Chapter 3
Impact of Dietary Antioxidants on Redox Homeostasis and Its Effects on Health and Disease

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ABSTRACT

This chapter discusses the roles of reactive oxygen species (ROS) in cells, including their role in oxidative stress and redox balance. It explores how dietary antioxidants affect redox homeostasis, their sources, mechanisms of action, and antioxidant capacity. The chapter also discusses how antioxidants affect ROS-mediated signaling cascades and endogenous antioxidant defense mechanisms. It discusses the use of antioxidants in pharmacological approaches to treat chronic illnesses like cancer, neurological disorders, and cardiometabolic diseases. It also addresses the antioxidant paradox, where excessive antioxidant supplementation can disrupt redox equilibrium, emphasizing the importance of balancing pro- and antioxidative forces.

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1. INTRODUCTION

1.1 Overview of Reactive Oxygen Species (ROS)

Free radical scavengers are highly reactive molecules containing oxygen radicals such as superoxide anions (O2−), hydroxyl radicals (•OH), and hydrogen peroxide (H2O2). These molecules act as proactive and reactive species in biological systems; they are related to cellular damage and oxidative stress, while at the same time, they are decisive factors in cellular signaling and metabolic regulation (Jomova et al., 2023). ROS generation is a consequence of normal cell functions, and it is provoked mainly within the mitochondria and other organelles and can be modulated by genetic and environmental factors, diet, etc. Several features of diet and nutrition affect the synthesis and scavenging of ROS. Natural foods are rich sources of vitamins and phytochemicals, and foods that are rich in such components include fruits, vegetables, and whole grains, which contain vitamin C, vitamin E, and flavonoids that help eliminate free radicals and maintain redox balance. On the other hand, unhealthy eating patterns involving high quantities of processed foods, sugars, and unhealthy fat greatly increase ROS formation and therefore oxidative stress, thus increasing cellular impairment and disease progression (Lobo et al., 2010). Furthermore, drinking water contaminated with additional heavy metals such as lead, cadmium, and mercury poses additional hazards. Heavy metals can produce ROS through different biochemical mechanisms and cause oxidative stress and damage in cells (Balali-Mood et al., 2021). Consuming unhealthy foods and being in contact with polluted water has a cumulative impact on ROS levels, which enhances the effect of oxidative stress in the body.

1.2 Effectiveness of Regulating Redox Balance

Oxidative homeostasis, on the other hand, involves the balance between the generation and neutralization of ROS. Oxidative stress is therefore a situation where the generation of ROS surpasses the body's capacity to control or neutralize these reactive species through antioxidant systems. This balance is essential for sustaining cellular processes and eliminating oxidative stress, which impairs lipids, proteins, and DNA (Pizzino, 2017). Abnormal redox status is implicated in many diseases, including cancer, neurodegenerative diseases, and metabolic diseases. The role of ROS in cancer development is worthy of attention. High concentrations of ROS can cause mutations in different DNA sequences in the cell nucleus, which, in turn, contribute to the development of cancer in different tissues (Baek et al., 2018). ROS reportedly participate in many signaling pathways that involve the control of cell division and survival and can also support tumor growth (Kumari, et al. 2018). Therefore, for

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