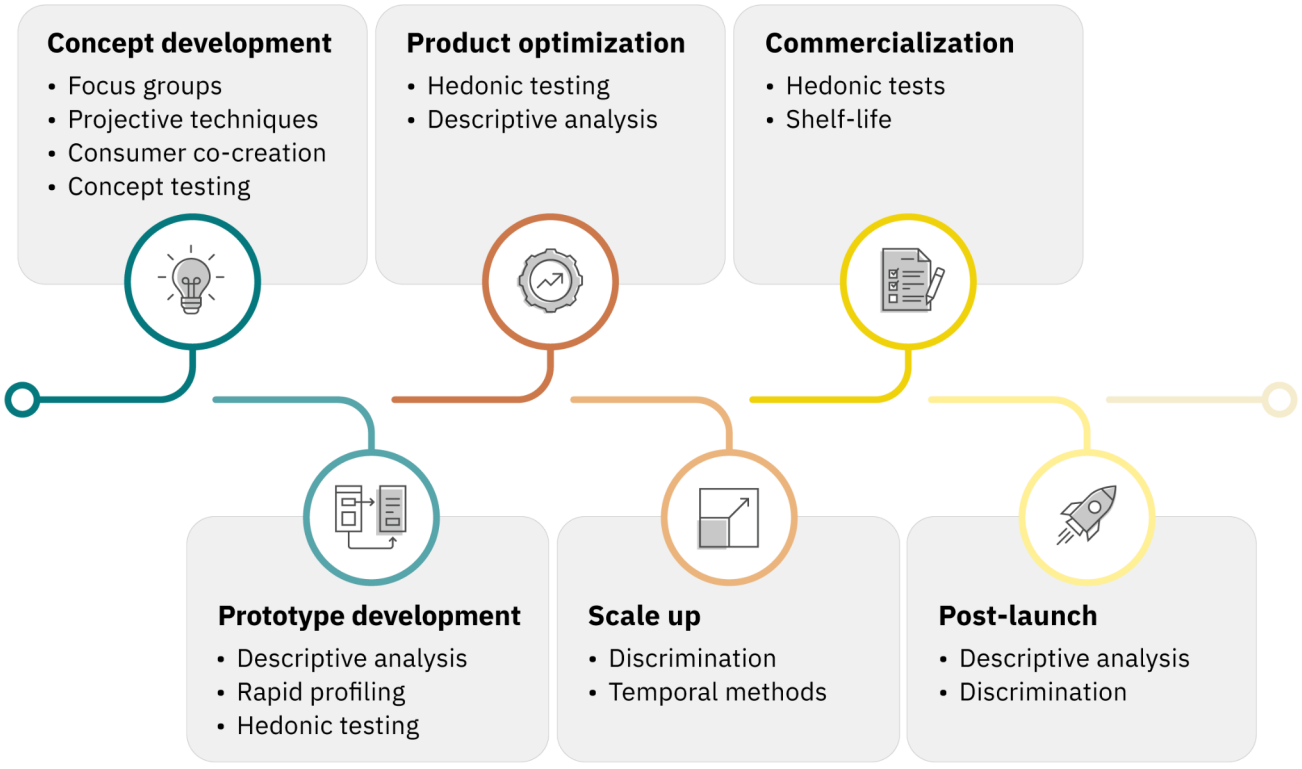


Figure 8: Planning for sensory testing. Examples of sensory methods across the product development timeline.

Concept development: What are the target attributes of this product?

Concept development begins with understanding consumer needs and positioning to generate and refine product ideas. This includes defining the following:

- Target consumer segments: identification of priority demographics or psychographics, such as specific diet types, or health-motivated consumers. Leveraging an attitudinal consumer segmentation (e.g., GFI's plant-based meat consumer segmentation) can provide particularly rich insights on targeting.
- Consumer needs and motivations: insights into what target consumers are looking for in alternative proteins (e.g., taste, health, price, convenience, sustainability).
- Positioning and value proposition: how the product will be differentiated in the marketplace, whether by mimicking animal-based products, highlighting plant-forward flavors, and/or emphasizing functional benefits.
- Feasibility considerations: initial evaluation of whether the concept can be delivered with available ingredients, processing technologies, and costs.

Once a concept is established, it is important to fully understand the competitive landscape. Sampling and assessing existing products help identify opportunities and specific target sensory attributes. For some products, the goal may be to achieve attributes and a sensory profile that match those of existing animal products. However, interviewees caution that this is difficult to achieve with current technology and may set unrealistic expectations. Instead, they recommend identifying specific attributes and corresponding intensities to target. While this can be done using a trained internal descriptive panel, it is more common to consider a flash profile in early development phases.

Best practice

Flash profiling is a common rapid method that can be conducted with employees to help identify specific attributes that should be represented in the product and those that should be minimized. It does not require a trained panel, thus reducing time and resources. Flash profiling is especially useful when a concept has been defined and there is a need to understand the sensory landscape of existing products in the category. It can also be advantageous to develop a shared lexicon and map out the sensory profiles of relevant products. Flash profiling provides a practical first step, offering a rapid, efficient way to identify key sensory attributes and guide early development priorities.

To conduct a flash profile:

- Provide all products blinded and in a randomized order to reduce bias.
- Ask participants to list all the attributes they experience from the samples, with an emphasis on the attributes that differentiate the products. It is important that participants are not given specific attributes and are allowed to identify and use terms that are familiar.
- Optionally, have participants include a rank ordering of key attributes they identified.
- Use aggregate data to create a consensus map based on terms that are shared or distinct across products.

Challenges of flash profiling:

- In a fast-paced industry like alternative proteins, the availability and formulation of commercial products change rapidly. Benchmarks should be evaluated regularly.
- Some categories may be highly saturated. It is not uncommon to sample more than 100 products (including both alternative and conventional) to establish a clear understanding of the product space.
- This process can be slow, taking multiple days and weeks to establish terminology and assess products.

Development phase: How close is the product to the target and benchmarks?

During the development and optimization phase, sensory evaluation focuses on determining how well a prototype aligns with its intended benchmark. This benchmark may be a conventional animal product, a leading competitor, or an internally defined target. Benchmarking provides critical context for market readiness, highlighting both product strengths and areas for improvement. Comparing prototypes against top-performing competitors helps identify key sensory drivers of success and set realistic development goals. Incorporating systematic sensory testing, such as through trained internal panels, generates consistent, high-quality data to guide formulation decisions and ensure that products progress toward their sensory targets.

Interviewees widely cited descriptive analysis as the standard method during development. Descriptive analysis is especially critical in the development phase for alternative proteins, where products often face challenges such as off-flavors (e.g., beany, earthy, bitter, metallic), unfamiliar textures, or color mismatches compared to animal-based products. A well-trained and calibrated panel should be maintained, with lexicons that capture both conventional sensory attributes (e.g., juiciness, chewiness, umami) and unique descriptors relevant to plant-based, fermentation-derived, or cultivated ingredients. These lexicons are generated during the earlier phases through flash profiling or initial descriptive panel work. For more information on this method, see: Descriptive sensory analysis: How are the products different?

Analyses should focus on identifying key sensory gaps relative to the benchmark or internal target, while also monitoring improvements across iterative prototypes. These practices ensure that descriptive analysis delivers actionable insights to guide formulation decisions and enhance consumer acceptance of alternative proteins.

There are benefits and trade-offs between maintaining internally trained panels and outsourcing to a third party:

- Internal descriptive analysis panels offer continuity and consistent measurement of sensory attributes over time, but require significant investment in training and protocol adherence. Maintaining panels of sufficient size (8–12 members) can be difficult, especially when employees may be unwilling to sample conventional animal products, yet doing so is critical for assessing benchmarks and success metrics.
- Third-party testing provides objectivity but is better suited to stable, consistent samples with minimal batch-to-batch variability, and may involve added costs and logistical coordination.

Best practice

Include enough participants to provide sufficient power and panel reliability. Too few participants can reduce statistical power and increase the risk of a false negative, also known as a Type II error, in which differences between products are not detected when they actually exist. This leads to inconclusive or misleading results, which can lead to poor guidance on product formulation and processing. Undersized trained panels (<8) compromise the sensitivity of sensory data, limiting their value for guiding product development decisions.

Ingredient development

Ingredient selection and development occur in the development phase, where multiple prototypes are created to consider different inputs. For some companies that specialize in ingredients, there may be distinct questions regarding ingredient function and sensory profile. Decisions about protein source, processing method, and selection of functional ingredients directly influence flavor, texture, and appearance. Many common sensory challenges, such as off-notes, gritty mouthfeel, or color instability, originate at the ingredient level, making it critical to identify and address them early. However, each ingredient has a different function and sensory profile depending on its application. Ingredients are typically first screened by a trained panel to identify attributes and compare against accepted ingredients in the category. The next phase assesses how they perform within different matrices.

However, it is unrealistic to run every prototype through descriptive analysis. Instead, rigorous, standardized benchtop testing practices can be used to screen and prioritize top ingredients or prototypes before advancing them to more resource-intensive sensory methods.

A typical approach includes:

- tasting the ingredient on its own in its most basic form, if it is safe and recommended to do so, to detect inherent sensory characteristics.
- testing the ingredient in a basic application or a simplified matrix to evaluate performance under minimal interference.
- comparing candidate ingredients using descriptive analysis.
- testing approved ingredients in final or near-final formulations, followed by consumer affective tests to confirm the ingredient supports overall product acceptance.

Commercialization phase: Is this product well-liked?

Affective testing, which measures consumer liking and preference, is the best practice when determining if a product is ready for launch. In cases where the goal is to match or outperform an animal product, affective testing can determine whether the alternative product achieves a similar level of liking. It is strongly recommended not to rely on employee or stakeholder opinions at this stage. Experts emphasized that employees do not reliably represent the target consumer and may introduce bias. Accurate data from representative real consumers is essential to making informed business decisions.

To achieve this, it is recommended to recruit at least 50 target consumers, though some interviewees suggested even higher numbers (100 to 120 participants), particularly for complex product categories, underscoring the importance of participant recruitment. With fewer than 50 consumers, high response variability reduces the ability to identify differences between products. If segment-specific insights are important (e.g., by demographic, values), ensure at least 50 participants per target segment to support reliable subgroup comparisons. The more consumers included, the more confident teams can be in the reliability and generalizability of the results.

Best practice: De-risking the move from development to commercialization

- Avoid using employees or stakeholders for affective testing. These individuals often do not represent the target market or average consumers.
- Recruit at least 50 participants who meet the target market. Having too few participants risks missing key differences, leading to uninformed decision-making.
- Identify the target consumer segment in advance during concept development so that sensory testing is designed around relevant consumer groups. Understand both what is liked and disliked about a product, not just overall liking. This is crucial for informing product development.
- Control for context and expectations. Clearly define what information is shared with participants during both recruitment and testing, as expectations can significantly influence ratings.
- Benchmark performance against a known standard or successful product in the marketplace as a practical strategy.
- Avoid asking too many questions. Long surveys can lead to participant fatigue and detract from the main objective of the study.
- Ensure product consistency. If testing spans multiple batches, confirm minimal to no variation and track potential differences.

Casual convenience testing, which is testing products in informal settings (e.g., grocery stores, events, or other public spaces), can provide quick feedback, but the setting is less controlled. Feedback is often collected through direct, unstructured conversations or basic survey platforms. While useful for early impressions, this type of feedback has its limitations for driving improvements or assessing liking. If using this approach, set it up carefully to reduce bias.

- AVOID: Employees wearing branded clothing, surrounded by marketing materials, with branded products: “Hey, I founded this company and this is our product, want to try it? Do you like it?”
- INSTEAD: Employees in plain clothes, “Hi, today we are looking to get feedback on alternative products. Would you like to try a sample of alternative protein chicken? Please scan this QR code first and then respond to the questions!”

This scenario minimizes bias, increases the rigor of data collection, and creates structured outputs that can be analyzed systematically.

Best practices for sensory testing setup, protocol, and presentation

The setup and design of sensory evaluation will be dictated by the selected method, with distinct considerations for each. However, several important factors must be considered when designing a rigorous sensory study.

Setting up the sensory space: Central location testing

The advantage of a central location test is the ability to control the environment—lighting, presentation, sound, and distractions—providing a consistent experience for all participants.

Basic considerations for a sensory space include:

- individual booths or partitioned areas to ensure participants evaluate samples independently, without influence from others.
- neutral and consistent lighting—daylight-balanced lighting is often recommended—to avoid unintentional color bias.
- controlled airflow and temperature to prevent external odors from interfering with evaluations.
- quiet space to minimize distractions.

Basic considerations should first focus on consistency, ensuring that lighting, odors, and the overall environment remain similar between test sessions. Changes in the environment across test sessions risk introducing systematic bias. Furthermore, consider that the time of day can influence perception, as can whether a participant is hungry or full. For example, in some locations, it may be customary to serve food that aligns with the time of day when the product is regularly consumed, or to perform all sensory testing in the morning. It is also best practice to assign a dedicated sample-preparation team that is responsible for checking temperatures, portion accuracy, and presentation consistency for every serving. Providing a calm, controlled, and consistent environment will help reduce systematic bias in the collection of sensory data.

Whenever possible, preparation areas should be physically separated from the sensory testing space to prevent panelists from seeing raw ingredients, branded packaging, or preparation steps that could bias expectations and ratings. Sensory evaluation is distinct from marketing research, which examines pricing, purchase intentions, and product claims or packaging. While marketing questions are sometimes included in sensory studies, such elements—particularly packaging and branding—can introduce biases (e.g., brand loyalty) that reduce rigor and add noise to the data.

There are questions in the sensory community on whether these controlled environments translate to real-world scenarios and different contexts. For example, does the same group of individuals exhibit similar overall liking at home or in a restaurant as they did in the controlled testing environment? For more information on these alternative methods and considerations, see the Technology in Sensory Testing section.

Recruitment and selection of participants

Selecting the right participants is one of the most critical factors in designing a valid and reliable sensory study. The ideal participant profile varies depending on the test's objective, whether the goal is to measure preference, detect differences, or generate detailed sensory descriptions. Participants should have normal sensory acuity (taste, smell, vision) and should be screened for food allergies or dietary restrictions that may prevent them from tasting certain foods or ingredients. Participants should be willing to follow instructions carefully and refrain from eating strong-flavored foods or using fragranced products before the session. Typically, there's no food or beverages for one hour before testing. Clear, consistent recruitment standards help ensure that data reflect the product's true sensory performance rather than noise introduced by unqualified or inattentive participants.

Discrimination testing

Discrimination tests can be conducted by a trained panel, either external or internal, or with consumers who are motivated, reliable, and capable of focusing on small sensory differences. It is less important that these participants be regular consumers or part of the target market than it is for affective testing. Often, a company will use employees because they are readily available and familiar with the product. Do this with caution, as employees may have biases or familiarity that make them more sensitive to changes than a typical consumer.

- **Typical number of participants**: 30–50 participants
- **Training**: May be trained or untrained.
- **Focus**: Must be reliable and able to detect subtle differences.
- **Target market**: Not required.
- **Considerations**: Employees are convenient but may carry bias or be more sensitive to differences than the average consumer.

Descriptive analysis

Descriptive analysis requires the highest level of participant skill and commitment. Individuals who have had sensory training are referred to as panelists.

- **Typical number of participants**: 8–12 trained panelists.
- **Training**: Extensive training to develop a shared sensory vocabulary and calibration. Reliability and consistency are critical; panelists must be willing to participate in repeated training and calibration sessions.
- **Focus**: Systematically identify, describe, and quantify specific sensory attributes.
- **Target market**: Not relevant. Panelists are selected based on reliability and ability to detect low-intensity attributes, discriminate among similar sensations, and avoid sensory fatigue.
- **Considerations**: Employees as panelists can show bias compared to externally trained panelists.

Affective testing

Affective tests primarily require that participants reflect the intended market. Identifying the target market is especially critical for alternative proteins and can include current users, omnivores, or both, while excluding employees, stakeholders, and investors who do not reflect that target. In some cases, such as comparing a plant-based burger to beef, participants must also be willing to regularly eat meat to make a fair comparison.

- **Typical number of participants:** 80–100+ consumers
- **Training**: None, participants are untrained consumers.
- **Focus**: Provide authentic feedback on the consumer experience, including liking and preference.
- **Target market**: Must reflect the intended consumer audience. Screening criteria may be broad or specific, depending on the company's mission, but typically include age, gender, dietary habits, and frequency of product usage.
- **Considerations**: All samples should be blinded, as information influences expectations. In a recent study, the same product labeled as "plant-based" and "dairy" resulted in significantly different liking ratings.[52]

The cost of sensory testing

Cost is often the unspoken factor shaping sensory testing decisions. External, trained panels are typically the most expensive option, given the time and expertise required for training. Consumer tests also carry significant costs, with one expert citing about $3,000 per product for each of 50 consumers, putting a typical study in the tens of thousands of dollars. Because of these cost realities, many companies rely on internal participants, which can be acceptable for early-stage prototyping or directional insights. However, when the goal is robust, consumer-relevant insights, external participants are strongly recommended despite the higher cost. These costs provide rigorous data to drive business decisions that can be offset by commercial performance and are often far more economical than the ramifications of a failed product.

Considerations for screening consumers and potential for segmentation

Recruiting the target consumers for affective testing includes identifying which consumer groups and characteristics should be screened before the study. A non-exhaustive list of potential characteristics to consider when screening for consumers in your hedonic test is provided below.

Table 1. Examples of screening variables to consider and their relevance to alternative proteins.

	Specific variables to consider	Relevance to alternative protein
Demographics	Age	Different generations show varying openness to alternative proteins
	Gender	May influence taste preferences or dietary choices
	Geographic location/region	Regional access, culinary norms, and product availability
	Income level	Affects purchase behavior and sensitivity to price
	Education level	Impacts understanding of food labels and food technology
	Ethnicity/cultural background	Cultural norms influence taste preferences and protein sources
Consumer characteristics	Dietary pattern (e.g., vegan, flexitarian, omnivore)	Helps identify current or potential users of alternative proteins
	Frequency of intake of alternative protein and animal products	Indicates familiarity and habitual use
	Familiarity with animal and alternative proteins	Influences expectations and potential bias in hedonic ratings
	Attitudes: reluctance to reduce animal consumption, acceptance concerns for food technology	Drives motivations for trying or rejecting alternative protein products
	Food neophobia, or fear of trying new foods	Affects willingness to try new or unfamiliar foods
	Motivations or values that drive food choices: health, sustainability, animal welfare, taste, cost	Helps segment consumers and interpret liking data
	Purchase behavior (e.g., past purchases, brand familiarity)	Reflects purchasing behavior of primary grocery shoppers (e.g., you purchase alternative proteins for family members but not for yourself)
	Ingredient or nutrition concerns (e.g., organic, non-GMO, clean label)	Critical for assessing consumer trust and acceptance of specific product characteristics

Consider including questionnaires in your study to segment consumers into convenient groups and aid in the interpretation of results. This practice can provide critical insights into data variation and differences in product ratings among consumer groups. For a more detailed perspective on attitudinally defined consumer segments within the plant-based meat category, explore GFI's plant-based meat consumer segmentation. The literature contains numerous additional examples, with some examining plant-based products more generally and others examining them more closely within product categories.[6,19,24,53–55]

By aligning participant selection with the specific objectives of the sensory test, researchers and product developers can generate reliable and actionable data that support informed product decisions.

Study design and protocol considerations

Sample preparation and handling should follow clear, standardized procedures to ensure reliability and comparability of results across participants and sessions. Clear instructions are also vital for a successful test: written and verbal instructions should explain exactly how participants are expected to handle, taste, and evaluate the samples to reduce participant confusion and ensure data consistency across all sessions. All participants must have a clear understanding of the study instructions.

Participant instruction best practices/tips:

- Choose the format that works best for the study—verbal, written, or recorded video—to demonstrate proper study procedures.
- Test instructions before the actual study to ensure they are clear and effective.
- Avoid internal jargon and complex sensory terms unless trained panels are involved.
- Provide clear examples for attributes that may be less familiar, especially aversive sensations (e.g., beany, metallic) and mouthfeel terms (e.g., sticky, astringent), which are often confusing for consumers.

Study protocols and procedures best practices:

- Control time between samples to allow participants sufficient time to rinse and remove any sensations before proceeding to the next sample. Generally, a 30-second to 1-minute interval should be forced between samples.
- Direct participants to clean their palates between samples using room-temperature purified water. Avoid saltines, once a standard practice, as they are no longer recommended due to their mouth-drying effects and impact on appetite.
- Encourage participants to consume samples in consumer studies. Expectorating is not a common practice as it does not reflect typical consumption and can distort perceptions of aftertaste and mouthfeel, both critical challenges for alternative proteins.

Consumer engagement

A common challenge in consumer testing is ensuring participants are attentive to the task, following directions, and using rating scales appropriately. Though there are a few approaches to assess attention and engagement, the easiest is to include participation checks or questions. For example, including one multiple-choice question where the instructions provide some relevant descriptive text, followed by "This question is an attention check question. Select the number four," is sufficient to assess attention. Individuals who do not select the number four are excluded from the analysis. Other researchers have used a brief questionnaire to assess participant engagement, helping to improve data quality.[56] These participation checks or questions can determine whether participants are following instructions on whether to cleanse their palate between samples, the order in which to taste products, and how to complete the evaluation form.

Samples: Preparation and presentation

Sample preparation

- Prepare noncommercial samples using the same equipment, recipes, or processing steps, and serve at the appropriate temperature for the product type. For example, plant-based burger prototypes should be cooked to the same safe internal temperature and rested for the same amount of time before serving.
- Assess one variable at a time. If the goal is to evaluate how a change influences products, adjust only that factor. Otherwise, differences may stem from uncontrolled variations in processing steps.
- For commercial products (not prototypes), always follow the manufacturer's cooking instructions.
- Maintain consistent cooking procedures across batches, testing sessions, and locations.

A broader question about sample preparation is whether the product should be tasted on its own or in a familiar context. Consumers experience products differently when sampled plain, such as plant-based milk or a meatball, versus when served with cereal or spaghetti and sauce. Best practice is first to assess the product alone, then follow up with meal-appropriate studies. A typical sequence is descriptive testing of the plain product, followed by affective consumer testing on the plain product, and finally, in-context evaluations. While this can be challenging for products not typically eaten plain, serving them alone provides a reliable reference for sensory properties.

Sample presentation

How samples are presented is as important as how they are prepared.

Best practices for sensory sample presentation:

- **Plating:** Present samples consistently and identically, with uniform portion sizes and the same arrangement for all participants.
- **Order:** Present samples in a balanced, randomized order to control for order effects such as first-sample bias or palate fatigue. First-sample bias occurs when the first product frames expectations for subsequent ones. Similar effects can arise from other early samples. The same principle applies to control samples, which should be integrated into the overall design to avoid order effects.
- **Labeling:** Use random, three-digit blinding codes typed in the same font, size, and placement. A three-digit code is best practice as it provides a clear way to identify samples while removing unintentional bias. By contrast, labels like A, B, C or 1, 2, 3, could be perceived as a way to rank or order samples.
- **Blinding:** Ensure participants remain unaware of any branding or manufacturer information, which is a core distinction from market research or focus group testing, where branding and marketing cues are often evaluated alongside the sample.

Controls and benchmarks

A control product provides a reference point for comparison, often a well-liked commercial product, whereas benchmarks are specific target values or ranges for specific sensory attributes or hedonic values (e.g., liking scores). For alternative protein products aiming for parity, including at least one conventional animal product is essential to make direct comparisons. While many companies more commonly compare to a leading alternative protein product, 70 percent of experts responded that it is critical to include a comparable and well-liked animal control product.

Selection of controls

A well-chosen control sample provides a critical reference against which new formulations or prototypes can be compared. Controls facilitate the interpretation of differences in liking or rating specific attributes, such as flavor, texture, or other sensory characteristics. The careful selection and inclusion of a consistent control or benchmark can be extremely advantageous and warrants significant time investment.

Best practices and tips for selecting controls:

- Choose controls that are well-liked and represent the true target. Selecting a poor quality control can mislead interpretation. For example, if a prototype is liked significantly more than a poor-quality control, it gives the erroneous impression that the prototype will perform well compared to the target category (see Figure 9 for more).
- Using sales data to select a leading control product is typically a reliable rationale. However, this approach has its challenges, particularly if targeting a specific market that may not align with the leading product in that category.
- Ensure consistency over time by including the same controls in multiple sessions. This allows results to be compared across test sessions and to track data over time.
- Avoid new-to-market products as controls, since formulations may vary over time, regions, and manufacturers, or products may be discontinued.
- Incorporate duplicate samples within a testing session to verify consistency in participant responses. If a participant rates the same product very differently when presented twice within a test session, this signals issues such as fatigue or a lack of attention or understanding.

Together, controls and duplicates enhance data quality by identifying outliers, verifying repeatability, and providing a clear context for determining whether sensory differences are both perceptible and relevant to the real-world consumer experience.

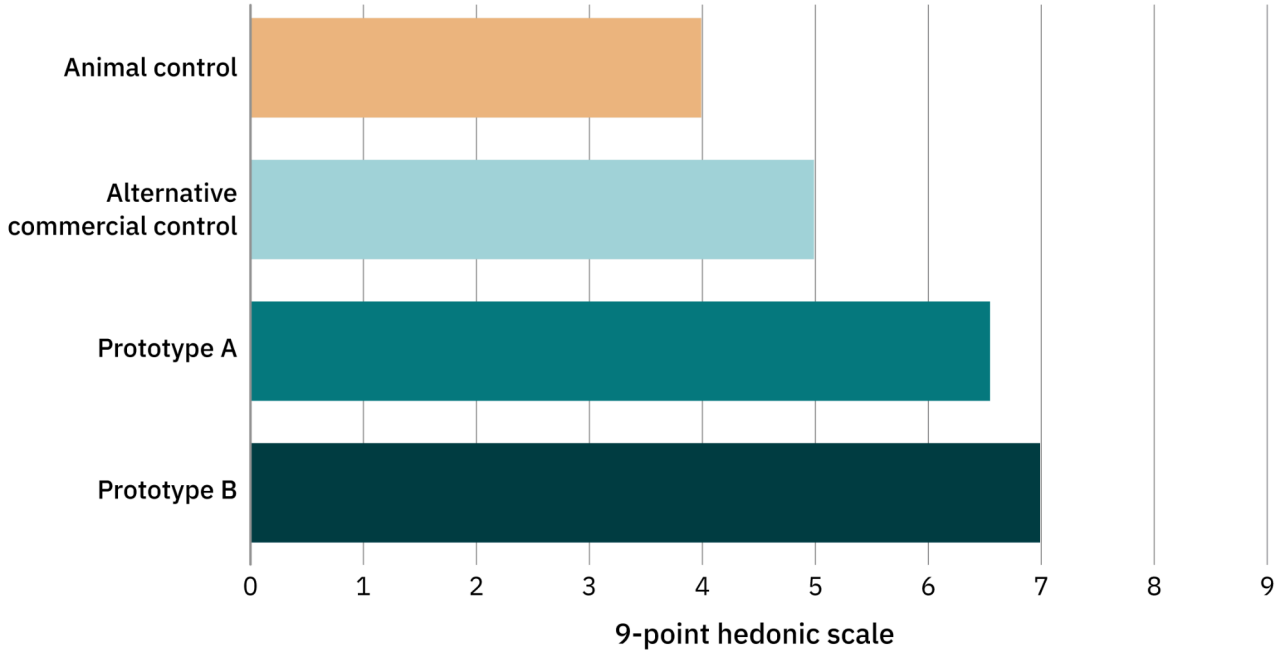


Figure 9. Bar graph reporting mean ratings for two alternative protein prototypes (A and B) compared to an animal-based control and a leading plant-based commercial alternative product. At first glance, both prototypes appear to be better liked than the controls. However, the animal and alternative commercial controls are not well-liked (4 and 5, respectively), making these conclusions poorly justified. Selecting a well-liked product within the target market is essential to ensure results are useful in making decisions. In addition, only viewing the mean ratings can mask variability in the data and potentially segmentation. Standard deviations and individual ratings should be examined to detect possible segmentation.

For studies involving multiple test days or sessions, detailed preparation protocols and checklists should be documented and followed strictly to ensure that every sample is prepared and served under the same conditions. Even small variations, such as a slight temperature difference during plating or inconsistent portion cutting, can influence sensory results and undermine study validity. Temperature influences the volatility of aromatic compounds and can affect taste perception; therefore, temperature differences between products or across studies make comparisons challenging. For example, if two samples in a triangle test have similar temperatures and one sample is cooler, the participants are likely to distinguish or select the odd sample based on temperature, leading to a misinterpretation of the results.

To improve the interpretation of results from studies conducted over days, it is recommended to include control samples in all testing sessions to ensure consistency at the individual and study level. If the control samples are perceived differently across testing days at the individual level, it might reveal that the participant did not follow the study instructions. At the study level, significant differences in ratings of the control sample across days may point to inconsistencies in the sample preparation or batch variation. The first suggests removing individual participants with poor reliability, whereas the second suggests that the study is not valid and should be redone.

For more guidance on the fundamental principles of setting up robust sensory evaluation protocols, Heymann and Lawless (2010) remains an essential reference, providing industry standards for sample coding, blinding, and preparation. Together, these rigorous preparation and presentation practices help sensory and product development teams generate reliable, actionable data that reflect true product differences, rather than unintended bias from inconsistent setups.

Data management, analysis, and reporting

Access to statistical expertise greatly improves the quality and impact of sensory research. Experts recommend that groups new to sensory testing—those without internal statistics or data science experience—hire a consultant to review statistical power ahead of time, taking into consideration the tasks and objectives. This can be extremely beneficial in streamlining the analysis of the final results. However, the team will likely need to work with the statistician to interpret the results and develop recommendations for next steps. Experts noted that best practice is to consult with an outside statistician for analysis or even to confirm internal findings.

At the same time, sensory software packages now include internal data analysis reports for basic summary statistics and analyses. However, they may be limited in their ability to examine more complex questions, like consumer segmentation. For advanced and complex questions, some programs may offer resources such as code that can be applied to external advanced statistical software tools (e.g., RStudio). Across platforms, data can be easily exported to file types that can be further analyzed with statistical software packages (SPSS, SAS, R, XLSTAT). Ensuring that appropriate conclusions are drawn from the data is critical, as inaccurate interpretations or overinterpretation may lead to costly mistakes.

Data quality and standard practices

Beyond sensory testing, the data are only as valuable as their quality. High-quality data are essential for reliable insights and guiding confident decision-making in the alternative protein industry, where products often challenge conventional sensory expectations. Ensuring data integrity begins with a rigorous study design that includes clear objectives, appropriate sample sizes, and well-defined sensory attributes. Consistency in sample preparation, presentation, and environmental conditions minimizes variability so that observed differences reflect true product performance rather than procedural noise.

Standardized data collection protocols, such as using validated scales (e.g., hedonic, JAR, intensity), digital platforms for data entry, and randomized sample orders, further support data reliability and allow for tracking and assessing performance over time. Panelist training and calibration, even for consumer panels, can reduce bias and improve reproducibility.

Common data quality issues in sensory studies include:

- inconsistent sample preparation (e.g., varying cooking times or temperatures), which can introduce uncontrolled variability.
- unbalanced or poorly randomized sample orders, leading to order effects or fatigue bias.
- incomplete or erroneous data entry, especially when using manual forms or unvalidated digital tools.
- participants misunderstanding scales or attributes, resulting in unreliable ratings.
- environmental distractions or uncontrolled testing conditions, which can affect participant focus and perception.

Maintaining clear documentation, traceability, and adherence to best practices helps mitigate these risks. Attention checks, as described earlier, can also ensure only engaged participants are included in the analysis. In a fast-moving field with evolving consumer expectations, robust data practices are not just technical necessities, but strategic enablers of credible, consumer-driven product development.

Best practices for data analysis

This section summarizes analysis steps and general tips that apply across all methods. Method-specific nuances appear in each method's "Tips on statistics" section, which contains examples of common statistical tests. However, more complex questions may require alternative statistical approaches.

- **Plan first.** Before conducting the study, define which data need to be reported, based on the question or decision that needs to be made, and in context with the overall objective at hand. Write a clear statistical analysis plan in advance.
- **Clean and organize data.** Once the study is complete, the first step is data cleaning—ensuring that the data were collected and exported correctly. This includes removing any protocol errors (e.g., the wrong sample was served or was not the right temperature) or data from participants who did not follow directions or who misused the scale.
- **Summarize, then analyze.** Next, organize the dataset with variables in a logical order. Start with simple summaries and visuals (summary statistics), calculating means and standard deviations, and testing for potential outliers. Choose statistical procedures that match the design (see method-specific "Stats Tip" boxes for more).
- **Check assumptions and use robust options.** Many statistical tests are only appropriate when certain assumptions are made, such as normal distribution. If assumptions look doubtful, consider data transformations or an appropriate nonparametric test.
- **Report more than p-values**. Smaller p-values do not imply larger or more meaningful differences. However, the effect size parameter, specific to each statistical test, can show the size of the difference between groups.
- **Look beyond averages.** Relying solely on average scores can mask true consumer sentiment, making it vital to analyze distribution and segment data for better decision-making.
- **Interpret small differences with caution.** Statistical significance does not guarantee practical importance. Interpreting small but significant differences can be complex and often leads to confusion about their interpretation and importance in driving decision-making.

Assessing sensory parity

For companies developing alternative proteins that aim to mimic conventional animal products, it is critical to assess whether the products deliver on this goal. Brands that promote their product as conventional meat analogs but fail to test performance against conventional benchmarks risk falling short of consumer expectations.

There are three ways to assess the sensory parity of alternative proteins with conventional benchmarks:

1. For a true assessment of parity, the gold standard would be a discrimination test between the alternative protein product and the conventional animal product. However, any apparent differences would result in discrimination, regardless of whether those differences were relevant to consumer acceptance. If participants are unable to discriminate between products, the conclusion is no detectable difference, not that the products are the same. This approach was not recommended by experts.
2. More common is to assess liking for specific attributes in addition to overall liking for the developed product and a leading commercial animal product. When there is no significant difference in liking scores between the two products, product developers may conclude that the alternative protein product has reached parity with regard to liking, if not absolute sensory parity.

3. A third option is similarity testing, which is similar to (1) but requires many more participants (300+) and stricter statistical thresholds. This approach is more resource-intensive but provides strong evidence that any differences between the alternative and conventional products are not meaningful. A similarity test can provide the statistical power to conclude that the products are the same.

Animal products as controls are less important for products that embrace the taste and flavor of plants. In this case, it is recommended to include other relevant commercial controls. Whatever the target for a given alternative protein product, product developers and sensory teams should be clear on their goals and use them to guide the selection of control products, participants for consumer sensory studies, and marketing strategies.

Lastly, for hedonic studies, especially where an animal control product is not well-liked or not included, set an internal target or benchmark. For example, when testing preliminary prototypes or concepts, products that reach at least 7 on a 9-point hedonic scale are selected to move forward in development. For additional rigor, examining the data beyond the mean and identifying whether a bimodal distribution exists may help further inform next steps (Figure 10).

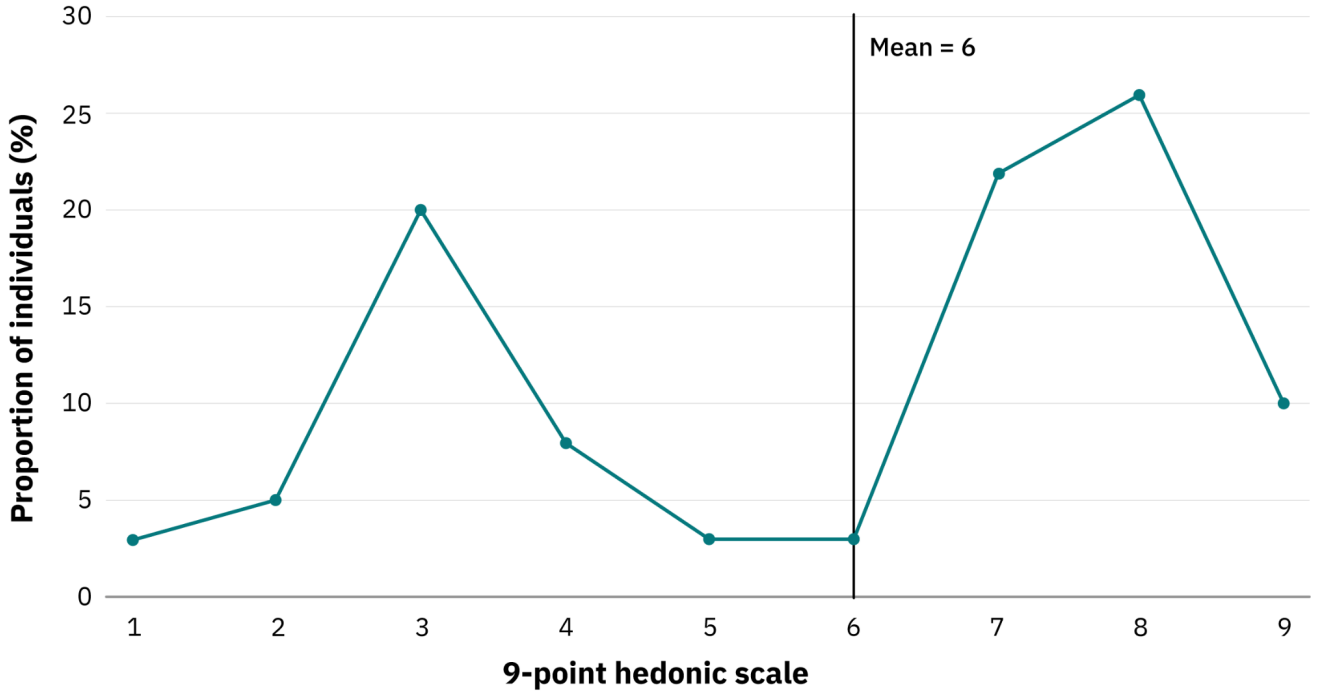


Figure 10. Example of a bimodal distribution, with the y-axis reporting the proportion of individuals selecting a specific value on the 9-point hedonic scale. The mean of the data is close to 6, indicating a well-liked product. However, when plotting the distribution, it is clear that the mean of 6 does not accurately represent the data, as only 3 individuals selected this value on our scale. In reality, 39% of participants selected 5 or below, suggesting they do not like this product, whereas 61% reported a value of 6 or above. This product may not be ready for commercialization, with 39% of the target market not liking the sampled product. This bimodal distribution reveals potential consumer segmentation and may warrant additional follow-up to investigate whether demographics or other consumer characteristics are driving these differences. These types of investigations may reveal a more concise target consumer.

Translating sensory data into actionable insights

Sensory data hold immense potential to guide product development, marketing strategy, and consumer engagement, especially in the alternative protein industry, where consumer expectations are evolving rapidly. To unlock that potential, present sensory data as an integrated narrative with context and alignment with business objectives, rather than as isolated metrics.

To bridge this gap, sensory scientists must go beyond reporting scores and statistical significance. Follow these steps to present sensory data as an integrated narrative.

1. Restate the business question and success criteria that defined the goals and objectives of the study.
2. Review the data collection procedure. Name all parts of the method and procedure so that results are interpretable without jargon.
3. Show the evidence by presenting clear figures (bar/box/spider) with one-sentence takeaways. Avoid number- or figure-only slides.
4. State one insight per claim (e.g., "texture is penalizing overall liking"), reported and framed in terms of its impact on consumer satisfaction and market as much as possible.
5. Spell out the implication. Translate data into actionable insights by identifying patterns, highlighting consumer-relevant attributes, and connecting sensory outcomes to product positioning or reformulation strategies.
6. Recommend the next steps with clear owners and timing.

Avoiding common pitfalls (e.g., overloading, overinterpretation)

Even well-designed sensory studies can fall short if results are not presented well. In the alternative protein industry, where sensory expectations are nuanced and evolving, missteps in study execution or interpretation can lead to misleading conclusions and costly development errors.

One frequent issue is overloading studies with too many attributes or samples, which can overwhelm participants and dilute the quality of responses. To avoid overloading studies:

- Don't use each study to gain as much insight as possible; keep to the goal of the test.
- Avoid mixing marketing objectives with sensory-specific goals, resulting in a study protocol that is not aligned with best practices of either sensory or marketing.
- Keep it simple and on target. Asking consumers to evaluate 10 plant-based burger prototypes across 15 sensory attributes in a single session can result in fatigue, rushed responses, and inconsistent data.
    - Instead, devise a more focused design that prioritizes key differentiators like texture, flavor, and juiciness, or test products across several sessions, including duplicates across sessions to assess reliability.

Avoid overinterpretation of small or statistically insignificant differences. In one case, a team reformulated a plant-based sausage based on a 0.2-point difference in the intensity rating of meaty flavor between a prototype and a benchmark sample. Despite the statistical significance of the difference, it remains unclear whether it is meaningful to consumers. The reformulation can add to the timeline and cost but fail to translate to increased consumer acceptance.

Avoiding these pitfalls requires thoughtful study design, clear communication across functions, and disciplined interpretation practices. Sensory data should be treated not just as numbers, but as strategic signals that are grounded in consumer reality and aligned with business goals.

Innovations and future directions

Multimodal sensory approaches

Traditional sensory testing relies heavily on explicit measures, such as liking scores and attribute ratings, to evaluate consumer responses to a product. While these methods are well-established and standard procedures, they rely on a participant's ability to reflect on and articulate their experience. Researchers and industry members find additional value in incorporating multimodal approaches that combine traditional sensory methods with implicit measures.[48] These implicit measures include emotional responses and behavioral observation to capture a more complete picture of how consumers experience a product.[35,57]

Implicit methodologies can include response-time tasks, eye tracking, or facial coding to measure automatic, subconscious reactions that participants may not be able to verbalize or may be unwilling to disclose. For example, facial expression analysis during testing can reveal subtle cues about emotional valence (e.g., disgust, surprise, satisfaction), while physiological measures (e.g., heart rate, skin conductance) can be used to explore arousal or engagement levels.[58] These tools offer valuable insight into the emotional and cognitive dimensions of sensory experience, especially for products that evoke complex or conflicted responses.[57]

These multimodal tools can be further applied to study how information provided about products, such as health and sustainability, evokes consumer responses beyond sensory-specific features.[59] Future research should continue to explore how integrating emotional response testing and implicit measures can enhance sensory testing, identifying areas for improvement to align with target audiences or to attract new consumers.

Technology in sensory testing

Emerging technologies are reshaping how sensory testing can be conducted, expanding far beyond traditional booths and central-location tests. While these testing facilities are standard practice, they may not translate to real-world experiences and behavior. Virtual reality (VR) and augmented reality (AR) are challenging traditional test settings, promising a more realistic and immersive testing environment that better replicates the contexts in which consumers actually consume foods and beverages, including alternative proteins. For example, VR can simulate a quick-service restaurant setting or buffet options, which can manipulate how different information (e.g., product description, nutrition facts, ingredients) and cues (e.g., background sounds, lighting, odors) influence food choices, or experience with a product, such as perceived flavor, mouthfeel, and overall liking.

Early research suggests that immersive technologies can reduce the artificiality of standard sensory booths, potentially generating insights that better align with real-world consumption behavior.[60] They can also hide visual cues so that participants evaluate products based on other sensory attributes. However, VR and AR setups also introduce new variables to manage, such as user comfort, equipment usability, and standardization of the virtual environment across participants.[61]

As the alternative protein industry pushes for products that perform well in realistic meal settings, VR, AR, and other immersive tools may help improve sensory testing, thereby bridging the gap between laboratory results and the real-world consumer experience.

For groups with limited access to conventional sensory testing settings, these technologies may provide a way to control the environment, as they often require a small room where food can be served. As the sensory community continues to investigate these methods, it has been suggested that these technologies may replace traditional sensory booths, providing an approach that can be adapted to represent different eating contexts while still being able to control other sensory inputs.

Information: Meeting consumers where they are

A primary reason consumers fail to try or decline to repurchase alternative protein products is that they do not taste like the conventional products (see: GFI's alternative protein consumer snapshot). Only price has a comparably significant role as a barrier to consumers choosing plant-based options. However, many interviewees agree that even well-liked alternative protein products are distinguishable from conventional animal products, suggesting that products do not have to taste like conventional animal products to be successful. Though widespread market success likely still depends on achieving exact biomimicry, interviewees consistently emphasized that the primary goal currently is to create products that taste good and are well-liked, even if they do not replicate every attribute of conventional animal products.

As the alternative protein sector continues to grow, understanding how information influences consumer expectations and sensory perceptions is becoming increasingly important. More than 90 percent of experts interviewed reported concerns about how product information influences consumer acceptance. Alternative protein products may be marketed with strong sustainability narratives, include health- or nutrition-related claims, or make animal ethics or welfare statements. However, the impact of these labels, information, and product claims on consumer perceptions and behavior is poorly understood. For example, highlighting that a product is healthy may lead some consumers to expect subpar taste.

Other information, such as product descriptions, may also influence perceptions. In a recent study, an informed condition with correct and incorrect product description labels were compared to a blinded condition.[52] It showed that even when a participant tastes the same product, different labels or scenarios have a significant impact on overall liking. Thus, it is essential to test products without prior knowledge and to consider how information, such as product descriptions or claims, influences perceptions by altering expectations.

It has been hypothesized that if consumers believe a product is better for the planet, they may perceive it more positively, or, in some cases, may forgive minor sensory flaws. Yet, this type of consumer research linking sustainability perceptions with sensory acceptance is rarely considered. Moreover, consumers are voicing concerns about the process of taking a plant, which is usually not tasty, and creating a similar texture and taste to animal products. This fear of novel technology applied to foods is associated with lower expected tastiness and lower likelihood of purchasing sustainable and alternative products.[17,62]

More work is needed to understand how much taste attributes can differ from those of conventional counterparts while still producing an acceptable product. Future work should explore how different labeling strategies, certifications, or claims may influence sensory expectations before tasting, and whether positive sensory experiences can strengthen trust.

Role of AI/ML in predicting sensory outcomes

The roles of artificial intelligence (AI) and machine learning (ML) in sensory science are expanding rapidly, and they are anticipated to aid in predicting sensory outcomes based on a product's formulation, ingredient profile, or physical-chemical composition. There is a movement to develop AI agents or "bots" to explore consumer perceptions of specific products or categories. By scraping internal and publicly accessible data (social media, websites, etc.), teams use AI to map perceptions of products, identify key terms associated with liking or rejection, and build AI agents. Though companies have invested in developing these AI agents to provide quick feedback on consumer reactions and screen early prototypes, they cannot replace sensory testing. Experts identified limitations such as overgeneralization or underrepresentation of certain ethnic groups. Ensuring checks for these common pitfalls will guide effective use of AI along the product development cycle.

ML is anticipated to aid in analyzing large datasets to examine links between ingredient combinations, processing methods, and instrumental measurements of human sensory responses. ML models are expected to help developers anticipate how changes in formulation may influence taste, flavor, mouthfeel, aroma, or overall liking. For example, these algorithms are expected to identify correlations between protein sources and flavor off-notes, or predict mouthfeel based on fat content and processing conditions. These predictive capabilities enable teams to screen prototypes more efficiently, refine formulations, and allocate sensory testing resources. While sensory evaluation and human data will remain essential, AI and ML may be a useful complement to traditional sensory testing, supporting quicker feedback during the development phase and improving the design of products that better meet consumer expectations.

Advances in taste, flavor, and texture

Achieving authentic flavor and mouthfeel remains one of the most complex challenges for the alternative protein industry. Alongside improvements in sensory methods, ongoing advances across pillars are steadily closing the gap:

- **Plant-based**: High-moisture extrusion, shear cell processing, and 3D printing are improving bite, flavor, and juiciness. New protein isolates, texturizers, and functional binders are further improving mouthfeel and flavor. Improved ingredient purification, enzyme treatments, and advanced flavor encapsulation are helping reduce undesirable off-notes.
- **Fermentation (biomass and precision)**: Biomass fermentation delivers inherent texture and umami by creating whole-muscle-like structures and high-protein ingredients, while precision fermentation is opening new pathways to produce natural flavors, fats, and aroma compounds that better replicate the sensory profile of meat and dairy foods.
- **Cultivated**: Progress in cell line selection, media optimization, scaffold/biomaterial design, and bioprocess design (including processes using co-culturing) is improving flavor, texture, and scaling possibilities.
- **Hybrid (cross-pillar)**: Combining alternative proteins (e.g., plant-based proteins + fermentation-derived or cultivated fats) can hit sensory targets more efficiently.
- **Blended (animal + alternative protein)**: Blending alternative protein ingredients with a portion of animal ingredients is gaining momentum as a practical and consumer-friendly strategy. By reducing the proportion of animal protein while providing the familiar taste, texture, and functionality that consumers expect, blended products offer a cognitively easy, familiar path that aligns with existing habits—lowering barriers to trial and supporting repeat purchase among flexitarians and mainstream consumers—while still delivering sustainability benefits and minimizing reliance on added ingredients.

Partnerships are critical. Cross-pillar collaborations among academic researchers, ingredient suppliers, and product developers—with sensory scientists embedded from the start—are essential to design alternative proteins with consumer preferences at the center, ultimately translating advances to greater adoption and long-term market growth.

Common questions, pain points, and red flags: A sensory scientist's perspective

Is it essential to achieve sensory parity?

Achieving true sensory parity, when an alternative protein product is indistinguishable from its animal-based counterpart, is regarded as the most effective approach to drive mainstream consumer adoption by meeting consumers where they are. Consumer research shows that not liking the taste of plant-based meat and preferring animal meat are key barriers to consumers trying plant-based meat and continuing to eat it. Additionally, consumers say the top factor that would convince them to buy a new plant-based meat product is if the taste and texture are exactly like conventional meat.

At the same time, sensory parity is widely regarded by experts as an unrealistic goal for many alternative protein products, given current technology. While investment must be made to advance the technology, there are practical considerations that may influence sensory evaluation in the meantime:

- Products may aim to be "well-liked" to satisfy consumer expectations, even if they are not identical to conventional meat or dairy counterparts.
- Each company needs to determine their goals and targets, and not overpromise when launching alternative protein products. If a product is marketed as tasting like animal meat, the product needs to meet that expectation.

How important is it to understand consumer segmentation?

Understanding consumer segmentation can be valuable in certain contexts, but it is not always necessary for sensory testing. Segmentation is most useful when a company wants to identify and target specific consumer groups, such as meat reducers, flexitarians, or plant-forward early adopters, who may differ in expectations, motivations, or sensory preferences. In these cases, running larger consumer studies with enough participants to capture variability across segments (often 150–300+ consumers) or targeting a specific consumer segment can provide actionable insights into positioning, messaging, and long-term adoption potential. However, for early-stage development or when resources are limited, it is often more efficient to focus on general consumer acceptability and clear sensory drivers of liking. In short, segmentation can help refine strategy, but it should be applied selectively and align with business goals and stage of development.

Can I use instrumentation to guide understanding of sensory perception?

It is common for product developers to turn to instrumental assessment (e.g., HPLC or texture analysis) to guide processing and ingredient choice. Though interviewees emphasized that sensory science is more useful when making business decisions, instrumentation can be useful in some instances during initial development with a clear target parameter in mind. Interviewees agreed that while instruments can reliably measure certain physical parameters, they are poor predictors of sensory experiences. One key reason is that flavor is multimodal, incorporating taste, smell, chemesthesis, and somatosensory (mouthfeel), and cannot be captured by a single instrument. For example, measuring hardness on a texture profile analyzer cannot account for repeated chewing, interaction with saliva, and other chemical interactions.

There are current efforts to utilize ML and AI to predict sensory perception from ingredient lists or instrumental analysis. While these tools may provide some insights, they are unlikely to replace the need to directly measure the human experience.

How can we best use sensory science as a development partner, rather than a checkpoint?

Sensory scientists bring critical expertise to the product development process, and their greatest value comes from their early engagement within cross-functional teams. Sensory evaluation is most effective when studies are designed around defined objectives and key questions, ensuring that the insights generated directly support decision-making. When integrated thoughtfully with broader R&D goals, sensory testing not only validates product performance but also guides efficient development, helping teams avoid unnecessary delays and reduce resource use. In this way, sensory science acts as a strategic partner in driving successful innovation.

Should we make decisions based on stakeholder and internal preferences?

Relying on stakeholder opinions or internal preferences instead of consumer-driven sensory data can lead to misaligned products and missed market opportunities. Sensory science offers a rigorous, unbiased way to assess consumer perception using established protocols and best practices, helping teams understand how real consumers experience the product. When decisions are guided by individuals invested in the product, bias that minimizes the voice of the target consumer is unavoidable. This criticism is noted across the food and beverage industries but is especially detrimental for alternative proteins, where products are still new to consumers. Failure to engage with consumers and not investing in sensory science have been cited as major industry gaps, driving the failure of entire product categories. A poor first experience with one product can shape a consumer's negative perception of the entire category. Greater investment across all alternative protein categories is needed to ensure positive first impressions and long-term adoption of sustainable diets.

Should we use employees for sensory studies?

It is common for companies to use employees to evaluate products because of convenience, low cost, and quick data collection. However, relying mainly on employees carries risks, even though it can provide valuable insights to drive product development and quality control.

Interviewees noted that high-risk business decisions should rely on third-party testing, while internal testing is suitable for lower-stakes decisions during initial development and prototype screening. Challenges with employee panels include availability, the need for ongoing training, and potential overfamiliarity with samples. Turnover can also disrupt panels, leading to lost investment, delays, and retraining needs.

When to use employees as participants:

- Market profiling: Evaluating the current market space and benchmarking against existing products, including conventional animal products.
    - Samples should be blinded, without product descriptions or brands, and evaluated independently.
    - Test across multiple days to limit fatigue.
- Internal batch checks: Before moving to a consumer study, confirm that products are free of defects or imperfections and generally meet the target profile. Best practice is to validate each batch internally, since variation can occur between batches.
- Trained panels for quantitative sensory evaluation: Use internal panels for assessing profile and comparing to a benchmark or predefined target. Panels should be trained following best practices (see: Descriptive analysis–QDA or Spectrum method) and perform regular assessments and reliability checks. Select employees who are reliable and regularly available.
- Quality assurance: Trained assessors can monitor the quality of commercial products against specific, well-defined profiles.
- Prototype narrowing: Employees are useful for screening and refining prototypes, particularly when extending established product lines.

When to use consumers (not employees):

- When seeking any data that involves liking, hedonic, or acceptability measures.
- Testing final versions before commercial launch.

Conclusions

Highlights and take-home messages

- Sensory science is essential for consumer acceptance of alternative proteins. Technical success is not enough if consumers don't like the product.
- Sensory testing is an investment. Assessing taste and consumer acceptance is a necessary priority, as taste is the number one driver of food choice.
- Sensory testing must be integrated throughout product development, from early concept screening to continued checks after launch.
- Effective sensory testing is not one-size-fits-all. The research question should drive the sensory method; choosing the right tool is critical to generate meaningful and actionable data.
- Use the right participants for the right questions. Consumers are essential for liking and market success, while employees can provide useful but limited input when properly trained and blinded.
- Sample size matters. Underpowered studies can mislead development or launch decisions, but well-designed, small-scale studies can generate meaningful data. Participant numbers must match the risk and complexity of the decision.
- Consumer perception is shaped by more than just the product; demographics, personality traits, emotional responses, and expectations all influence sensory evaluation outcomes.
- Benchmarking is critical. Including conventional animal products or category leaders helps move products toward sensory parity and consumer expectations.
- First impressions matter. Poor early experiences with alternative proteins can negatively shape consumer perceptions of the entire category.

Gaps and future research

While consumer studies of alternative proteins have generated valuable insights, important gaps remain that should guide future research and sensory study design. First, the terminology is inconsistent: "alternative proteins" encompasses plant-based, fermentation-derived, and cultivated meat, while "hybrid" and "blended" are used inconsistently for either cross-pillar combinations (e.g., plant-based + cultivated) or mixes of alternative proteins with animal ingredients. This lack of clarity complicates cross-study comparisons and contributes to consumer confusion. From a sensory evaluation perspective, how products are described likely influences expectations and acceptance, making it critical to track how evolving language, awareness, and availability affect consumer perception.

Another gap lies in the limited study of dynamic sensory experiences. Most published work focuses on static profiles, offering only a snapshot of the overall experience. More studies are needed to examine the temporal and dynamic sensory profiles of alternative protein food products, as the industry faces challenges with raw vs. cooked aromas, mouthfeel, and unpleasant aftertastes, all attributes that unfold during consumption.

While companies should prioritize their target consumer when designing studies, published research on alternative proteins has been criticized for relying heavily on WEIRD (western, educated, industrialized, rich, and democratic) individuals. This reliance makes consumer segmentation less clear for those outside these demographics and reduces understanding of how underrepresented populations perceive these products. For companies seeking greater adoption and a wider consumer base, expanding studies beyond the initial target market can help plan for future growth. Collaborations between industry, academia, and consumer research agencies will be essential to close these research gaps and foster innovation in sensory science tailored to this rapidly evolving field.

Resources and opportunities for further learning

Sensory conferences

- Pangborn Sensory Science Symposium
- Society of Sensory Professionals
- Society of Ingestive Behavior
- Institute for Food Technologists

Journals and resources

- *Food Quality and Preference*
- *Journal of Sensory Studies*
- *Foods*
- Society of Sensory Professionals online database of methods
- ASTM – Protocols and best practices for sensory testing

Textbooks

- *Sensory Evaluation of Food: Principles and Practices* (Heyman and Lawless 2010)
- *Sensory Evaluation Techniques* (Meilgaard, Carr, and Civille 2007)

Online training and courses

- Institute for Food Technologists (IFT)
- UC Davis Continuing Education
- Penn State World Campus
- Sensory Spectrum

Sensory software

- Compusense
- FIZZ
- RedJade
- Sensory Spectrum Tools
- SIMS

GFI's industry consultants list – see section on sensory and consumer testing

For a concise, easy-to-post reference of this guide, please see Sensory evaluation of alternative proteins: A quick-start guide

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About GFI

The Good Food Institute is a nonprofit think tank working to make the global food system better for the planet, people, and animals. Alongside scientists, businesses, and policymakers, GFI's teams focus on making plant-based and cultivated meat delicious, affordable, and accessible. Powered by philanthropy, GFI is an international network of organizations advancing alternative proteins as an essential solution needed to meet the world's climate, global health, food security, and biodiversity goals. To learn more, please visit gfi.org.

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