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GEROPROTECTIVE POTENTIAL OF PLANT AND SYNTHETIC ANTIOXIDANTS

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Aging is an inevitable stage of life, a natural process that we all experience and often strive to slow down. As life expectancy on Earth continues to rise, the quest for longevity and vitality becomes increasingly significant. However, alongside this increase in lifespan, we face the emergence of diseases associated with aging and genetic mutations that can lead to various health complications. This dual challenge has long been a concern for researchers and healthcare professionals.

To mitigate the negative impact of aging on health, it is crucial to explore ways to slow down this process. This article discusses several promising options that suggest their effectiveness against aging, potentially acting as geroprotectors. Among these, antioxidants are perhaps the most popular choice due to their ability to reduce oxidative stress caused by free radicals—unstable molecules that can damage cells and contribute to aging.

In addition to traditional antioxidants, synthetic antioxidants such as enzyme mimetics are becoming a focal point of therapeutic research. These compounds aim to replicate the action of natural enzymes that combat oxidative stress, offering a novel approach to age-related health issues. Furthermore, polyphenols, naturally occurring compounds found in various fruits, vegetables, and beverages like tea and red wine, have garnered attention for their potential health benefits.

Together, these compounds may contribute to new research opportunities aimed at combating age-related pathology and improving overall health outcomes. By understanding and harnessing the power of antioxidants, enzyme mimetics, and polyphenols, we may pave the way for innovative interventions that not only extend lifespan but also enhance the quality of life for individuals as they age. The pursuit of effective geroprotectors represents a vital frontier in promoting healthy aging and preventing age-related diseases.

Key words: geroprotection; antioxidants; polyphenols; synthetic antioxidants; aging

Reviewing the literature in recent decades, it is impossible not to notice in publications a reflection of the widespread search for ways to slow down human aging and pre-vent diseases that aggravate aging. Already, it seems, ways have been found to control many of the diseases that accompany aging: there are drugs that can significantly control heart disease, diabetes, arthritis, and even Alzheimer's disease. However, there are still no means that can prevent the occurrence of these age-associated diseases. The search for safe drugs that treat aging in general by slowing cellular degradation or making the elderly more resistant to the factors that cause physical and mental decline is still in its infancy. The goal of anti-aging medicine is to slow the aging process and mitigate its associated consequences, such as susceptibility to cancer, diabetes, cardiovascular and neurodegenerative diseases. It is clear that although some biological substances or technologies have now shown promising results in preclinical settings and even in the clinic, it will take considerable time to test their long-term effects in humans.

Nevertheless, it is objectively clear that there is a reason to hurry: people over 70 represent the fastest-growing segment of the population, which is most noticeable in the United States [58]. The World Health Organization (WHO) projects that between 2015 and 2050, the proportion of the world's population over 60 will almost double from 12% to 22% [83]. Currently, 80% of the world's adults aged 65 years and older have at least one chronic disease, and 68 percent have two or more [16]. There is no doubt that in the near future, there will be more and more people living in their 80s, 90s, and 100s. The need to keep these older people healthy is obvious. Improving the quality of life of people in late age may even be a boon for the economy and a breakthrough for the healthcare system, which annually spends huge sums on the treatment of age-associated diseases.

Drug regulators are currently debating this but have not yet recognized aging as a preventable disease, so there is no clear path to licensing drugs to treat it. However, there is reason to hope that the situation will change. Several substances can already be identified as leading candidates for use in reducing the risk of age-related pathology in this way, as they go beyond individual diseases and could help support health more broadly. They are briefly described below.

Thus, metformin, a diabetes drug taken by millions, has been tested as a geroprotector for many years. There is some evidence that metformin has protective properties against cardiovascular disease and may reduce the risk of other age-related diseases such as cancer, dementia, and stroke [65]. Similar anti-aging effects have been described in recent years for another group of antidiabetic drugs, namely sodium-glucose co-transporter type 2 (SGLT2) inhibitors - canagliflozin, empagliflozin, dapagliflozin [39, 64, 65]. Whether older people taking metformin or empagliflozin can avoid or at least delay the development of age-related diseases will likely be determined in large, long-term clinical trials.

Rapamycin, discovered in the 1970s, is now used to prevent organ rejection after transplantation and to treat some types of cancer. However, it has been repeatedly proven in mice that rapamycin prevents cancer in rodents and slows the progression of dementia; rapamycin also helps mice maintain muscle mass, slows the development of cardiovascular diseases, and can prolong the life of old mice [47, 57]. The current focus is on whether rapamycin will provide the same benefits in slowing disease in humans.

Senolytics, as a new class of drugs, target senescent cells, also called zombie cells, which are damaged cells that refuse to die. As we age, the body becomes less efficient at removing them, so they begin to accumulate and release chemicals that can cause chronic inflammation, damage nearby cells, and cause typical age-associated pathology [22, 46]. Researchers are now testing the ability of senolytics to prevent or slow the progression of age-related human diseases such as Alzheimer's disease, osteoarthritis, cardiovascular disease, and kidney disease [2, 69].

Aim – to evaluate the efficacy of synthetic antioxidants and polyphenols for the geroprotective properties.

In this review, we sought to draw the main attention to biologically active substances, both of plant origin and synthesized, that have antioxidant properties (we propose to consider only exogenous antioxidants).

The phrase «antioxidant and aging» occurs quite often; when searching, it was found in 14,524 articles in PubMed, 1,704 articles in the past year alone, and a total of 49,600,000 results were obtained for this query in Google.

This interest of researchers is obviously due to the fact that among the many theories explaining the causes of aging, one of the main ones is the theory of oxidative stress, first formulated by Denham Harman [29, 30]. It should be taken into account that it is an antioxidant, antiradical activity that is assumed to be one of the general anti-aging mechanisms, starting with the theory of aging put forward by D. Harman [29] and further developed at present [12, 80].

We found it possible to present some introductory concepts related to antioxidants here. Free radicals are chemical compounds that contain at least one unpaired electron in their outer shell, which usually makes them highly reactive. The most common free radicals and reactive molecules in biological systems are formed from oxygen (reactive oxygen species, ROS) and nitrogen (reactive nitrogen species, RNS). ROS or RNS are formed during electron transfer reactions by losing or gaining electron(s) [25]. The terms reactive oxygen species (ROS) and reactive nitrogen species (RNS) refer to reactive radical and non-radical derivatives of oxygen and nitrogen, respectively.

Free radicals play an important role in cell proliferation, differentiation, migration, apoptosis, and necrosis. Low to moderate levels of ROS and RNS are required to maintain many important physiological functions. On the contrary, excessive production of these forms is responsible for the disruption of redox homeostasis, which in turn leads to oxidative stress and indirect damage to important biomolecules, including DNA, proteins, and membranes [42]. Oxidative stress, characterized by a shift in the balance between forming and eliminating free radicals towards accumulation, is a common denominator in the pathogenesis of chronic diseases and aging [29].

The concept of oxidative stress has been interpreted in different ways, but the most common is the following: an imbalance between oxidants and antioxidants in favor of oxidants, leading to disruption of redox signaling and control and/or molecular damage [68].

Oxidative stress and the aging process are closely related to each other. It has been proven that both acute and chronic oxidative stress lead to the induction of a premature aging program both in vitro and in vivo [19, 41, 78]. With the advent of the concept of oxidative stress, it was proposed that diseases associated with oxidative stress could be "cured" by increasing the supply of antioxidants.

That is why research on the anti-aging properties of antioxidants began quite a long time ago, which attracted a lot of public attention [20]. First of all, research was carried out on vitamins with antioxidant properties - C, A, E, and D. The first results seemed promising, and today for a large number of people the words "antioxidants" and "anti-aging" are associated with each other as closely as the words "oxidants" and "aging".

However, over the past few years, paradigms have changed. Large-scale clinical studies have shown only limited health benefits from taking antioxidants in the form of vitamins E, A, C, or α-tocopherol, β-carotene, and selenium [25, 27]. Cochrane reviews state that supplementation with antioxidant vitamins A, C, and selenium does not affect mortality in either healthy people or patients; on the contrary, vitamin E was found to increase mortality [7].

A systematic review and meta-analysis of studies describing the effects of antioxidant vitamin and mineral supplements on cardiovascular disease risk and all-cause mortality [32] found that no effect was observed for commonly used multivitamins, vitamin D, calcium, and vitamin C, and there was an increased risk of all-cause mortality when taking niacin (with statins).

Work has begun to accumulate showing the pro-oxidant effects of antioxidants and the negative effects of some antioxidants on normal, healthy cells that maintain physiological levels of ROS [37, 45].

It is now believed that, despite the ability of these antioxidants to scavenge peroxides and free radicals in cell-free systems, their ability to exhibit these properties in vivo has not yet been confirmed. And even the known cytoprotective activity is explained mainly by the ability not to suppress, but to activate multiple redox pathways, which causes biphasic hormetic reactions and highly pleiotropic effects in cells. It has been established that N-acetylcysteine, β-carotene, selenium, and vitamins influence redox homeostasis through the formation of low molecular weight redox-active compounds (H2O2 or H2S), known for their ability to stimulate cellular endogenous antioxidant defense and promote cytoprotection in low concentrations, but have prooxidant effects at high concentrations [3, 74]. Probably, taking into account the two-phase response of cells to the pleiotropic effect of antioxidants can help explain many contradictory results obtained in fundamental and applied research and build a more logical strategy for their use.

Polyphenols occupy a special position among antioxidants. Among natural antioxidants, polyphenols are the most frequently studied compounds. Polyphenols are macro-molecules with a molecular weight of more than 200 Daltons that quickly diffuse through cell membranes [56]. Larger polyphenols are biosynthesized in situ from smaller polyphenols into non-hydrolysable tannins [48]. Some polyphenols contain repeating phenolic molecules of pyrocatechol, resorcinol, pyrogallol, and chloroglucinol, linked by esters (hydrolyzable tannins) or more stable C-C bonds [71]. The main feature of polyphenols is their antioxidant and antiradical activity, which is even more important than their anti-inflammatory effect [9]. The mechanism of antioxidant action of polyphenols includes hydrogen atom transfer, single electron transfer, sequential proton loss electron transfer, and transition metal chelation [88].

These compounds are potent ROS scavengers in vitro, but it is important to remember that they are readily oxidized to form quinones, semiquinones, and hydrogen peroxide (H2O2) and thus can have pro-oxidant effects, especially in cell culture [44, 85]. Unlike vitamins E and C, there appear to be no specific transport mechanisms for the accumulation of polyphenols in the human body, and indeed polyphenols are rapidly metabolized through processes such as methylation and glucuronidation; such metabolism reduces their antioxidant activity [82]. Levels of unconjugated polyphenols in vivo are generally very low, especially in the brain [63], and based on studies of biomarkers of oxidative damage, there have been previous reports that polyphenols do not have systemic antioxidant effects in vivo [55, 82]. However, most recent studies have refuted this and suggest that polyphenols improve autophagy by clearing misfolded proteins in neurons, suppress neuroinflammation and oxidative stress, and protect against neuro-degeneration in vivo [11, 86].

When considering the systemic distribution and action of polyphenols, it is important to remember that the effect of polyphenols does not begin to unfold in the blood, but in the gastrointestinal tract, the situation may be different. The poor absorption of polyphenols leads to their high concentrations in the gastrointestinal tract, where polyphenols may already have an antioxidant (or other) effect there [26, 33]. Rapid metabolism of phenols by colon bacteria leads to the formation of compounds that may have real therapeutic value [50, 82]. For example, due to the low bioavailability of anthocyanins, their intestinal metabolites, as suggested by B Wang et al. [79] play a critical role in providing health benefits by participating in the so-called gut microbiota-heart or gut microbiota-brain axes. Increasing evidence suggests that polyphenols delay aging and alleviate age-related diseases indirectly through interactions with the microbiota [23, 31, 91].

Overall, polyphenols may play a special role in the gastrointestinal tract and most of the preventive and therapeutic effects may be realized, at least in part, through antioxidant effects in the gut microbiome [28]. Their beneficial effects on human health appear to be due not only to direct antioxidant effects but also to indirect interactions with the intestinal microbiota.

We consider it necessary to note that the results of clinical studies of polyphenols vary significantly depending on whether an isolated polyphenol is used in the study (resveratrol, curcumin, fisetin, quercetin, and others) or a natural mixture or concentrate of polyphenols typical of a particular natural product source of polyphenols is used. It is still unclear whether the protective effects are due to individual antioxidant polyphenols or to unique combinations of polyphenols found in different foods [8].

For example, over the past 20 years, there have been nearly 200 studies evaluating resveratrol for at least 24 indications, including cancer, menopausal symptoms, diabetes, metabolic syndrome, and cardiovascular disease. But there are still no agreed-upon treatment regimens for any specific condition or endpoint, other than the fact that resveratrol is generally well tolerated at doses up to 1 g/day. In addition, resveratrol has been found to consistently reduce inflammatory markers and improve aspects of impaired metabolism [10]. Researchers generally conclude that resveratrol may provide health benefits to humans, but larger, higher-quality clinical trials are needed to move this intriguing compound from health food stores to clinics.

More definitive conclusions are obtained by researchers of total polyphenols (polyphenols of wine or grapes, blueberries, strawberries, and other berries and plants). Thus, while taking the Mediterranean diet (MED) or the Green-MED diet enriched with poly-phenols, it was possible to record a significant decrease in biological age for 256 participants with abdominal obesity or dyslipidemia after an 18-month randomized controlled trial DIRECT PLUS (a difference of ~ 8.9 months) [87]. The Green-MED diet (high in polyphenols) has been found to be neuroprotective in age-related brain atrophy [35].

Total polyphenols have shown promising effects in the treatment of chronic age-associated diseases, as they have potent anti-inflammatory, antioxidant, and cholesterol-lowering effects [67]. Thus, a mixture of strawberries, blueberries, chokeberries, and black currants reduced systolic blood pressure and LDL levels, while increasing HDL levels [17]. In another study, strawberries alone reduced LDL cholesterol levels as well as vascular cell adhesion molecule-1 (VCAM-1) levels in patients with metabolic syndrome [4].

Red wine polyphenols have been extensively studied for their protective effects on vascular health in both animals and humans. In a meta-analysis [81] a significant improvement in systolic blood pressure was proven (- 2.6 mm Hg, 95% CI: - 4.8, - 0.4).

Polyphenols are promising bioactive substances that have beneficial effects on age-related cognitive decline. In a study by J Bensalem et al. [6], the effect of polyphenol-rich grape and blueberry extract on the memory of healthy elderly people (60-70 years old) was assessed. An improvement in age-related episodic memory decline in people with severe cognitive impairment has been established.

Results of a double-blind randomized trial [84] in 61 healthy subjects aged 65–80 years demonstrate that daily intake of blueberry powder equivalent to 178 g wet weight improves vascular and cognitive function and reduces 24-hour ambulatory systolic blood pressure in healthy older adults. This suggests that blueberry (poly) phenols may reduce future cardiovascular disease risk in older adults and improve episodic memory processes in older adults at risk for cognitive decline. The meta-analysis also confirms that the use of polyphenols may be a potential means of preventing muscle loss as humans age [51].

A complex of coffee, tea, and beet polyphenols reduced body weight in obese patients in a randomized clinical trial [52]. Dietary polyphenols are hypothesized to be effective in preventing obesity through various multi-target weight loss mechanisms. Polyphenol supplementation significantly altered anthropometric parameters in obese subjects aged <50 years, for periods ≥3 months, and at doses <220 mg per day [90]. Overall, dietary polyphenols show promise in preventing and treating obesity in aging populations [1].

A meta-analysis of 14 studies with a total of 50,366 participants with metabolic syndrome [59] found a reduction in the chances of developing metabolic syndrome by an average of 22% when using polyphenols.

Another meta-analysis suggests that modulation of the microbiota by total lingonberry polyphenols and probiotics reduces atherosclerotic plaques by a mechanism mediated in part by activation of *Akkermansia muciniphila* and reduction of TMAO [49]. A study by F. Liu et al. [43] confirmed a positive correlation between the use of lingonberry polyphenols and the activity of *Akkermansia muciniphila* in the colon.

Typically, synthetic antioxidants identical to natural ones are isolated (for example, synthetic precursors of reduced glutathione, synthetic superoxide dismutase (SOD) mimetics, synthetic carotenoids and polyphenols, acetylcarnitine, acetylcysteine, ascorbic acid, β-carotene, cholecalciferol, α-lipoic acid, and others) and synthetic antioxidants, having no natural analogs (probucol, pentoxifylline, ubiquinone, metal compounds and others) [72].

Synthetic small molecules with antioxidant activity can be used as therapeutic agents, but are more commonly used as antioxidant dietary supplements to slow down the oxidation of nutrients, particularly lipids and proteins.

Among the synthesized antioxidants identical to natural ones, antioxidant enzyme mimetics can be distinguished. Since superoxide dismutase (SOD), catalase, and glutathione peroxidase are the most important antioxidant enzymes playing a key role in redox homeostasis, this makes them attractive biomolecules for the design of small molecular metal complexes with ROS scavenging properties under pathological conditions. Perhaps the most frequently studied are metal complexes with magnesium, which have superoxide dismutase mimetic properties. Manganese is a transition metal capable of oscillating between several oxidation states, making it suitable for hosting superoxide anion radicals and creating SOD mimetic compounds [77]. To date, a large number of Mn-based complexes have been synthesized and studied - salen derivatives, nitro-gen-centered ligands, cyclic polyamines, carboxylate/aminocarboxylate ligands, porphyrins, peptides, phthalocyanines [18]. Several Mn(II)-based cyclic polyamines and Mn(III) porphyrins have entered early clinical trials with mixed results [5].

Several SOD mimetic compounds simultaneously exhibit the properties of SOD mimetic and catalase. For example, the Mn-salen complex (EUK-8) exhibits both SOD and catalase mimetic properties and has been found to antagonize sepsis- or lipopolysaccharide-induced pulmonary dysfunction [21].

Various glutathione peroxidase mimetic compounds have also been tested. For example, an organic compound based on selenium, ebselen, has a wide spectrum of action. This compound and its modified analog BXT-51072 were able to delay neurological deficits and acute ischemic stroke, presumably by reducing oxidative stress levels [18].

Among the antioxidants that have no natural analogs, we propose to consider aminopyridines. This is due to the fact that in the last decade, excessive production of nitric oxide nNOS has been recognized as a key player in the induction and progression of neurodegenerative diseases. Although normal production activity is at physiological levels [24]. However, since nNOS is important for neurotransmission, its overproduction is associated with the formation of an extremely reactive oxidant, peroxy-nitrite (ONOO-) [73], in the presence of superoxide. nNOS has also been shown to be involved in some chronic neurodegenerative pathologies such as Alzheimer's disease [14], Parkinson's disease [89], Huntington's disease [53], amyotrophic lateral sclerosis [15], neuronal damage during stroke [70].

Selective inhibitors of human nNOS are precisely antioxidants based on a 2-aminopyridine framework with a shortened side amino chain [13, 76].

Aminopyridines are a class of heterocycles with a relatively high probability of exhibiting biological activity. The biological activity of aminopyridine derivatives is being intensively studied [54]. Among them, 2-aminopyridines stand out, for which antioxidant and cytoprotective effects have been recorded (these effects can be considered precursors of senolytic action) [76]. Using 2-aminopyridine derivatives as pharmacophores, pharmaceutical companies around the world are seeking to synthesize small molecules with antioxidant activity for use against various biological targets [60]. A series of potent, selective, and highly permeable human neuronal nitric oxide synthase (hnNOS) inhibitors based on a difluorobenzene ring coupled to a 2-aminopyridine scaffold are reported for the treatment of neurodegenerative diseases [75]. The antimicrobial activity of substituted 2-aminopyridines has been established [36, 61]. The combination of antioxidant capacity with antifungal and antibacterial effects has been established for a number of new substituted 2-aminopyridine δ-lactone [62]. A number of data indicate that 2-aminopyridine derivatives are promising lead molecules for the development of new anti-tuberculosis drugs [40].

4-Aminopyridine derivatives have been identified as non-selective blockers of several voltage-gated potassium channels and are being tested in the symptomatic treatment of demyelinating diseases such as spinal cord injury or multiple sclerosis [54].

It was discovered that some 3-aminopyridine-2 (1H)-ones obtained for the first time have high antiradical activity [38].

Among a number of new compounds, derivatives of 3-(arylmethylamino)-6-methyl-4-phenylpyridin-2(1H)-one 3a-d showed high antiradical activity against DPPH• and ABTS•+ radicals, in some cases exceeding the reference drug - ascorbic acid, which indicates high relevance for further studies of the resulting derivatives. The same 3-(arylmethylamino) pyridone derivatives were studied for cytoprotective effects. The results of measuring the level of viability of MCF-7 cells during incubation with the study of 3-(arylmethylamino) pyridone compounds also seem promising as a cytoprotective basis for the manifestation of geroprotective activity [66].

The geroprotective potential of some plant and synthetic antioxidants has been de-scribed quite fully, including in vivo models of pathology. However, it is obvious that for plant polyphenols, the lack of standardization of the elemental composition of the sub-stances used reduces the likelihood of licensing them as medicines. Total polyphenolic substances are still used as food additives, although the prospects for clinical use as gero-protectors are clearly present.

New research opportunities may arise from synthesized compounds with high anti-radical activity against reactive nitrogen species and acceptable toxicity, which are ex-pected to better control oxidative damage at the molecular level.

We hope that this approach will contribute to a rational pharmacological perspective and look forward to the success of studies of total natural and synthetic antioxidants as substances that reduce the risk of age-associated pathology.

Authors' contribution:

Z. Shulgau, A. Nurgozhina, A. Gulyayev – concept and design of the study.

D. Sadvokassova, Sh. Sergazy – collection and processing of the material.

Z. Shulgau, A. Nurgozhina, D. Sadvokassova, Sh. Sergazy – writing the text.

A. Gulyayev – editing.

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The authors declare no conflicts of interest.

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ГЕРОПРОТЕКТИВНЫЙ ПОТЕНЦИАЛ РАСТИТЕЛЬНЫХ И СИНТЕТИЧЕСКИХ АНТИОКСИДАНТОВ

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Старение – неизбежный этап жизни, естественный процесс, который мы все переживаем и часто стремимся замедлить. Поскольку продолжительность жизни на Земле продолжает расти, стремление к долголетию и жизненной силе становится все более значимым. Однако наряду с этим увеличением продолжительности жизни мы сталкиваемся с возникновением заболеваний, связанных со старением, и генетических мутаций, которые могут привести к различным осложнениям со здоровьем. Эта двойная проблема давно беспокоит исследователей и специалистов в области здравоохранения.

Чтобы смягчить негативное влияние старения на здоровье, крайне важно изучить способы замедления этого процесса. В этой статье рассматриваются несколько перспективных вариантов, которые предполагают их эффективность против старения, потенциально выступая в качестве геропротекторов. Среди них антиоксиданты, пожалуй, являются самым популярным выбором из-за их способности снижать окислительный стресс, вызванный свободными радикалами — нестабильными молекулами, которые могут повреждать клетки и способствовать старению.

В дополнение к традиционным антиоксидантам, синтетические антиоксиданты, такие как миметики ферментов, становятся центром терапевтических исследований. Эти соединения направлены на воспроизведение действия природных ферментов, которые борются с окислительным стрессом, предлагая новый подход к проблемам со здоровьем, связанным с возрастом. Кроме того, полифенолы, природные соединения, содержащиеся в различных фруктах, овощах и напитках, таких как чай и красное вино, привлекли внимание из-за их потенциальной пользы для здоровья.

Вместе эти соединения могут способствовать новым возможностям исследований, направленных на борьбу с возрастной патологией и улучшение общих показателей здоровья. Понимая и используя силу антиоксидантов, миметиков ферментов и полифенолов, мы можем проложить путь для инновационных вмешательств, которые не только продлят продолжительность жизни, но и улучшат качество жизни людей по мере их старения. Поиск эффективных геропротекторов представляет собой важный рубеж в содействии здоровому старению и профилактике возрастных заболеваний.

Ключевые слова: геропротектор; антиоксиданты; полифенолы; синтетические антиоксиданты; старение

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ӨСІМДІК ЖӘНЕ СИНТЕТИКАЛЫҚ АНТИОКСИДАНТТАРДЫҢ ГЕРОПРОТЕКТОРЛЫҚ ПОТЕНЦИАЛЫ

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Қартаю – өмірдің еріксіз кезеңі, біз бәріміз бастан кешіретін және жиі баяулатуға тырысатын табиғи процесс. Жер бетіндегі өмір сүру ұзақтығы артып келе жатқандықтан, ұзақ өмір сүруге және өміршеңдікке ұмтылу барған сайын маңызды бола бастады. Дегенмен, өмір сүру ұзақтығының осылай артуымен бірге біз қартаюға байланысты аурулардың және денсаулықтың әртүрлі асқынуларына әкелетін генетикалық мутациялардың пайда болуына тап боламыз. Бұл екі жақты проблема ұзақ уақыт бойы зерттеушілер мен денсаулық сақтау мамандарын алаңдатып келеді.

Қартаюдың денсаулыққа кері әсерін азайту үшін процесті баяулатудың жолдарын зерттеу өте маңызды. Бұл мақалада олардың қартаюға қарсы тиімді болуы мүмкін және геропротектор ретінде қызмет ететін бірнеше перспективалы нұсқалар қарастырылады. Олардың ішінде антиоксиданттар еркін радикалдар – жасушаларды зақымдауы және қартаюға ықпал ететін тұрақсыз молекулалар тудыратын тотығу стрессін төмендету қабілетіне байланысты ең танымал таңдау болып табылады.

Дәстүрлі антиоксиданттардан басқа, синтетикалық антиоксиданттар, мысалы, ферментті миметика, терапевтік зерттеулердің негізгі бағытына айналуда. Бұл қосылыстар тотығу стрессімен күресетін табиғи ферменттердің әрекетін қайталауға бағытталған, жасына байланысты денсаулық мәселелеріне жаңа көзқарас ұсынады. Сонымен қатар, полифенолдар, шай және қызыл шарап сияқты түрлі жемістер, көкөністер мен сусындарда кездесетін табиғи қосылыстар денсаулыққа әлеуетті пайдасы үшін назар аударды.

Бұл қосылыстар бірге жасқа байланысты патологиялармен күресуге және денсаулықтың жалпы нәтижелерін жақсартуға бағытталған жаңа зерттеу мүмкіндіктеріне әкелуі мүмкін. Антиоксиданттардың, ферменттік миметиктердің және полифенолдардың күшін түсіну және пайдалану арқылы біз өмір сүру ұзақтығын ұзартуға ғана емес, сонымен қатар қартайған сайын адамдардың өмір сүру сапасын жақсартуға мүмкіндік беретін инновациялық араласуларға жол аша аламыз. Тиімді геропротекторларды іздеу салауатты қартаюды ілгерілету және жасқа байланысты аурулардың алдын алудағы маңызды шекара болып табылады.

Кілт сөздер: геропротектор; антиоксиданттар; полифенолдар; синтетикалық антиоксиданттар; қартаю