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Reference

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Editors

Handbook of Nutraceuticals

Science, Technology and Engineering

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About this book

This book covers different stages of development of nutraceuticals and nano nutraceuticals, emphasizing their manufacturing techniques and formulations. The physicochemical behaviour ofnutraceuticals and nano nutraceuticals and innovative characterization techniques are presented. Various types of formulation methods and pharmacologic and pharmacokinetic evaluations are described. Moreover, the controlled delivery of nutraceuticals and nano nutraceuticals components is covered in several chapters. The book reviews various classes of natural and biodegradable polymers used to prepare nutraceuticals and nano nutraceuticals based delivery system. It provides details about in vitro evaluation for testing the effectiveness of nutrient delivery systems. The bioavailability, food additives, and encapsulation techniques are discussed. A chapter on the future of controlled release technologies of nutraceuticals and nano nutraceuticals is an additional highlight of this book.

Synergism in Nutraceutical Formulations

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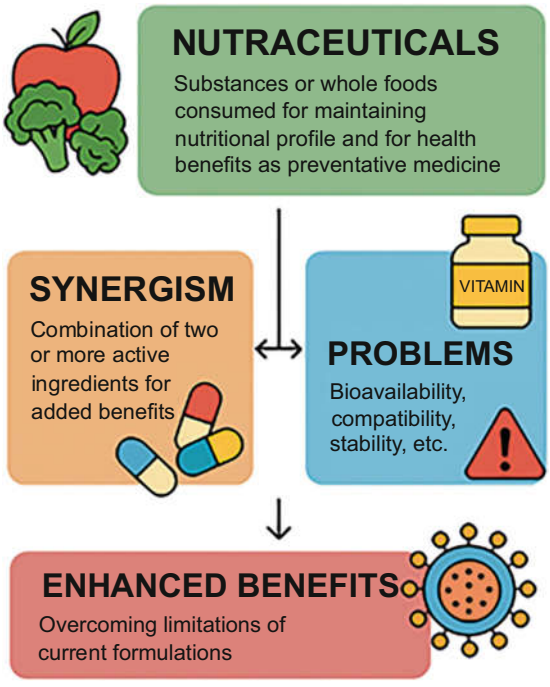
Abstract

Nutraceuticals are bioactive compounds or functional foods consumed to sustain nutrition and support disease prevention. Derived from *nutrition* and *pharmaceuticals*, the concept merges food science with therapeutic potential. Synergism in nutraceutical formulations arises when two or more bioactive agents interact to produce enhanced pharmacological or physiological outcomes that surpass the sum of their individual effects. This principle addresses key challenges of monotherapy: poor bioavailability, limited target specificity, and rapid metabolic degradation by enabling multicomponent, mechanistically complementary formulations. Recent innovations such as nano-encapsulation and codelivery systems further enhance absorption, stability, and efficacy of synergistic blends. This chapter provides a comprehensive overview of molecular and formulation-based synergism in nutraceuticals, focusing on mechanistic interactions, formulation challenges, and future directions toward *supernutraceuticals* that integrate advanced bioengineering and traditional dietary wisdom.

Graphical Abstract



Keywords

Nutraceuticals · Bioactive synergy · Nanocarriers · Bioavailability · Pharmacokinetic enhancement · Functional foods

Introduction

Nutrient synergy is nothing but the concept in which there are the mixed effects of two or more nutrients working together to have a greater physiological impact on the body than when each of the nutrients is consumed individually (Atale and Rani 2025). Traditionally, nutrition science has been observed to utilize the reductionist approach for better understanding of the impact of diet, nutrition, and nutrients on the health of the individual, where most research has attempted to draw conclusions by the isolation of a single nutrient and the examination of its effect on the specific health results, patient welfare, and biological mechanism (Townsend et al. 2023). However, modern nutritional biochemistry recognizes that nutrients do not act in isolation, and their interactions at cellular and systemic levels define overall health outcomes. The study is based on how a nutrient gets to influence the body and sans merit, as we have known, that consuming single nutrients orally in appropriate quantities would contribute to the prevention of certain nutrient inadequacies like vitamin C for scurvy prevention, vitamin D for rickets prevention, and folic acid for neural tube defects prevention. The DRIs which are nothing but "Dietary References Intake" were integrated by the "Food & Nutrition Board of the National Academies of Sciences, Engineering, and Medicine" and comprise several types of nutrient reference values, which have been observed to intend to reduce the risks prevailed in both nutrient deficiency and over intake of nutrients (Gombart et al. 2020). In recent decades, the focus has gradually shifted from nutrient sufficiency to nutrient synergy—examining how combinations of bioactive compounds act through complementary molecular pathways to produce amplified therapeutic or preventive effects. This shift forms the foundation of nutraceutical synergism, which integrates nutrition science with pharmacological principles of absorption, distribution, metabolism, and excretion (ADME).

Synergy, in pharmacology, has been discussed in many ways, like, through the amelioration of drug's absorption, its distribution, its metabolism, and its elimination (ADME). This pharmacological analogy helps bridge the understanding between drug synergy and nutraceutical synergy, emphasizing how combinations of natural bioactives may modify ADME characteristics to improve efficacy. Even in nutraceuticals, ADME and synergy together play a greater role in pharmacological and biological properties of an active constituent. The changes seen in ADME result from the interactions that happen between drugs that affect all the distinct biological targets present in the body, such as receptors, enzymes, or ion-gated channels (Calzetta et al. 2024). In various study disciplines, synergy has been often interpreted in broader terms, in which those ingredients that target all the differing physiological pathways are seen to work together for an efficient physiological impact. For