





Exploring Semantic Ambiguities in Biotechnology, Food Science, and Nutrition

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Abstract	Article History
<p>This paper examines semantic ambiguities in biotechnology, food science, and nutrition, analyzing their impact on scientific communication, regulatory coherence, and public understanding. Key terms including probiotics, enriched, bioavailability, and functional foods are explored through a qualitative thematic analysis of foundational texts such as Hill et al. (2014) on probiotics, the FDA Food Labeling Guide (2022) on enriched, Boon et al. (2019) on bioavailability, and the FAO (2018) report on functional foods- selected for their established authority and prevalent use in expert discourse and education. Additional examples demonstrate how multiple interpretations and misunderstandings manifest in scientific, regulatory, and consumer domains. The findings highlight the urgent need for systematic clarification, harmonization of terminology, and targeted educational strategies to foster transparency, improve policy enforcement, and enhance consumer literacy in evolving biotechnological and nutritional landscapes.</p> <p>Keywords: Semantic ambiguity, regulatory terminology, food and nutrition vocabulary.</p>	<p>Received: 12 Oct 2025 Accepted: 24 Oct 2025 Published: 26 Oct 2025</p>  <p>Scan QR Code to view¹</p> <p>License: CC BY 4.0</p>  <p>Open Access article.</p>
<p>How to cite this paper: Prodanovska-Poposka, V. (2025). Exploring semantic ambiguities in biotechnology, food science, and nutrition. <i>IPS Journal of Nutrition and Food Science</i>, 4(4), 614–617. https://doi.org/10.54117/5gtx3235</p>	

Introduction

In biotechnology, food science, and nutrition, terminology is not merely descriptive, as it profoundly shapes perceptions, policy, and practice. Precise language forms the foundation of scientific communication, regulatory frameworks, and consumer understanding. Semantic clarity is therefore essential because ambiguous or polysemous terms often cause research misinterpretation, regulatory inconsistencies, and diminished public trust. Ambiguity in language not only clouds scientific discourse but also complicates enforcement of labeling laws and misleads consumers, thus undermining their capacity to make informed choices.

The rapid emergence of biotechnological innovations, such as cultured meat and gene editing, introduces new lexicons requiring precise, shared definitions to facilitate cross-disciplinary understanding and regulate novel products effectively. Simultaneously, legacy terms such as organic or fermentation have evolved across disciplines and social contexts, acquiring diverse meanings that pose challenges to communication efforts. For example, fermentation is a well-defined microbial process scientifically, but it may be culturally associated with spoilage or traditional practices,

influencing public acceptance of fermented foods differently across populations.

Food terminology's semantic representation is deeply influenced by cultural experience and contextual usage. Research indicates that individuals conceptualize and categorize foods based on sensory features, preparation methods, and consumption contexts, with meaning shaped by personal and societal factors. This variability contributes to the diversity of interpretations for seemingly straightforward terms, increasing opportunities for confusion and miscommunication. This is critically evident in terms like "cross-contamination," which in food science and law denotes a precise, hazardous transfer of pathogens, but is often used metaphorically in public discourse, potentially diluting its urgency and complicating public health communication (Nwakoby et al., 2025). Moreover, emerging food ontologies and knowledge graphs strive to structure and unify food-related terminology to support data harmonization, health mapping, and consumer guidance, reflecting the current scientific effort to address semantic fragmentation.

This paper investigates the complex nature of semantic ambiguities in critical biotechnology, food science, and

nutrition terms, providing illustrative examples drawn from academic literature, regulatory texts, and marketplace observations. By mapping out where and how semantic ambiguities manifest, and exploring their implications, the study aims to propose pathways towards enhanced linguistic precision, policy clarity, and informed public discourse.

Literature Review

Semantic ambiguity, whereby words or phrases have multiple meanings or are interpreted inconsistently, is widely regarded as a significant barrier to effective communication in health and science fields. This challenge is particularly acute in disciplines such as biotechnology, food science, and nutrition, where precise terminology is critical to scientific accuracy, regulatory clarity, and public understanding. Hill et al. (2014) provide a foundational and widely recognized definition of *probiotics*, emphasizing essential characteristics such as microbial viability and clinically documented health benefits. Despite this rigor, commercial and public usage of the term often diverges from these scientific criteria, leading to heterogeneous and sometimes misleading claims about probiotic products. Such discrepancies contribute to confusion among consumers and skepticism among health professionals, illustrating how semantic ambiguity can undermine trust and dilute scientific meaning.

The Food Labeling Guide published by the U.S. Food and Drug Administration (2022) represents a significant regulatory effort to curb ambiguity in food-related terminology such as *enriched* products. The guide aims to standardize definitions and ensure that consumers receive clear, accurate information about nutritional content. Nonetheless, lay interpretations often extend beyond the strict regulatory meaning, attributing broader positive health implications to the term *enriched* that the regulatory definitions do not support. This semantic drift exemplifies how words with established scientific meanings can evolve in public discourse, complicating efforts for regulatory enforcement and consumer education. Boon et al. (2019) highlight the complex and multifaceted nature of *bioavailability*, which is a concept critical to understanding nutrient absorption, metabolism, and physiological impact. They emphasize how *bioavailability* encompasses biochemical, physiological, and pharmacokinetic factors that are difficult to measure precisely and challenging to convey consistently in public health communications. This complexity exacerbates misunderstandings among consumers and even among healthcare professionals, as the term can be employed variably depending on experimental conditions or interpretative frameworks. Such variability stresses the importance of clarity and consensus in terminology to support evidence-based nutritional advice.

The problem of semantic ambiguity is further compounded in a global context. The Food and Agriculture Organization (FAO, 2018) further elucidates how semantic ambiguity manifests in the context of *functional foods*. These are broadly defined as foods providing health benefits beyond basic nutrition, but the cultural, regulatory, and linguistic variation in how this term is applied across different countries creates challenges in standardizing health claims. The report

underlines the considerable regulatory and cultural differences that hinder consistent use and understanding of *functional foods*, highlighting the pressing need for harmonized definitions and comprehensive consumer education worldwide.

Taken together, these studies reveal how semantic ambiguity persists at the intersection of science, regulation, and public perception. The fluctuating meanings of critical terms such as *probiotics*, *enriched*, *bioavailability*, and *functional foods* not only obstruct scholarly dialogue but also impede policy development and effective public engagement, emphasizing the need for ongoing efforts to refine terminology and foster clearer communication in food and health sciences.

Methodology

This study synthesizes multidisciplinary literature from research articles, regulatory texts, and communication studies to explore semantic ambiguity in biotechnology, food science, and nutrition. The analysis is based on a targeted review of foundational texts, selected for their established authority and prevalent use in expert discourse, including the seminal works of Hill et al. (2014), the U.S. FDA (2022), Boon et al. (2019), and the FAO (2018). A qualitative thematic analysis approach was employed to identify, analyze, and report patterns of semantic ambiguity and its practical effects as they manifest across scientific, legal, and popular narratives. Thematic analysis is a flexible method to analyze qualitative data that involves systematic coding of data, searching for themes, refining those themes, and interpreting them within a broader conceptual framework (Braun & Clarke, 2006).

This method allowed for the identification of recurrent patterns related to how key terms are defined, used, and understood differently depending on contexts such as scientific research, regulatory documentation, and consumer perception. Both explicit and latent meanings were considered to capture not only the direct linguistic variability but also the underlying conceptual disagreements and implications. Central to this process was an iterative review of focused terms, including but not limited to *probiotics*, *enriched*, *bioavailability*, and *functional foods*. The analysis involved systematically coding these texts for instances of definitional conflict, contextual shifts, and noted misunderstandings. Each term was examined for multiplicity of meanings, contextual shifts, and resultant misunderstandings that arise from inconsistent use. These interpretations were then framed within their observed consequences for scientific communication efficacy, policy formulation and enforcement, and consumer behavior and trust.

The thematic analysis proceeded through several key steps: initial data familiarization through comprehensive literature review, generation of initial codes highlighting semantic divergences, organization of codes into coherent potential themes, theme review and refinement, and finally, construction of an interpretive narrative linking thematic findings to the theoretical and practical concerns in the discipline. This systematic approach ensured a rigorous

analytical framework capable of exposing nuances in semantic ambiguity that might otherwise be overlooked in traditional literature reviews. By integrating insights across disciplinary boundaries and data sources, the study provides a multifaceted understanding of how semantic ambiguity operates and impacts the biotechnology, food science, and nutrition fields, laying the groundwork for improved terminological clarity and communication strategies.

Results

Semantic Ambiguities with Multiple Interpretations

Cultured Meat: Scientifically refers to meat grown from cultured animal cells; colloquially associated with sophistication or cultural refinement, generating potential for consumer confusion (Mattick & Landis, 2018).

Genetic Engineering: Scientifically precise gene alteration contrasts with broader public notions of unnatural manipulation, fueling ethical debates and policy divergence (National Academies, 2016).

Probiotics: Defined by effective live strains delivering health benefits; commercial use often generalizes the term to enhance product appeal, diluting scientific clarity (Hill et al., 2014).

Functional Foods: Intended to denote health benefits beyond nutrition; marketing often employs a lax usage implying general wellness enhancement, challenging regulatory precision (FAO, 2018).

Fermentation: A microbial metabolic process in food production; folk interpretations can include spoilage or unrest, influencing consumer attitudes (Schwan & Fleet, 2015).

Organic: Legally defined by certified production practices, but public often equates it with naturalness, leading to misconceptions (Organic Trade Association, n.d.).

Cross-Contamination: Safety-critical term in food science used metaphorically in other domains, risking dilution of strict meaning (IFIC Foundation, 2019).

Essential Oils: Scientific usage as flavor/aroma compounds contrasts with therapeutic aromatherapy associations, affecting consumer expectations and regulatory approaches (Tisserand & Young, 2014).

Extraction: Scientific separation process contrasted with forceful removal interpretations in lay contexts (Smith, 2010).

Preservatives: Food safety agents viewed skeptically by consumers due to negative connotations (IFIC Foundation, 2019).

Enriched: Formally nutrient replacement post-processing, colloquially conceived as enhancement, inviting consumer misperception (FDA, 2022).

To further illustrate the practical consequences of these ambiguities, Table 1 summarizes the divergence between common public interpretations and the established scientific or regulatory definitions for a selection of key terms.

Table 1: Public and Regulatory Misunderstandings

Term	Public/Consumer Understanding	Regulatory/Scientific Reality	Reference
Organic	Often perceived as inherently more nutritious or safer than conventional food.	Defined by certified production methods; nutritional superiority is not conclusively proven.	Organic Trade Association, n.d.
Fermentation	Sometimes associated with spoilage or unfamiliar traditional practices, limiting acceptance of fermented foods.	Microbial metabolic process with established health benefits; culturally variable acceptance.	Schwan & Fleet, 2015
Genetic Engineering	Public apprehension and ethical concerns slow acceptance of genetically modified crops.	Scientifically precise gene modification techniques with regulatory oversight and safety evaluations.	National Academies, 2016
Preservatives	Viewed negatively as artificial or harmful additives, driving demand for "natural" alternatives.	Food safety agents evaluated for safety; essential for shelf-life and contamination prevention.	IFIC Foundation, 2019
Bioavailability	Difficult for consumers to grasp complexity; often oversimplified in dietary advice and public understanding.	Complex biochemical and physiological process influencing nutrient absorption and health outcomes.	Boon et al., 2019

Discussion

Semantic ambiguities exert profound practical impacts across multiple domains, complicating multidisciplinary discourse, regulatory harmonization, and public education. When key terms lack clear, stable definitions, communication between scientists, policy-makers, industry representatives, and consumers becomes fragmented and sometimes contradictory. This fragmentation obstructs dialogue essential for collaborative problem-solving in complex fields such as biotechnology and nutrition. Effective mitigation of semantic ambiguity requires multifaceted strategies. Foremost is the establishment of harmonized definitions, where stakeholders collaboratively agree on precise meanings to be used consistently in research, regulation, and marketing. Coupled with this is the critical role of unambiguous labeling on food products and biotechnological innovations, which anchors abstract scientific terms in concrete consumer experiences, thereby reducing misunderstanding and building trust. Sustained educational efforts are imperative to reinforce and update public awareness about evolving terminology and its implications. The pace of technological innovation in food science and biotechnology accelerates constantly, introducing novel concepts and products that demand updated terminologies. Communication strategies must anticipate and accommodate cultural and linguistic diversity, as public perceptions are shaped not only by scientific facts but also by cultural narratives and social context, reflecting the complex semantic landscape. In this context, scientific rigor must coexist with transparency, integrity, and inclusiveness. Transparency about what is known, unknown, and under debate invites informed engagement rather than alienation. Inclusiveness ensures that terminology and communication resonate across socio-cultural groups, reducing gaps in understanding and enhancing equitable policy impact.

Conclusion

This analysis has demonstrated that semantic ambiguity is not merely a linguistic concern but a significant impediment to progress in biotechnology, food science, and nutrition. The examination of terms such as *probiotics*, *enriched*, and *organic* reveals a consistent pattern where divergent interpretations fracture communication, complicate regulation, and mislead consumers. These ambiguities ultimately erode public trust and hinder the development of coherent food and health policies. The findings underscore that effective mitigation hinges on a tripartite strategy: the establishment of harmonized definitions through stakeholder collaboration, the implementation of unambiguous labeling to bridge the gap between science and the public, and the deployment of targeted educational initiatives that address both scientific literacy and cultural contexts. As this study has illustrated, precision in language is foundational to transparency and trust. Ultimately, the journey toward semantic clarity is essential for building resilient and sustainable food systems. By prioritizing terminological precision, the scientific and regulatory communities can foster an environment where innovation is understood, policy is effective, and consumers are truly empowered to make informed choices. Future efforts must focus

on the dynamic interplay of language, science, and society to navigate the evolving challenges of the global food landscape (Ancelin et al., 2025).

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