ГИГИЕНА

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Biologically active food components as an element in the prevention of coronavirus infection: A review

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Immune cells play a vital role in protecting the human body from pathogens and viruses. The deficiency of a number of nutrients in the diet negatively affects the state of the immune system, which disrupts the chemical, structural, and regulatory processes in the body. The purpose of the article is to consider the role of various biologically active nutrients and bioactive substances in increasing innate and adaptive human immunity for the prevention of COVID-19 in the population. Using the research method of scientific electronic libraries, bibliographic bases of articles on medical sciences, it was found that such vitamins as C, D, A, and E, minerals (zinc, iron, selenium), resveratrol, turmeric flavonoids, garlic, green tea, elderberry extract, biologically active substances from an aqueous extract of wormwood leaves help prevent coronavirus infection or reduce the severity of the disease, having immunomodulatory, anti-inflammatory, antioxidant and antiviral properties. In the context of the ongoing pandemic of coronavirus infection, recommendations for including the biologically active substances described above in the diet can be extrapolated to the entire population to maintain the immune system and the body's resistance to infection.

Keywords: immunity, COVID-19, coronavirus infection, biologically active nutrients, vitamins, minerals.

Introduction

On February 11, 2020, the World Health Organization (WHO) determined the official name of the infection caused by the new severe acute respiratory syndrome coro-

navirus SARS-CoV-2 (Severe Acute Respiratory Syndrome — related Coronavirus) — COVID-19. SARS-CoV-2 is an enveloped positive-single-stranded RNA virus belonging to the β-coronavirus genus[1]. To cause disease, a virus must enter, replicate, and damage a human cell, escaping immunological defenses to infect neighboring cells. In its replication cycle, SARS-CoV-2 follows the steps of attachment, endocytosis, biosynthesis, maturation, and exocytosis.

The functional receptor for the penetration of the SARS-CoV-2 virus into a target cell in humans is an angiotensin-converting enzyme type II — ACE-2 (membrane protein, exopeptidase, catalyzing the conversion of angiotensin I to angiotensin 1–9 and angiotensin II to angiotensin 1–7) [1–4]. The protein is mainly located on the membranes of type II pneumocytes, enterocytes of the small intestine, endothelial cells of arteries and veins, and smooth muscle cells in most organs [5]. In addition to the direct baroreguling function, ACE-2 suppresses inflammation, mainly in the lung tissue, participates in the transport of amino acids, and supports the vital activity of the intestinal microbiome. The virus' transmembrane spike glycoprotein (S protein, or SARS-CoV-S) binds to ACE-2 in the cell membrane; thus, the virus is attached to the target cell. Cell surface proteases, such as transmembrane serine protease 2 (TMPRSS2), then act on the SARS-CoV-S protein to fuse the virus with the host cell membrane. As a result, SARS-CoV enters the target cell, where it begins to replicate [6]. In addition to ACE-2, two more enzymes play an important role in the introduction of coronavirus into the cell: furin and 3-CL protease [7; 8].

In order for the COVID-19 virus to be able to block ACE-2, the viral proteins on its surface must first be modified by the enzyme furin (a cellular serine protease located in the Golgi apparatus and cleaving some proteins, which are thus converted into mature/active forms). A series of coronavirus mutations increased furin sensitivity, allowing the virus to bind much more strongly to ACE-2, making it much more infectious and virulent, leading to a pandemic. Certain dietary components and plant compounds inhibit the activity of furin. The 3CL protease is the most important for the replication and spread of the coronavirus family.

A 3CL-like protease (coronavirus SARS 3CLpro) is able to catalytically cleave the peptide bond between glutamine and a small amino acid (serine, alanine, or glycine). It has been called the "Achilles heel" of the coronavirus and has been the subject of new antiviral drug development. Some dietary flavonoids inhibit 3CL protease in laboratory studies and may reduce the severity of infection.

To ensure the functioning of innate and adaptive immunity, it is necessary to consume an adequate amount of biologically active nutrients that act on the immune system through gene expression and correction of intestinal microbiocenosis [9–11]. The impact on ACE-2, furin and 3-CL protease with the help of various biologically active food substances is also important in the prevention and treatment of coronavirus diseases.

[1] Vremennye metodicheskie rekomendatsii "Profilaktika, diagnostika i lechenie novoi koronavirusnoi infektsii (COVID-19)". Versiia 17 (14.12.2022) [Temporary guidelines "Prevention, diagnosis and treatment of novel coronavirus infection (COVID-19)". Version 17 (14.12.2022)]. Available at: https://static-0.minzdrav.gov.ru/system/attachments/attaches/000/061/252/original/%D0%92%D0%9C%D0%A0_COVID-19_V17.pdf (accessed: 04.02.2023).

Purpose of the study

Substantiation of the use of nutrients and biologically active food substances in the nutrition of the population, which contribute to an increase in human immunity and affect the activity of ACE-2, furin and 3-CL protease, for the prevention of coronavirus infection.

Methods

The work used the method of literary research and analysis of modern domestic and foreign scientific literature on the research topic. The review analyzes the data of scientific electronic libraries eLIBRARY. RU, bibliographic databases of articles on medical sciences MEDLINE and PubMed-NCBI.

Results and discussions

For the prevention of infectious diseases, including coronavirus infection, adequate intake of micronutrients plays an important role in maintaining immunity and increasing the functional reserves of the body. This requires such components as an increase in the innate and acquired immunity of a person before a disease, sufficient sleep (at least 7–8 hours a day), moderate physical activity, and positive emotions. Improving human immunity can be provided by the consumption of a normalized amount of protein in the diet, vitamins C, D, A and E, a number of minerals, especially zinc, copper, iron and selenium, curcumin, quercetin, polyphenols [9; 11–13]. Garlic, green tea, propolis, melatonin, an aqueous extract of wormwood leaves and echinacea, as well as probiotics and prebiotics, are important for improving immunity. The table shows the functional food components, which, in addition to their anti-inflammatory, antioxidant and antibacterial properties, have antiviral activity, confirmed by numerous studies [11; 12].

According to the Guidelines[2], a person should receive proteins in the amount of 75 to 114 g/day for men and from 60 to 90 g/day for women, depending on the intensity of physical activity, of which 50 % are animals. The lack of proteins in the diet leads to a decrease in the effectiveness of the functioning of the body's immune defenses, since the synthesis of antibodies, lymphocytes, neutrophils, lysozyme, adrenal cortex hormones, biologically active substances and other participants in the body's defense reactions requires the entire spectrum of amino acids.

However, for people suffering from COVID-19, attempts to improve the body's immune function by increasing protein intake can be harmful. In coronavirus infection, it is necessary to reduce inflammation and prevent hyperreactivity of the innate immune system [9]. An increased protein content in food, especially of animal origin, during the period of illness can worsen the patient's well-being, since meat products are rich in tryptophan and arginine. The latter increase the production of Th-17 cells, which increases

[2] Normy fiziologicheskikh potrebnostei v energii i pishchevykh veshchestvakh dlia razlichnykh grupp naseleniia Rossiiskoi Federatsii: Metodicheskie rekomendatsii MR 2.3.1.0253-21 [Norms of physiological needs for energy and nutrients for various groups of the population of the Russian Federation: Guidelines 2.3.1.0253-21]. Moscow, 2021; Rekomenduemye urovni potrebleniia pishchevykh i biologicheski aktivnykh veshchestv: Metodicheskie rekomendatsii MR 2.3.1.1915-04 [Recommended levels of consumption of food and biologically active substances: Guidelines 2.3.1.19150-0404]. Moscow, 2004.

Functional food components and their antiviral properties (indicating primary food products) [11]

Functional Components	Basic Foods	Functional Significance (antiviral properties)
Vitamin A	Milk, eggs, liver, fatty fish, fortified cereals, dark orange or green vegetables, orange fruit, and tomato juice	Reduces the incidence of pneumonia and helps relieve the clinical symptoms and signs of pneumonia and shorten the length of hospital stay in children
Vitamin C	Oranges and orange juice, red and green peppers, strawberries, black currants, kiwi, broccoli, potatoes	Reduces the duration of colds, reduces the intensity of colds, reduces the frequency and duration of colds and pneumonia
Vitamin D	Fatty fish, liver, eggs, fortified foods (spreads and some breakfast cereals)	Reduces the frequency of respiratory infections. Vitamin D deficiency is associated with an increased risk of community-acquired pneumonia
Vitamin E	Vegetable oils, wheat germ, nuts and seeds	Increases the activity of natural killers and has an anti-inflammatory effect in colds and pneumonia
Zinc, copper, iron	Shellfish, meat, cheese, some grains and seeds, cereals, nuts, liver, and some vegetables	Children with recurrent respiratory infections showed decreased levels of zinc, copper and iron in their hair
Zinc	Shellfish, meat, cheese and cereals	Oral zinc supplements may help reduce the duration of cold symptoms; they also reduce the prevalence of pneumonia
Quercetin	Capers, onion, apple, berries and cilantro (coriander)	Interacting with the viral subunit HA2 inhibits the H5N1 virus; inhibitory activity at an early stage of influenza infection
Turmeric	Turmeric rhizome (Curcuma longa)	Binding to three protein receptors: RBD-S (PDB ID: 6LXT), PD-ACE2 (PDB ID: 6VW1), and SARS-CoV-2 protease (PDB ID: 6LU7)
Polyphenols	Pomegranate, apricots, peaches, mango, spinach, broccoli, orange, tomato, apple and berries	Reduce the inflammatory response in adipocytes, macrophages, and other immune cells to prevent and fight inflammation

overall inflammation in the body. Another amino acid, leucine, is able to activate the mTOR protein (from the English mammalian target of rapamycin, a special intracellular protein that regulates the development of muscle fibers), which also contributes to the growth of the number of Th-17 lymphocytes. Decrease mTOR production by reducing inflammation, mTOR inhibitors found in coffee, extra virgin olive oil, and dietary deficiencies in amino acids. Authors who have conducted studies in humans or animals infected with SARS-CoV-2 link an unregulated innate immune system response to the leading cause of pathology mediated by SARS-CoV-2 [13; 14].

The most compelling evidence for an immunostimulating role in viral diseases has been obtained for vitamins C and D, as well as zinc.

Ascorbic acid, for which more than 100 functions are known in the body, is involved in the functioning of the body's immune system by enhancing the activity of the T-cell link of immunity, as well as stimulating the bactericidal activity and migratory ability of neutrophils; has a regenerating effect, increasing the level of cyclic adenosine monophosphate (3'-, 5'-cAMP) in tissues by suppressing the activity of phosphodiesterase; participates in the synthesis of corticosteroids (anti-inflammatory action), as well as in the synthesis of con-

nective tissue, etc. Physiological requirement for adults 100 mg/day, for children — from 30 to 90 mg/day depending on age, an adequate intake level for adults — 70–100 mg/day, the upper acceptable intake level is 700 mg/day[3]. Studies by many authors point to the antiviral activity of vitamin C [11; 15–17].

Vitamin D. Ergocalciferol (D2) is found in food, synthesized by ultraviolet irradiation from provitamin — ergosterol, which is part of plant tissues. Cholecalciferol (D3) is formed from 7-dehydrocholesterol contained in the skin under the influence of ultraviolet rays (up to 80 % of the daily requirement for vitamin D), it is also found in animal products. Vitamin D synthesized by the skin circulates 2–3 times longer than vitamin D obtained from food [18; 19].

Already by 2010, the results of numerous studies were obtained indicating the antibacterial and antiviral effects of vitamin D [20; 21]. Vitamin D, modulating the activity of T-lymphocytes, mast cells, and antigen-presenting cells, helps to reduce the excessive inflammatory response, increasing the levels of anti-inflammatory IL-10, reducing the levels of IgE, cytokines-alarmins, IL-17, histamine, leukotrienes. The discovery of calcitriol receptors in many cells of the immune system (on T-lymphocytes, macrophages, immature thymus lymphocytes and mature CD8 cells), as well as the ability of mononuclear phagocytes to produce 1,25-dihydroxyvitamin D3, proved the involvement of vitamin D in the functioning of the immune system [19].

W. B. Grant et al. [21] also state that vitamin D reduces the risk of infections through mechanisms that include the induction of cathelicidins and defensins that reduce viral replication, the rate and concentration of pro-inflammatory cytokines that cause inflammation, which damages the lung mucosa and leads to pneumonia, and also by an increase in the concentration of anti-inflammatory cytokines. At the same time, the authors argue that dietary supplements with vitamin D reduce the risk of infections that cause respiratory infections, influenza and COVID-19.

Elimination of vitamin D deficiency is fundamentally important for maintaining innate antiviral immunity in all age groups [20], reducing the risk of a «cytokine storm» and compensating for comorbid diseases associated with vitamin D deficiency (type 2 diabetes mellitus, arterial hypertension, coronary heart disease — IHD, bronchial asthma, chronic obstructive pulmonary disease (COPD), which aggravate the course of coronavirus infection [14]. So, T. L. Karonova, A. T. Andreeva, M. A. Vashukova [18] found that vitamin D deficiency and obesity increase the risk of severe and fatal coronavirus infection. W. B. Grant et al. [21] recommend that people at risk for influenza and/or COVID-19 take 10,000 IU/day of vitamin D3 for several weeks to rapidly increase blood levels, and then at 5,000 IU/day until vitamin D3 levels are reached in the blood above 40–60 ng/ml (100–150 nmol /l).

Healthy people need a minimum physiological dose of vitamin D in the summer months of 500 IU/day, and from September to June — 1,000 IU/day. In the clinical guidelines "Vitamin D deficiency in adults: diagnosis, treatment and prevention" devel-

[3] Normy fiziologicheskikh potrebnostei v energii i pishchevykh veshchestvakh dlia razlichnykh grupp naseleniia Rossiiskoi Federatsii: Metodicheskie rekomendatsii MR 2.3.1.0253-21 [Norms of physiological needs for energy and nutrients for various groups of the population of the Russian Federation: Guidelines 2.3.1.0253-21]. Moscow, 2021; Rekomenduemye urovni potrebleniia pishchevykh i biologicheski aktivnykh veshchestv: Metodicheskie rekomendatsii MR 2.3.1.1915-04 [Recommended levels of consumption of food and biologically active substances: Guidelines 2.3.1.19150-04]. Moscow, 2004.

oped by the Russian Association of Endocrinologists to maintain the level of 25(OH)D 30 ng/ml, the following regimen for taking Aquadetrim is presented: 1,000–2,000 IU daily orally (2–4 drops per day); 6,000–14,000 IU once a week orally (15–30 once a week).

Vitamin A has an immunostimulating effect by accelerating the proliferation of lymphocytes and activating phagocytosis; is an antioxidant; necessary for the function of the eyes, the condition of the skin, and mucous membranes, the synthesis of chondroitin sulfates (growth vitamin) [22–24]. Vitamin A reduces the incidence of pneumonia and alleviates its clinical manifestations.

Zinc has a multifaceted effect on all parts of the immune system [10]. It is necessary for the synthesis of T-helpers, the formation of antibodies, and the blast transformation of B-lymphocytes. Zinc has an immunostimulatory effect, and increases the activity of T and B lymphocytes, the phagocytic activity of neutrophils. The biochemical basis of zinc activity is considered to be its ability to block the RNA polymerase enzyme, which is necessary for viral replication [25–27]. 118 zinc-containing proteins are involved in human antiviral immunity, 11 of which are directly related to protection against single-stranded RNA viruses, which include SARS-CoV-2 [28]. The Zn-dependent protein TRIM5α (tripartite motif-containing proteins — TRIMs) inhibits the release of viral RNA inside the cell. The Zn-dependent proteins TRIM22, ISG15, and the iron/folate (B9)-dependent protein viperine, whose gene expression is regulated by vitamin D, inhibit viral replication and virus budding from the plasma membrane.

In addition, zinc is involved in the metabolism of vitamin A, is part of corticosteroids (protection against stress, anti-inflammatory effect), provides the function of taste evaluation by the papillae of the tongue, stimulating the synthesis of thickening by the parotid glands, participates in spermatogenesis, testosterone synthesis. An increased concentration of zinc prevents the penetration of virions into cells and blocks its reproduction process. Zinc has become even more popular due to the development of the COVID-19 pandemic [28].

Zinc and selenium deficiency occurs in 30–40 % of Russians. Among older people with comorbid pathology or alcohol abusers, the deficiency of these trace elements is observed in 60–80 %. Given this situation, zinc and selenium preparations can be taken without examining their content in the body for no more than 3 months and in moderate doses: for zinc 5–10 mg/day, for selenium — 50 mcg/day. With a significant deficiency, the intake is needed longer, and the doses are larger. For zinc, this is 80 mg/day, and for selenium — 100–200 mcg/day. With coronavirus infection, such doses can be taken for 3 weeks. The main dietary sources of zinc are seafood, meat, eggs, nuts, and legumes.

Administration of higher than recommended daily doses of nutrients, such as vitamins D, C, E, zinc, and ω-3 fatty acids, may have a beneficial effect in the setting of disease, potentially reducing SARS-CoV-2 viral load and length of hospital stay [9; 29].

Selenium is an essential component of antioxidant protection. Actively participating in antioxidant protection, selenium exhibits synergism with respect to the action of tocopherols and also ensures the reactivation of ascorbic acid as a result of its interaction with selenium-containing thioredoxin reductase. Selenoprotein P protects vascular endothelial cells from reactive nitrogen radicals. Epidemiological studies demonstrate that selenium deficiency alters immune responses and reduces resistance to viral infection.

The leader in selenium content is the Brazil nut. Reliable sources of selenium are animal products (seafood, meat products, nuts), as they contain a stable amount of it. In plant

products, the content of selenium directly depends on its concentration in the soil. Selenium is present in cereals, meat products, and mushrooms in the form of selenomethionine and selenocysteine, in onions and garlic — in the form of selenocysteine oxide, and in nuts — in the form of selenocystathionine. The assimilation of selenium from mixed diets is practically not inhibited and reaches 80 % or more.

Antiviral compounds in various fruits and plants can act on viruses and host cells. Thus, pomegranate peel juice and extract, as well as extracts of many berries, can prevent influenza A virus (IAV) replication in vitro [30]. Clinical studies have shown that garlic, due to some bioactive sulfur-containing substances (proteins, polyphenols and sulfoxide), as well as ground garlic with honey, having antiviral properties, are effective against influenza and acute respiratory viral infections [31–33].

American scientists have discovered the anti-coronavirus properties of an aqueous extract of wormwood leaves. The results of the study are published in the bioRxiv online library. Wormwood can produce artemisinin, a substance with antiviral activity that helps to suppress the replication of the coronavirus even after it enters the cell.

Black elderberries contain many valuable compounds and may be helpful in controlling COVID-19. It has been established that elderberry extract has antiviral activity and inhibits the release of pro-inflammatory cytokines TNF- and α, IFN-γ and IL-2, indicating that elderberries act as immunomodulators [33].

To improve the performance of ACE-2, regular aerobic exercise, a diet of whole foods of plant origin, the use of curcumin (a set of turmeric flavonoids) and resveratrol (a natural phytoalexin, a derivative of trans-stilbene, a polyphenol) are recommended. Resveratrol is synthesized by some plants to protect them from bacteria or fungi. Inhibits the growth of the coronavirus, and reduces the inflammation caused by it.

Resveratrol reduces the number of free radicals and enzymes involved in inflammatory reactions and the formation of reactive oxygen species (including myeloperoxidase, NADPH oxidase) [34]. In animal and cellular studies, resveratrol increases levels of key antioxidant enzymes: mitochondrial superoxide dismutase-2 (SOD2) and Nrf2 (nuclear factor-2) protein, which is key components of antioxidant defense, as well as glutathione, catalase, and heme oxygenase-1 [11]. In a study on brain cells, resveratrol increased the activity of heme oxygenase-1, which protects the brain from damage. This effect is enhanced by melatonin.

To increase the bioavailability of resveratrol, it is necessary to combine resveratrol with other polyphenols or flavonoids. Thus, the counting of resveratrol, quercetin and genistein is highly synergistic. Low dosages of these natural compounds can provide similar benefits in the aggregate. In addition, you can increase the bioavailability of resveratrol by taking liposomal or nano-resveratrol, as well as along with foods rich in fats.

Curcumin is a plant-derived polyphenolic compound found in the rhizomes of Curcuma longa. Curcumin can be used as a biologically active food supplement with protective, in relation to free radical oxidation, and antioxidant properties [35]. According to the current legislation of the EAEU, the adequate daily dose of curcumin for a person is 50 mg, the upper allowable dose is 150 mg. Research has demonstrated the health-promoting effects of curcumin in healthy middle-aged people [36]. Materials published in the databases PubMed, Web of Science, platform eLIBRARY.RU for 2008–2021 testify to the immunotropic, anti-inflammatory, antioxidant effects of curcumin.

Melatonin is a hormone produced by the pineal gland. It supports antiviral immunity and also helps control NLRP3 (cryopyrin). Melatonin is produced in the dark,

mostly between 2–3 am. Melatonin synthesis decreases with age, which may be one of the factors influencing the outcome of COVID-19 in elderly patients. Melatonin is able to prevent infection with the SARS-CoV-2 coronavirus, the development of a severe form of COVID-19. Melatonin is found in cherries, cherries, and bananas.

Probiotics increase the activity of natural killer cells, prevent the attachment of the virus to target cells, increase sensitivity to cytokines and thus activate innate immunity. In addition, probiotics, interacting with the intestinal microbiota, stimulate specific immunological processes and increase immunity [37; 38].

Conclusions

It has been established by the method of literary research that vitamins such as C, D, A and E, minerals (zinc, iron, selenium), resveratrol, turmeric flavonoids, garlic, green tea, elderberry extract, biologically active substances from the aqueous extract of wormwood leaves play an important role. in the prevention of coronavirus infection, having immunomodulatory, anti-inflammatory, antioxidant, and antiviral properties. Optimal nutrient intake through diets influences the immune system through gene expression, cell activation, and modification of signaling molecules. Various food ingredients are also determinants of the microbial composition of the gut, subsequently shaping the body's immune responses.

In the context of the ongoing pandemic of coronavirus infection and the high probability of infection, recommendations for including the above biologically active substances in the diet in the composition of foods and dietary supplements can be extrapolated to the entire population in order to maintain the immune system and body resistance to infection, as well as reduce the risk of forming wrong food stereotypes.

References

1. Shatunova P. O., Bykov A. S., Svitich O. A., Zverev V. V. Angiotensin converting enzyme 2. Approaches to pathogenetic therapy of COVID-19. *Zhurnal Microbiologii, Epidemiologii i Immunobiologii*, 2020, vol. 97, pp. 339–345 (In Russian).
2. Hisashi Kai, Mamiko Kai. Interactions of coronaviruses with ACE2, angiotensin II, and RAS inhibitors — lessons from available evidence and insights into COVID-19. *Hypertension Research,* 2020, vol. 43, pp. 648–654.
3. Li W., Moore M. J., Vasilieva N., Sui J., Wong S. K., Berne M. A., Wang X. Angiotensin-converting enzyme 2 is a functional receptor for the SARS coronavirus. *Nature,* 2003, vol. 426, pp. 450–453.
4. Turner A. J., Hiscox J. A., Hooper N. M. ACE2: from vasopeptidase to SARS virus receptor. *Trends Pharmacol. Sci.,* 2004, vol. 25, pp. 291–294.
5. Kabbani N., Olds J. L. Does COVID19 infect the brain? If so, smokers might be at a higher risk. *Molecular Pharmacology*, 2020, vol. 97, no. 5, pp. 351–353.
6. Hoffmann M., Kleine-Weber H., Schroeder S., Krüger N., Herrler T., Erichsen S., Schiergens T. S., Herrler G., Wu Nai-Huei, Nitsche A., Möller M. A., Drosten C., Pöhlmann S. SARS-CoV-2 cell entry depends on ACE2 and TMPRSS2 and is blocked by a clinically proven protease inhibitor. *Cell,* 2020, vol. 181, no. 2, pp. 271–280.
7. Tutelian V. A., Nikityuk D. B., Burlyaeva E. A., Khotimchenko S. A., Baturin A. K., Starodubova A. V., Kambarov A. O., Sheveleva S. A., Zhilinskaya N. V. COVID-19: new challenges for medical science and practical healthcare. *Voprosy pitaniia*, 2020, vol. 89, no. 3, pp. 6–13. (In Russian)
8. Yuki K., Fujiogi M., Koutsogiannaki S. COVID-19 pathophysiology: A review. *Clinical Immunology,* 2020, vol. 215 (108427).
9. Marchenkova L. A., Makarova E. V., Yurova O. V. The role of micronutrients in the complex rehabilitation of patients with a new coronavirus infection COVID-19. *Voprosy pitaniia*, 2021, vol. 90, no. 2, pp. 40–49. (In Russian)

10. Shipelin V. A., Shumakova A. A., Semin M. O., Trusov N. V., Balakina A. S., Timonin A. N., Gmoshinsky I. V., Nikityuk D. B. Influence of the complex of L-carnitine and resveratrol on the physiological, biochemical and morphological parameters of rats in the norm and with alimentary obesity. *Voprosy pitaniia*, 2021, no. 1, pp. 30–39. (In Russian)
11. Omer A. K., Khorshidi S., Mortazavi N., Rahman H. S. A Review on the Antiviral Activity of Functional Foods Against COVID-19 and Viral Respiratory Tract Infections. *Int. J. Gen. Med.,* 2022, vol. 10, no. 15, pp. 4817–4835.
12. Gromova O. A., Torshin I. Yu. The importance of zinc in maintaining the activity of innate antiviral immunity proteins: an analysis of publications on COVID-19. *The Russian Journal of Preventive Medicine*, 2020, vol. 23, no. 3, pp. 131–139. (In Russian)
13. Channappanavar R., Zhao J., Perlman S. T cell-mediated immune response to respiratory coronaviruses. *Immunologic Research,* 2014, vol. 59, pp. 118–128.
14. Argano C., Bocchio M. R., Giuseppe N., Scibetta S., Lo Monaco M., Corrao S. Protective Effect of Vitamin D Supplementation on COVID-19-Related Intensive Care Hospitalization and Mortality: Definitive Evidence from Meta-Analysis and Trial Sequential Analysis. *Pharmaceuticals,* 2023, vol. 16, p. 130.
15. Hemilä H. Vitamin C and SARS coronavirus. *J. Antimicrob. Chemother.,* 2003, vol. 52, no. 6, pp. 1049–1050.
16. Calder P. C., Carr A. C., Gombart A. F., Eggersdorfer M. Reply to "Overstated Claims of Efficacy and Safety. Comment On: Optimal Nutritional Status for a Well-Functioning Immune System Is an Important Factor to Protect against Viral Infections". *Nutrients,* 2020, vol. 12, no. 9, p. 1181.
17. Carr A. C., Rowe S. The emerging role of vitamin C in the prevention and treatment of COVID-19. *Nutrients,* 2020, vol. 12, no. 11, p. 3286.
18. Karonova T. L., Andreeva A. T., Vashukova M. A. Serum 25(OH)D level in COVID-19 patients. *Journal Infectology*, 2020, vol. 12, no. 3, pp. 21–27. (In Russian)
19. Smirnova G. E., Vitebskaya A. V., Shmakov N. A. The role of vitamin D in the development of the child's body and the correction of its deficiency. *Pediatriia. Prilozhenie k zhurnalu "Consilium medicum"*, 2010, no. 3, pp. 7–12. (In Russian)
20. Grant W. B., Goldstein M., Mascitelli L. Ample evidence exists from human studies that vitamin D reduces the risk of selected bacterial and viral infections. *Exp. Biol. Med.,* 2010, vol. 235, no. 12, pp.1395–1396.
21. Grant W. B., Lahore H., McDonnell S. L., Baggerly C. A., French C. B., Aliano J. L., Bhattoa H. P. Evidence that vitamin d supplementation could reduce risk of influenza and covid-19 infections and deaths. *Nutrients,* 2020, vol. 12, no. 4, p. 988.
22. Hurwitz J. L., Jones B. G., Penkert R. R., Gansebom S., Sun Y., Tang L., Bramley A. M., Jain S., McCullers J. A., Arnold S. R. Low Retinol-Binding Protein and Vitamin D Levels Are Associated with Severe Outcomes in Children Hospitalized with Lower Respiratory Tract Infection and Respiratory Syncytial Virus or Human Metapneumovirus Detection. *J. Pediatr.,* 2017, no. 187, pp. 323–327.
23. Biesalski H. K., Nohr D. Importance of vitamin A for lung function and development. *Mol. Aspects Med.,* 2003, no. 24, pp. 431–440.
24. Timoneda J., Rodríguez-Fernandez L., Zaragoza R., Marín M. P., Cabezuelo M. T., Torres L., Vina J. R., Barber T. Vitamin A deficiency and the lung. *Nutrients,* 2018, no. 10, p. 1132.
25. Berezhnoi V. V., Korneva V. V. Complex approaches to curing teenage deficiencies of iron, zink and vitamins of B group. *Modern Pediatrics*, 2016, no. 3, pp. 45–54. (In Russian)
26. Stolpovskaya E. V., Trofimova N. N., Malkov Yu. A., Babkin V. A. Development of a technological scheme for the preparation complex of zinc with dihydroquercetin. *The Chemistry of Plant Raw Materials Academic Journal,* 2017, no. 4, pp. 65–72. (In Russian)
27. Kumar A., Kubota Y., Chernov M., Kasuya H. Potential role of zinc supplementation in prophylaxis and treatment of COVID-19. *Med. Hypotheses,* 2020, vol. 144.
28. Sankova M. V., Kytko O. V., Dydykina I. S., Chilikov V. V., Laptina V. I., Markina A. D. Improving zinc sufficiency as a pathogenetically substantiated platform for maintaining immunity during the SARS-CoV-2 pandemic. *Voprosy pitaniia*, 2021, vol. 90, no. 2, pp. 26–39. (In Russian)
29. Keflie T. S., Biesalski H. K. Micronutrients and bioactive substances: Their potential roles in combating COVID-19. *Nutrition,* 2021, vol. 84, no. 4, pp. 111–103.
30. Moradi M.-T., Karimi A., Shahrani M., Hashemi L., Ghaffari-Goosheh M.-S. Anti-Influenza Virus Activity and Phenolic Content of Pomegranate (Punica granatum L.) Peel Extract and Fractions. *Avicenna J. Med. Biotechnol.,* 2019, vol. 11, no. 4, pp. 285–291.
31. Lissiman E., Bhasale A. L., Cohen M. Garlic for the common cold. *Cochrane Database Syst. Rev.,* 2014, vol. 11, pp. CD006206–CD006206.

32. Yang F., Zhang Y., Tariq A., Jiang X., Ahmed Z., Zhihao Z., Idress M., Azizullah A., Adnan M., Bussmann R. W. Food as medicine: a possible preventive measure against coronavirus disease (COVID-19). *Phytother. Res.,* 2020, vol. 34, no. 12, pp. 3124–3136.
33. Rouf R., Uddin S. J., Sarker D. K., Islam M. T., Ali E. S., Shilpi J. S., Nahar L., Tiralongo E., Sarker S. D. Antiviral potential of garlic (Allium sativum) and its organosulfur compounds: a systematic update of pre-clinical and clinical data. *Trends Food. Sci. Technol.,* 2020, vol. 104, pp. 219–234.
34. Tutelyan V. A., Nikityuk D. B. The global challenge of the 21st century — COVID-19: the answer to nutrition. *Voprosy pitaniia*, 2021, no. 1, pp. 30–39. (In Russian)
35. Gizinger O. A., Khisamova A. A. Curcumin in the correction of oxidative and immune disorders during exercise. *Voprosy pitaniia*, 2021, vol. 90, no. 1 (533), pp. 65–73. (In Russian)
36. Di Silvestro R. A., Joseph E., Zhao S., Bomser J. Diverse effects of a low dose supplement of lipidated curcumin in healthy middle-aged people. *Nutrition Journal,* 2012, vol. 11, no. 1, pp. 79–86.
37. Yan F., Polk D. B. Probiotics and immune health. *Curr. Opin. Gastroenterol.,* 2011, vol. 27, no. 6, pp. 496–501.
38. Singh P., Tripathi M. K., Yasir M., Khare R., Tripathi M. K., Shrivastava R. Potential Inhibitors for SARS-CoV-2 and Functional Food Components as Nutritional Supplement for COVID-19: A Review. *Plant Foods Hum. Nutr.,* 2020, vol. 75, no. 4, pp. 458–466.

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Биологически активные компоненты пищи как элемент профилактики коронавирусной инфекции: обзор литературы

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Иммунные клетки играют жизненно важную роль в защите организма человека от патогенов и вирусов. Негативно отражается на состоянии иммунной системы дефицит ряда нутриентов в рационе питания, что нарушает химические, структурные и регуляторные процессы в организме. Целью статьи является рассмотрение роли различных биологически активных нутриентов и биоактивных веществ в повышении врожденного и адаптивного иммунитета человека для профилактики у населения COVID-19. Методом исследования научных электронных библиотек, библиографических баз статей по медицинским наукам установлено, что такие витамины, как C, D, A и E, минеральные вещества (цинк, железо, селен), ресвератрол, флавоноиды куркумы, чеснок, зеленый чай, экстракт бузины, биологически активные вещества из водного экстракта листьев

полыни способствуют профилактике коронавирусной инфекции или снижению степени тяжести заболевания, обладая иммуномодулирующими, противовоспалительными, антиоксидантными и противовирусными свойствами. В условиях продолжающейся пандемии коронавирусной инфекции рекомендации по включению в рацион питания описанных выше биологически активных веществ могут быть экстраполированы на все население с целью поддержания иммунной системы и резистентности организма к инфекции.

Ключевые слова: иммунитет, COVID-19, коронавирусная инфекция, биологически активные нутриенты, витамины, минеральные вещества.

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