Nutrition 30 (2014) 511–517

Contents lists available at ScienceDirect

Nutrition

journal homepage: www.nutritionjrnl.com

Review

Effect of fruit and vegetable antioxidants on total antioxidant capacity of blood plasma

Joanna Harasym Ph.D., M.Sc., Eng *, Remigiusz Oledzki Ph.D., M.Sc.

Food Biotechnology Department, Institute of Chemistry and Food Technology, Wroclaw University of Economics, Wroclaw, Poland

ARTICLE INFO

Article history:
Received 31 July 2013
Accepted 23 August 2013

Keywords:
Reactive oxygen species
Total antioxidant capacity
Antioxidants
Vitamins
Cardiovascular and neurodegenerative diseases

ABSTRACT

For a long time, the increased consumption of fruits and vegetables was considered critical in protecting humans against a number of diseases, such as cancer, diabetes, neurodegenerative diseases, and heart and brain vascular diseases. Presently, it is thought that the protective properties of these foods result from the presence of low-molecular antioxidants that protect the cells and their structures against oxidative damage. The alleged effect of reducing the risk for many diseases is not only due to the effect of individual antioxidants, such as α-tocopherol, ascorbic acid, or β-carotene, but also may be the result of antioxidant compounds not yet known or synergy of several different antioxidants present in fruits and vegetables. Studies on macromolecules (DNA, nucleotides, proteins) free-radical–related damage showed that diets enriched with extra servings of fruits and vegetables rich in β-carotene, tocopherols, and ascorbic acid had only limited effect on the inhibition of oxidation processes. A number of studies have shown, however, that consuming less common fruits and vegetables contribute much more to the reduction of free-radical processes, most likely because they contain a large amount of non-vitamin antioxidants, such as polyphenols and anthocyanins.

Introduction

Fruits and vegetables have a beneficial effect on the human body related to anti-nutrients such as low-molecular antioxidant substances, which are used in disease prevention and improving health and quality of life [1]. Recent research has explained that certain plant chemicals, such as terpenes, flavonoids, and anthocyanins, once considered irrelevant in the human diet, have much more powerful antioxidant properties than well-known antioxidant vitamins [2,3].

These properties come from the antioxidant defense system that protects plants from damage caused by their existence in an oxygen environment [4]. To counteract reactive oxygen species (ROS) accumulation in tissues, large amounts of antioxidants were developed [5] that inhibit free-radical cascade, preventing harmful ROS reaction with important plant constituents [6].

Provided in the diet, antioxidants neutralize ROS, which are produced in the system during physiological processes. The main internal sources of ROS are respiratory chain enzymatic reactions, processes of phagocytosis, prostaglandin synthesis, and reactions of cytochrome P450 system. Important internal sources responsible for ROS production are peroxisomal xanthine oxidase-catalyzed reactions, arachidonic acid pathway reactions, and reactions with transition metals [6,7]. Intensification of ROS production occurs during increased physical activity, tissue ischemia and reperfusion, inflammation, and certain mental states such as stress and depression [8].

Since the beginning of human life on Earth, its performance is inextricably linked to ongoing physical and chemical interactions between the human body and the environment. The natural environment that surrounds the human now is strongly degraded and polluted in many places around the world. Entering into water, air, or soil solids, liquids, gases, or energy in amounts or composition negatively influencing the nature (climate, water, land, etc.) causes many changes that affect the antioxidant status of the human body. Some of the substances or energy entered into the environment contain ROS or contribute to their formation. Therefore, to effectively prevent the excessive quantities of oxygen-free radicals penetrating the human system from the environment, it is necessary to provide appropriately increased amounts of antioxidants with food. Exogenous antioxidants from food, by promoting endogenous antioxidant activity, contribute to the strengthening of defense mechanisms

JH is responsible for revision, and design of the manuscript; generation, collection, analysis, and interpretation of the data.

RO is responsible for conception of the review; generation, collection, analysis, and interpretation of the data; and drafting of the manuscript. Both authors approved the final version of manuscript.

* Corresponding author. Tel.: +48 713680249.
E-mail address: joanna.harasym@ue.wroc.pl (J. Harasym).

0899-9007/$ - see front matter © 2014 Elsevier Inc. All rights reserved.
http://dx.doi.org/10.1016/j.nut.2013.08.019

against excessive numbers of ROS. Their work is primarily to neutralize free radicals or decrease their level of activity [2,4].

Research shows that uncontrolled and long-lasting oxidative stress plays an important role in initiation and progression of cardiovascular disease (CVD; ischemic heart disease and chronic heart failure, high blood pressure), hyperlipidemia, diabetes (insulin resistance), cataracts, cancer, and joint diseases [6,9]. Oxidative stress in the nervous system is the result of a disorder of prooxidant/antioxidant balance and domination of prooxidative reactions. Its growth at the cellular level may be associated with the influence of several factors such as toxic effects of alcohol and drugs, trauma, inflammation, viral and bacterial infections, or excessive exercise [2,6].

The human nervous system, including the brain, spinal cord, and peripheral nerves, is characterized by high concentrations of both the fatty acids and the iron ions (II). The high content of lipid compounds in nervous tissue, in combination with its high metabolic activity makes this system particularly susceptible to oxidative damage (lipid peroxidation). The high content of IIs is essential for brain development, but in excess, it also favors neuron damage, because IIs are powerful catalysts of ROS production, which leads to increased oxidative stress. Moreover, certain areas of the brain, such as substantia nigra, which have a high accumulation of catecholamines, are particularly susceptible to destructive action of free radicals. Catecholamine neurotransmitters such as adrenaline, noradrenaline, or dopamine, are prone to the phenomenon of spontaneous breakdown to form a radical (autoxidation), or may be metabolized to free radicals by endogenous enzymes such as monoamine oxidase, thereby to increased oxidative stress [2,6].

Oxidative stress is also a key factor in the pathogenesis of CVD (e.g., atherosclerosis). One such mechanisms is occurrence of oxidation-specific fractions of cholesterol molecules—low-density lipoprotein (LDL). For the immune system, oxidized LDL particles are unwanted and macrophages capturing them become filled with fat foam cells, which form so-called plaque. The oxidation of LDL by ROS occurs most intensively in lining of the coronary arteries, which through increased deposition process in vessels may lead to a reduction in coronary artery patency and, consequently, to a heart attack. The process of oxidation can largely be prevented by eating a diet rich in fruits and vegetables that are high in antioxidants [2,6].

ROS plays an important role in the mechanism of other disorders of the cardiovascular system, which are cardiomyopathies (e.g., arrhythmia, atrial fibrillation, hypertension). In this case, the ROS effect is to stimulate the heart in an excessive or chronic oxidative stress to intensified work. The source of such stimulation is the reaction of the sympathetic nervous system to the developing nervous tension and ROS that activate β-adrenergic receptors on cardiac muscle fibers, whereby the fibers are strongly shrinking accelerating action of the heart. It has been observed that administration of antioxidants reduces the production of ROS in mitochondria, thereby inhibiting cardiac overstimulation of the β-adrenergic receptors, which in turn results in the weakening of heart muscle contractions [2,6].

ROS affects the whole body, leading to weakening of immune function and acceleration of the aging process. Antioxidant substances contained in plants may help protect the human system from diseases resulting from a weakened immune system [1]. The vast majority of low-molecular antioxidants present in plants is not synthesized in human body, so its rational consumption is essential for enhancing immunodefense [10].

The aim of this study was to analyze the current findings concerning the determination of antioxidant capacity of commonly consumed fruits and vegetables and also to point out the health aspects of plant antioxidant effects on the human body. The purpose was achieved through the synthesis of current views on the effects of antioxidants present in fruits and vegetables on the antioxidant defenses of the human body and bringing the most important information on physiological and biochemical mechanisms affecting plasma antioxidant capacity after consumption of fruits and vegetables. The work also contains a few questions that currently stimulate research carried out in a number of centers. The main problem is to clarify the extent to which fruit and vegetable consumption has an effect on antioxidant status of human blood plasma. Also, changes in fruit and vegetable antioxidant potential during most common culinary processing types have been summarized.

Total antioxidant status

There are many methods for determining the antioxidant activity of plant foods, mostly based on various substances generating free radicals and on different mechanisms for levels of measuring neutralization. To determine in vitro all types of antioxidant capacity of plant food, several different measuring methods often are applied [11].

Scientific literature commonly uses the term *total antioxidant capacity* (TAC), which determines the ability of tested material to neutralize oxygen-free radical specific form, irrespectively to specific antioxidant activity of present antioxidants [12]. Many methods have been developed to measure TAC of plant extracts. One of them is the oxygen radical absorbance capacity (ORAC) technique, which is also an effective method for measuring TAC of human blood plasma [13].

ORAC is a fluorometric method that allows quick assessment of tested material ability to neutralize ROS. It is based on oxidation reaction between fluorescent substance particles and free radical supplier such as an azo compound. Forming peroxide radicals destroys fluorescent molecules, causing a loss of fluorescence. Antioxidants contained in evaluated extract protects molecules of fluorescent substance against oxidative breakdown. Levels of protection of fluorescent substance and the change of fluorescence after the addition of antioxidant is recorded using a fluorometer [13].

The ORAC technique is used to measure the antioxidant capacity of foods (fruits, vegetables, prepared foods, and food supplements). Many experts are concerned that fruits and vegetables with the highest antioxidant capacity value confirmed by ORAC have a higher ability to neutralize ROS [13].

ORAC value often is given in separate specification of a natural hydrophilic ($ORAC_H$) and lipophilic ($ORAC_L$) antioxidants or a total $ORAC_{TOTAL}$ value is given, which is the sum of $ORAC_H$ and $ORAC_L$ [11]. The ORAC technique is a standardized method of measuring antioxidant activity approved by U.S. Department of Agriculture and provides a very precise method to determine ability of test material to neutralize ROS. Food products or raw materials with high ORAC values are generally considered rich in antioxidants, thus having a high ability to protect cells from free-radical damage [14].

Antioxidant potential of various fruits and vegetables species

As TAC of fruits and vegetables depend on species, the intake of food with low-value antioxidant potential results in low antioxidant status in blood plasma. In turn, consumption of extra portions of fruits and vegetables with a high value of antioxidant