

Plant-Based Natural Products for Combating Aging-Related Diseases

Edited by
Azamal Husen, Arpan Modi, and Megha Barot



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3 Molecular Networks and Signaling Pathways in Aging and Aging-Related Diseases

*Mensur Osman Yassin, Malik Nasibullah, Rina Tripathi,
Pankaj Tripathi, and Azamal Husen*

3.1 INTRODUCTION

Aging is a natural and progressive biological process characterized by the gradual decline of physiological and cellular functions, leading to increased vulnerability to chronic diseases and functional impairments (Kirkwood, 2005; Niccoli and Partridge, 2012). Rather than resulting from a single molecular alteration, aging is now recognized as a complex, systems-level process driven by the interaction of genetic, metabolic, environmental, and lifestyle-related factors (López-Otín et al., 2013; Kennedy et al., 2014). At the cellular level, aging involves the accumulation of molecular damage and disturbances in key biological processes such as energy metabolism, stress response signaling, protein homeostasis, mitochondrial function, and genomic stability (Campisi et al., 2019; Li et al., 2024). These processes are regulated through interconnected molecular networks that normally function in a coordinated manner to maintain cellular and organismal homeostasis. However, with advancing age, the efficiency of these regulatory systems gradually declines, resulting in impaired cellular communication, oxidative stress, chronic inflammation, tissue degeneration, and increased susceptibility to age-related diseases including cardiovascular disorders, neurodegeneration, diabetes, and cancer (Franceschi et al., 2018; López-Otín et al., 2023). The remarkable increase in global life expectancy over the last century has significantly shifted the focus of biomedical research toward aging and age-related health challenges (Peng et al., 2026). Although advances in healthcare, nutrition, and living conditions have contributed to longer lifespans, they have also led to a substantial rise in chronic non-communicable diseases associated with aging. Disorders such as cardiovascular diseases (CVDs), neurodegenerative conditions, metabolic syndromes, and cancer now represent major public health concerns and place considerable pressure on healthcare systems worldwide. Importantly, these diseases often share common underlying biological mechanisms rather than developing independently. Processes such as oxidative stress, chronic low-grade inflammation, mitochondrial dysfunction, and dysregulated cellular signaling are widely recognized as central contributors to aging and disease progression (Kennedy et al., 2014; Franceschi et al., 2018). Therefore, understanding the molecular basis of these interconnected mechanisms is essential for developing effective strategies aimed at extending healthspan, improving quality of life, and reducing the overall burden of age-related diseases (López-Otín et al., 2023; Li et al., 2024).

Earlier studies on aging primarily focused on individual genes or single biochemical pathways in an attempt to explain the aging process. Although these reductionist approaches provided important insights, they are no longer considered sufficient to fully explain the complexity of aging and age-related diseases. Recent advances in aging biology emphasize that aging is regulated through highly interconnected molecular networks in which multiple signaling pathways continuously interact through feedback loops and cross-regulatory mechanisms (Guarente, 2013; López-Otín et al., 2023). These networks include nutrient-sensing pathways, cellular stress response systems, inflammatory signaling cascades, and metabolic regulators that collectively influence cellular survival, repair mechanisms, and overall physiological function. Disturbances in one pathway can affect

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