# COVID-19, Coenzyme Q10 and Selenium

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## Abstract

In COVID-19 infection, a balance must be achieved in immune defence against the virus without precipitating a cytokine storm, which is responsible for lung injury and respiratory distress in severe cases. The initial immune response and the subsequent resolution of inflammation are likely to be dependent on nutritional status, as one contributing factor. Here, we have reviewed the potential link between two specific nutrients, coenzyme Q10 (CoQ10) and selenium, with effects on oxidative stress and inflammation in viral infection. We conclude that both reagents show promise in the treatment of patients with COVID-19 disease. This could gave particular relevance over the next several months as promising vaccines are deployed to minimize the COVID-19 spread and as a potential preventative or mitigating approach for future epidemics and pandemics.

**Key words** COVID-19, SARS-CoV-2, coenzyme Q10, CoQ10, selenium, supplement

### 1 Introduction

There is currently there is no effective treatment for COVID-19 (Coronavirus disease 2019), since antibiotics are ineffective against viral infections, and a vaccine against the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) which causes COVID-19 is only likely to become available to a significant extent in early 2021. The best defence against such viral infections is therefore an optimally functioning immune system. An important factor determining immune function and resistance to infection is an individual's nutritional status. In order to determine, on a rational basis, whether nutritional supplementation could be potentially beneficial with regard to SARS-CoV-2 infection, one must first consider how the immune system functions.

In simplistic terms, the immune system is comprised of two parts, the innate immune system and the adaptive immune system. As the name implies, the innate immune system is present and operational from birth, providing a rapid and non-specific first-line response to invading microorganisms. The innate immune system comprises a number of components, the most prominent being phagocytic cells (macrophages, neutrophils, natural killer cells) which destroy engulfed invading microorganisms via the generation of free radicals. Subsequent to the innate response, the adaptive immune system may be activated, depending on the severity of infection. Adaptive immunity is a slower responding but more specific form of immune defence, involving B and T lymphocytes. B lymphocytes produce antibodies to neutralise specific antigens, whereas T lymphocytes have a role in destroying infected host cells. Communication between the various cell types of the two branches of the immune system is facilitated via cytokines, protein chemical messenger molecules.

There is a common misconception that inflammation, which involves the release of pro-inflammatory cytokine substances, is a wholly negative process within the body. However, inflammation is the body's normal response to infection or injury, and is essential for tissue healing, although this process should resolve following the initial immune response to viral infection [**1**]. This resolution occurs via negative feedback mechanisms involving the generation of specific molecules such as resolvins, protectins and maresins [**2**].

In COVID-19 infection, a balance must therefore be achieved in immune defence against the virus, without precipitating the so-called cytokine storm, the uncontrolled release of pro-inflammatory cytokines responsible for lung injury and respiratory distress in severely

affected patients [**3**]. Both the initial immune response to viral infection and the mechanism for subsequent resolution of inflammation are therefore dependent on an individual's nutritional status. In this article, we have reviewed the link between two specific nutrients, coenzyme Q10 (CoQ10) and selenium, and free radical induced oxidative stress (an imbalance between reactive oxygen generation and antioxidant capacity), inflammation and virus infection, with regard to the potential benefits of CoQ10 and selenium supplementation in the treatment of patients with COVID-19.

## 2 CoQ10

CoQ10 is a lipid soluble molecule comprising a central benzoquinone moiety, to which is attached a 10-unit polyisoprenoid lipid tail. The benzoquinone ring contains redox active sites, while the polyisoprenoid chain is responsible for positioning the CoQ10 molecule within the mid-plane of the lipid bilayer of various cell membrane types [**4**]. CoQ10 is usually described as a vitamin-like substance, although by definition, CoQ10 is not a vitamin since it is produced by various tissues within the human body [**5**].

CoQ10 has a number of vital cellular functions, particularly within mitochondria, but also elsewhere within the cell [**4**]. Within mitochondria, CoQ10 has a key role as an electron carrier transferring electrons derived from complex I and II to complex III, ensuring a continuous passage of electrons within the mitochondrial electron transport chain which is required for the process of oxidative phosphorylation with the concomitant product of ATP [**5**]. CoQ10 serves as an important lipid soluble antioxidant protecting cellular membranes, both mitochondrial and extra-mitochondrial organelles (Golgi apparatus, lysosomes, endoplasmic reticulum, peroxisomes) together with circulatory lipoproteins against free radical induced oxidative damage [**4**]. The antioxidant function of CoQ10 is attributed to its fully reduced ubiquinol form [**4, 5**]. In addition to acting as an antioxidant directly, CoQ10 is also involved in the regeneration of the antioxidants vitamin C and vitamin E, respectively [**6**]. CoQ10 has also been reported to be involved in the mediation of inflammation by its ability to regulate the expression of genes involved in this process [**7**]. A recent study also indicated that CoQ10 plays a central role in maintaining the acidic environment of the lysosomal compartment [**8**]. CoQ10 exists in both oxidised (ubiquinone) and reduced

(ubiquinol) forms, and the normal functioning of CoQ10 involves continual inter-conversion between these two forms [**4**].

The daily requirement for CoQ10 is not known with certainty, but has been estimated to be approximately 500 mg/day, based on a total body pool of 2000 mg and average tissue turnover time of 4 days [**9**]. A small amount of CoQ10 (approximately 5mg) is obtained from the daily diet, with most of the daily requirement being synthesised within the body [**9**]. CoQ10 is produced in many tissues, with the liver being the principal site of production based on organ mass and metabolic activity level. Optimal production occurs in an individual when they are around 25 years of age, after which production steadily declines, with the production level at age 65 being approximately 50% of that at age 25 [**10**]. In addition to the effect of aging, CoQ10 levels are also reduced by certain prescribed drugs (particularly statins), and in a variety of diseases [**11**]. Indeed, a study by Becker et al. reported that early statin usage appeared to be associated with increased risk of post-stroke infection [**12**]. However, controversy exists at present as to whether statin induced lowering of circulatory cholesterol levels may predispose individuals to developing COVID -19 [**13**].

CoQ10 therefore has a number of cellular functions of potential relevance to the immune system. Firstly, there is the role of CoQ10 in cellular energy supply. Since the immune response has intensive energy requirements, an adequate supply of CoQ10 is required to enable the various cell types of the immune system to function optimally. Secondly, is the role of CoQ10 as an antioxidant, in protecting cells from free radical induced oxidative damage, since phagocytic cells destroy invading pathogens via the production of free radicals. The antioxidant action of CoQ10 may protect phagocytic cells from self-destruction caused by their secretion of free radicals. Finally, CoQ10 is able to moderate directly the action of genes involved in inflammation, and may have a role in controlling the release of pro-inflammatory cytokines [**7**].

A recent study by Ghosh et al. reported the ability of SARS-CoV-2 to utilise a lysosomal dependent exocytosis pathway for viral release into the extracellular environment from the host cell [**14**]. However, as a consequence of the viral exploitation of this process, SARS-CoV-2 de-acidifies the lysosome by an as of yet unknown mechanism. This de-acidification was reported to decrease lysosomal hydrolytic enzyme activity in addition to impairing the antigen presentation role of the organelle in the adaptive immune response. Therefore, the

possibility arises that therapeutic strategies aimed at reversing the de-acidification of the lysosome may enhance the immune response against the virus and mitigate the spread of infection. In view of the essential role that CoQ10 plays in maintaining lysosomal acidification [**8**], CoQ10 supplementation may be an appropriate therapeutic strategy to consider in the treatment of COVID-19. **Fig.** 1 summarises the functions of CoQ10 in the immune function.

## 3 Selenium

Selenium is a trace element obtained from the normal diet. In the UK, a deficiency of selenium in soil is manifest upwards through the food chain, such that the average UK diet contains only about half of the recommended selenium intake of 70 μg per day. Selenium is essential for the normal functioning of both the innate and adaptive immune systems. In the innate immune system, selenium is required for the differentiation, motility and action of neutrophils and macrophages, for the production of antimicrobial proteins, and for recovery from inflammation. In the adaptive immune system, selenium is required for the differentiation and proliferation of lymphocytes, for cytokine production, and for antibody production (**Fig. 2**). Adequate levels of selenium are important for initiating immunity, but they are also involved in regulating excessive immune responses and chronic inflammation [**15**]. It is also of note that selenium reduces the formation of thrombosis in the blood vessels. Blood coagulation disorders leading to the formation of micro-clots (particularly in the kidneys) are a significant cause of death in patients with COVID-19 [**16**].

Of particular note is the synergistic interaction at the cellular level between CoQ10 and selenium. In addition to its role as a cofactor of the antioxidant enzyme glutathione peroxidase, one of the major functions of selenium is as a component of the enzyme thioredoxin reductase, which is required for recycling of the ubiquinol from the CoQ10 molecule [**17**]. Supplementation with CoQ10 alone is therefore likely to be sub-optimal in effect if the level of selenium is also deficient, although this has yet to be confirmed or refuted in patient studies [**17**].

# 4 Oxidative stress, inflammation and virus infection

## 4.1 Oxidative stress

Free radicals are highly reactive chemical species produced in all cells as an unwanted by-product of normal cell metabolism, with the potential to cause damage in a wide range of tissues. The body is protected from such damage by antioxidants, including vitamin C, vitamin E, CoQ10 and selenium containing proteins. The body is also exposed to free radicals produced by external agents, including infectious microorganisms. Free radical production is a characteristic of infection by a wide range of viruses, including influenza-type viruses [**18**]. The additional free radicals generated by viruses have the potential to overwhelm the cellular antioxidant defence, with harmful consequences for the cells. This imbalance between free radical generation and defence is known as oxidative stress.

Oxidative stress is especially likely to occur in individuals with sub-optimal levels of CoQ10 or selenoproteins, resulting from impaired endogenous synthesis or dietary deficiency respectively. Dietary deficiency of selenium is known to occur in various countries worldwide (including Europe), but particularly in certain regions of China. This is thought to be one reason why many viral infections, including the current coronavirus pandemic, originate from China. Dietary selenium deficiency resulting in oxidative stress in the host can alter the viral genome, such that a normally benign or mildly pathogenic virus becomes highly virulent. Once such mutations occur, even individuals with a normal diet become susceptible to infection by the newly pathogenic viral strain.

Some of the most compelling evidence regarding the detrimental effect of selenium deficiency and susceptibility to viral infection relates to Keshan disease, a heart condition affecting the population in regions of China with selenium deficient soils. Keshan disease results from the effects of infection by an endemic coxsackievirus, and dietary supplementation with selenium was shown to completely prevent development of this disorder, by elevating host anti-viral immunity and preventing viral mutations that can lead to increased virulence.

## 4.2 Inflammation

Inflammation is part of the body's normal response to injury or infection. The inflammatory process is characterised by increased blood flow to the affected tissue, macrophage infiltration, and the subsequent release of a range of chemical mediators (cytokines) involved in tissue repair. Cytokines can be both pro-inflammatory and anti-inflammatory. Examples of pro-inflammatory cytokines involved in tissue repair include interleukin-1 (IL-1), IL-6 and tumour necrosis factor (TNF). Under normal circumstances the inflammatory process is then switched off via a negative feedback loop mechanism involving anti-inflammatory cytokines such as IL-10 and IL-11. When this does not occur, uncontrolled inflammation results, which in turn has been implicated in a variety of degenerative disorders, as well as in patients more severely affected following COVID-19 infection.

A proportion of patients infected with COVID-19 are subject to uncontrolled inflammation, the so-called cytokine storm, which can result in multi-organ damage and failure, particularly in the lungs, heart, liver and kidneys. COVID-19 patients subject to such organ damage typically have sustained high circulating levels of IL-1, IL-6 and TNF [**19**]. One area of COVID-19 research which to date has received relatively little attention is the role of nutrients in the inflammation negative feedback loop. There is evidence that a number of nutrients, including CoQ10 and selenium [**15**], as well as vitamin D3 [**20**] and beta 1,3/1,6 glucans [**21**], have important roles in mediating the inflammation negative feedback mechanism. There is also evidence that levels of these nutrients, especially selenium and vitamin D [**22, 23**], may be deficient in the UK population, particularly in the elderly, who may therefore be at increased risk of uncontrolled inflammation following COVID-19 infection [**24**]. It follows that supplementation with these nutrients may reduce the risk of tissue damage resulting from uncontrolled inflammation in patients following COVID-19 infection. In addition to the effect of aging, CoQ10 levels are also reduced by certain prescribed drugs (particularly statins), and in a variety of diseases [**11**].

## 5 Supplementation CoQ10 and selenium

Several clinical studies have linked depleted CoQ10 levels and increased susceptibility to infection. Chase et al. reported significantly reduced serum CoQ10 levels in patients with

influenza compared to healthy control subjects [**25**]. In children hospitalised with pandemic influenza (H1N1), Kelekci et al. reported a significant correlation between depletion of serum CoQ10 levels and chest radiographic findings [**26**]. In a randomised controlled trial, elderly patients with pneumonia showed significantly improved recovery following administration of CoQ10 (200 mg/day for 14 days) compared to placebo [**27**].

In addition to the effect of aging, CoQ10 levels are also reduced by certain prescribed drugs (particularly statins), and in a variety of diseases [**11**]. In a clinical study by Israel et al., intake of CoQ10 was associated with a significantly reduced risk of hospitalisation from COVID-19 [**28**]. Moreno Fernández-Ayala et al. reviewed evidence for mitochondrial dysfunction as a key factor determining the severity of COVID-19 infection [**29**]. In particular the authors noted the increased susceptibility to COVID-19 infection in individuals over 65 years of age, the same age by which levels of endogenous CoQ10 have become substantially depleted. Similarly, Gvozdjakova et al. considered one of the main consequences of COVID-19 infection to be virus-induced oxidative stress causing mutations in one or more of the genes responsible for CoQ10 synthesis, in turn resulting in mitochondrial dysfunction [**30**]. Also of note is the computational study by Caruso et al., in which the authors identified CoQ10 as a compound capable of inhibiting the SARS-CoV-2 virus, via binding to the active site of the main viral protease [**31**]. In addition to the effect of aging, CoQ10 levels are also reduced by certain prescribed drugs (particularly statins), and in a variety of diseases [**11**].

Selenium supplementation has been shown to modulate the inflammatory response in respiratory distress syndrome patients, by restoring the antioxidant capacity of the lungs, moderating the inflammatory responses through IL-1β and IL-6 levels, and significantly improving the respiratory mechanics [**32**]. In addition, Zhang et al. recently reported a link between regional selenium status and the reported recovery outcome in COVID-19 cases in China [**33**].

In a Swedish randomized placebo-controlled study, healthy elderly subjects low in selenium were given selenium supplementation combined with CoQ10. This supplementation was shown to reduce the non-specific inflammatory response as measured by plasma CRP and other biomarkers of inflammation, and also cardiovascular mortality [**34, 35**]. As severe

coronavirus infections are characterized by an overactive inflammation, this relief in inflammatory response by optimizing the selenium status is of considerable interest.

## 6 Conclusions and future perspectives

Because of the potential variability in quality of CoQ10 supplements, it is important to note that any CoQ10 used in clinical studies should be manufactured to pharmaceutical standards, and be of documented bioavailability in human subjects. When supplemental CoQ10 is first produced (via a yeast fermentation process), it is obtained in the form of crystals that cannot be absorbed from the digestive tract. It is essential that these crystals are dispersed into single CoQ10 molecules (and remain dispersed during the back pain/gall bladder product shelf-life) to enable optimum bioavailability. The absence of such crystal dispersion in supplemental CoQ10 formulations reduces bioavailability in human subjects by 75% [**36**].

Supplemental selenium is available in liquid form (with market authorisation) for injection, and in tablet form for oral ingestion. Dietary selenium deficiency can be prevented by taking supplemental selenium (100-200 μg per day). It is important to note that selenium has a relatively narrow therapeutic window. Too high an intake of selenium can be potentially harmful, and the Department of Health recommend that the daily intake should not exceed 350 μg. Because of potential variability in the levels of selenium in supplements, it is important to take a selenium supplement manufactured to pharmaceutical standards.

We conclude that the positive effects of CoQ10 and selenium supplementation on free radical induced oxidative stress and inflammation show promise in the treatment of patients with COVID-19 disease. This could be particularly important in the final months before the vaccines are rolled out to minimize the spread of this devastating virus and as a potential preventative measure for future epidemics and pandemics.

**References**

1. Koh TJ, DiPietro LA (2011) Inflammation and wound healing: the role of the macrophage. Expert Rev Mol Med 13:e23. doi: 10.1017/S1462399411001943

2. Serhan CN, Dalli J, Colas RA, Winkler JW, Chiang N (2015) PProtectins and maresins: New pro-resolving families of mediators in acute inflammation and resolution bioactive metabolome. Biochim Biophys Acta1851(4):397-413
3. Hu B, Huang S, Yin L (2020 The cytokine storm and COVID-19. J Med Virol. Jun 27:10.1002/jmv.26232. doi: 10.1002/jmv.26232. Online ahead of print
4. Crane FL (2001) Biochemical functions of CoQ10. J Am Coll Nutr 20(6):591-598
5. Hargreaves IP (2003) Ubiquinone: Cholesterol's reclusive cousin. Ann Clin Biochem 40 (Pt 3):207-218
6. Rodick TC, Seibels DR, Babu JR, Huggins KW, Mathews ST (2018) Potential role of CoQ10 in health and disease. Nutr Diet Suppl 10:1-11
7. Schmelzer C, Lindner I, Rimbach G, Niklowitz P, Menke T, Döring F (2008) Functions of CoQ10 in inflammation and gene expression. Biofactors 32(1-4):179-183
8. Heaton RA, Heales S, Rahman K, Sexton DW, Hargreaves I (2020) The effect of cellular coenzyme Q(10) deficiency on lysosomal acidification. J Clin Med. 2020 Jun 9(6):1923. doi: 10.3390/jcm9061923
9. Weber C, Bysted A, Hłlmer G (1997) The coenzyme Q10 content of the average Danish diet. Int J Vitam Nutr Res 67(2):123-129
10. Kalén A, Appelkvist EL, Dallner G (1989) Age-related changes in the lipid compositions of rat and human tissues. Lipids 24(7):579-584
11. Hargreaves IP, Duncan AJ, Heales SJ, Land JM (2005) The effect of HMG-CoA reductase inhibitors on coenzyme Q10: possible biochemical/clinical implications. Drug Saf 28(8):659-676
12. Becker K, Tanzi P, Kalil A, Shibata D, Cain K (2013) Early statin use is associated with increased risk of infection after stroke. J Stroke Cerebrovasc Dis 22(1):66-71
13. Greenhalgh T, Koh G, Choon H, Car J (2020) Covid-19: a remote assessment in primary care. BMJ 368:m1182. doi: 10.1136/bmj.m1182
14. Ghosh S, Dellibovi-Ragheb TA, Kerviel A, Pak E, Qiu Q, Fisher M et al (2020) β-Coronaviruses use lysosomes for egress instead of the biosynthetic secretory pathway. Cell S0092-8674(20)31446-X. doi: 10.1016/j.cell.2020.10.039. Online ahead of print
15. Huang Z, Rose AH, Hoffmann PR (2012) The role of selenium in inflammation and immunity: from molecular mechanisms to therapeutic opportunities. Antioxid Redox Signal 16(7):705-743

16. Fogarty H, Townsend L, Ni Cheallaigh C, Bergin C, Martin-Loeches I, Browne P et al (2020) COVID-19 Coagulopathy in caucasian patients. Br J Haematol 189(6):1044-1049
17. Hargreaves IP, Mantle D (2019) Supplementation with selenium and coenzyme Q10 in critically ill patients. Br J Hosp Med (Lond) 80(10):589-593
18. Guillin OM, Vindry C, Ohlmann T, Chavatte L (2019) Selenium, selenoproteins and viral infection. Nutrients 11(9):2101. doi: 10.3390/nu11092101
19. Conte P, Ronconi G, Caraffa A, Gallenga C, Ross R, Frydas I et al (2020) Induction of pro-inflammatory cytokines (IL-1 and IL-6) and ling inflammation by COVID-19 or SARS-COV-2: anti-inflammatory strategies. J Biol Regul Homeost Agents 34(2):327-331
20. Chen Y, Liu W, Sun T, Huang Y, Wang Y, Deb DK et al (2013) 1,25-Dihydroxyvitamin D promotes negative feedback regulation of TLR signaling via targeting microRNA-155-SOCS1 in macrophages. J Immunol; 190(7):3687-3695
21. Poltajainen A, Matikainena S, Nymanb T Aleniusa H, Veckman V (2013) Beta-glucan inducible microRNAs negatively regulate inflammatory response. Cytokines 63:290. doi: 10.1016/j.cyto.2013.06.202
22. Crowe FL, Jolly K, MacArthur C, Manaseki-Holland S, Gittoes N, Hewison M et al (2019) Trends in the incidence of testing for vitamin D deficiency in primary care in the UK. BMJ Open 9(6):e028355. doi: 10.1136/bmjopen-2018-028355
23. Grant WB, Lahore H, McDonnell SL, Baggerly CA, French CB, Aliano JL et al (2020) Evidence that vitamin D supplementation could reduce risk of influenza and COVID-19 infectioin and deaths. Nutrients 12(4):988. doi: 10.3390/nu12040988
24. Dancer RC, Parekh D, Lax S, D'Souza V, Zheng S, Bassford CR et al (2015) Vitamin D deficiency contributes directly to Acute Respiratory Distress Syndrome (ARDS). Thorax 70(7):617-624
25. Chase M, Cocchi MN, Liu X, Andersen LW, Holmberg MJ, Donnino MW (2019) Coenzyme Q10 in acute influenza. Influenza Other Respir Viruses 13(1):64-70
26. Kelekci S, Sen V, Yolbas I, Uluca U, Tan I, Gurkan M (2012) The relationships between clinical outcome and the levels of total antioxidant capacity and CoQ10 in children with pandemic influenza (H1N1) and seasonal flu. Eur Rev Med Pharmacol Sci 16(8):1033-1038

27. Farazi A, Sofian M, Jabbariasl M, Nayebzadeh B (2014) Coenzyme Q10 administration in community-acquired pneumonia in the elderly. Iran Red Crescent Med J 16(12):e18852. doi: 10.5812/ircmj.18852.
28. Israel A, Schaffer A, Cicurel A, Feldhamer I, Tal A, Cheng K, Sinha et al (2020) Large population study identifies drugs associated with reduced COVID 19 severity.. medRxiv. doi: 10.1101/2020.10.13.20211953
29. Moreno Fernández-Ayala DJ, Navas P, López-Lluch G (2020) Age-related mitochondrial dysfunction as a key factor in COVID-19 disease. Exp Gerontol. Nov 7;142:111147. doi: 10.1016/j.exger.2020.111147. Online ahead of print
30. Gvozdjakova A, Klauco F, Kucharska J, Sumbalova Z (2020) Is mitochondrial bioenergetics and coenzyme Q10 the target of a virus causing COVID-19? Bratisl Lek Listy 121(11):775-778
31. Caruso F, Rossi M, Pedersen JZ, Incerpi S (2020) Computational studies reveal mechanism by which quinone derivatives can inhibit SARS-CoV-2. Study of embelin and two therapeutic compounds of interest, methyl prednisolone and dexamethasone. J Infect Public Health. Oct 14; S1876-0341(20)30671-7. doi: 10.1016/j.jiph.2020.09.015. Online ahead of print
32. Mahmoodpoor A et al (2018) The Effect of Intravenous Selenium on Oxidative Stress in Critically Ill Patients with Acute Respiratory Distress Syndrome. Immunol Invest 48(2):147-159
33. Zhang J, Taylor EW, Bennett K, Saad R, Rayman MP (2020) Association between regional selenium status and reported outcome of COVID 19 cases in China. Am J Clin Nutr 111(6):1297-1299
34. Alehagen U, Johansson P, Björnstedt M, Rosén A, Dahlström U (2013) Cardiovascular mortality and N-terminal-proBNP reduced after combined selenium and coenzyme Q10 supplementation: a 5-year prospective randomized double-blind placebo-controlled trial among elderly Swedish citizens. Int J Cardiol 167(5):1860-1866
35. Alehagen U, Lindahl TL, Aaseth J, Svensson E, Johansson P (2015) Levels of sP-selectin and hs-CRP Decrease with Dietary Intervention with Selenium and Coenzyme Q10 Combined: A Secondary Analysis of a Randomized Clinical Trial. PLoS One 10(9):e0137680. doi: 10.1371/journal.pone.0137680

36. López-Lluch G, Del Pozo-Cruz J, Sánchez-Cuesta A, Cortés-Rodríguez AB, Navas P (2019) Bioavailability of coenzyme Q10 supplements depends on carrier lipids and solubilization. Nutrition 57:133-140

**Fig. 1** Functions of coenzyme Q10 in the immune system

**Fig. 2** Min roles of selenium in the immune system