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REVIEW ARTICLE

Artificial intelligence in gastronomy: transforming culinary innovation, food design, and consumer experience

Inteligencia artificial en la gastronomía: transformando la innovación culinaria, diseño de alimentos y experiencia del consumidor

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Abstract Artificial intelligence (AI) has expanded its application in gastronomy across six main areas: computational culinary knowledge, assisted creativity, food design and personalization, intelligent execution, enhanced experience, and cultural and consumer sustainability. Evidence indicates that AI enables the analysis of relationships among ingredients, the generation and reformulation of recipes, the optimization of products according to nutritional, sensory, and environmental criteria, the personalization of recommendations, and the support of culinary processes through robotics and computer vision. It also contributes to predicting preferences, reducing food waste, and promoting more sustainable consumer decisions. However, important limitations remain regarding data quality, sensory validation, privacy, user acceptance, authorship, algorithmic bias, and the representation of cultural diversity. In this context, the most promising approach is augmented gastronomy based on human–AI collaboration, in which technology complements, rather than replaces, human creativity, cultural knowledge, and sensory judgment.

Keywords artificial intelligence, gastronomy, culinary innovation, food design, personalized gastronomy, consumer experience.

Resumen La inteligencia artificial (IA) ha ampliado su aplicación en la gastronomía en seis áreas principales: conocimiento culinario computacional, creatividad asistida, diseño y personalización de alimentos, ejecución inteligente, mejora de la experiencia y sostenibilidad cultural y del consumidor. La evidencia indica que la IA permite analizar relaciones entre ingredientes, generar y reformular recetas, optimizar productos según criterios nutricionales, sensoriales y ambientales, personalizar recomendaciones y apoyar procesos culinarios mediante robótica y visión computacional. Asimismo, contribuye a predecir preferencias, reducir desperdicios y promover decisiones de consumo más sostenibles. Sin embargo, persisten limitaciones relacionadas con la calidad de los datos, la validación sensorial, la privacidad, la aceptación de los usuarios, la autoría, los sesgos algorítmicos y la representación de la diversidad cultural. En este contexto, el enfoque más prometedor es la gastronomía aumentada basada en la colaboración humano-IA, donde la tecnología complementa, en lugar de sustituir, la creatividad, el conocimiento cultural y el juicio sensorial humano.

Palabras clave inteligencia artificial, gastronomía, innovación culinaria, diseño de alimentos, gastronomía personalizada, experiencia del consumidor.

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Introduction

Gastronomy represents a complex field in which food transcends its basic nutritional function to become an expression of sensory perception, creativity, cultural identity, and social interaction (Pieroni, 2023). Culinary practices have historically relied on the knowledge, experience, and intuition of chefs to select ingredients, establish flavor combinations, develop preparation techniques, and create novel dishes. Consequently, culinary innovation has traditionally been characterized by an iterative process in which sensory experience, craftsmanship, and tacit knowledge play central roles (Siraj & Khan, 2024). Unlike conventional food production systems, where optimization is frequently based on standardized technological parameters, gastronomy involves dynamic interactions among ingredients, preparation methods, human perception, cultural traditions, and creative expression. The increasing availability of large-scale food databases, digital culinary repositories, chemical information on food components, and computational methods is progressively transforming this scenario by making different aspects of culinary knowledge amenable to systematic analysis and computational modeling (Bagler & Goel, 2024).

The emergence of computational approaches to food has provided an important conceptual bridge between food science, computer science, and gastronomy. Computational gastronomy has been proposed as an interdisciplinary field aimed at representing culinary knowledge in computational formats, allowing the analysis of ingredient combinations, culinary patterns, flavor relationships, nutritional characteristics, and cultural dimensions of food (Bagler & Goel, 2024). From this perspective, recipes are not considered merely as descriptions of cooking procedures but as complex information structures containing relationships among ingredients, preparation techniques, sensory attributes, and cultural contexts. The computational representation of gastronomy enables artificial intelligence (AI) and machine learning algorithms to identify patterns within extensive culinary datasets that would be difficult to detect through conventional approaches, contributing to a deeper understanding of culinary creativity and innovation (Bagler & Goel, 2024).

Within this framework, AI has evolved from being an analytical tool for processing food-related information toward becoming an active component of culinary innovation. Machine learning, deep learning, natural language processing, computer vision, and generative models have expanded the possibilities for analyzing recipes, predicting food relationships, designing new culinary concepts, and supporting decision-making processes in gastronomy (Fernandes & Rodrigues, 2026). Recent studies have demonstrated that AI applications in food-related domains encompass multiple interconnected areas, including ingredient recognition, recipe recommendation, food pairing, personalized food systems, sensory prediction, robotic cooking, and sustainable food design (Song & Li, 2026). However, unlike traditional technological applications in food science, AI in gastronomy operates within a domain where creativity, cultural meaning, and human experience remain fundamental components of value creation.

One of the most established computational applications with direct relevance to gastronomy is the identification of food-pairing relationships. Traditionally, the development of novel ingredient combinations has depended strongly on the expertise and intuition of chefs and gastronomes. Nevertheless, machine learning approaches have demonstrated the ability to integrate information from recipes, food composition databases, and chemical properties of flavor compounds to identify latent relationships among ingredients. Park et al. (2021) developed FlavorGraph, a large-scale food–chemical graph integrating recipe information and flavor molecules, demonstrating that graph-based computational approaches can generate food representations and recommend ingredient combinations. These findings indicate that AI can provide a scientific complement to culinary expertise by revealing hidden relationships between ingredients and supporting the discovery of innovative flavor combinations.

The rapid development of generative artificial intelligence has subsequently expanded the role of AI in gastronomy from pattern recognition and recommendation toward the generation of novel culinary solutions. Generative models, particularly large language models and multimodal artificial intelligence systems, are capable of learning complex patterns from extensive culinary datasets and producing new recipes, ingredient combinations, and gastronomic concepts. However, recipe generation and food design represent related but distinct applications (del Moral, 2026). While AI-generated recipes focus primarily on creating plausible culinary instructions or combinations of ingredients, AI-driven food design involves the optimization of multiple and sometimes conflicting objectives, including sensory quality, nutritional composition, functionality, cost, cultural acceptability, and environmental sustainability (Song & Li, 2026).

Recent experimental evidence demonstrates the potential of generative AI to contribute directly to food innovation. Tac et al. (2026) showed that generative artificial intelligence could learn patterns from human-generated food data and create novel burger formulations optimized according to different objectives, including taste perception, nutritional value, and environmental sustainability. Importantly, these AI-generated products were subsequently evaluated through sensory testing with human participants, demonstrating that AI-generated food concepts can progress beyond computational plausibility toward experimentally validated gastronomic products. This represents a significant transition in the field, moving AI applications from digital assistance toward evidence-based culinary and food design (Tac et al., 2026).

Another emerging domain is personalized gastronomy, in which AI systems integrate individual-level information to generate recommendations or culinary solutions adapted to specific preferences and requirements. Unlike conventional recommendation systems based mainly on previous consumption patterns, AI-driven personalization can incorporate dietary restrictions, nutritional objectives, sensory preferences, and lifestyle characteristics (Wang et al., 2025). This approach has particular relevance for health-oriented gastronomy, where personalized food recommendations may contribute to improved dietary adherence and consumer satisfaction. Similarly, AI-assisted ingredient substitution and recipe reformulation approaches have demonstrated potential for modifying culinary preparations according to nutritional or functional objectives while preserving desirable food characteristics (Song & Li, 2026).

Beyond the generation and optimization of culinary concepts, AI is also transforming the physical execution of gastronomic processes. Computer vision systems enable ingredient identification, monitoring of cooking stages, and assessment of food characteristics, whereas robotic systems integrate AI-based perception, planning, and manipulation to perform culinary tasks (Hassoun & Galanakis, 2025). These technologies represent a transition from AI as a computational assistant toward AI as an interactive component of the culinary environment. Nevertheless, intelligent culinary execution remains challenging because cooking requires adaptation to variability in ingredients, environmental conditions, and sensory outcomes, aspects that are difficult to fully reproduce through algorithmic approaches.

AI applications in gastronomy also extend toward the analysis and prediction of gastronomic experiences. Sensory perception, consumer acceptance, and food preferences are influenced not only by measurable characteristics such as flavor compounds, texture, or nutritional composition but also by cultural background, emotions, memories, social context, and perceptions of authenticity (Oliveira et al., 2025). Therefore, technological performance alone does not determine the success of AI-assisted gastronomy. Recent research investigating consumer responses to AI involvement in recipe creation and food production indicates that acceptance depends on factors such as trust, perceived creativity, authenticity, and the role attributed to human culinary expertise (Kim et al., 2025).

The integration of AI into gastronomy also raises broader ethical, cultural, and sustainability considerations. Culinary knowledge is frequently associated with collective traditions, cultural identity, and human craftsmanship; therefore, the use of AI systems trained on culinary datasets raises questions regarding authorship, intellectual property, cultural representation, and potential biases (Gurel, 2026). Moreover, although AI may contribute to sustainable gastronomy through ingredient optimization, waste reduction, and resource-efficient menu development, the environmental implications associated with computational requirements and digital infrastructures should also be considered within comprehensive sustainability assessments.

Despite the rapid expansion of AI applications in gastronomy, scientific knowledge remains fragmented across multiple research areas, including computational gastronomy, food pairing, recipe generation, personalized gastronomy, food design, robotics, sensory science, consumer behavior, and sustainability (Pennells et al., 2025). Existing studies frequently focus on specific technological applications without providing an integrated perspective of how these components interact throughout the gastronomic innovation process. Therefore, a comprehensive framework is required to organize AI applications according to their functional contribution to gastronomy, ranging from the computational representation of culinary knowledge to the generation, execution, evaluation, and societal impact of AI-assisted gastronomic experiences.

Accordingly, this narrative review aimed to critically examine the emerging applications of artificial intelligence in gastronomy through six interconnected domains: (i) computational culinary knowledge, (ii) AI-assisted culinary creativity, (iii) AI-driven food design and personalized gastronomy, (iv) intelligent culinary execution, (v) AI-enhanced gastronomic experience, and (vi) consumer, cultural, and sustainable gastronomy (Figure 1). By integrating evidence from food science, computational intelligence, sensory research, hospitality studies, and emerging AI technologies, this review discusses current achievements, limitations, ethical challenges, and future perspectives toward the development of human–AI collaborative gastronomy.

From computational gastronomy to AI-enabled gastronomy: the evolution of culinary intelligence

The digital representation of culinary knowledge

The application of computational approaches to gastronomy has emerged from the recognition that food practices contain complex patterns that can be represented, analyzed, and modeled through digital technologies. Culinary knowledge has traditionally been transmitted through experience, cultural practices, and sensory learning; however, the increasing availability of digital recipe repositories, food composition databases, and large-scale culinary datasets has enabled new approaches for understanding the structure of food and cooking practices (Ahn et al., 2011; Bagler & Goel,

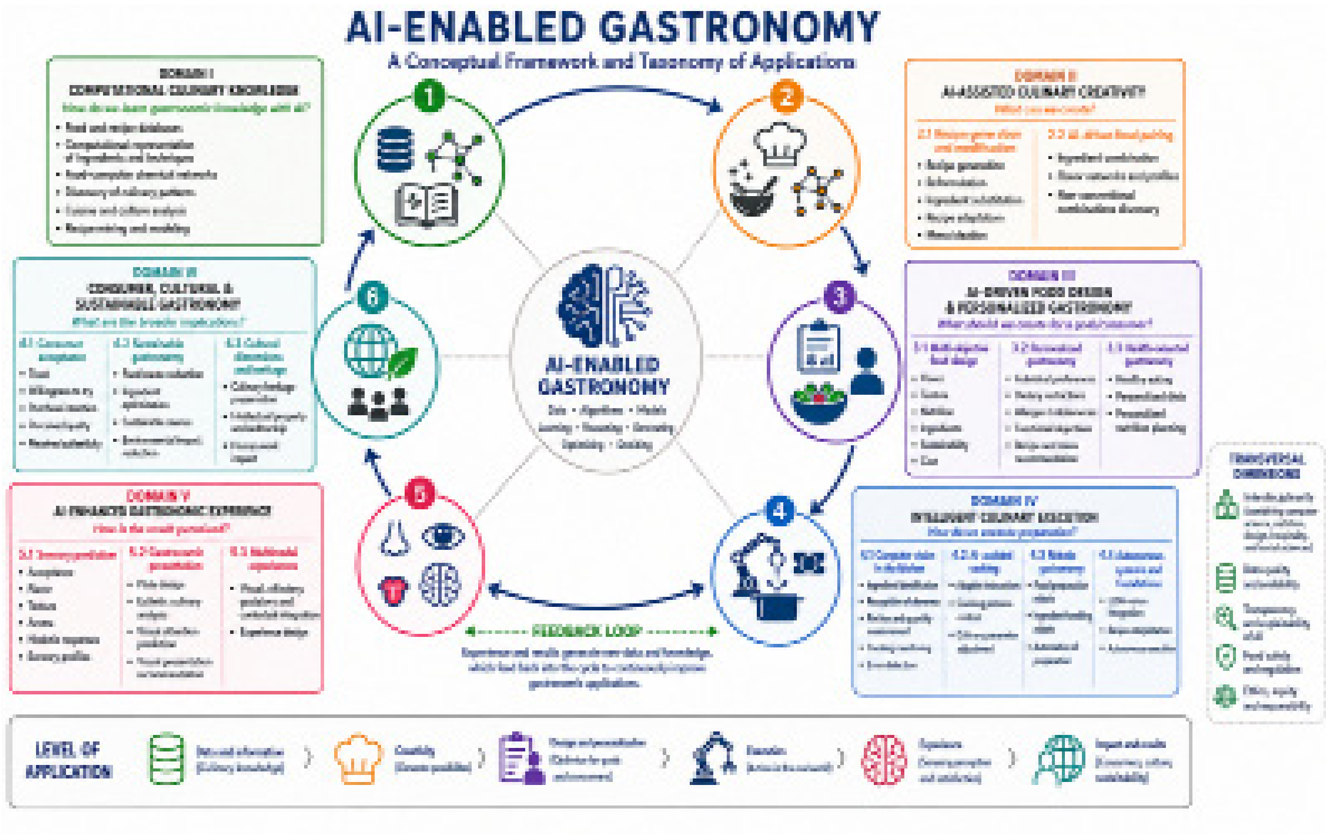

Figure 1. Conceptual framework for AI-Enabled gastronomy and its applications.

Note: Graphic design created using OpenAI ChatGPT (GPT-5.5-mini) based on information provided by the authors. The use of artificial intelligence was limited to the visual representation and aesthetic optimization of the figure; the scientific content, analysis, and interpretation are the sole responsibility of the authors.

2024).

One of the first challenges in computational gastronomy was the transformation of culinary knowledge into structured information. Recipes contain multiple layers of information, including ingredient selection, quantities, preparation sequences, cultural context, and sensory expectations. The computational representation of these elements allows researchers to investigate culinary systems beyond individual recipes, identifying patterns associated with ingredient combinations, regional cuisines, and flavor structures. In this sense, computational gastronomy does not seek to replace traditional culinary knowledge but rather to create formal representations that allow its analysis through mathematical and computational models (Bagler & Goel, 2024).

A relevant contribution to this field was provided by Ahn et al. (2011), who analyzed thousands of recipes from different cultures and demonstrated that culinary traditions are influenced by distinct patterns of ingredient combinations. Their findings suggested that Western cuisines frequently combine ingredients based on shared flavor compounds, whereas East Asian cuisines often emphasize ingredient contrasts, providing empirical evidence that culinary practices contain detectable structural patterns. This study represented an important milestone by demonstrating that culinary creativity could be investigated using quantitative approaches.

The development of computational gastronomy has therefore established the conceptual foundation for AI applications in food by transforming recipes and ingredients into analyzable data structures. Through this perspective, food becomes not only a cultural and sensory product but also an information system composed of multiple interconnected variables (Bagler & Goel, 2024).

Artificial intelligence as a tool for discovering culinary patterns

The emergence of artificial intelligence has expanded computational gastronomy by introducing algorithms capable of learning complex relationships from large and heterogeneous datasets. Unlike traditional statistical approaches, machine learning methods can identify nonlinear associations among ingredients, sensory attributes, chemical compounds, and consumer preferences (Siddique et al., 2025).

In gastronomy, this capability has been particularly relevant because culinary outcomes depend on multiple interacting factors. Flavor perception, for example, results from complex interactions among volatile compounds, taste molecules, texture, aroma, preparation methods, and contextual factors. AI approaches can integrate these dimensions to generate predictive models and identify relationships that are difficult to detect through conventional culinary experimentation (Park et al., 2021).

One of the most representative examples is FlavorGraph, developed by Park et al. (2021). This computational framework integrated recipe information with food chemical data to construct a large-scale graph representing relationships between ingredients and flavor compounds. Through graph-based learning approaches, the model generated food representations and identified potential ingredient pairings. This contribution demonstrated that AI can provide a scientific basis for exploring culinary creativity by revealing hidden relationships within food systems.

Similarly, natural language processing techniques have enabled the analysis of textual culinary information contained in recipes, menus, and gastronomic descriptions. These approaches allow AI systems to extract semantic relationships, identify cooking patterns, and generate representations of culinary knowledge. Consequently, AI has evolved from a tool for data analysis toward a system capable of interpreting and generating gastronomic information (Oz & Oz, 2025).

From computational gastronomy to AI-enabled gastronomy

The transition from computational gastronomy to AI-enabled gastronomy represents a conceptual shift. While computational gastronomy primarily focuses on understanding and representing culinary knowledge, AI-enabled gastronomy incorporates predictive and generative capabilities that allow systems to participate actively in culinary innovation (del Moral, 2025).

This transformation has been accelerated by advances in deep learning, large language models, and generative artificial intelligence. These technologies enable systems to process multimodal information, including text, images, chemical data, and sensory information, creating new opportunities for recipe generation, food design, personalized gastronomy, and intelligent culinary assistance (Xu et al., 2026).

Generative AI represents a particularly important development because it changes the role of computational systems from analytical observers to creative collaborators. Large language models trained on extensive textual datasets can generate recipes, modify existing formulations, propose ingredient substitutions, and provide culinary recommendations (Rita et al., 2024). However, the generation of a recipe does not necessarily imply the creation of a successful gastronomic product. Culinary quality depends on factors such as sensory acceptability, feasibility of preparation, nutritional composition, cultural appropriateness, and sustainability.

Therefore, the current evolution of AI in gastronomy requires moving beyond the concept of automated recipe generation toward a broader framework of human–AI culinary collaboration, where artificial intelligence supports creativity, optimization, and decision-making while human expertise remains essential for interpretation, cultural adaptation, and sensory evaluation (Kim et al., 2025; Tac et al., 2026).

The AI-enabled gastronomic innovation cycle

Based on recent developments, AI applications in gastronomy can be understood as an interconnected innovation cycle rather than isolated technological solutions. This cycle begins with the computational representation of culinary knowledge and progresses through several stages (Figure 2) (Bagler & Goel, 2024; Pennells et al., 2025).

At the first stage, AI analyzes existing culinary knowledge through databases, graphs, and computational models. At the second stage, it supports creative processes through recipe generation and ingredient combination. Subsequently, AI contributes to food design by optimizing formulations according to nutritional, sensory, and environmental objectives. At later stages, intelligent systems can assist in cooking execution through computer vision and robotics, while sensory and consumer analyses evaluate the success of AI-assisted gastronomic innovations (Kuhl, 2025; Pennells et al., 2025).

This perspective highlights that AI should not be considered a single technology applied to gastronomy but rather an ecosystem of computational approaches influencing different stages of the gastronomic process. Such an integrated view is necessary because current research remains fragmented among food computing, recommendation systems, robotics, sensory science, hospitality studies, and sustainability research (Pennells et al., 2025).

Second, AI systems depend strongly on the quality and diversity of the datasets used for training. Culinary databases may overrepresent certain cultures, ingredients, or gastronomic traditions, potentially limiting the diversity of AI-generated culinary solutions. Therefore, future developments require more inclusive datasets capable of representing global gastronomic diversity (Cao et al., 2024; Kuhl, 2025).

Third, the evaluation of AI-generated culinary innovations requires multidisciplinary validation. Computational performance alone is insufficient; successful AI applications should be assessed through sensory evaluation, consumer studies, nutritional analysis, sustainability assessment, and real-world culinary implementation (Motoki et al., 2025; Şener & Ulu, 2024; Tac et al., 2026).

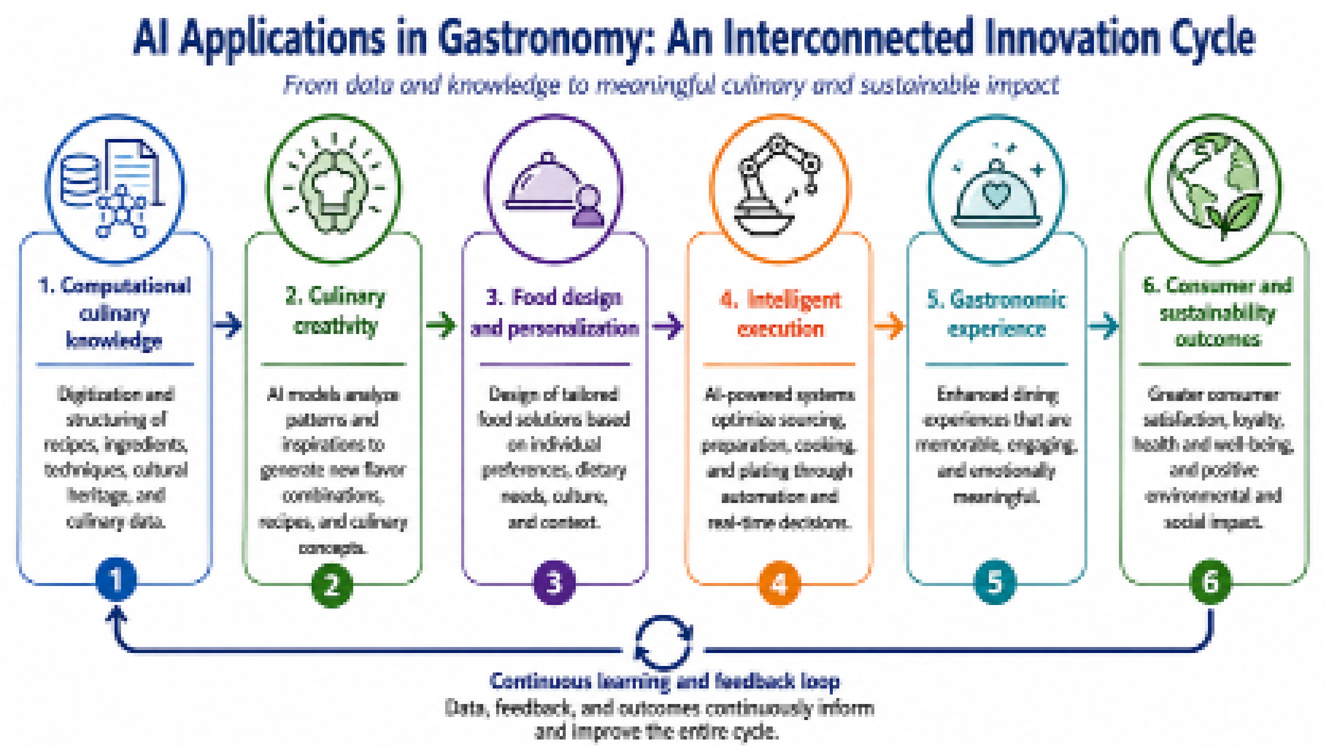

Figure 2. Interconnected innovation cycle of artificial intelligence in gastronomy.
Note: Graphic design created using OpenAI ChatGPT (GPT-5.5-mini) based on information provided by the authors. The use of artificial intelligence was limited to the visual representation and aesthetic optimization of the figure; the scientific content, analysis, and interpretation are the sole responsibility of the authors.

Challenges in defining AI-assisted gastronomy

Despite significant technological advances, several conceptual and methodological challenges remain. First, the ability of AI systems to generate culinary outputs does not necessarily equate to creativity in the human sense. Human culinary creativity involves intention, cultural knowledge, emotional expression, and contextual understanding, dimensions that remain difficult to reproduce computationally (Şener & Ulu, 2024).

Consequently, AI-enabled gastronomy should be understood not as the replacement of culinary expertise but as an emerging field where computational intelligence interacts with human creativity, sensory knowledge, and cultural understanding. This perspective provides the conceptual basis for analyzing the specific applications of AI across the six domains proposed in this review (Kuhl, 2025; McGuire et al., 2024).

AI-assisted culinary creativity: from recipe generation to computational flavor discovery

Artificial intelligence as a creative partner in gastronomy

Creativity represents one of the defining characteristics of gastronomy and constitutes the foundation of culinary innovation. Traditionally, the creation of new dishes has depended on the chef's expertise, sensory memory, cultural knowledge, and ability to transform available ingredients into meaningful gastronomic experiences. Culinary creativity is therefore not limited to the combination of ingredients but involves a complex process of ideation, experimentation, evaluation, and adaptation influenced by cultural, technical, and sensory factors (Ekincek & Günay, 2023).

The incorporation of artificial intelligence into gastronomic creativity introduces a new paradigm in which computational systems can assist, expand, and challenge traditional creative processes. Rather than replacing human creativity, AI-based systems can function as collaborative tools capable of exploring large solution spaces, identifying non-obvious relationships, and generating alternatives that may stimulate human innovation. This approach aligns with the concept of augmented creativity, in which computational systems enhance human capabilities by providing new forms of information processing and idea generation (Davis et al., 2016).

In gastronomy, AI-assisted creativity is particularly relevant because culinary innovation involves navigating highly complex combinations of variables. A chef designing a new dish must simultaneously consider ingredient compatibility, flavor balance, texture, preparation feasibility, cultural expectations, nutritional aspects, and consumer preferences. AI systems can support this process by analyzing extensive culinary datasets and identifying patterns that may not be evident through individual experience alone (Bagler & Goel, 2024).

Therefore, the role of AI in culinary creativity should be understood as a transition from individual culinary intuition toward human–AI co-creation, where computational systems provide exploratory capacity while chefs contribute contextual understanding, sensory judgment, and cultural interpretation (Kuhl, 2025; McGuire et al., 2024).

AI-generated recipes and computational culinary ideation

One of the most visible applications of AI in gastronomy is automatic recipe generation. Early computational approaches focused mainly on recommending recipes based on existing databases, ingredient availability, or user preferences, while subsequent generative systems demonstrated the feasibility of automatically producing ingredients and cooking instructions from structured culinary information (Lee et al., 2020; Bondevik et al., 2024; Bagler & Goel, 2024). However, recent advances in natural language processing and generative artificial intelligence have enabled systems capable of producing original recipe concepts, modifying existing formulations, and suggesting alternative preparation strategies (Bagler & Goel, 2024; Zhou et al., 2025).

Recipe generation systems generally rely on large collections of culinary texts, including recipes, ingredient lists, preparation instructions, and gastronomic descriptions. Through machine learning and language modeling approaches, these systems learn statistical relationships between ingredients, cooking methods, and recipe structures. As a result, AI models can generate novel combinations while maintaining certain levels of culinary coherence (Lee et al., 2020; Bagler & Goel, 2024).

Large language models have significantly expanded these capabilities because they can process contextual information and generate human-like culinary descriptions. Recent studies have demonstrated that generative models can assist in recipe creation, ingredient substitution, and culinary adaptation by using learned patterns from extensive food-related datasets (Song & Li, 2026; Morales-Garzón et al., 2025; Senath et al., 2025; Zhou et al., 2025). These systems have potential applications in professional kitchens, culinary education, food innovation laboratories, and personalized consumer services.

Nevertheless, recipe generation presents important limitations. A computationally plausible recipe does not necessarily correspond to a successful gastronomic product. AI systems may generate combinations that are linguistically coherent but technically unrealistic, difficult to prepare, culturally inappropriate, or sensory unacceptable. Consequently, computational evaluation should be complemented by human, sensory, and consumer validation (Şener & Ulu, 2024; Motoki et al., 2025; Tac et al., 2026). This requirement has already begun to be addressed experimentally: Tac et al. produced AI-generated foods and evaluated them with 101 consumers in a restaurant setting, demonstrating the importance of linking computational generation with actual sensory performance. Therefore, human evaluation and experimental validation remain essential components of AI-assisted culinary creativity.

AI-driven ingredient combination and food pairing

Among AI applications in gastronomy, food pairing represents one of the most scientifically established areas. The central premise of food pairing research is that ingredient compatibility can be partially explained by relationships among chemical compounds, sensory attributes, and culinary traditions (Ahn et al., 2011; Park et al., 2021).

A landmark contribution was provided by Ahn et al. (2011), who developed a flavor network based on the analysis of recipes and chemical compound data. Their study demonstrated that Western cuisines frequently combine ingredients sharing common flavor compounds, whereas some Asian culinary traditions tend to avoid excessive overlap and emphasize contrasting flavor profiles. This work provided quantitative evidence that culinary practices contain underlying structures that can be analyzed computationally.

Building upon these concepts, Park et al. (2021) developed FlavorGraph, a large-scale food–chemical graph integrating millions of recipes with flavor molecule information. Using graph-based representation learning, the authors demonstrated that AI models could generate meaningful representations of foods and identify potential ingredient pairings. This approach represents an important advance because it moves beyond simple recipe similarity toward a deeper understanding of flavor relationships. AI-driven food pairing has several potential applications, including the discovery of unconventional ingredient combinations, the development of innovative recipes, the exploration of regional culinary traditions, the creation of novel flavor profiles, and the provision of support for chefs during menu development.

However, food pairing algorithms should not be interpreted as autonomous creators of culinary meaning. Flavor compatibility is only one dimension of gastronomy, and successful dishes also depend on texture, appearance, cultural context, preparation technique, and emotional response (Kuhl, 2025; Pieroni, 2023).

AI-assisted recipe modification and ingredient substitution

Another important application within culinary creativity is recipe modification. Unlike recipe generation, which aims to create new culinary concepts, recipe modification focuses on adapting existing preparations according to specific objectives or constraints. AI systems can support recipe modification by replacing unavailable ingredients, adapting formulations to dietary restrictions, reducing allergen content, improving nutritional composition, incorporating more sustainable ingredients, and maintaining sensory similarity after reformulation (Morales-Garzón et al., 2025; Oz & Oz, 2025; Senath et al., 2025).

Ingredient substitution is particularly challenging because ingredients perform multiple simultaneous functions in food systems. For example, replacing wheat flour, sugar, fat, or eggs may affect not only flavor but also structure, texture, moisture retention, and consumer acceptance. Consequently, AI-based substitution systems require integration of culinary knowledge, food chemistry, and sensory information (Oz & Oz, 2025; Senath et al., 2025).

Recent developments in computational recipe intelligence suggest that future systems will increasingly incorporate multimodal information, including textual descriptions, ingredient functionality, nutritional databases, and sensory attributes, allowing more accurate and context-aware recipe adaptation (Song & Li, 2026).

Human–AI co-creation in culinary innovation

The emergence of AI-assisted creativity raises fundamental questions regarding authorship and the role of chefs in future gastronomy. Although generative systems can produce novel culinary proposals, creativity in gastronomy involves more than generating combinations. Culinary creativity includes intention, cultural interpretation, emotional communication, and the ability to transform food into meaningful experiences (del Moral, 2025; Kuhl, 2025).

Consequently, the most plausible future scenario is not the replacement of chefs by AI systems but the development of collaborative models in which humans and artificial intelligence contribute complementary capabilities. AI can provide extensive exploration of possibilities, rapid analysis of culinary information, and generation of alternatives, whereas chefs provide sensory evaluation, cultural awareness, ethical judgment, and experiential knowledge (McGuire et al., 2024; Kuhl, 2025).

This perspective is consistent with emerging evidence showing that consumers continue to attribute important value to human involvement in food creation. Kim et al. (2025) demonstrated that perceptions of AI involvement influence consumer responses toward AI-generated food, suggesting that transparency, trust, and the perceived preservation of human expertise will be critical factors in the adoption of AI-assisted gastronomy.

Limitations and future perspectives of AI-assisted culinary creativity

Despite significant advances, several challenges limit the widespread implementation of AI in culinary creativity. First, current models depend heavily on the quality and representativeness of culinary datasets. Many available databases may not adequately represent global gastronomic diversity, potentially reinforcing cultural biases (Cao et al., 2024; Kuhl, 2025).

Second, AI evaluation remains insufficiently standardized. The success of a generated recipe cannot be determined exclusively by computational metrics such as similarity, coherence, or prediction accuracy. Gastronomic innovation requires sensory evaluation, expert assessment, consumer acceptance studies, and validation under realistic culinary conditions (Motoki et al., 2025; Tac et al., 2026).

Third, the relationship between AI-generated novelty and genuine creativity remains an open scientific question. Future research should investigate whether AI systems merely recombine existing culinary knowledge or whether they can contribute to genuinely innovative gastronomic concepts (Kuhl, 2025; Şener & Ulu, 2024).

Overall, AI-assisted culinary creativity represents one of the most promising areas of AI-enabled gastronomy. By expanding the exploration space of culinary possibilities while maintaining human sensory and cultural judgment, AI may become a powerful instrument for the development of new gastronomic experiences (Şener & Ulu, 2024; Kuhl, 2025).

AI-driven food design and personalized gastronomy: from computational creativity to optimized culinary solutions

From recipe generation to intelligent food design

The evolution of artificial intelligence in gastronomy has progressively shifted from the generation of culinary ideas toward the systematic design and optimization of food solutions. While recipe generation focuses primarily on creating plausible combinations of ingredients and preparation procedures, food design involves a more complex process in which multiple attributes must be simultaneously considered, including sensory quality, nutritional composition, technological functionality, sustainability, economic feasibility, and consumer acceptance (Song & Li, 2026; Tac et al., 2026).

In conventional food development, the creation of new products generally follows iterative experimental approaches involving formulation, sensory evaluation, physicochemical characterization, and reformulation. Although effective, these approaches are frequently time-consuming and require extensive resources. AI-driven food design introduces a data-based alternative by integrating information from food composition databases, consumer preferences, sensory studies, and technological parameters to predict and optimize potential formulations (Song & Li, 2026).

This transformation represents an important conceptual change: AI is no longer used only to answer “what recipe can be created?”, but rather “what food solution best satisfies a defined set of objectives?”. Consequently, AI-driven food design represents the convergence between computational creativity, food science, and decision optimization (Song & Li, 2026).

AI-assisted optimization of food formulations

Food design is inherently a multi-objective optimization problem because improving one attribute may negatively affect another. For example, increasing nutritional density may alter sensory properties, reducing environmental impact may require ingredient substitution, and modifying functional components may influence texture or consumer acceptance (Song & Li, 2026; Tac et al., 2026).

AI methods, particularly machine learning algorithms, deep neural networks, and optimization models, can analyze relationships between formulation variables and product outcomes. These approaches allow researchers to predict how changes in ingredients or processing conditions may influence sensory, nutritional, and technological characteristics (Pennells et al., 2025; Fernandes & Rodrigues, 2026).

Recent developments in computational recipe intelligence highlight that AI systems are increasingly capable of integrating heterogeneous information sources, including ingredient functionality, nutritional composition, preparation methods, and sensory descriptors, to support formulation decisions (Song & Li, 2026).

Such approaches may accelerate the development of innovative foods by reducing experimental cycles and identifying promising formulations before physical production. Table 1 shows the potential applications in computational recipe intelligence. However, AI-based optimization does not eliminate the need for experimental validation. Food systems are complex biological matrices, and predicted performance must be confirmed through physicochemical, sensory, and consumer studies (Motoki et al., 2025; Tac et al., 2026).

Table 1. Applications of artificial intelligence for the formulation of innovative and sustainable foods

Application of computational recipe intelligence	Potential contribution of AI-assisted formulation
Optimization of nutritional profiles	Adjusting ingredient proportions to improve protein, fiber, micronutrient, or other nutritional targets while maintaining product quality.
Development of functional foods	Identifying ingredient combinations that enhance functional properties and support the formulation of foods with targeted health-related characteristics.
Reformulation of traditional products	Modifying established formulations while preserving desirable sensory and technological characteristics.
Reduction of undesirable components	Supporting the reduction of components such as excess sugar, sodium, saturated fat, or other undesirable constituents through alternative formulations.
Incorporation of alternative proteins	Identifying suitable plant-based, microbial, or other alternative protein sources and optimizing their proportion in formulations.
Improvement of sustainability indicators	Evaluating ingredient alternatives and formulations according to environmental and resource-efficiency considerations.
Adaptation to specific consumer groups	Designing formulations according to particular nutritional, sensory, dietary, or demographic requirements.

Generative AI for novel food creation

A particularly innovative development within AI-driven food design is the use of generative artificial intelligence for creating novel food products. Unlike conventional optimization algorithms that search for solutions within predefined parameters, generative models can propose new formulations by learning complex patterns from existing food knowledge (Kuhl, 2025; Tac et al., 2026).

Tac et al. (2026) provided experimental evidence of this capability by demonstrating that generative AI could design burger formulations optimized according to different objectives, including taste preference, nutritional characteristics, and environmental sustainability. Importantly, the AI-generated products were physically produced and evaluated through sensory testing, showing that generative models can contribute to real-world food innovation rather than only producing theoretical outputs.

This approach introduces the concept of generative food design, in which AI functions as a creative and analytical partner during product development. Potential applications extend beyond conventional recipes to include the development of sustainable alternative foods, personalized meals tailored to specific dietary or nutritional needs, functional food formulations with targeted health benefits, gastronomic products with optimized sensory profiles, and novel combinations of ingredients and preparation strategies (Kuhl, 2025; Tac et al., 2026).

Nevertheless, the use of generative AI in food design introduces new challenges. Generated formulations may reproduce biases present in training datasets, prioritize computational objectives over cultural relevance, or overlook practical limitations related to availability, cost, and culinary feasibility (Cao et al., 2024; Kuhl, 2025).

Personalized gastronomy: toward individualized culinary experiences

Personalized gastronomy represents another emerging application of AI in which food recommendations and culinary experiences are adapted according to individual characteristics. Unlike traditional personalization approaches based mainly on previous consumption patterns, AI-driven systems can integrate multiple dimensions, including dietary restrictions, health objectives, sensory preferences, lifestyle, and contextual information (Agrawal et al., 2025; Wang et al., 2025).

This concept is closely related to developments in precision nutrition, where AI is increasingly used to analyze complex interactions between dietary patterns, biological characteristics, and health outcomes. Recent reviews have highlighted the potential of AI to integrate personalized health data with food production systems, enabling the development of intelligent food recommendations and individualized nutritional strategies (Agrawal et al., 2025).

Within gastronomy, personalized AI systems may support the generation of individualized menus, adaptive restaurant recommendations, personalized recipes, and the management of dietary restrictions. They may also facilitate nutrition-oriented culinary planning and optimize food choices according to individual consumer goals, preferences, and dietary requirements. For example, a future AI-based gastronomic platform could consider an individual's sensory preferences, nutritional requirements, allergies, cultural background, and environmental priorities to generate personalized culinary experiences (Agrawal et al., 2025).

AI-powered personalization in restaurants and food services

The hospitality and restaurant sectors represent one of the most immediate environments for implementing AI-driven personalization. Restaurants increasingly collect information related to customer preferences, ordering behavior, and consumption patterns, creating opportunities for AI-based recommendation systems (Wang et al., 2025).

AI-powered decision-making systems can analyze customer data to support personalized menus, targeted recommendations, demand forecasting, and service optimization. In the restaurant sector, machine learning approaches have been investigated for improving personalized food recommendations and enhancing customer experiences through data-driven decision-making (Shettigar & Sumangala, 2026).

However, personalization in gastronomy involves a delicate balance between technological efficiency and customer perception. Excessive dependence on algorithmic recommendations may reduce spontaneity, exploration, and the social dimensions traditionally associated with dining experiences. Therefore, AI personalization should enhance consumer choice rather than restrict culinary discovery (Bondevik et al., 2024).

AI, sustainability, and responsible food design

One of the most promising applications of AI-driven food design is the development of more sustainable gastronomic solutions. Food systems face increasing challenges associated with resource consumption, greenhouse gas emissions, food waste, and demand for alternative ingredients. AI can contribute by identifying formulations that balance nutritional quality, sensory acceptance, and environmental performance (Hassoun & Galanakis, 2025; Kuhl, 2025).

AI-assisted approaches may support the reduction of food waste through optimized ingredient utilization and the development of more sustainable menus. They may also facilitate the incorporation of alternative proteins, promote the valorization of food by-products, and optimize the use of resources during food production, thereby contributing to greater resource efficiency and more sustainable food systems (Hassoun & Galanakis, 2025; Kuhl, 2025).

Recent research on AI-enabled food systems has emphasized the potential of artificial intelligence to integrate nutritional objectives with sustainable food production strategies, particularly through intelligent formulation and personalized nutrition approaches (Agrawal et al., 2025). Nevertheless, sustainability assessments should consider the complete life cycle of AI-assisted food systems. The environmental benefits obtained through optimized formulations must be evaluated against the computational requirements and infrastructure associated with AI implementation.

Challenges and future perspectives

Despite its considerable potential, AI-driven food design and personalized gastronomy remain emerging fields with several unresolved challenges (Pennells et al., 2025).

First, the relationship between computational optimization and human sensory perception requires further investigation. A formulation predicted as optimal by an algorithm may not necessarily generate the expected consumer response (Motoki et al., 2025; Tac et al., 2026).

Second, personalized gastronomy requires access to large amounts of individual data, raising concerns regarding privacy, data ownership, and ethical management (Oliveira et al., 2025; Gurel, 2026).

Third, AI systems must become more culturally aware. Gastronomy is strongly connected with identity and traditions; therefore, personalized and generated foods should respect cultural diversity rather than promote standardized culinary solutions (Cao et al., 2024; Kuhl, 2025).

Future research should prioritize the development of integrated AI systems capable of combining the food composition data, sensory science, nutritional information, consumer psychology, sustainability metrics, and cultural knowledge. Ultimately, AI-driven food design and personalized gastronomy represent a transition from mass-oriented food development toward more adaptive, intelligent, and consumer-centered gastronomic systems. Rather than replacing culinary expertise, AI has the potential to expand the capabilities of chefs, food scientists, and gastronomic professionals by enabling evidence-based innovation and personalized culinary experiences (Kuhl, 2025; Pennells et al., 2025).

Intelligent culinary execution: computer vision, AI-assisted cooking, and robotic gastronomy

From computational design to physical culinary execution

The evolution of artificial intelligence in gastronomy has progressed from the digital representation of culinary knowledge and the generation of food concepts to the physical execution of cooking processes. While previous AI applications have primarily focused on understanding recipes, generating culinary ideas, and optimizing food formulations, intelligent culinary execution addresses a different challenge: enabling computational systems to interact with the physical environment and perform, monitor, or assist in gastronomic operations (Sochacki et al., 2024; Pennells et al., 2025).

Cooking represents a particularly complex domain for automation because it involves dynamic processes characterized by uncertainty, variability, and continuous sensory adaptation. Unlike industrial manufacturing environments, where production conditions can be highly standardized, culinary environments involve heterogeneous ingredients, changing physical properties during processing, and decisions traditionally guided by human perception. Consequently, intelligent culinary execution requires the integration of multiple AI capabilities, including computer vision, machine learning, robotic manipulation, sensor fusion, and adaptive control systems (Wang et al., 2022; Sochacki et al., 2024).

The emergence of intelligent culinary systems reflects a transition from AI as a source of culinary knowledge toward AI as an embodied agent capable of interacting with food materials and culinary environments. This development represents one of the most technologically challenging domains within AI-enabled gastronomy because successful cooking requires not only following instructions but also recognizing ingredients, interpreting cooking states, adjusting parameters, and responding to unexpected variations (Wang et al., 2022; Sochacki et al., 2024).

Computer vision for food recognition and cooking process monitoring

Computer vision represents one of the most mature AI technologies applied to culinary environments. Through image acquisition and deep learning algorithms, computer vision systems can identify ingredients, evaluate food appearance, monitor preparation stages, and estimate quality attributes associated with cooking processes (Pennells et al., 2025).

Food recognition systems have been extensively investigated because accurate identification of food items is fundamental for applications such as dietary monitoring, automated inventory management, and intelligent kitchen assistance. Deep learning approaches, particularly convolutional neural networks (CNNs), have demonstrated high performance in recognizing food categories from images despite challenges associated with variations in illumination, presentation style, and cultural diversity of dishes (Bossard et al., 2014; Kawano & Yanai, 2014).

The application of computer vision in gastronomy extends beyond ingredient identification. AI-based imaging systems can monitor changes occurring during cooking, including color development, surface characteristics, browning reactions, and structural transformations. These capabilities are relevant because many culinary decisions traditionally performed through visual assessment by chefs, such as determining cooking degree or product readiness, could potentially be supported by automated systems (Sochacki et al., 2024).

For example, image-based analysis has been applied to evaluate food quality attributes and classify cooking stages, providing opportunities for more consistent preparation and quality control. Such approaches may be particularly valuable in professional kitchens where standardization of culinary outcomes is required (Pennells et al., 2025).

However, computer vision systems face significant limitations. Food appearance is strongly influenced by cultural presentation styles, plating techniques, ingredient variability, and environmental conditions. Therefore, robust culinary vision systems require diverse datasets representing different cuisines, preparation methods, and gastronomic contexts (Wang et al., 2022; Pennells et al., 2025).

AI-assisted cooking systems and intelligent kitchen environments

Beyond perception, AI technologies are increasingly being integrated into intelligent kitchen environments designed to assist human cooks during food preparation. These systems combine multiple information sources, including recipe databases, sensors, computer vision, and predictive models, to provide real-time guidance and adaptive recommendations (Sochacki et al., 2024; Pennells et al., 2025).

Unlike conventional automated cooking devices that execute predefined programs, AI-assisted cooking systems have the potential to dynamically adjust processes according to observed conditions. For example, an intelligent cooking assistant may modify temperature, cooking time, or ingredient proportions based on the detected state of a preparation (Sochacki et al., 2024).

This capability represents an important distinction between automation and intelligence. Automation follows predetermined instructions, whereas intelligent systems incorporate perception, learning, and adaptation. In gastronomy, this distinction is essential because cooking frequently requires contextual decisions rather than simple procedural execution (Sochacki et al., 2024).

Research in human–robot interaction has demonstrated that collaborative systems can support complex tasks by combining robotic precision with human cognitive abilities. Within culinary environments, this principle suggests that future kitchens may involve cooperative models where AI systems handle repetitive, precise, or physically demanding tasks while chefs focus on creativity, sensory evaluation, and decision-making (McGuire et al., 2024; Sochacki et al., 2024).

Robotic gastronomy: toward autonomous food preparation

Robotic gastronomy represents the most advanced manifestation of intelligent culinary execution, integrating artificial intelligence with mechanical systems capable of manipulating food. Unlike industrial food robots designed for repetitive manufacturing tasks, culinary robots must operate in highly variable environments where ingredients differ in shape, texture, moisture content, and mechanical properties (Wang et al., 2022; Sochacki et al., 2024).

One of the pioneering examples of robotic cooking was developed by Moley Robotics, which introduced a robotic kitchen concept capable of reproducing cooking movements learned from human chefs. Although still limited compared with human culinary expertise, such systems demonstrated the feasibility of combining robotic manipulation with culinary knowledge (Sochacki et al., 2024).

Academic research has also explored robotic systems capable of food manipulation, preparation, and assembly. These systems commonly rely on computer vision for object recognition, robotic arms for manipulation, and machine learning algorithms for task optimization. The development of robotic cooking has been particularly investigated in contexts such as automated meal preparation, assistive technologies for elderly populations, and professional kitchen automation (Wang et al., 2022; Sochacki et al., 2024).

Nevertheless, fully autonomous robotic cooking remains challenging. Food materials are deformable, unpredictable, and highly variable. Manipulating dough, cutting vegetables, handling fragile ingredients, or controlling cooking transformations requires advanced perception and dexterity. Consequently, current robotic systems are better understood as assistants rather than replacements for professional chefs (Wang et al., 2022; Sochacki et al., 2024).

AI for culinary precision, reproducibility, and quality control

A significant contribution of intelligent culinary execution is the possibility of improving reproducibility and consistency in food preparation. Professional gastronomy frequently faces challenges related to variability between chefs, shifts, and locations. AI-assisted systems may reduce such variability by monitoring critical parameters and providing standardized execution protocols (Sochacki et al., 2024; Pennells et al., 2025).

In this context, AI can contribute to a precise control of cooking parameters, monitoring of food transformation, standardization of recipes across multiple locations, reduction of preparation errors, and optimization of resource utilization. These applications are particularly relevant for restaurant chains, institutional food services, and gastronomic enterprises seeking consistency without eliminating culinary identity (Sochacki et al., 2024; Pennells et al., 2025).

Furthermore, AI-assisted monitoring systems may contribute to food safety by detecting deviations in preparation processes, identifying contamination risks, and ensuring compliance with standardized procedures. Although food safety applications have been more extensively studied in industrial food systems, similar principles can be transferred to intelligent culinary environments (Hassoun & Galanakis, 2025; Pennells et al., 2025).

Challenges of intelligent culinary execution

Despite technological advances, intelligent culinary execution faces considerable scientific and practical limitations (Wang et al., 2022; Sochacki et al., 2024).

First, cooking involves complex physical transformations that are difficult to model computationally. Changes in texture, aroma development, heat transfer, and ingredient interactions require sophisticated predictive models integrating food science and artificial intelligence (Wang et al., 2022; Sochacki et al., 2024).

Second, robotic manipulation of food remains technically challenging because food materials are soft, variable, and often fragile. Unlike rigid industrial components, foods require adaptive handling strategies (Wang et al., 2022).

Third, the implementation of AI systems in professional kitchens raises questions regarding the preservation of craftsmanship and culinary identity. Gastronomy is not only a technical process but also an artistic and cultural activity. Excessive automation could potentially reduce the experiential and human dimensions that contribute to gastronomic value (del Moral, 2025; Kim et al., 2025).

Therefore, the future of intelligent culinary execution will likely depend on collaborative approaches rather than complete automation. Human–AI culinary systems may provide the greatest benefits by combining computational precision with human creativity, sensory expertise, and cultural understanding (Sochacki et al., 2024; Kuhl, 2025).

Future perspectives: toward the intelligent kitchen

The future intelligent kitchen will likely integrate multiple AI technologies into a unified ecosystem capable of perceiving, reasoning, and acting. Such systems may combine computer vision for food recognition, predictive models for cooking optimization, robotic manipulation, digital twins of culinary processes, sensory prediction models, and personalized consumer information. This evolution may transform kitchens from passive environments into adaptive computational spaces where AI assists decision-making throughout the culinary process (Sochacki et al., 2024; Pennells et al., 2025).

However, the ultimate objective should not be the replacement of chefs but the creation of enhanced culinary environments where technology expands human capabilities. Intelligent culinary execution, therefore, does not represent the automation of gastronomy but the emergence of a new model of augmented culinary practice, where artificial intelligence and human expertise interact to produce more consistent, innovative, and personalized gastronomic experiences (Sochacki et al., 2024; Kuhl, 2025).

AI-enhanced gastronomic experience: sensory science, consumer perception, and human–AI interaction

The gastronomic experience as a multidimensional phenomenon

The success of a gastronomic innovation cannot be determined exclusively by technological performance, nutritional composition, or computational optimization. Food consumption represents a complex human experience in which sensory perception, emotions, cultural identity, social interactions, expectations, and contextual factors interact to determine acceptance and appreciation. Therefore, the integration of artificial intelligence into gastronomy must consider not only how food is created or prepared, but also how it is experienced by individuals (Velasco et al., 2021; Pieroni, 2023).

Traditional sensory science has demonstrated that food perception results from interactions between objective food properties and subjective consumer responses. Attributes such as aroma, taste, texture, appearance, and mouthfeel influence acceptance, but these perceptions are also modulated by psychological and contextual factors, including previous experiences, cultural background, and expectations (Velasco et al., 2021). Consequently, AI applications in gastronomy require approaches capable of integrating both measurable food characteristics and complex human responses.

In this context, AI-enhanced gastronomic experience refers to the application of artificial intelligence to understand, predict, personalize, and improve interactions between consumers and food. This domain includes sensory prediction, consumer preference modeling, intelligent recommendation systems, adaptive dining experiences, and analysis of human responses toward AI-generated or AI-assisted foods (Nunes et al., 2023; Motoki et al., 2025).

Artificial intelligence and sensory prediction

Sensory evaluation has traditionally depended on trained panels and consumer studies, which provide valuable information but are often expensive, time-consuming, and difficult to apply during early stages of product development. AI-based approaches offer the possibility of predicting sensory attributes by integrating physicochemical information, chemical composition, processing parameters, and consumer data (Nunes et al., 2023; Motoki et al., 2025).

Machine learning models can identify relationships between instrumental measurements and sensory perceptions, enabling predictions of attributes such as sweetness, bitterness, aroma intensity, texture characteristics, and overall acceptability. These approaches are particularly relevant in food development because they can accelerate formulation processes by identifying promising products before extensive sensory testing (Nunes et al., 2023).

The integration of sensory science and AI represents a transition from descriptive evaluation toward predictive gastronomy. Instead of assessing consumer response only after a product has been developed, AI systems may contribute to anticipating sensory outcomes during the design phase (Nunes et al., 2023; Motoki et al., 2025).

However, sensory perception remains one of the greatest challenges for AI because human responses are influenced by individual variability and contextual factors. A model trained on sensory data may accurately predict average consumer responses but may fail to capture emotional, cultural, or experiential dimensions of food perception (Velasco et al., 2021; Motoki et al., 2025).

AI-based consumer preference modeling and personalized gastronomic experiences

One of the most relevant applications of AI in gastronomy is the prediction and personalization of consumer preferences.

Modern food environments generate large amounts of data through online ordering platforms, restaurant interactions, social media, and digital food applications. AI systems can analyze these data sources to identify consumption patterns and generate personalized recommendations (Bondevik et al., 2024).

Unlike conventional recommendation systems based only on previous purchases, AI-based gastronomic personalization can integrate multiple variables, including sensory preferences, dietary restrictions, nutritional objectives, cultural background, previous experiences, and environmental preferences. This capability creates opportunities for personalized gastronomic experiences in restaurants, digital food platforms, and healthcare-oriented nutrition systems (Agrawal et al., 2025; Wang et al., 2025).

In hospitality environments, AI-driven recommendation systems may assist customers in selecting dishes according to their preferences or dietary requirements. Similarly, restaurants may use predictive models to design menus adapted to specific consumer profiles, improving satisfaction and reducing food waste (Wang et al., 2025).

Nevertheless, personalization introduces important questions regarding consumer autonomy. Excessive algorithmic filtering may reduce exposure to culinary diversity by continuously recommending options similar to previous choices. Therefore, AI personalization should balance optimization with exploration, allowing consumers to discover new gastronomic experiences (Bondevik et al., 2024).

AI, authenticity, and consumer acceptance of AI-generated food

A central challenge in AI-enabled gastronomy is the relationship between technological innovation and perceived authenticity. Food consumption is not only a physiological process but also a cultural and emotional experience. Consumers frequently associate culinary value with human creativity, craftsmanship, tradition, and authenticity (Pieroni, 2023; Kim et al., 2025).

Therefore, the acceptance of AI-generated or AI-assisted foods depends not only on product quality but also on perceptions regarding the role of artificial intelligence in the creative process. Recent studies in hospitality and food service indicate that consumers may evaluate AI-generated foods differently depending on whether AI is perceived as a supportive tool or as a replacement for human culinary expertise (Kim et al., 2025).

This distinction is particularly important in gastronomy because chefs are traditionally associated with creativity, identity, and emotional connection. A dish created with AI assistance may be accepted when consumers perceive AI as enhancing human creativity, but resistance may occur when technology is considered a substitute for human involvement (Kim et al., 2025; Kuhl, 2025).

Consequently, transparency regarding AI participation, communication strategies, and preservation of human involvement will likely become essential factors in the adoption of AI-assisted gastronomy (Kim et al., 2025).

Multimodal AI and the future of gastronomic interaction

Recent advances in multimodal artificial intelligence provide new opportunities for creating interactive gastronomic experiences. These systems can integrate different types of information, including text, images, sensory descriptions, consumer feedback, and contextual data (Pennells et al., 2025; Xu et al., 2026).

In future gastronomic environments, AI systems may function as intelligent culinary assistants capable of interacting with consumers throughout the dining experience. Examples include conversational systems recommending dishes according to preferences; adaptive menus responding to consumer feedback; AI-generated explanations of culinary heritage; personalized nutritional guidance; and interactive dining experiences combining food and digital storytelling (Pennells et al., 2025; Xu et al., 2026).

Such applications may redefine the relationship between consumers and food by transforming meals from static experiences into dynamic interactions (Motoki et al., 2025; Xu et al., 2026).

However, the implementation of these systems requires careful consideration of privacy, data management, and the balance between technological mediation and authentic human experiences (Kim et al., 2025; Gurel, 2026).

AI-enhanced gastronomy and emotional dimensions of food

Although AI has demonstrated strong capabilities in pattern recognition and prediction, emotional aspects of gastronomy remain difficult to computationally represent. Food experiences involve memories, cultural meanings, social relationships, and personal narratives that cannot be completely reduced to measurable variables (Velasco et al., 2021, Kuhl, 2025).

For this reason, future AI applications should move beyond purely functional optimization and incorporate broader concepts of human experience. Gastronomic success should not be evaluated only through computational accuracy but also through emotional satisfaction, cultural relevance, and social value (Kuhl, 2025; Motoki et al., 2025).

The integration of AI with sensory science, consumer psychology, and gastronomic studies may provide a more complete understanding of food experiences. Such interdisciplinary approaches will be essential for developing AI systems that enhance rather than simplify human relationships with food (Figure 3) (Kuhl, 2025; Motoki et al., 2025).

Figure 3. Interdisciplinary framework for human-centered AI in gastronomy.
Note: Graphic design created using OpenAI ChatGPT (GPT-5.5-mini) based on information provided by the authors. The use of artificial intelligence was limited to the visual representation and aesthetic optimization of the figure; the scientific content, analysis, and interpretation are the sole responsibility of the authors.

Future research should therefore focus on developing AI systems that combine predictive capability with human-centered design principles. The objective should not be to automate gastronomic experiences but to create intelligent environments capable of enriching sensory perception, personalization, and interaction (Kuhl, 2025; Motoki et al., 2025).

Overall, an AI-enhanced gastronomic experience represents the stage where computational intelligence meets human perception. After assisting in culinary creativity, food design, and cooking execution, AI must ultimately demonstrate its value through the most important criterion in gastronomy: the human experience of food (Velasco et al., 2021; Kuhl, 2025).

Consumer, cultural, and sustainable gastronomy: ethical challenges and future directions of AI in food experiences

Beyond technological performance: the human dimension of AI-enabled gastronomy

The integration of artificial intelligence into gastronomy cannot be evaluated exclusively according to technological efficiency, predictive accuracy, or innovation potential. Food is a complex cultural artifact in which biological, social, emotional, and symbolic dimensions converge. Therefore, the long-term success of AI-assisted gastronomy will depend not only on the capacity of algorithms to generate recipes, optimize formulations, or automate culinary processes, but also on their ability to preserve and enhance the human meanings associated with food (Pieroni, 2023; Kuhl, 2025).

Historically, gastronomy has functioned as a mechanism for cultural expression, identity construction, and social interaction. Culinary practices transmit collective memories, geographical knowledge, and traditions developed across generations. Consequently, the incorporation of AI into food systems introduces a fundamental question: how can computational intelligence contribute to gastronomic innovation without reducing food experiences to purely algorithmic outputs? (Pieroni, 2023)

This challenge distinguishes gastronomy from other technological domains. While AI can optimize measurable variables such as nutritional composition, ingredient compatibility, or consumer preference prediction, gastronomic value also emerges from intangible dimensions, including authenticity, craftsmanship, cultural narratives, and emotional connection. Therefore, AI-enabled gastronomy requires a human-centered approach in which technological capabilities are integrated with cultural knowledge and sensory experience (Pieroni, 2023; Kuhl, 2025).

Consumer acceptance and trust in AI-assisted gastronomy

Consumer acceptance represents one of the main determinants of the future adoption of AI applications in gastronomy. Although AI technologies have demonstrated significant capabilities in food creation, recommendation, and personalization, consumer perceptions regarding the role of artificial intelligence remain complex and sometimes contradictory (Kim et al., 2025; Wang et al., 2025).

Acceptance of AI-generated or AI-assisted foods depends on multiple factors, including perceived usefulness, trust, transparency, perceived control, and the degree of human involvement in the culinary process. In gastronomic contexts, consumers may appreciate AI when it is perceived as a tool that enhances creativity, improves personalization, or supports chefs; however, acceptance may decrease when AI is interpreted as replacing human expertise and culinary craftsmanship (Kim et al., 2025; Wang et al., 2025).

Recent studies have demonstrated that the perceived role of AI in food preparation influences consumer responses. Kim et al. (2025) reported that consumers evaluate AI involvement in culinary production not only according to the final product but also according to perceptions of authenticity, human contribution, and the symbolic meaning of food creation. These findings highlight that technological acceptance in gastronomy involves both functional and emotional dimensions.

Therefore, the successful implementation of AI in restaurants and food services will require communication strategies that emphasize collaboration between humans and machines rather than technological substitution. The future gastronomic experience may depend on establishing a balance in which AI provides computational capabilities while chefs remain central actors responsible for creativity, interpretation, and cultural adaptation (Kim et al., 2025; Kuhl, 2025).

Cultural heritage and the preservation of gastronomic diversity

One of the most significant opportunities of AI in gastronomy is its potential contribution to the documentation, preservation, and dissemination of culinary heritage. Traditional gastronomic knowledge is frequently transmitted orally and through practical experience, making it vulnerable to loss due to globalization, social changes, and declining intergenerational transmission (Pieroni, 2023; Bagler & Goel, 2024).

AI-based systems can contribute to the digital preservation of culinary traditions by analyzing recipes, historical documents, images, and cultural information. Natural language processing and knowledge representation techniques may enable the creation of digital repositories capable of capturing relationships between ingredients, preparation methods, geographic origins, and cultural meanings (Bagler & Goel, 2024; Pennells et al., 2025).

Computational gastronomy has already demonstrated that culinary practices contain measurable patterns associated with cultural traditions and ingredient relationships. Ahn et al. (2011) showed that different culinary cultures exhibit distinct structures in ingredient combinations, suggesting that computational analysis can reveal characteristics of gastronomic identity.

However, the application of AI to cultural gastronomy requires caution. Culinary traditions cannot be fully represented by ingredient lists or recipe structures because they involve social practices, historical contexts, symbolic meanings, and local knowledge. Therefore, AI systems should function as tools for documentation and support rather than as mechanisms for standardizing or replacing traditional culinary practices (Pieroni, 2023; Cao et al., 2024).

An important future direction involves the development of culturally aware AI systems capable of recognizing regional diversity and avoiding the homogenization of global gastronomy. Such systems should incorporate diverse datasets representing underrepresented cuisines and communities, ensuring that AI contributes to the preservation rather than the erosion of gastronomic heritage (Cao et al., 2024; Kuhl, 2025).

Sustainable gastronomy and the role of artificial intelligence

Sustainability has become a central challenge for global food systems, requiring transformations in production, consumption, and waste management practices. Gastronomy, as an interface between food production and consumption, has an important role in promoting sustainable behaviors through ingredient selection, menu development, and culinary innovation (Hassoun & Galanakis, 2025; Kuhl, 2025).

AI offers several opportunities to support sustainable gastronomy by enabling data-driven decision-making throughout the food chain. Potential applications include the optimization of ingredient utilization; reduction of food waste; prediction of consumer demand; development of sustainable menus; identification of alternative ingredients; valorization of food by-products; and optimization of resource consumption (Hassoun & Galanakis, 2025; Pennells et al., 2025).

Within food design, AI can assist in creating formulations that balance sensory quality, nutritional value, and environmental performance. The work of Tac et al. (2026) represents an example of this approach, demonstrating that generative AI can contribute to designing food products optimized according to multiple objectives, including sustainability-related criteria.

Similarly, AI-driven recommendation systems may support consumers in making environmentally conscious choices by incorporating information about carbon footprint, ingredient origin, seasonality, and nutritional characteristics. In restaurants, predictive analytics can reduce overproduction by improving demand forecasting and inventory management (Bondevik et al., 2024).

Nevertheless, the sustainability contribution of AI must be evaluated critically. Artificial intelligence systems require computational infrastructure, energy consumption, and extensive data processing. Therefore, the environmental benefits generated through optimized food systems should be assessed considering the complete life cycle of AI implementation (de Vries, 2023; Kuhl, 2025).

Ethical considerations: authorship, transparency, and responsibility

The integration of AI into gastronomy introduces new ethical challenges related to authorship, intellectual property, responsibility, and transparency. Traditional culinary innovation is strongly associated with individual or collective creativity, raising questions regarding the ownership of AI-generated recipes, dishes, and gastronomic concepts (del Moral, 2025; Gurel, 2026).

If an AI system generates a novel recipe based on thousands of existing culinary examples, determining authorship becomes complex. The contribution of the algorithm, the dataset creators, the software developers, and the human culinary professionals involved in the process must be considered (del Moral, 2025; Gurel, 2026).

Furthermore, transparency regarding AI participation may influence consumer trust. Diners may expect to know whether a dish was created entirely by a chef, generated with AI assistance, or produced through automated systems. Clear communication may become essential to prevent misconceptions and preserve consumer confidence (Kim et al., 2025).

Another ethical concern involves algorithmic bias. Since AI systems learn from existing datasets, they may reproduce inequalities present in those datasets. For gastronomy, this could result in the underrepresentation of certain cultures, ingredients, or culinary traditions. Ensuring diversity and inclusivity in training datasets will therefore be essential for responsible AI development (Cao et al., 2024; Kuhl, 2025).

The future of human–AI collaboration in gastronomy

The future of AI-enabled gastronomy will likely not be characterized by autonomous systems replacing chefs or traditional culinary practices. Instead, the most realistic scenario is the emergence of collaborative models in which AI expands human capabilities (McGuire et al., 2024; Kuhl, 2025).

In this paradigm, chefs, food scientists, gastronomes, and consumers interact with intelligent systems that provide analytical support, creative inspiration, personalization, and optimization. AI may become a new type of culinary instrument, comparable to previous technological innovations that transformed gastronomy without eliminating human creativity (McGuire et al., 2024; Kuhl, 2025).

Future AI-assisted gastronomic ecosystems may integrate computational culinary knowledge, generative food design, intelligent cooking systems, and sensory prediction to support increasingly sophisticated approaches to culinary innovation. They may also incorporate personalized nutrition and sustainable decision-making, while contributing to the preservation and revitalization of culinary traditions and cultural heritage (Kuhl, 2025; Pennells et al., 2025).

Such integration requires interdisciplinary collaboration among food scientists, computer scientists, sensory researchers, chefs, nutritionists, ethicists, and social scientists (Kuhl, 2025; Pennells et al., 2025).

Ultimately, the value of AI in gastronomy should not be measured by its ability to imitate human cooking but by its capacity to enrich human relationships with food. The future of gastronomy will likely emerge from a balance between technological intelligence and human wisdom, where artificial intelligence catalyzes creativity, sustainability, and more meaningful culinary experiences (McGuire et al., 2024 Kuhl, 2025).

Conclusions

Artificial intelligence is emerging as a transformative force in gastronomy, expanding the possibilities of culinary creativity, food design, intelligent preparation, personalized experiences, and sustainable innovation. However, the future of AI-enabled gastronomy should not be defined by technological substitution but by the development of human-centered collaborative systems in which artificial intelligence enhances, rather than replaces, culinary expertise, cultural knowledge, and sensory judgment. Despite significant advances, important research gaps remain, including the limited availability of diverse and representative gastronomic datasets, the lack of standardized methodologies for evaluating AI-generated foods, insufficient understanding of consumer acceptance, and unresolved ethical issues related to authorship, cultural appropriation, transparency, and data privacy. Future research should prioritize multidisciplinary approaches integrating food science, artificial intelligence, sensory evaluation, nutrition, sustainability, and social sciences to develop more robust and culturally aware AI systems. Furthermore, experimental validation through sensory studies, consumer trials, and real-world culinary applications will be essential to move beyond computational predictions toward evidence-based gastronomic innovation. Ultimately, the most promising scenario is not an autonomous AI replacing chefs, but a new paradigm of augmented gastronomy in which human creativity and artificial intelligence interact synergistically to create food experiences that are innovative, personalized, sustainable, and culturally meaningful.

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Conflicts of interest

The authors declare that they have no conflicts of interest.

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