nutraceuticals

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Editorial

Nutraceuticals and Their Anti-Inflammatory Effects

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Inflammation is an essential biological response that enables host defense, tissue repair, and restoration of homeostasis after injury or infection. However, when inflammatory signaling becomes persistent, dysregulated, or metabolically maladaptive, it contributes to the pathophysiology of a wide spectrum of non-communicable diseases, including obesity, type 2 diabetes, cardiovascular disorders, inflammatory bowel disease, neurodegenerative conditions, cancer, and age-related functional decline. In this context, chronic low-grade inflammation has emerged as a key biological interface between diet, metabolism, immune regulation, oxidative stress, the intestinal microbiota, and long-term health outcomes.

Nutraceuticals are increasingly relevant within this scientific landscape. The term nutraceutical is commonly used to describe food-derived substances, isolated nutrients, phytochemicals, dietary supplements, or bioactive preparations that may provide physiological benefits beyond basic nutrition. Nutraceuticals include phenolic compounds, flavonoids, carotenoids, organosulfur compounds, polyunsaturated fatty acids, dietary fibers, prebiotics, probiotics, postbiotics, bioactive peptides, vitamins, minerals, and compounds derived from terrestrial and marine sources. These diverse molecules are of particular interest because they frequently act through multitarget mechanisms, modulating inflammatory pathways, redox homeostasis, epithelial barrier function, lipid mediator networks, and host–microbiota interactions rather than acting through a single pharmacological target [1].

This Special Issue, entitled "Nutraceuticals and Their Anti-Inflammatory Effects", aims to provide an updated and multidisciplinary view of the role of nutraceuticals in the prevention, modulation, and adjunctive management of inflammation-associated disorders. The topic is timely because the global burden of chronic inflammatory diseases continues to increase, while patients, clinicians, researchers, and industry stakeholders seek evidence-based strategies that bridge nutrition science, molecular biology, clinical medicine, and food technology. Within this field, nutraceuticals should not be presented as replacements for validated medical therapies, but rather as promising tools that may complement healthy dietary patterns and support personalized approaches to reducing inflammatory risk.

At the molecular level, many nutraceuticals exert anti-inflammatory effects by modulating transcription factors and signaling pathways that regulate cytokine production, oxidative stress, and innate immune activation. Among these pathways, nuclear factor kappa B (NF-κB) is one of the most widely studied because it regulates the transcription of several pro-inflammatory mediators, including cytokines, chemokines, cyclooxygenase-2 (COX-2), and inducible nitric oxide synthase (iNOS). In parallel, nuclear factor erythroid 2-related factor 2 (Nrf2) contributes to cytoprotection by promoting antioxidant and electrophile-response genes. The interplay between NF-κB and Nrf2 illustrates why compounds such as polyphenols, isothiocyanates, curcuminoids, and other phytochemicals have attracted considerable attention as modulators of inflammation and oxidative stress (Table 1) [2].

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The NLRP3 inflammasome is another important target in nutritional immunology. This intracellular multiprotein complex contributes to the maturation of interleukin-1β and interleukin-18 and is involved in inflammatory and auto-inflammatory conditions, including metabolic syndrome, diabetes, gout, atherosclerosis, liver fibrosis, respiratory disorders, neuroinflammation, and cancer-related inflammation. Several classes of food-derived bioactive compounds, including polyphenols, organosulfur compounds, terpenes, fatty acids, carotenoids, vitamins, polysaccharides, probiotics, and amino acid derivatives, have been reported to influence NLRP3 activation in experimental models. These observations reinforce the notion that diet and nutraceuticals may influence inflammation through coordinated effects on cellular stress, mitochondrial function, pattern recognition signaling, and immune-metabolic crosstalk [3].

Polyphenols are among the most extensively investigated families of anti-inflammatory nutraceuticals. They are present in fruits, vegetables, tea, coffee, cocoa, olive oil, cereals, legumes, herbs, and spices. Their biological effects are linked not only to their direct antioxidant capacity but also to their ability to modulate cell signaling, enzyme activity, inflammatory gene expression, and gut microbial ecology. In particular, dietary polyphenols and their metabolites can influence the intestinal microbiota, while microbial metabolism can transform polyphenols into smaller metabolites with distinct bioactivities. This bidirectional relationship is especially relevant because the intestinal microbiota contributes to immune education, intestinal barrier integrity, short-chain fatty acid production, and systemic inflammatory tone [4,5].

Curcumin, the principal curcuminoid of turmeric, provides a useful example of both the promise and the challenges of nutraceutical research. Experimental and clinical studies suggest that curcumin may regulate NF-κB, mitogen-activated protein kinase (MAPK), activator protein 1 (AP-1), Janus kinase/signal transducer and activator of transcription (JAK/STAT), NLRP3 inflammasome, and Nrf2/Keap1 pathways, with reported effects on inflammatory mediators such as TNF-α, interleukins, iNOS, nitric oxide, and C-reactive protein. Nevertheless, the translation of curcumin into clinical practice is limited by low aqueous solubility, variable absorption, rapid metabolism, and formulation-dependent bioavailability. This example highlights the need to evaluate nutraceuticals not only as molecules but also as formulations, food matrix components, metabolites, and clinically testable interventions [6].

Omega-3 polyunsaturated fatty acids provide another paradigmatic model for understanding how nutrients can influence inflammation. Beyond altering membrane composition and eicosanoid balance, eicosapentaenoic acid and docosahexaenoic acid are precursors of specialized pro-resolving lipid mediators, including resolvins, protectins, and maresins. These mediators participate in the active resolution of inflammation by reducing neutrophil infiltration, promoting non-phlogistic efferocytosis, supporting macrophage phenotypic transitions, and modulating cytokine production. Therefore, the anti-inflammatory potential of omega-3 fatty acids should be understood not only as suppression of inflammatory initiation, but also as enhancement of endogenous resolution programs [7].

The following table summarizes the major nutraceutical classes relevant to this Special Issue and illustrates the diversity of mechanisms to be considered in future submissions.

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Table 1. Anti-inflammatory effects of nutraceuticals by modulating transcription factors and signaling pathways that regulate cytokine production, oxidative stress, and innate immune activation.

Nutraceutical Class	Representative Examples	Main Anti-Inflammatory Mechanisms of Interest
Polyphenols and flavonoids	Quercetin, catechins, anthocyanins, resveratrol, hydroxytyrosol.	Modulation of NF-κB, Nrf2, cytokine expression, oxidative stress, endothelial function, and microbiota-derived metabolites.
Curcuminoids and spice-derived compounds	Curcumin, gingerols, capsaicinoids.	Regulation of NF-κB, MAPK, AP-1, JAK/STAT, NLRP3, COX-2, iNOS, and inflammatory mediator release.
Omega-3 fatty acids and lipid mediators	EPA, DHA, resolvins, protectins, maresins.	Eicosanoid balance, specialized pro-resolving mediator formation, macrophage reprogramming, efferocytosis, and resolution of inflammation.
Prebiotics, probiotics, postbiotics, and fibers	Inulin, beta-glucans, lactobacilli, bifidobacteria, microbial metabolites.	Barrier function, short-chain fatty acid production, microbiota composition, mucosal immunity, and systemic inflammatory tone.
Carotenoids and isoprenoids	Lycopene, lutein, astaxanthin, carotene derivatives.	Antioxidant defense, immune modulation, lipid peroxidation control, and regulation of redox-sensitive inflammatory pathways.
Bioactive peptides and amino acid derivatives	Marine peptides, fermented-food peptides, glutamine-related compounds.	Immune-metabolic regulation, epithelial repair, oxidative stress control, and modulation of cytokine production.

Despite the strong mechanistic rationale for nutraceutical anti-inflammatory effects, the field must address several methodological and translational challenges. First, many promising findings are derived from in vitro or animal studies using concentrations that may not be achievable in human tissues after dietary intake. Second, the biological activity of nutraceuticals depends on bioaccessibility, bioavailability, metabolism, chemical stability, formulation, and interactions with the food matrix. Third, interindividual variability in genetics, age, sex, metabolic status, medications, baseline diet, and gut microbiota composition can influence responses. Fourth, clinical trials often differ substantially in the source of the compound, dose, duration, population, comparator, and outcome selection. These issues complicate evidence synthesis and may partly explain inconsistent findings across clinical studies [1,4,6].

For this reason, future research should prioritize well-designed randomized controlled trials, standardized and chemically characterized interventions, validated biomarkers of inflammation and resolution, and mechanistic endpoints that connect molecular changes with clinically meaningful outcomes. Studies integrating metabolomics, lipidomics, microbiome profiling, nutrigenomics, and systems biology may be particularly valuable. Such approaches can help clarify whether a nutraceutical acts directly, through its metabolites, through microbial transformation, through modification of the dietary matrix, or through broader changes in host metabolism.

Safety also deserves careful attention. The perception that natural products are inherently safe can lead to inappropriate self-medication, excessive dosing, or underestimation of interactions with drugs and medical conditions. Some nutraceuticals may have pro-oxidant effects at high concentrations, interfere with nutrient absorption, modify platelet function, or interact with anticoagulants, antidiabetic agents, immunosuppressants, chemotherapeutic agents, and other medications. Therefore, anti-inflammatory efficacy should always be evaluated alongside toxicology, pharmacokinetics, formulation quality, contaminants, regulatory standards, and population-specific risk–benefit considerations.

The scientific promise of nutraceuticals lies in their capacity to connect food, biology, and health in a translational framework. Their anti-inflammatory potential extends beyond inhibiting isolated mediators; it also modulates oxidative stress, immune cell function, lipid mediator resolution pathways, mitochondrial activity, epithelial barrier integrity, and microbiota–host communication. This systems-level perspective is particularly appropriate for chronic inflammatory diseases, whose pathogenesis involves overlapping metabolic, immune, environmental, and behavioral determinants.

In conclusion, this Special Issue seeks to encourage high-quality original research, systematic reviews, narrative reviews, mechanistic studies, clinical trials, and translational perspectives that clarify the role of nutraceuticals in inflammatory biology. By bringing together evidence from nutrition, immunology, pharmacology, food chemistry, clinical medicine, and biotechnology, the Special Issue aims to advance a rigorous and balanced understanding of nutraceuticals as modulators of inflammation. The ultimate objective is to support scientifically grounded innovation that may contribute to safer, more personalized, and more effective strategies for improving human health.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Caponio, G.R.; Lippolis, T.; Tutino, V.; Gigante, I.; De Nunzio, V.; Milella, R.A.; Gasparro, M.; Notarnicola, M. Nutraceuticals: Focus on Anti-Inflammatory, Anti-Cancer, Antioxidant Properties in Gastrointestinal Tract. *Antioxidants* **2022**, *11*, 1274. [CrossRef] [PubMed]
2. Krajka-Kuźniak, V.; Baer-Dubowska, W. Modulation of Nrf2 and NF-κB Signaling Pathways by Naturally Occurring Compounds in Relation to Cancer Prevention and Therapy. Are Combinations Better Than Single Compounds? *Int. J. Mol. Sci.* **2021**, *22*, 8223. [CrossRef] [PubMed]
3. Spano, M.; Di Matteo, G.; Ingallina, C.; Ambroselli, D.; Carradori, S.; Gallorini, M.; Giusti, A.M.; Salvo, A.; Grosso, M.; Mannina, L. Modulatory Properties of Food and Nutraceutical Components Targeting NLRP3 Inflammasome Activation. *Nutrients* **2022**, *14*, 490. [CrossRef] [PubMed]
4. Nemzer, B.V.; Al-Taher, F.; Kalita, D.; Yashin, A.Y.; Yashin, Y.I. Health-Improving Effects of Polyphenols on the Human Intestinal Microbiota: A Review. *Int. J. Mol. Sci.* **2025**, *26*, 1335. [CrossRef] [PubMed]
5. Cano, R.; Bermúdez, V.; Galban, N.; Garrido, B.; Santeliz, R.; Gotera, M.P.; Duran, P.; Boscan, A.; Carbonell-Zabaleta, A.-K.; Durán-Agüero, S.; et al. Dietary Polyphenols and Gut Microbiota Cross-Talk: Molecular and Therapeutic Perspectives for Cardiometabolic Disease: A Narrative Review. *Int. J. Mol. Sci.* **2024**, *25*, 9118. [CrossRef] [PubMed]
6. Peng, Y.; Ao, M.; Dong, B.; Jiang, Y.; Yu, L.; Chen, Z.; Hu, C.; Xu, R. Anti-Inflammatory Effects of Curcumin in the Inflammatory Diseases: Status, Limitations and Countermeasures. *Drug Des. Dev. Ther.* **2021**, *15*, 4503–4525. [CrossRef] [PubMed]
7. Hong, S.; Lu, Y. Omega-3 Fatty Acid-Derived Resolvins and Protectins in Inflammation Resolution and Leukocyte Functions: Targeting Novel Lipid Mediator Pathways in Mitigation of Acute Kidney Injury. *Front. Immunol.* **2013**, *4*, 13. [CrossRef]