A strong immune system doesn’t have to be just a dream. Over the last few decades, several strategies for boosting the immune system have been studied, with the aim of reducing the incidence and severity of infectious diseases. Furthermore, investigations into the possibility of improving the fight against cancer continue. Simple and powerful tools are already in our hands: the antioxidants. As we get older, or when we are particularly stressed, high levels of reactive oxygen species (ROS) accumulate, promoting oxidative stress and inflammation throughout the body. In this situation, normal body functions, in particular the immune systems, are severely impaired by an excess of oxygen radicals and pro-inflammatory molecules. For this reason, blocking the side effects of ROS with antioxidants may help us improve our immune system performance.

**We are what we eat**

Ludwig Feuerbach (1804–1872) was probably right: we are what we eat. Not only because, as he said, if we eat well we can think better, but also because if we choose to eat well, our health will be substantially improved. As a result, this may also help protect our body from infections. Eating fruit and vegetables five or more times a day can significantly boost the immune system. This is particularly evident in the elderly, where it has been shown that increased fruit and vegetable consumption improves antibody production after vaccination. This is because fruit and vegetables are rich in antioxidants, they help directly by scavenging ROS levels, which are high in old age (Figure 1). It is now clear that antioxidant supplements improve both the innate (antigen-independent) and adaptive (antigen-specific) arms of the immune system. In particular, regarding the adaptive immune cells, antioxidant molecules can support both ‘weapons’ of adaptive immunity, T and B cells. Low antioxidant levels are associated with impaired immune responses and increased susceptibility to infections. This may also occur in situations in which individuals are exposed to environmental sources of free radicals, such as UV light, smoke or heavy metals. Under these conditions, the available antioxidants in the body are rapidly consumed, and therefore optimal function of the immune system is hampered.

Despite all of this, ROS cannot be completely removed from our cells. ROS are required for general cell physiology, including activation of signalling pathways required for cell proliferation, migration or the secretion of molecules. In addition, oxygen radicals support antibody production by adaptive immune cells (in particular, plasma cells). Fortunately, the ROS levels required to achieve positive physiological function are much lower than the amount responsible for oxidative stress, so eating fruit and vegetables is not harmful!
Identifying key antioxidants to boost our immunity

So which antioxidants are important for us?

Vitamin C, which is highly enriched in berries, kiwifruit, citrus fruit, papaya, tomatoes, broccoli and snow peas (Figure 2), has a strong ability to donate electrons rapidly, thus protecting important biomolecules such as lipids, carbohydrates, proteins and nucleic acids from damage by oxidants generated during normal cell metabolism and through exposure to toxins and pollutants. Infections and stress are known to reduce vitamin C concentrations in leukocytes and plasma. Vitamin C supports many aspects of both innate and adaptive immunity, including the production and function of neutrophils and leukocytes, and the enhancement of phagocytosis, cellular motility and chemotaxis. Furthermore, it indirectly supports immunity through the regeneration of vitamin E. Randomized controlled intervention trials have shown that vitamin C supplementation reduces the severity and duration of respiratory infections, such as pulmonary tuberculosis and pneumonia. In addition, it has been shown that high-dosage intravenous administration of vitamin C may improve symptoms and prolong the life of patients with terminal cancer.

In addition to vitamin C, vitamin E also protects cells from lipid peroxidation. Immune cells are rich in polyunsaturated fatty acids, and vitamin E may therefore be beneficial in protecting these cells from oxidative damage. In contrast to vitamin C, vitamin E is lipid soluble, and can easily be stored in cell membranes, consequently vitamin E deficiencies are rare in developed countries.

Another natural compound known to have impressive antioxidant properties is astaxanthin. This molecule has a blood-red pigment and belongs to the terpenes class. Mainly produced by the rainwater microalgae (Haematococcus pluvialis) and the yeast fungus Xanthophyllomyces dendrorhous, astaxanthin is responsible for the red colour found in salmon, red trout, Red Sea bream, flamingoes and crustaceans, which typically consume microalgae. The importance of these molecules can be seen in residents of Okinawa, known for their long average life expectancy, low risk of age-associated diseases and strong immune systems. The Okinawa diet is mainly based on fruit and vegetables, but also on marine-derived foods, such as algae, fish and crustaceans (Figure 3). An important role is played by astaxanthin, which has been shown to display the highest antioxidant and anti-inflammatory activity among all the compounds included in the diet, with an antioxidant power 550 times stronger than vitamin E and 6000 higher than vitamin C. Most importantly, astaxanthin can also reduce serum levels of C-reactive protein (CRP), a typical marker of inflammation and commonly used to identify the presence of diseases and cancer. In addition to this, astaxanthin is known as a strong booster of the immune system and a higher frequency and improved activity of immune cells was observed in people taking this molecule. Furthermore, astaxanthin supports the proliferation of adaptive immune cells, and enhances cytokine and antibody production in vitro and in vivo. Therefore, eating food containing astaxanthin and/or supplementing your diet with astaxanthin capsules, may not only help improve your immunity, but it may also improve overall health.

The most promising so far: N-acetylcysteine (NAC)

Another antioxidant which has recently shown its strong neutralizing power is N-acetylcysteine (NAC). NAC is a precursor of glutathione, an important endogenous antioxidant, pivotal in the detoxification processes in the liver and a key player in neutralizing free radicals in all cells. In the elderly and under stress conditions, glutathione levels in the body are dramatically reduced. While glutathione is rapidly degraded, it has been shown that NAC, when administered orally, can replenish systemic glutathione levels. As glutathione is an antioxidant, it can neutralize ROS, and thus it can reduce oxidative stress in the body. In addition, NAC is known to neutralize oxygen radicals in a glutathione-independent manner.

Since the early 1960s, NAC has been used in clinics for its mucolytic properties, and has also been proposed as a supportive treatment for influenza pneumonia. More recently, it has been suggested that the positive impact of NAC in the treatment of these conditions is largely related to direct and indirect antioxidant effects. It is now clear that NAC can target the key mechanisms involved in the pathogenesis of lower respiratory tract...
viral infections, among which is inflammation. During these inflammatory processes, high levels of cytokines are produced, inducing the so-called ‘cytokine storm’. Inflammation supports the accumulation of ROS, which then promotes a further increase in the production of pro-inflammatory molecules, leading to the inflammation-oxidative stress cycle as a result. Low levels of cytokines and ROS are needed to initiate immune responses, however, the over-production of these molecules leads to immune suppression and tissue damage. In accordance with this, NAC can act both as an antioxidant and anti-inflammatory drug by reducing cytokines/chemokines, for example, after influenza infection. For this reason, NAC has been used for several years as an adjuvant treatment for influenza pneumonia in human patients, helping to reduce symptomatology and improve cell-mediated immunity.

Interestingly, NAC can help, not only in the context of lower respiratory tract viral insults, but also by targeting other viral and bacterial infections, and can act as a general immune system booster. In addition, the beneficial effects of NAC on a broad spectrum of diseases, such as ulcerative colitis, cancer, Parkinson’s and Alzheimer’s diseases, the pathogenesis of which is supported by inflammation and ROS, have been observed. In this context, NAC may play the most important role of all when it comes to boosting our immune systems. Hopefully, we will soon have all the answers to fight age-related diseases and improve our immune systems!

**Conclusion: boosting our immune system targeting oxidative stress**

In summary, we can say that healthy eating plays an important role in our overall health, and when considering diet, we should always think about our immune system and ways in which we can take care of it. Our immune system does not just protect us from the flu or bacterial infections, but it is also fundamental for us in fighting against chronic, or less curable diseases, such as cancer. It isn’t always possible to eat a well-balanced diet, and for this reason, incorporating selected natural antioxidants such as vitamin C or astaxanthin, or synthetic molecules such as NAC, may be the secret weapon to help us regain or maintain our health. While research in the field of antioxidants continues, there is plenty of existing knowledge to be utilized when it comes to ways in which we can help improve our own immune system.

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**Further reading**

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