Heliyon 8 (2022) e11216

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Review article

Effect of food and key micronutrients on Covid-19: A review

Mahdi Shavandi [a,*], Atena Sarani [b]

[a] Department of Chemical Engineering, Iranian Research Organization for Science & Technology (IROST), Tehran, Iran
[b] Department of Food Science and TechnoLogy, Gorgan University of Agricultural Sciences and Natural Resources, Gorgan, Iran

ARTICLE INFO

Keywords:
Food safety
Micronutrients
Mineral
Nutrition
SARS-CoV-2
Vitamin

ABSTRACT

Humanity has faced different pandemics in history. The Covid-19 pandemic has made a new course in the world caused by SARS-CoV-2 that can be transmitted to humans. Finding alternative methods to prevent and control the disease through food and some micronutrients is important. This review summarizes effect of food and key micronutrients on Covid-19. There are currently no reports of the feasibility of transmission through the food sector. However, malnutrition and deficiency of some nutrients can lead to disorders of immune system. Coronavirus may be transferred through raw and uncooked foods; more safety and preventive measures are needed. Furthermore, sufficient intake of omega-3 fatty acids, minerals and vitamins are required for proper immune system function. Therefore, a healthy diet is required for prevent Covid-19. Personal hygiene and employee awareness is the two most important features in the prevention of Covid-19. Further studies are needed to confirm these results.

1. Introduction

In 2019 Wuhan, a central city in China, emergence of a new coronavirus (2019-nCoV) was reported (Chen et al., 2020). It was presented that presumably bats are the source of several emerging viruses. These viruses (CoVs severe acute respiratory syndrome (SARS), Middle East respiratory syndrome (MERS), porcine epidemic diarrhea (PED) and severe acute diarrhea syndrome (SADS) might cause serious illness (Banerjee et al., 2019). Historically, enzootic infections in animals (mammals and birds) through coronaviruses (CoVs) was reported. In the last few decades there are reports that CoVs are capable of infecting humans. CoVs can also cause disease humans to different degrees (upper and lower respiratory tract infections and severe respiratory illnesses) (Schoeman and Fielding, 2019). Overall, 2019-nCoV genome has 89% similarity with SARS of bat and 82% with SARS-CoV of human (Chan et al., 2020; Zhang et al., 2020). SARS-CoV-2 is a highly contagious infectious disease caused by a new coronavirus. CoVs can be transmitted from person to person through close contact. Each person infected with the virus can infect an average of about 3 other people (Zhu et al., 2020; Cohen and Normile, 2020; Li et al., 2020; Alimohamadi and Sepandi, 2020). It was reported that in the absence of specific treatment for this new virus, finding other procedures to hamper and control the outbreak of the virus is needed. Eating a balanced and healthy diet that contains all the essential nutrients is necessary for maintaining. Balance in micronutrients is a key factor in maintaining an immune system. The importance of healthy eating in increasing immunity and reducing disease has been known for many years. Several studies reported that a lack of certain nutrients reduces the function of the immune system and thus increases the likelihood of infections. Aim of this paper is to review key food-based micronutrients in Covid-19. Remove word interventions.

2. Food safety

As of April 21, 2020, there is no report that foodstuff is a probable route for the new coronavirus SARS-CoV-2 transmission by the European Food Safety Authority (EFSA) and the United States Food and Drug Administration (FDA) (Rizou et al., 2020). In prior prevalence through MERS and SARS-68 CoV, food was not a transmission route (EFSA, 2020; FDA, 2020a). It was reported that conditions of the stomach at pH < 3.5, destroyed SARS-CoV (Darnell et al., 2004). Virus outbreak, may cross the barrier of animal species and make humans sick. Therefore, some traditions of eating and cooking may be a risk factor for Re-outbreak of the virus (Lu et al., 2015; Cheng et al., 2007). The German Federal Institute for Risk Assessment (BfR: German: Bundesinstitut für Risikobewertung) reported that coronavirus may be transferred from an infected person to fresh food products or food packaging. Furthermore, the virus can be transferred from frozen food to humans (BfR, 2020). SARS-CoV-2 is highly resistant at 4 °C, and is resistant at −20 °C for up to 2 years (WHO,

* Corresponding author.
E-mail address: shavandimahdi097@gmail.com (M. Shavandi).

https://doi.org/10.1016/j.heliyon.2022.e11216
Received 22 July 2021; Received in revised form 3 February 2022; Accepted 18 October 2022

2020). However, it was reported that SARS-CoV-2 after 5 min incubation at 70 °C were inactivated (Chin et al., 2020). Therefore, cooking temperatures at >70 °C are sufficient for viral inactivation (BfR, 2020), to be after the sentence on transferring virus from the hands or food. It should be noted, people involved in food preparation should adopt standard hygiene practices include careful touching raw animal products to prevent transmission of contaminate, washing raw foodstuffs before eating, cooking eggs or meat perfectly, and cover the face with a mask when sneezing or coughing (Safefood, 2020). It was reported that Covid-19 survived on plastic and stainless steel up to 3 and 2 days, respectively, at 21–23 °C and 40% relative humidity. The Covid-19 virus was not detected on cardboard and copper, after 24 and 4 h, respectively (Van Doremalen et al., 2020).

To date, there have been no reports of Covid-19 survival on food packages and surfaces. The transmission and survival of SARS-CoV-2 via/on food packages and surfaces are investigated based on data present for other viral respiratory diseases such as MERS-CoV and SARS-CoV. However, the food safety execution handling systems including Good Manufacturing Practices (GMP), and Hazard Analysis and Critical Control Points (HACCP) are necessary to reduce the risk of Covid-19 disease. Actions such as active packaging, good hygienic practices, sanitation, and cleaning are also needed from farm to fork (Olaimat et al., 2020). The FDA (2020b), created instructions for consumers during food preparation, shopping and handling. However, food handlers such as consumers and employees of food establishments should abide by good hygienic and sanitation practices to avoid Covid-19 transmission and observe all provisions of the food safety system (Olaimat et al., 2020). In an online poll, data from 3000 respondents to questions on personal protection and food hygiene were investigated. It was reported that most people adopted the recommended personal protection and hygiene measures to avoid disease by Covid-19. In order to avoid disease by Covid-19 should be continued preventive recommendations and sufficient risk advice. it was reported that some substantial fault can lead to disease by Covid-19, including: ineffective materials for environment or food sanitization and cleaning (28%), not wearing a mask in public places (6%) and improper hand disinfection and washing (10–12%) (de AFF Finger et al., 2021). In a research report, a multi-country survey of 16 countries with the participation of 825 food companies was conducted. It was reported that personal hygiene and employee awareness is the two most important features in the prevention of Covid-19 (Djekic et al., 2021).

To slow down the spreading of the virus during the COVID-19 pandemic, people around the world have to change their behaviors. Hygiene measures and health regulations include social (physical) distancing, self-isolation, and observance with personal hygiene laws, particularly orderly and thorough hand washing. In an online survey (1434 participants) it was found that in the group of direct questioning, 94.5% of the contributors claimed to observance proper hand hygiene laws while in the group of indirect questioning a significantly lower estimate of only 78.1% was observed (Mieth et al., 2021). In a research study, hygiene measures and health regulations of 7,403 university students in ten countries were surveyed. It was reported that compliance related to hygiene (hand washing, coughing behaviours) is uniformly distinct from compliance related to social distancing behaviours. Treating public health compliance as a single concept obscures the dimensionality of compliance behaviours, perhaps resulting in worse prediction of individual compliance behaviour and difficulties in developing effective public health recommendations. Varied sorts of treatments may be required to affect these different behaviours (Wismans et al., 2020).

In addition to food safety practices, people should be made aware of the benefits of a healthy diet with evidence-based nutrients that may prevent viral illness. The remainder of this review will focus on the evidence supporting these nutrients.

3. Vitamin A

Vitamin (Vit) A is an unsaturated nutritional organic compound (Damodaran et al., 2007). It was reported that Vit A has important functions for body growth, preservation of the immune system and vision (Tanumihardjo, 2011). Usually Vit A is a yellow, fat-soluble substance in the form of retinol in foods (Rafeeq et al., 2020; Semba, 1998). The carotenes such as α-carotene, β-carotene, γ-carotene, and xanthophyll, are absorbed when eating vegetarian food (Karabacak and Karabacak, 2019; DeMan et al., 1999). Many of the body's defense mechanisms versus disease depend on providing sufficient amounts of Vit A. Vit A affects various aspects of the immune system, including: creatine and mucosal expression, apoptosis, growth, development and function of most white blood cells, immunoglobulin production and cytokine expression (Semba, 1998, 1999). It was reported that Vit A shortage is heavily involved in measles and diarrhea (Kańtoch et al., 2002). Vit A and other retinoids can be decreased measles-associated mortality (Trottier et al., 2009). Several studies propose that Vit A decreases illness and fatality in various infectious illnesses, including human immunodeficiency virus (HIV) infection, measles disease, diarrhoeal and malaria (Villamor et al., 2002; Semba, 1999). In a research study, effect of calcitriol (synthetic version of Vit D_3) and all-trans retinoic acid (derivative of Vit A) in experimental autoimmune encephalomyelitis (EAE), and multiple sclerosis (MS) at the mice was investigated. The expression of ROR-γt and IL-17 genes was significantly reduced and the authors reported that this method could be considered as a novel plan for MS inhibition and therapy (Parastouei et al., 2018). In one study, effect of reduced Vit A content in foods on antibody responses of 40 animal feed calves inseminated with inactivated cow coronavirus (BCoV) vaccine were investigated. It was shown that reduced Vit A content in foods may endanger the efficacy of viral vaccines and calves more exposed to infectious illness (Jee et al., 2013). Vit A food sources include turkey, liver, egg yolks, milk and dairy products, spinach, lettuce, carrots, apricots, cantaloupe, cabbage and pumpkin (Çalışlar, 2019; Booth et al., 1992).

4. B vitamins

B Vits are essential micronutrients that are involved in carbohydrate metabolism, boosting immune system function and promoting cell growth. Vit B_2, B_3, B_5 and B_1, are essential coenzymes for energy metabolism (Riordan et al., 2012). A study reported that B_2 and UV light considerably decreased the titer of the Middle East respiratory syndrome coronavirus (MERS-CoV) in human plasma products to below the limit of detection (Keil et al., 2016). The main sources of B- Vits in food are meat, fish, poultry, milk and dairy products, eggs, legumes and cereals (Strain et al., 2017).

5. Vitamin C

Vit C is a water soluble Vit found in raw and plant foods including citrus fruit, such as oranges, peppers, strawberries, blackcurrants, and broccoli, also Vit C were synthesized from glucose in the liver of most mammalians, guinea pigs, and some fruit bats (Brand et al., 1982; Li et al., 2006). It was reported that Vit C in mmol/L concentration accumulated in white blood cells and platelets. For this reason might be significant for the functioning of immune system (Levine et al., 1996; Jafari et al., 2019; Li et al., 2006; Bergsten et al., 1990; Washko et al., 1993; Evans et al., 1982). In a research study in mice, the effects of Vit C shortage was investigated on the immune system response to illness with influenza. It was reported that Vit C was required for a sufficient immune system response in restrictive lung illness after influenza illness (Li et al., 2006). In several studies beneficial Vit C effects were investigated on

diverse infections (Hemilä, 2017). Vit C can strengthen the immune system against SARS (Hemilä, 2003).

6. Vitamin D

Usually foods don't contain any Vit D and sunshine causes the production of Vit D in the human skin. Vit D is present in different levels in fatty fish, tuna, and cod liver oil; there is enrichment of food such as milk, some cereals, and some bread products with Vit D (Holick, 1996). It was reported that Vit D has been effective on infection acute in young animals (Nonnecke et al., 2014). Vit D in serum decreased the risk of many chronic diseases including cancers (McDonnell et al., 2016), diabetes (Pittas et al., 2019), chronic Respiratory Infections (Zhu et al., 2016), cardiovascular diseases (Gholami et al., 2019), and high blood pressure (Manson et al., 2019). Vit D in serum decreased the risk of viral diseases such as dengue virus infection (Arboleda and Urcuqui-Inchima, 2016), herpes virus (Brice et al., 2018), H_9N_2 influenza (Gui et al., 2017), HIV (Borella et al., 2014), and Viral respiratory infections (Currie et al., 2013; Aregbesola et al., 2013; Jackson et al., 2004). Recent research reinforces the finding that 10–20 μg/day of Vit D can decrease all-cause of fatality and cancer fatality in middle-aged and older peoples. Albeit doses of Vit D was more than those reviewed in the past but found no new clue that supplementation could have an effect on most non-skeletal conditions, such as disease of cardiovascular, adiposity, glucose metabolism, mood disorders, muscular function, colorectal adenomas, and tuberculosis, or on perinatal and maternal conditions. New research were scarce on cancer outcomes. Based on the results from 83 tests showed that Vit D had no significant effect on systemic inflammation biomarkers. It was reported that supplementation of Vit D might help to prevent asthma exacerbations and common upper respiratory tract infections (Autier et al., 2017). In a research study, the Vit D immunomodulatory role were analyzed specifically in viral infections and Covid-19. Vit D levels could be valuable in predicting severe forms of Multisystem Inflammatory Syndrome (MIS) in children; correction of abnormal levels of Vit D may influence the course of severe MIS (Feketea et al., 2021).

7. Vitamin E

Vit E has a hydrophobic tail and is lipid-soluble. It was reported that Vit E has beneficial effect on influenza illness in mice. Vit E is an antioxidant with an important role in lung and liver conservation. Vit E alone does not possess specific antiviral action (Mileva and Galabov, 2018); this comes from the fruits, vegetables, natural fats and oils providing Vit E (Eitenmiller and Lee, 2004). A study reported that deficiency of Vit E cause increase illness in mice hearts with a myocarditis coxsackievirus B3 (CVB3/20) (Beck et al., 1994). Various studies in fauna (animal and human) has shown that Vit E increase the strength of immune system and prevents various infectious diseases (Lee and Han, 2018).

8. Free fatty acids

In research reports, omega-6 and omega-3 long-chain polyunsaturated fatty acids (PUFAs) have demonstrated considerable effects on innate and adaptive immune system. Omega-3 include eicosapentaenoic acids (EPAs) and their metabolites are powerful intermediary of eliminate inflammation (Buckley et al., 2014; Henson, 2005). It was reported that macrophage-derived extracellular vesicles (EVs) had mediate long-lasting inhibitory affects hepatitis C virus (HCV) reiteration, and which can be blunted by PUFAs (Cai et al., 2018). In a research, effect of All-trans retinoic acid (ATRA) is a bioactive derived of Vit A, and docosahexaenoic acid (DHA) on 15 MS patients was investigated. It was reported that DHA and ATRA may be assistance control illness advancement by a combination of the two compounds (Mousavi Nasl-khameneh et al., 2018). In a similar study, effect of ATRA, DHA and Vit D_3 on EAE at mice was investigated. It was suggested that these combinations are caused be decrease in inflammation, therapy and prevention of EAE/MS and probably other autoimmune illness (Shiri-Shahsavar et al., 2016). The balance in fatty acid (C_{20} and C_{22} essential fatty acids) levels in AIDS patient's probably a valuable therapeutic purpose. Omega−3 and PUFAs are known to inactivate envelope viruses (Begin et al., 1989; Leu et al., 2004).

9. Iron

Iron is a vital element for the body because a shortage of iron causes growth to stop, anemia, a lack of modulation of cytokine activities, lack of nitric oxide production, lack of immune cell proliferation, and a lack of immune system modulation (Weiss, 2002). It was reported that the innate immune response meticulously controls iron metabolism. The host and pathogen need iron (Wessling-Resnick, 2018). Successful human pathogens have mechanisms to circumvent nutritional immunity. Therefore, iron compactness and dispensation must be intently controlled (Cassat and Skaar, 2013).

10. Zinc

Zinc has an important role in growth and development, cartilage growth and multiple enzymatic reactions (O'Connor et al., 2020; Brandão-Neto et al., 1995). It was reported that oxidative stress is a significant participating factor in many chronic illnesses, and zinc plays an important role as anti-inflammatory and antioxidant (Prasad et al., 2004). Several studies also reported that zinc acts as an effective anti-inflammatory (Mariani et al., 2006, 2008). Furthermore, increase Zn (2+) concentration with pyrithione (PT) can significantly disrupt the replication of different RNA viruses, such as poliovirus and influenza (Te Velthuis et al., 2010).

11. Selenium

Selenium (Se) has an extensive range of effects, such as pleiotropic, antioxidant and anti-inflammatory. It was reported that higher Se status or Se supplementation has effects, such as antiviral effects, successful reproduction in humans and decreases the danger of autoimmune thyroid illness (Rayman, 2012). Se has a great role in redox signaling, redox homeostasis and antioxidant defense in viral infection. Se deficiency, has been associated with the multiple viruses pathogenicity (Guillin et al., 2019).

12. Conclusion

The Covid-19 pandemic created many challenges in food and nutrition. Prevention and control of the disease through ensuring food safety and supplying key micronutrients is important. In this review, key nutrients that increase the function of immune system were investigated. Therefore, ensuring food safety and providing adequate amounts of fat-soluble vits E, D, A, and water-soluble B-complex and C, and sufficient amount of minerals such as selenium, zinc, and iron and omega-3 long-chain fats through a proper diet or through dietary supplements may be effective factor in the prevention or therapy of Covid-19.

Declarations

Author contribution statement

All authors listed have significantly contributed to the development and the writing of this article.

Funding statement

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Data availability statement

No data was used for the research described in the article.

Declaration of interest's statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

References

Arboleda, J.F., Urcuqui-Inchima, S., 2016. Vitamin D-regulated microRNAs: are they protective factors against dengue virus infection? Adv. Virol.

Alimohamadi, Y., Sepandi, M., 2020. Basic reproduction number: an important indicator for the future of the COVID-19 epidemic in Iran. J. Mil. Med. 22 (1), 96–97.

Aregbesola, A., Voutilainen, S., Nurmi, T., Virtanen, J.K., Ronkainen, K., Tuomainen, T.P., 2013. Serum 25-hydroxyvitamin D3 and the risk of pneumonia in an ageing general population. J. Epidemiol. Commun. Health 67 (6), 533–536.

Autier, P., Mullie, P., Macacu, A., Dragomir, M., Boniol, M., Coppens, K., et al., 2017. Effect of vitamin D supplementation on non-skeletal disorders: a systematic review of meta-analyses and randomised trials. Lancet Diabetes Endocrinol. 5 (12), 986–1004.

Banerjee, A., Kulcsar, K., Misra, V., Frieman, M., Mossman, K., 2019. Bats and coronaviruses. Viruses 11 (1), 41.

Beck, M.A., Kolbeck, P.C., Rohr, L.H., Shi, Q., Morris, V.C., Levander, O.A., 1994. Vitamin E deficiency intensifies the myocardial injury of coxsackievirus B3 infection of mice. J. Nutr. 124 (3), 345–358.

Begin, M.E., Manku, M.S., Horrobin, D.F., 1989. Plasma fatty acid levels in patients with acquired immune deficiency syndrome and in controls. Prostagl. Leukot. Essent. Fat. Acids 37 (2), 135–137.

Bergsten, P., Amitai, G., Kehrl, J., Dhariwal, K.R., Klein, H.G., Levine, M., 1990. Millimolar concentrations of ascorbic acid in purified human mononuclear leukocytes. Depletion and reaccumulation. J. Biol. Chem. 265 (5), 2584–2587.

BfR (German: Bundesinstitut für Risikobewertung, The German Federal Institute for Risk Assessment), 2020. Can the New Type of Coronavirus Be Transmitted via Food and Objects? – BfR. https://www.bfr.bund.de/en/can_the_new_type_of_coronavirus_be_transmitted_via_food_and_objects_- 244090.html.

Booth, S.L., Johns, T., Kuhnlein, H.V., 1992. Natural food sources of vitamin A and provitamin A. Food Nutr. Bull. 14 (1), 1–15.

Borella, E., Nesher, G., Israeli, E., Shoenfeld, Y., 2014. Vitamin D: a new anti-infective agent? Ann. N. Y. Acad. Sci. 1317 (1), 76–83.

Brand, J.C., Cherikoff, V., Lee, A., Truswell, A.S., 1982. An outstanding food source of vitamin C. Lancet 2 (8303), 873.

Brandão-Neto, J., Stefan, V., Mendonça, B.B., Bloise, W., Castro, A.V.B., 1995. The essential role of zinc in growth. Nutr. Res. 15 (3), 335–358.

Brice, D.C., Toth, Z., Diamond, G., 2018. LL-37 disrupts the Kaposi's sarcoma-associated herpes virus envelope and inhibits infection in oral epithelial cells. Antivir. Res. 158, 25–33.

Buckley, C.D., Gilroy, D.W., Serhan, C.N., 2014. Proresolving lipid mediators and mechanisms in the resolution of acute inflammation. Immunity 40 (3), 315–327.

Cai, C., Koch, B., Morikawa, K., Suda, G., Sakamoto, N., Rueschenbaum, S., et al., 2018. Macrophage-derived extracellular vesicles induce long-lasting immunity against hepatitis C virus which is blunted by polyunsaturated fatty acids. Front. Immunol. 9, 723.

Çalışlar, S., 2019. The Important of beta carotene on poultry nutrition. Selcuk J. Agric. Food Sci. 33 (3), 252–259.

Cassat, J.E., Skaar, E.P., 2013. Iron in infection and immunity. Cell Host Microbe 13 (5), 509–519.

Chan, J.F.W., Kok, K.H., Zhu, Z., Chu, H., To, K.K.W., Yuan, S., Yuen, K.Y., 2020. Genomic characterization of the 2019 novel human-pathogenic coronavirus isolated from a patient with atypical pneumonia after visiting Wuhan. Emerg. Microb. Infect. 9 (1), 221–236.

Chen, Y., Liu, Q., Guo, D., 2020. Emerging coronaviruses: genome structure, replication, and pathogenesis. J. Med. Virol. 92 (4), 418–423.

Cheng, V.C.C., Lau, S.K.P., Woo, P.C.Y., Kwok, Y.Y., 2007. Severe acute respiratory syndrome coronavirus as an agent of emerging and reemerging infection. Clin. Microbiol. Rev. 20 (Issue 4), 660–694. American Society for Microbiology (ASM).

Chin, A.W.H., Chu, J.T.S., Perera, M.R.A., Hui, K.P.Y., Yen, H.-L., Chan, M.C.W., Peiris, M., Poon, L.L.M., 2020. Stability of SARS-CoV-2 in different environmental conditions. Lancet Microbe.

Cohen, J., Normile, D., 2020. New SARS-like Virus in China Triggers Alarm. American Association for the Advancement of Science.

Currie, S.M., Findlay, E.G., McHugh, B.J., Mackellar, A., Man, T., Macmillan, D., et al., 2013. The human cathelicidin LL-37 has antiviral activity against respiratory syncytial virus. PLoS One 8 (8), e73659.

Damodaran, S., Parkin, K.L., Fennema, O.R. (Eds.), 2007. Fennema's Food Chemistry. CRC press.

Darnell, M.E.R., Subbarao, K., Feinstone, S.M., Taylor, D.R., 2004. Inactivation of the coronavirus that induces severe acute respiratory syndrome, SARS-CoV. J. Virol Methods 121 (1), 85–91.

de AFF Finger, J., Lima, E.M., Coelho, K.S., Behrens, J.H., Landgraf, M., Franco, B.D., Pinto, U.M., 2021. Adherence to food hygiene and personal protection recommendations for prevention of COVID-19. Trends Food Sci. Technol.

DeMan, J.M., Finley, J.W., Hurst, W.J., Lee, C.Y., 1999. Principles of Food Chemistry. Aspen Publishers, Gaithersburg, pp. 111–162.

Djekic, I., Nikolić, A., Uzunović, M., Marijke, A., Liu, A., Han, J., et al., 2021. Covid-19 pandemic effects on food safety-Multi-country survey study. Food Control 122, 107800.

EFSA (The European Food Safety Authority), 2020. Coronavirus: no evidence that food is a source or transmission route. https://www.efsa.europa.eu/en/news/coronavirus-no-evidence-food-source-or-transmission-route.

Eitenmiller, R.R., Lee, J., 2004. Vitamin E: Food Chemistry, Composition, and Analysis. CRC Press.

Evans, R.M., Currie, L., Campbell, A., 1982. The distribution of ascorbic acid between various cellular components of blood, in normal individuals, and its relation to the plasma concentration. Br. J. Nutr. 47 (3), 473–482.

FDA (Food and Drug Administration), 2020a. Food Safety and the Coronavirus Disease 2019 (COVID-19) | FDA. https://www.fda.gov/food/food-safety-during-emergencies/food-safety-and-coronavirus-disease-2019- covid-19.

FDA (Food and Drug Administration), 2020b. Shopping for Food during the COVID-19 Pandemic - Information for Consumers. FDA, White Oak Campus.

Feketea, G., Vlacha, V., Bocsan, I.C., Vassilopoulou, E., Stanciu, L.A., Zdrenghea, M., 2021. Vitamin D in corona virus disease 2019 (COVID-19) related multisystem inflammatory syndrome in children (MIS-C). Front. Immunol. 12, 607.

Gholami, F., Moradi, G., Zareei, B., Rasouli, M.A., Nikkhoo, B., Roshani, D., Ghaderi, E., 2019. The association between circulating 25-hydroxyvitamin D and cardiovascular diseases: a meta-analysis of prospective cohort studies. BMC Cardiovasc. Disord. 19 (1), 248.

Gui, B., Chen, Q., Hu, C., Zhu, C., He, G., 2017. Effects of calcitriol (1, 25-dihydroxy-vitamin D3) on the inflammatory response induced by H9N2 influenza virus infection in human lung A549 epithelial cells and in mice. Virol. J. 14 (1), 1–11.

Guillin, O.M., Vindry, C., Ohlmann, T., Chavatte, L., 2019. Selenium, selenoproteins and viral infection. Nutrients 11 (9), 2101.

Hemilä, H., 2003. Vitamin C and SARS coronavirus. J. Antimicrob. Chemother. 52 (6), 1049–1050.

Hemilä, H., 2017. Vitamin C and infections. Nutrients 9 (4), 339.

Henson, P.M., 2005. Dampening inflammation. Nat. Immunol. 6 (12), 1179–1181.

Holick, M.F., 1996. Vitamin D and bone health. J. Nutr. 126 (suppl_4), 1159S–1164S.

Jackson, M.L., Neuzil, K.M., Thompson, W.W., Shay, D.K., Yu, O., Hanson, C.A., Jackson, L.A., 2004. The burden of community-acquired pneumonia in seniors: results of a population-based study. Clin. Infect. Dis. 39 (11), 1642–1650.

Jafari, D., Esmaeilzadeh, A., Mohammadi-Kordkhayli, M., Rezaei, N., 2019. Vitamin C and the immune system. In: Nutrition and Immunity. Springer, Cham, pp. 81–102.

Jee, J., Hoet, A.E., Azevedo, M.P., Vlasova, A.N., Loerch, S.C., Pickworth, C.L., et al., 2013. Effects of dietary vitamin A content on antibody responses of feedlot calves inoculated intramuscularly with an inactivated bovine coronavirus vaccine. Am. J. Vet. Res. 74 (10), 1353–1362.

Kańtoch, M., Litwińska, B., Szkoda, M., Siennicka, J., 2002. Importance of vitamin A deficiency in pathology and immunology of viral infections. Rocz. Panstw. Zakl. Hig. 53 (4), 385.

Karabacak, Ç.E., Karabacak, H., 2019. Factors affecting carotenoid amount in carrots (Daucus carota). Ecol. Life Sci. 14 (2), 29–39.

Keil, S.D., Bowen, R., Marschner, S., 2016. Inactivation of Middle East respiratory syndrome coronavirus (MERS-CoV) in plasma products using a riboflavin-based and ultraviolet light-based photochemical treatment. Transfusion 56 (12), 2948–2952.

Lee, G.Y., Han, S.N., 2018. The role of vitamin E in immunity. Nutrients 10 (11), 1614.

Leu, G.Z., Lin, T.Y., Hsu, J.T., 2004. Anti-HCV activities of selective polyunsaturated fatty acids. Biochem. Biophys. Res. Commun. 318 (1), 275–280.

Levine, M., Conry-Cantilena, C., Wang, Y., Welch, R.W., Washko, P.W., Dhariwal, K.R., et al., 1996. Vitamin C pharmacokinetics in healthy volunteers: evidence for a recommended dietary allowance. Proc. Natl. Acad. Sci. USA 93 (8), 3704–3709.

Li, W., Maeda, N., Beck, M.A., 2006. Vitamin C deficiency increases the lung pathology of influenza Virus–Infected gulo−/− mice. J. Nutr. 136 (10), 2611–2616.

Li, Q., Guan, X., Wu, P., Wang, X., Zhou, L., Tong, Y., et al., 2020. Early transmission dynamics in Wuhan, China, of novel coronavirus–infected pneumonia. N. Engl. J. Med.

Lu, G., Wang, Q., Gao, G.F., 2015. Bat-to-human: spike features determining "host jump" of coronaviruses SARS-CoV, MERS-CoV, and beyond. Trends Microbiol. 23 (8), 468–478. Elsevier Ltd.

Manson, J.E., Cook, N.R., Lee, I.M., Christen, W., Bassuk, S.S., Mora, S., et al., 2019. Vitamin D supplements and prevention of cancer and cardiovascular disease. N. Engl. J. Med. 380 (1), 33–44.

Mariani, E., Cattini, L., Neri, S., Malavolta, M., Mocchegiani, E., Ravaglia, G., Facchini, A., 2006. Simultaneous evaluation of circulating chemokine and cytokine profiles in elderly subjects by multiplex technology: relationship with zinc status. Biogerontology 7 (5-6), 449–459.

Mariani, E., Neri, S., Cattini, L., Mocchegiani, E., Malavolta, M., Dedoussis, G.V., et al., 2008. Effect of zinc supplementation on plasma IL-6 and MCP-1 production and NK cell function in healthy elderly: interactive influence of+ 647 MT1a and− 174 IL-6 polymorphic alleles. Exp. Gerontol. 43 (5), 462–471.

McDonnell, S.L., Baggerly, C., French, C.B., Baggerly, L.L., Garland, C.F., Gorham, E.D., et al., 2016. Serum 25-hydroxyvitamin D concentrations≥ 40 ng/ml are associated with> 65% lower cancer risk: pooled analysis of randomized trial and prospective cohort study. PLoS One 11 (4), e0152441.

Mieth, L., Mayer, M.M., Hoffmann, A., Buchner, A., Bell, R., 2021. Do they really wash their hands? Prevalence estimates for personal hygiene behaviour during the COVID-19 pandemic based on indirect questions. BMC Publ. Health 21 (1), 1–8.

Mileva, M., Galabov, A.S., 2018. Vitamin E and influenza virus infection. Vit. E Health Dis. 67.
Mousavi Nasl-khameneh, A., Mirshafiey, A., Naser Moghadasi, A., Chahardoli, R., Mahmoudi, M., Parastouei, K., et al., 2018. Combination treatment of docosahexaenoic acid (DHA) and all-trans-retinoic acid (ATRA) inhibit IL-17 and RORγt gene expression in PBMCs of patients with relapsing-remitting multiple sclerosis. Neurol. Res. 40 (1), 11–17.
Nonnecke, B.J., McGill, J.L., Ridpath, J.F., Sacco, R.E., Lippolis, J.D., Reinhardt, T.A., 2014. Acute phase response elicited by experimental bovine diarrhea virus (BVDV) infection is associated with decreased vitamin D and E status of vitamin-replete preruminant calves. J. Dairy Sci. 97 (9), 5566–5579.
Olaimat, A.N., Shahbaz, H.M., Fatima, N., Munir, S., Holley, R.A., 2020. Food safety during and after the era of COVID-19 pandemic. Front. Microbiol. 11, 1854.
O'Connor, J.P., Kanjilal, D., Teitelbaum, M., Lin, S.S., Cottrell, J.A., 2020. Zinc as a therapeutic agent in bone regeneration. Materials 13 (10), 2211.
Parastouei, K., Mirshafiey, A., Eshraghian, M.R., Shiri-Shahsavar, M.R., Solaymani-Mohammadi, F., Chahardoli, R., et al., 2018. The effect of 1, 25 (OH) 2 D3 (calcitriol) alone and in combination with all-trans retinoic acid on ROR-γt, IL-17, TGF-β, and FOXP3 gene expression in experimental autoimmune encephalomyelitis. Nutr. Neurosci. 21 (3), 210–218.
Pittas, A.G., Dawson-Hughes, B., Sheehan, P., Ware, J.H., Knowler, W.C., Aroda, V.R., et al., 2019. Vitamin D supplementation and prevention of type 2 diabetes. N. Engl. J. Med. 381 (6), 520–530.
Prasad, A.S., Bao, B., Beck, F.W., Kucuk, O., Sarkar, F.H., 2004. Antioxidant effect of zinc in humans. Free Radic. Biol. Med. 37 (8), 1182–1190.
Rafeeq, H., Ahmad, S., Tareen, M.B.K., Shahzad, K.A., Bashir, A., Jabeen, R., Shehzadi, I., 2020. Biochemistry of Fat Soluble Vitamins, Sources, Biochemical Functions and Toxicity. The Saudi Journal of Life Sciences, Haya.
Rayman, M.P., 2012. Selenium and human health. Lancet 379 (9822), 1256–1268.
Riordan, H.D., Mikirova, N., Taylor, P.R., Feldkamp, C.A., Casciari, J.J., 2012. The effects of a primary nutritional deficiency (Vitamin B study). Food Nutr. Sci. 3 (9), 1238.
Rizou, M., Galanakis, I.M., Aldawoud, T.M., Galanakis, C.M., 2020. Safety of foods, food supply chain and environment within the COVID-19 pandemic. Trends Food Sci. Technol. 102, 293–299.
Safefood, 2020. COVID-19 Advice - Safe Food. https://www.safefood.qld.gov.au/covid-19-advice/.
Schoeman, D., Fielding, B.C., 2019. Coronavirus envelope protein: current knowledge. Virol. J. 16 (1), 1–22.
Semba, R.D., 1998. The role of vitamin A and related retinoids in immune function. Nutr. Rev. 56 (1), S38–S48.
Semba, R.D., 1999. Vitamin A and immunity to viral, bacterial and protozoan infections. Proc. Nutr. Soc. 58 (3), 719–727.
Shiri-Shahsavar, M.R., Mirshafiee, A., Parastouei, K., Ebrahimi-Kalan, A., Yekaninejad, S., Soleymani, F., et al., 2016. A novel combination of docosahexaenoic acid, all-trans retinoic acid, and 1, 25-dihydroxyvitamin D 3 reduces T-bet gene expression, serum interferon Gamma, and clinical scores but promotes PPARγ gene expression in experimental autoimmune encephalomyelitis. J. Mol. Neurosci. 60 (4), 498–508.
Strain, J.J., Hughes, C., Pentieva, K., Ward, M., Hoey, L., McNulty, H., 2017. The B-Vitamins. In: Sustainable Nutrition in a Changing World. Springer, Cham, pp. 185–203.
Tanumihardjo, S.A., 2011. Vitamin A: biomarkers of nutrition for development. Am. J. Clin. Nutr. 94 (2), 658S–665S.
Te Velthuis, A.J., van den Worm, S.H., Sims, A.C., Baric, R.S., Snijder, E.J., van Hemert, M.J., 2010. Zn2+ inhibits coronavirus and arterivirus RNA polymerase activity in vitro and zinc ionophores block the replication of these viruses in cell culture. PLoS Pathog. 6 (11), e1001176.
Trottier, C., Colombo, M., Mann, K.K., Miller Jr., W.H., Ward, B.J., 2009. Retinoids inhibit measles virus through a type I IFN-dependent bystander effect. Faseb. J. 23 (9), 3203–3212.
Van Doremalen, N., Bushmaker, T., Morris, D.H., Holbrook, M.G., Gamble, A., Williamson, B.N., et al., 2020. Aerosol and surface stability of SARS-CoV-2 as compared with SARS-CoV-1. N. Engl. J. Med. 382 (16), 1564–1567.
Villamor, E., Mbise, R., Spiegelman, D., Hertzmark, E., Fataki, M., Peterson, K.E., et al., 2002. Vitamin A supplements ameliorate the adverse effect of HIV-1, malaria, and diarrheal infections on child growth. Pediatrics 109 (1) e6–e6.
Washko, P.W., Wang, Y., Levine, M., 1993. Ascorbic acid recycling in human neutrophils. J. Biol. Chem. 268 (21), 15531–15535.
Weiss, G., 2002. Iron and immunity: a double-edged sword. Eur. J. Clin. Invest. 32, 70–78.
Wessling-Resnick, M., 2018. Crossing the iron gate: why and how transferrin receptors mediate viral entry. Annu. Rev. Nutr. 38, 431–458.
WHO, 2020. COVID-19 and Food Safety: Guidance for Food Businesses. https://www.who.int/publications-detail/covid-19-and-food-safety-guidance-435 for-food-businesses.
Wismans, A.B., Letina, S., Thurik, R., Wennberg, K., Baptista, R., Barrientos Marín, J., et al., 2020. Hygiene and social distancing as distinct public health related behaviours among university students during the COVID-19 pandemic. Social Psychol. Bull. 15 (4).
Zhang, N., Wang, L., Deng, X., Liang, R., Su, M., He, C., et al., 2020. Recent advances in the detection of respiratory virus infection in humans. J. Med. Vrol. 92 (4), 408–417.
Zhu, M., Wang, T., Wang, C., Ji, Y., 2016. The association between vitamin D and COPD risk, severity, and exacerbation: an updated systematic review and meta-analysis. Int. J. Chronic Obstr. Pulm. Dis. 11, 2597.
Zhu, N., Zhang, D., Wang, W., Li, X., Yang, B., Song, J., et al., 2020. A novel coronavirus from patients with pneumonia in China, 2019. N. Engl. J. Med.