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MINI REVIEW

The potential of microgreen as the dietary antioxidant in COVID-19 pandemic: mini review

[1,*]Rohmanna, N.A., [2]Majid, Z.A.N.M. and [3]Robbani, S.

[1]*Department of Agroindustrial Technology, Faculty of Agriculture, University Lambung Mangkurat, South Kalimantan, Indonesia*
[2]*Department of Plantation Crop Cultivation, Politeknik Hasnur, South Kalimantan, Indonesia*
[3]*Department of Agroindustrial Technology, Faculty of Engineering and Computer Science, Nahdlatul Ulama Indonesia University, Indonesia*

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Abstract

Microgreens were tiny vegetables with a higher nutrient content than mature vegetables. Microgreens could be consumed directly as a garnish or salad. It was a high source of antioxidants and suitable for consumption. This review focused on providing a general description of microgreen production techniques, the nutritional content of microgreens, and their role in stimulating the immune system, mainly in preventing COVID-19. Several microgreens from various vegetables show high antioxidants, phytochemicals, and nutrients. This component is suitable for consumption to improve immunity system performance. The micronutrients contribute to immune function. There are four phases of the immune response in the body, namely physical barriers, innate immune response, inflammatory response, and adaptive immune response. When the body detects the presence of a foreign substance, the immune system will immediately respond by activating the immune function that utilizes T and B cells to kill them. Therefore, microgreen is one of the great dietary antioxidants for consumption.

1. Introduction

A microgreen is a type of tiny plant (Tan *et al.,* 2020; Turner *et al.,* 2020). Microgreens are immature vegetables produced from grains, including vegetables, fruits, or herbs. Microgreens can be cultured on various growing media and harvested about 7-21 days after germination (depending on the type of plant) or when cotyledon leaves have developed and the first true leaves have appeared (Kowitcharoen *et al*., 2021). Recently, it has been popular for health (Xiao *et al.,* 2012). These plants are harvested when the first true leaves sprout (Mir *et al.,* 2017; Kusumitha *et al.,* 2021) in about 10-14 days (Tan *et al.,* 2020; Turner *et al.,* 2020), depending on the type of plant. Ideally, this plant is grown indoors (Ampim *et al.,* 2020; Turner *et al.,* 2020) with the least light. Commonly, microgreens are consumed fresh in salads, soups, and sandwiches as edible garnishes (Xiao *et al.,* 2012).

Various microgreens have been developed and commercialized, including broccoli (Weber, 2017), spinach (Kusumitha *et al.,* 2021), sunflower (Dalal *et al.,* 2020), roselle (Ghoora *et al.,* 2020), and Bassil (Bulgari *et al.,* 2021). Ghoora *et al.* (2020) showed that microgreen Roselle and fennel are high in OPCI (overall phytochemical composite index) and APCI (antioxidant potential composite index) and have potential as Dietary antioxidants. Several studies have shown that microgreens have more saturated micronutrients than mature plants (Tan *et al.,* 2020; Bulgari *et al.,* 2021) and high antioxidants (Senevirathne *et al.,* 2019; Ghoora *et al.,* 2020), and phytochemical compounds (Marton *et al.,* 2010; Xiao *et al.,* 2012), including chlorophyll (Bulgari *et al.,* 2021), phenolic compounds (Kusumitha *et al.,* 2021), vitamin C (Senevirathne *et al.,* 2019), vitamin E (Xiao *et al.,* 2012), β-carotene (Senevirathne *et al.,* 2019), and tannins (Gunjal, 2020). According to Mrityunjaya *et al.* (2020), this nutrient has a role in stimulating the immune system, mainly in the COVID-19 pandemic.

COVID-19 is a type of virus that attacks the respiratory system. Boosting the immune system is one of the factors to restrict the spread of virus infections. Commonly, diseases caused by viruses are "self-limiting diseases" that depend on the body's defences. Several studies have shown that people with weakened immune systems are more tolerant of virus attacks. One of the

*Corresponding author.
Email: *novianti.rohmanna@ulm.ac.id*

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causes of weakened immunity is micronutrient deficiency. Consuming dietary antioxidants and micronutrients such as vitamins A, D, C, E, B6, B12, folate, zinc, iron, copper, and selenium can boost immunity. These micronutrients have an essential role in the immune response (Shakoor *et al.,* 2021). According to several studies, vitamin E (Lee and Han, 2018), vitamins A (Huang *et al.,* 2018), vitamins D (Hribar *et al.,* 2020), and vitamin C (Devaki and Raveendran, 2017) can boost the immune system response (Table 1) and increase protection against various infectious diseases. Vitamin D is needed by the body to support the work of T cells, which play a role in producing cytokines. Cytokines contribute to activating immune cells to protect themselves against virus attacks. In addition, vitamin A plays a vital role in the growth of T cells and stimulates the function of T cells to attack foreign substances.

The combination of vitamins A, C, and E also significantly improved the number and activity of immune cells. Nutrient deficiency can affect the body's immune response. Research showed that vitamin A, B6, C, D, and E deficiency could modify the immune response. Nutrients can function as antioxidants to protect cells, support the development and activity of immune cells, and stimulate antibody production. Research showed that nutritional deficiencies improved the risk of bacterial, virus, and other infections, including the COVID-19 attack. One of the antioxidant and micronutrient dietary can be obtained by consuming microgreens. This review intended to combine some focus studies to overview potential microgreens as the antioxidant dietary during the COVID-19 pandemic.

2. Microgreens production techniques

Microgreen cultivation needs minimum or indirect daylight (Ampim *et al.,* 2020). Commonly, this plant is grown indoors with an optimal temperature of 24-29°C, and then using a lighting system can support the growth of microgreens (Samuolienė *et al.,* 2019). Lighting is one of the essential factors, especially for plants grown indoors. The role of the light presence is to support the growth and development of these plants, including the formation of phytochemical compounds (Kopsell and Sams, 2013) such as Chlorophyll (Inanc, 2011), phenolics (Kumar and Goel, 2019), flavonoids (Ghoora *et al.,* 2020), vitamin C (Chambial *et al.,* 2013), and β-carotene (Yadav *et al.,* 2016).

Indifference to photosynthesis, the photoresponse depends on the wavelength and intensity of light (Samuolienė *et al.,* 2019). According to Gao *et al.* (2021), variations in light intensity can control plant growth and production of phytochemical compounds and produce high-quality products. The use of light-emitting diodes (LED) and their comfort in regulating light intensity also affect plant growth and phytochemical content (Zhang *et al.,* 2020). According to Viršilė *et al.* (2019), the total light intensity (PPFD, photosynthetic photon flux density) of 100 and 200 mol m^{-2} s^{-1} increased the total protein content of tatsoi. In lettuce, Anthocyanin content was found to be highest in the 290 mol m^{-2} s^{-1} (6/2 hrs) and lowest in the 200 mol m^{-2} s^{-1} (6/2 hrs) treatment, whereas chlorophyll fluorescence was observed to be highest in the 260 mol m^{-2} s^{-1} (6/2 hrs) and the lowest in the 290 mol m^{-2} s^{-1} (9/3 hrs) treatment (Kang *et al*., 2013).

Gao *et al.* (2021) showed that broccoli microgreens grown under 50 µmol $m^{-2}s^{-1}$ had the highest fresh weight, dry weight, and moisture content, while the

Table 1. The roles of micronutrient for imunne system.

Antioxidant Compound	The role for immune system	References
Vitamin A	Development and differentiation of Th 1 and Th2 cells	Maggini *et al.* (2008)
	Maintaining vision, promoting growth and development, and protecting epithelium and mucus integrity in the body	Huang *et al.* (2018)
	Metabolized intracellularly to retinoic acid (RA), which is well known as a regulator of cell proliferation and differentiation.	Ross and Restori (2013)
Vitamin D	Inhibit metabolic stress and energetic expenditure in a cell microenvironment and contexts such as mitochondria of brown adipose tissue.	Mcleod and Havran (2011)
	It helps cells maintain their energetic and survival homeostasis by modulating the stress and damage response, primarily ruled by the immune system	Chirumbolo *et al.* (2017)
Vitamin C	Stimulates proliferation of lymphocytes, resulting in the boosted generation of antibodies	Carr and Maggini (2017)
	Assists epithelial barrier function against pathogens and stimulates the oxidant scavenging activity of the skin	Carr and Maggini (2017)
	Enrich cytokines production and synthesis of immunoglobulins in response to infection.	Sorice et al. (2014)
Vitamin E	Represses Th2 response.	Haryanto *et al.* (2015)
	Modulates T cell function by directly impacting T cell membrane integrity, signal transduction, and cell division, and also indirectly affects inflammatory	Lewis *et al.* (2019)

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phytochemical content was the lowest. The increasing light intensity can increase the chlorophyll content while decreasing the carotenoid content. The contents of soluble protein, soluble sugar, free amino acid, flavonoid, vitamin C, and glucosinolates except for progoitrin in broccoli microgreens were higher under 70 $\mu mol \cdot m^{-2}s^{-1}$. Overall, 50 $\mu mol\ m^{-2}s^{-1}$ is the optimal light intensity to increase the growth of microgreen broccoli. In comparison, 70 $\mu mol\ m^{-2}s^{-1}$ is more feasible to increase the phytochemicals of broccoli microgreens in artificial light.

Combining the two lights can optimize the photosynthesis process, increasing product quality and plant productivity (Samuolienė *et al.,* 2019). Son and Oh (2013) showed that combining blue LEDs with red LEDs can increase the chlorophyll and phenolic compounds. According to Samuolienė *et al*. (2017), applying blue light intensity in cultivating Mustard, beet, and parsley microgreens can increase the accumulation of photosynthetic and carotenoid pigments. Applying intense blue light under 33% can increase the concentrations of chlorophylls a and b, carotenoids, α- and β-carotenes, lutein, violaxanthin, and zeatin on microgreens 1.2 to 4.3 times higher. Meanwhile, a lower dose of blue light affected the accumulation of metabolites, not directly related to the light reaction, such as tocopherol (16%).

3. The nutritional content of microgreens

Microgreens are one of the dietary antioxidants. Antioxidants and phytochemicals act as free radical scavenging. Antioxidants are used to prevent cardiovascular, cancer (Xiao *et al*., 2012), and improve the immune system (Pangrazzi, 2019), while phytochemicals act as antimicrobial, antioxidant, and anti-inflammatory activities (Gunjal, 2020).

Several microgreens (Table 2) are known to produce chemical compounds, including ascorbic acid, lutein, chlorophyll, phenolics, and antioxidants (Ghoora *et al.,* 2020). This compound also acts as a natural antioxidant. Table 1 shows the results of the analysis of antioxidant activity and phytochemical compounds on various microgreens.

Ghoora *et al*. (2020) investigated the phytochemical content of ten types of green vegetables (Onion, Mustard, Carrot, Fennel, Sunflower, Roselle, French Basil, Radish, Spinach, and Fenugreek), such as ascorbic acid (AsA), Lutein (LUT), chlorophyll (Chl), total phenolics (TP), and total flavonoids (TF). These compounds also act as antioxidants. The results showed that microgreen roselle had the highest AsA, TP, and TF content of 139.8±3.2, 73.6±9.5, and 6.5±0.2 mg/100 g FW, respectively, and DPPH RSA IC50 and ILAP activities were 81.7±1.9 g/ml and 84.4±3.2%, respectively. It also had higher OPCI (76.8) and APCI (89.4) values than OPCI (55.9) and APCI (36.7) of mature spinach leaves.

APCI or the antioxidant potential composite index was obtained based on DPPH (2,2-diphenyl-1-picrylhydrazyl), FRAP (Ferric reducing antioxidant power), TEAC (Trolox equivalent antioxidant capacity), and ILAP (inhibition of linoleic acid peroxidation) activities. The APCI value indicates that microgreens can substitute ripe leafy vegetables and are rich in antioxidants. Meanwhile, OPCI or overall phytochemical composite index indicates that the food has good phytochemical antioxidants. However, not each microgreen has higher OPCI and APCI values than mature leafy vegetables. According to Ebert *et al.* (2014), mature spinach leaves had a higher concentration of lutein than microgreens. In contrast, according to Ghoora *et al.* (2020), microgreens had higher concentrations of carotenoids than baby greens, but there was no significant difference in chlorophyll content.

Kusumitha *et al.* (2021)' showed that dill microgreen contains higher levels of vitamin C (46 mg/100 g) than microgreen fenugreek, green amaranth, red amaranth, and spinach. Vitamin C is an essential vitamin for human health. This vitamin plays a role as an anti-carcinogenic, anti-atherogenic, and antioxidant. Ebert *et al*. (2014) showed that the vitamin C content in microgreen amaranth was 2.7-fold.

According to Di Gioia and Santamaria (2015), data on the chemical compound of microgreens are limited. Several studies have shown that the content of bioactive and phytochemical compounds in microgreens is higher than that of mature plants. The results of Oh *et al.* (2010), showed that microgreen lettuce (Lactuca sativa), seven days after germination, contained higher antioxidant and total phenolic compounds than the mature leaves. Based on the results of Xiao *et al.* (2012), the content of vitamins and carotenoids in microgreens is much higher than in mature plants, while the results of Sun *et al*. (2013) showed that the polyphenol profile of microgreen Brassica was more complex than that of mature plants.

4. The role of antioxidants and nutrients

Microgreens are vegetables high in micronutrients (Kusumitha *et al.,* 2021) including antioxidants (Samuolienė *et al.,* 2017). The content of antioxidants in food plays a vital role in preserving the quality and maintaining the health of humans (Sehwag and Das, 2013). Vitamin C, B-carotene, chlorophyll, phenolic

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Table 2. Analysis of antioxidant activity and phytochemical compounds on various microgreens.

Antioxidant Compound	Microgreen		References
Vitamin C (mg/100 g)	Red cabbage	147.0±3.6	Xiao *et al*. (2012)
	Borage	85.27±3.97	Corrado *et al*. (2021)
	Purslane	276.9±19.6	Corrado *et al*. (2021)
	Celery	45.8±3.1	Xiao *et al*. (2012)
	Fenugreek	14.66×10^{-3}	Kusumitha *et al*. (2021)
β-carotene (mg/100 g)	Red cabbage	11.5±1.2	Xiao *et al*. (2012)
	Borage	132.0±15.6	Corrado *et al*. (2021)
	Purslane	19.7±2.6	Corrado *et al*. (2021)
	Celery	5.6±0.1	Xiao *et al*. (2012)
	Fenugreek		Kusumitha *et al*. (2021)
Total Chlorophyll (mg/100 g)	Borage	61.2±0.7	Corrado *et al*. (2021)
	Purslane	63.6±1.8	Corrado *et al*. (2021)
	Fenugreek	59.2±6	Ghoora *et al*. (2020)
	Onion	29.5±0.1	Ghoora *et al*. (2020)
	Mustard	52.8±0	Ghoora *et al*. (2020)
	Broccoli	0.33×10^{-2}	
Phenolic Acids (mg/100 g)	Borage	302.6±18.3	Corrado *et al*. (2021)
	Purslane	681.2±4.96	Corrado *et al*. (2021)
	Fenugreek	23.5±0.5	Ghoora *et al*. (2020)
	Onion	21.4±3.7	Ghoora *et al*. (2020)
	Mustard	49.3±0.4	Ghoora *et al*. (2020)
	Broccoli	0.12	
Vitamin E (mg/100 g)	Red cabbage	24.1±5.5	Xiao *et al*. (2012)
	Celery	18.7±5.1	Xiao *et al*. (2012)
Vitamin A (µg/100 g)	Dill	0.66	Kusumitha *et al*. (2021)
	Fenugreek	0.66	Kusumitha *et al*. (2021)
	Green amaranth	0.63	Kusumitha *et al*. (2021)
DPPH (µg/mL)	Fenugreek	228.7±0.7	Ghoora *et al*. (2020)
	Onion	452.4±51.3	Ghoora *et al*. (2020)
	Mustard	168.4±14.8	Ghoora *et al*. (2020)
ABTS (mMol Trolox/100 g)	Borage	62.60±1.17	Corrado *et al*. (2021)
	Purslane	82.83±0.82	Corrado *et al*. (2021)
	Radish	06±0.2	Wojdylo *et al*. (2020)
	Beetroot	0.2±0	Wojdylo *et al*. (2020)
	amaranth	0.6±0.1	Wojdylo *et al*. (2020)
FRAP (µmol Fe^{2+}/g)	Fenugreek	10.0±0.2	Ghoora *et al*. (2020)
	Onion	7.0±0.5	Ghoora *et al*. (2020)
	Mustard	9.3±1.1	Ghoora *et al*. (2020)

Source: Ghoora *et al.* (2020)

acids, and tocopherols are some parts of the natural sources of antioxidants (Sarker *et al.,* 2020). This component helps maintain the immune system, preventing cancer, cardiovascular, diabetes, and tumours. One of the roles of vitamin E as an antioxidant is in collaboration with vitamin A, vitamin C, and B carotene to prevent cataracts (Abdulwaliyu *et al.,* 2013).

The health advantages of microgreens have been studied using rodent models in a few functional studies. The result showed that red cabbage microgreens reduced mass gain caused by high-fat food, significantly reduced LDL levels, and expression of inflammatory mediators in the liver in mice (Huang *et al.,* 2016). Some studies have suggested that red cabbage microgreens contain high polyphenols known as antioxidant and anti-inflammatory properties (Xiao *et al.,* 2015). Table 3 shows the roles of several antioxidants on microgreens.

Antioxidants and nutrients in microgreens can restrict COVID-19. COVID-19 is a virus characterized by pneumonia and ARDS (Mrityunjaya *et al.,* 2020). COVID-19 is caused by the novel severe acute respiratory syndrome (SARS)-like coronavirus (SARS-CoV-2). It can be transmitted through droplets of saliva or discharge from the nose when an infected person coughs or sneezes (Dhand and Li, 2020). One of the causes of a person being infected with COVID-19 is a decrease in the immune system. A decrease in the immune system is one of the factors that cause a person to be infected with COVID-19. Therefore the strategy for restricting the spread of COVID-19 infections is to improve immune system performance. The immune system plays a role in protecting the body from foreign agents and tissue healing. Some people infected with the

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Table 3. The roles of several antioxidants on microgreens.

Antioxidant Compound	The role for health	Microgreen	References
Total Ascorbic Acid	Plays a role in protecting against free radical damage, tissue healing, protecting the immune system, and therapeutic agents for diseases and disorders (Chambial *et al*., 2013)	Red cabbage Borage, Purslane Celery Fenugreek Broccoli	Xiao *et al*. (2012) Corrado *et al*. (2021) Xiao *et al*. (2012) Kusumitha *et al*. (2021); Ghoora *et al*. (2020) Gao *et a*l. (2021); Tan *et al*. (2020)
β-carotene	Neutralize free radicals-reactive oxygen that can damage lipids in cell membranes and genetics, resulting in cardiovascular disease and cancer (Yadav *et al*., 2016)	Red cabbage Borage, Purslane Celery Fenugreek	Xiao *et al*. (2012) Corrado *et al*. (2021) Xiao *et al*. (2012) Kusumitha *et al*. (2021)
Total Chlorophyll	Prevent tumor and cancer, anti-inflammation, and wound healing (Inanc, 2011)	Borage, Purslane Fenugreek Broccoli	Corrado *et al*. (2021) Ghoora *et al*. (2020) Tan *et al*. (2020)
Phenolic Acids	Reduce the risk of many oxidative stress-related diseases viz. cancers, diabetes and cardiovascular (Kumar and Goel, 2019)	Borage, Purslane Fenugreek Broccoli	Corrado *et al*. (2021) Ghoora *et al*. (2020) Tan *et al*. (2020)
Tocopherol	Tocopherol (Vitamin E) plays a role in delaying ageing, accelerating wound healing, increasing body immunity and protecting red blood cells (Yadav *et al*., 2016)	Red cabbage, Celery Mustard, beet, parsley	Xiao *et al*. (2012) Samuoliene *et al*. (2017)

COVID-19 virus show no symptoms, and others show pneumonia, multi-organ failure, and even death (Guan *et al.,* 2020). Some research shows that people with weakened immune systems are sensitive to attack this virus. One of the causes of weakened immunity is micronutrient deficiency. Global Nutrition 2020 reported that micronutrient deficiency is one of the factors that cause the body to be easily attacked by the COVID-19 virus. Consuming antioxidant dietary and micronutrients such as vitamins A, D, C, E, B6, B12, folate, zinc, iron, copper, and selenium can boost immunity. These micronutrients have an essential role in the immune response (Gombart *et al.,* 2020). According to Lee and Han (2018), vitamin E can boost the immune system response and increase protection against various infectious diseases. It is related to vitamins A (Huang *et al.,* 2018), D (Hribar *et al.,* 2020), and C (Devaki and Raveendran, 2017)

Figure 1 shows that micronutrients can support the function of the immune system against pathogens. There are four stages of the immune response in the body, namely physical barriers, innate immune response, inflammatory response, and adaptive immune response. When the virus enters the body, it takes immunity and unique antibodies. Antibodies play a role in repairing body damage caused by various factors, including pathogenic microorganism attacks. When pathogens try to attack the body, the first line of defence is physical barriers such as skin, gastrointestinal tract, and cilia. Then the pathogens that successfully enter will be trapped through a biochemical process. In this process, the body will immediately destroy foreign substances through immune cells. The foreign substance that enters the body will activate the immune function that utilizes T and B cells.

B cells are lymphocytes that play an important role in humoral immunity, while other lymphocytes, namely T cells, play an important role in cellular immunity. The main function of B cells is to make antibodies against antigens, while T cells protect all systems in the body directly by activating the immune system at its maximum. In this process, the specific antigen of the foreign substance will be recognized and form antibodies against it.

4. Conclusion

Microgreens are vegetables that are rich in antioxidants and nutrients. The content of micronutrients in microgreens plays a role in the immune response and produces large amounts of immune cells. Therefore, micronutrients can increase the immune system and protect the body from foreign substrates such as COVID-19. In addition, microgreens can also prevent cancer and other diseases. Microgreens are antioxidants dietary could be used as health-promoting food ingredients.

Conflict of interest

The authors declare no conflict of interest.

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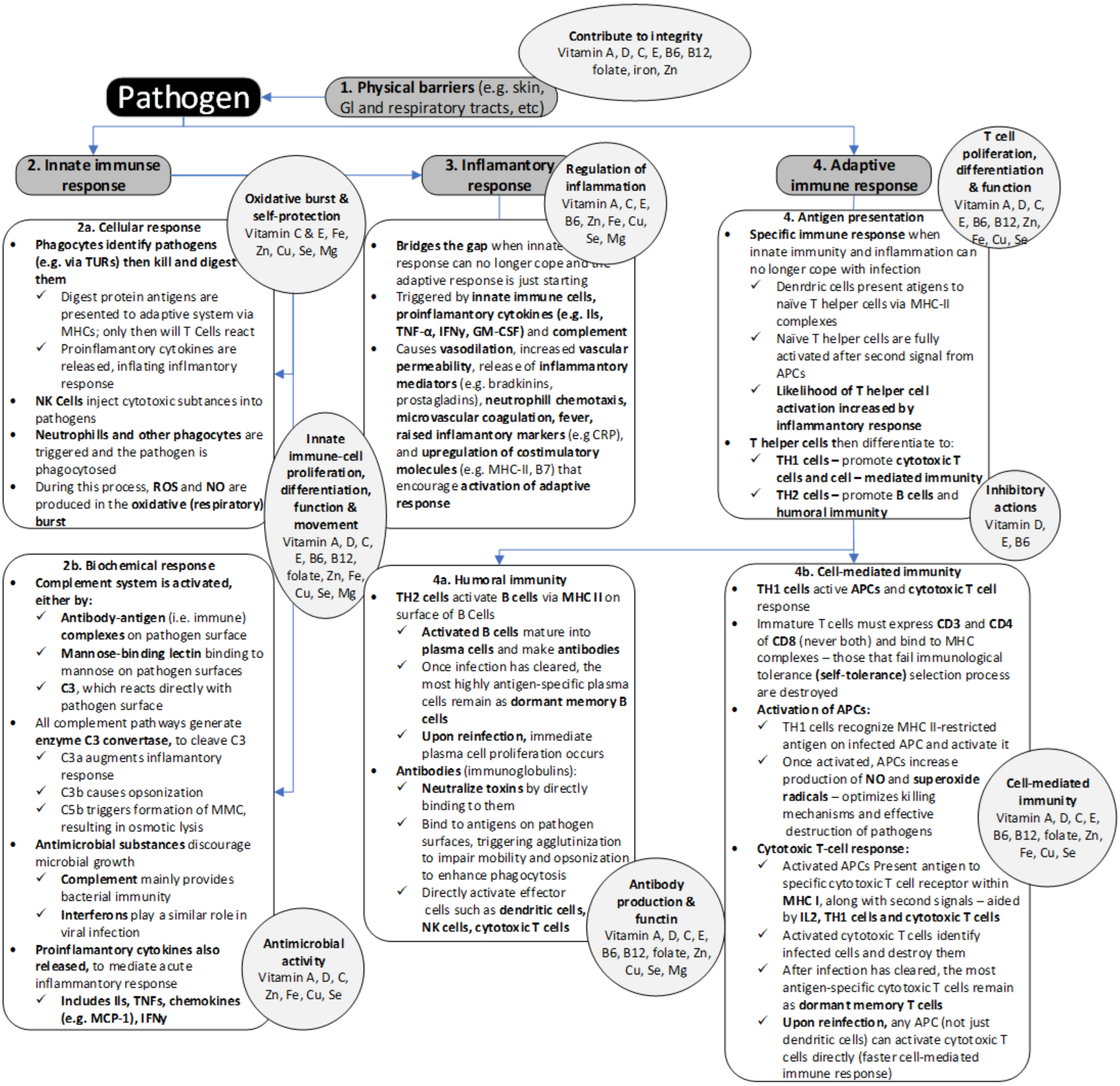

Figure 1. Micronutrients have key roles at every stage of the immune response. APCs: antigen-presenting cells, C3: complement component 3, CRP: C-reactive protein, Cu: copper, Fe: iron, IFNs: interferons, Igs: immunoglobulins, ILs: interleukins, GI: gastrointestinal, GM-CSF: granulocyte-macrophage colony stimulating factor, MAC: membrane attack complex, MCP-1: monocyte chemoattractant protein-1, Mg: magnesium, MHCs: major histocompatibility complexes, NK: natural killer, NO: nitric oxide, ROS: reactive oxygen species, Se: selenium, TLRs: toll-like receptors, TNF: tumor-necrosis factors, Zn: zinc. Source: Gombart *et al*. (2020)

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