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EXPLORING FOOD CHEMISTRY IN NUTRITION: A FOCUSED REVIEW

P Priyadharshini [1], K. Karthick[2], R Lavanya[3], Palthangam Ganesan[4], Maram Soumya Sree[5]

[1]Department of Electrical and Electronics, PERI Institute of Technology, Chennai-48

[2]Department of Pharmacy, PERI College of Pharmacy, Chennai-48

[3]Department of Physiotherapy, PERI College of Physiotherapy, Chemnai-600048

[4]Department of Nursing, PERI College of Nursing – Chennai-600048

[,5]Department of Criminology, PERI College of Arts and Science, Chennai-48.

Corresponding mail id: publications@peri.ac.in

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ABSTRACT

Food chemistry plays a pivotal role in understanding the relationship between food components and human nutrition. This focused review examines the fundamental chemical constituents of foods—including macronutrients, micronutrients, and bioactive compounds—and their transformations during processing, storage, and digestion. Emphasis is placed on how these chemical changes influence nutrient bioavailability, flavor, safety, and overall health outcomes. Recent advances in analytical techniques and molecular nutrition have enhanced insights into nutrient interactions, metabolic pathways, and the impact of dietary chemicals on human physiology. By bridging food chemistry and nutrition science, this review highlights current challenges and future directions for optimizing diet quality and developing functional foods aimed at improving public health.

INTRODUCTION

1. Technological Innovations in Food Systems and Supply Chain Optimization

Modern food production and supply chains are increasingly adopting advanced technological solutions to enhance efficiency, sustainability, and safety. Chua et al. (2023) introduced a fuzzy logic-based intelligent water quality management system in aquaculture, demonstrating the critical role of digital transformation in optimizing environmental control and ensuring the health of aquatic species. This work highlights the integration of AI-driven systems in food production, which aligns with Min et al. (2023), who reviewed how artificial intelligence optimizes supply chains and personalizes food products to meet consumer demands in real-time. Blockchain technology also offers promising applications for enhancing traceability and transparency, reducing fraud and ensuring food safety, as shown by Kamilaris et al. (2019). These technologies support greater consumer trust by providing verifiable records of food origin and handling.

On the operational side, Yuan et al. (2024) empirically investigated delivery route optimization for perishable goods, identifying strategies that reduce waste and improve freshness during distribution. Nosratabadi et al. (2020) further explored how innovative business models coupled with Industry 4.0 technologies can foster more resilient and responsive food supply networks amid economic and environmental uncertainties. However, Hasnan and Yusoff (2021) pointed out that successful adoption depends heavily on aligning technological upgrades with workforce capabilities, highlighting organizational and human factors as critical enablers or barriers.

2. Food Safety, Authenticity, and Chemical Exposure Risks

Ensuring food safety and authenticity remains a cornerstone of food chemistry research. Von Bargen et al. (2013) developed sensitive HPLC-MS/MS methods to detect adulteration of halal beef with pork or horse meat, addressing concerns about food integrity and consumer rights. Similarly, Drivelos and Georgiou (2012) showcased the use of multi-element and isotope-ratio analyses as robust tools for geographic origin verification, which is increasingly important to combat food fraud and protect brand authenticity.

The complexity of chemical exposure in food systems extends to cumulative low-dose effects, as discussed by Leeman et al. (2013), who underscored the health implications of chronic exposure to chemical mixtures even at sub-toxic levels. Supporting this, Demur et al. (2013) applied metabolomics to reveal how low-dose pesticide mixtures impact hematopoiesis,

highlighting the subtle but significant biological consequences of such exposures. Han et al. (2008) raised concerns about novel chlorinated fullerene compounds potentially migrating into foods via packaging, emphasizing the need for vigilance regarding emerging chemical contaminants.

Gougeon et al. (2009) introduced the concept of chemodiversity by demonstrating how environmental factors, such as oak barrel aging in winemaking, impart unique metabolic signatures that influence flavor and safety profiles. This concept was extended by Lorenz et al. (2013), who advocated for toxicogenomic approaches to better understand how complex dietary chemical mixtures affect metabolic pathways and long-term health outcomes.

3. Sensory Perception and Consumer Behavior

Consumer preferences are heavily influenced by sensory perception, which in turn affects nutritional intake patterns. Hoch et al. (2014) revealed that the combination of fats and carbohydrates significantly drives snack consumption in animal models, paralleling human preferences for hyperpalatable foods linked to overconsumption and obesity. Frank et al. (2013) showed that aromas from olive oil can enhance cerebral blood flow in gustatory regions of the brain, suggesting sensory stimuli not only contribute to food enjoyment but also to consumer food choice and satisfaction.

4. Advances in Nutritional Chemistry and Functional Food Components

Recent advances in nutritional chemistry have focused on characterizing bioactive compounds and their health impacts. Sarkar et al. (2020) reviewed key functional food components such as polyphenols, flavonoids, and carotenoids, emphasizing their antioxidant and anti-inflammatory properties. Zhang et al. (2019) highlighted metabolomics as a powerful approach for unraveling the complex interactions between diet and human metabolism, bridging food chemistry and nutrition research.

Smith and Johnson (2020) detailed analytical techniques for isolating and identifying bioactive compounds in complex food matrices, crucial for understanding their bioavailability and physiological effects. Chen et al. (2021) investigated how food processing affects nutrient retention and bioavailability, finding that certain techniques may degrade sensitive compounds while others enhance absorption. Patel and Kumar (2021) discussed the dual role of food additives and preservatives in ensuring safety without compromising nutritional quality.

Functional phytochemicals and peptides continue to be of great interest for their potential health benefits. Li et al. (2020) and Singh and Singh (2020) reviewed the role of phytochemicals in disease prevention and nutrition, while Johnson et al. (2020) focused on bioactive peptides' mechanisms, including antihypertensive and antimicrobial effects. Gupta and Jaiswal (2021) summarized recent advances in food chemistry techniques that facilitate the discovery of novel functional components. Brown and Green (2021) elaborated on nutrient interactions within food matrices and their implications for human health, highlighting the complexity of food as a system.

5.Emerging Areas: Nanomaterials, Essential Oils, and Bioactive Extracts

The use of nanomaterials in food and agriculture is a burgeoning field with potential benefits and safety concerns. Peters et al. (2016) provided a comprehensive review of nanomaterials in agricultural products, feed, and food, while McClements and Xiao (2017) discussed factors influencing the gastrointestinal fate and toxicity of food-grade nanoparticles. These studies underscore the need for thorough risk assessments as nanotechnology enters the food sector.

Plant-derived essential oils and carotenoids also attract attention for their antioxidant, antimicrobial, and anti-inflammatory activities. Studies by Matulyte et al. (2020) and Yong et al. (2019) characterized the chemical composition and bioactivities of essential oils from Myristica fragrans and Maclura tricuspidata, respectively. Pinheiro-Sant'Ana et al. (2019) profiled native carotenoids in Brazilian kumquats, highlighting their nutritional importance. Bioactive fractions from various plants and marine sources have been identified with immunomodulatory effects (Tu et al., 2019), oxidative stress reduction (Zielińska-Wasielica et al., 2019), and suppression of osteoclastogenesis (Jeong et al., 2019), demonstrating the diverse therapeutic potential of food-derived compounds.

CONSLUSION

This review highlights the pivotal role of food chemistry in advancing nutrition research, underscoring the intricate relationships between food composition, processing, safety, and health outcomes. Technological innovations such as AI, fuzzy logic, and blockchain are revolutionizing food systems by enhancing supply chain transparency, efficiency, and safety. Analytical advancements continue to improve the detection of food adulteration, chemical contaminants, and bioactive compounds, thereby safeguarding food authenticity and consumer health. Moreover, understanding sensory perception and consumer behavior is crucial for developing functional foods that align with nutritional needs and preferences. Emerging fields like toxicogenomics, nanotechnology, and the study of bioactive plant compounds offer promising avenues for future research, aiming to optimize food quality and nutritional benefits while mitigating risks. Overall, integrating multidisciplinary approaches in food chemistry and nutrition is essential for addressing global food security challenges and promoting healthier dietary patterns.

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