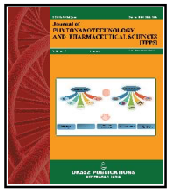
Journal of Phytonanotechnology and Pharmaceutical Sciences 2(4): 1-5, 2022

Online ISSN:2583-0376

http://jpps.ukaazpublications.com

DOI: http://dx.doi.org/10.54085/jpps.2022.2.4.1

Journal of Phytonanotechnology and Pharmaceutical Sciences



Review Article : Open Access

Nanoencapsulated nutraceuticals: Potential drug delivery systems for immune health

Nupur Mehrotra◆

Department of Biochemistry, SVKM's Mithibai College of Arts, Chauhan Institute of Science & Amrutben Jivanlal College of Commerce and Economics (Autonomous), Affiliated to University of Mumbai, Vile-Parle (West), Mumbai-400056, MH, India

Article Info

Article history

Received 10 November 2022

Revised 12 December 2022

Accepted 13 December 2022

Published Online 30 December 2022

Keywords

Nanonutraceuticals

Immunity

Vitamin C

Curcumin

Resveratrol

Selenium

Zinc

Abstract

Nanotechnological products along with nutraceuticals are fast emerging as sought after products for good health. The enhancement in usage of these technological improvisations is mainly attributed to the better bioavalability, reduction in adverse reactions due to targeted delivery and over toxicity, sustained release requiring fewer doses/day and better sustainability. In current times especially after the pandemic, the emphasis on development of nanonutraceuticals, as supplements, and its consumption, to not only maintain health and immunity but also to treat a number of diseases, has taken a boost. The current review summarizes the utility of some nanonutraceuticals for health through strengthening immunity, which can further lead to healthy being from many disorders/diseases.

1. Introduction

The SARS-CoV2 infection initiated since November 2019, spread rapidly and in March 2020, WHO declared it as a pandemic. With widespread mortality, the world recognised the nonpareil role of immunity in maintaining good health. It has always been accepted that nutrition plays a significant role in strengthening immunity. Hereditary predispositions along with environment have also been known to influence immunity. Over-nutrition as in obesity as well as malnutrition, results in adversely affecting immunity leading to malfunctioning of innate as well as adaptive immune responses, thereby leading to a higher vulnerability to infection (Calder and Yaqoob, 2020). A positive correlation exists between nutrition and functionality of the immune system. A strong support to the immune system is provided by micronutrients as vitamins A, C and D ; copper, magnesium, selenium, zinc, *etc.* (Gombart *et al.*, 2020; Maggini *et al.*, 2018).

Studies have recommended that foods rich in (a) antioxidants and vitamins, *e.g.*, vegetables and fresh fruits (Cena and Chieppa, 2020), nuts (Yahfoufi *et al.*, 2018), (b) omega-3 fatty acids (Seidelmann *et al.*, 2018), (c) micronutrients (Jampilek and Kralova, 2020), have a positive influence on the immune system. A new branch of science is nutraceuticals which is defined as foods and their derivatives, supplemented along with diet catering to important nutrients that support holistic wellness. These nutraceuticals use natural phytoconstituents with therapeutic effects and helps to maintain good health. As they are natural in origin, the adverse reactions are minimal and thus, the market for nutraceuticals has been growing exponentially in the past few decades.

The most convenient and desirable route of delivery of drugs or nutraceuticals or supplements is oral which has inherent issues especially low availability and first pass metabolism (Jampilek and Kralova, 2018, 2019). Nanoformulations are now evolving as the desired route for drug delivery, because it allows the targeted distribution of drugs to the selected tissues as well as controlled and sustained release, overcoming the undesired drug accumulation

Corresponding author: Dr. Nupur Mehrotra

Department of Biochemistry, SVKM's Mithibai College of Arts, Chauhan Institute of Science & Amrutben Jivanlal College of Commerce and Economics (Autonomous), Affiliated to University of Mumbai, Vile-Parle (West), Mumbai-400056, MH, India

E-mail: nupur.mehrotra@mithibai.ac.in

Tel.: +91-9833452122

(Jampilek *et al.*, 2019). Further bioavailability of the drug is enhanced and drug resistance is overcome (Pentak *et al.*, 2016; Placha and Jampilek, 2019).

Amongst the nanotechnology based delivery systems developed and used in industries, as food, pharmacy as well as agriculture are micelles, liposomes, nanoemulsions/suspensions, solid lipid nanoparticles, lipid nanocapsules, lipid-polymer hybrid and nanostructured lipid carriers. For better bioavailability and to reduce adverse effects, natural and non-toxic biodegradable polymers as pectin, alginate, gums as xanthan, arabic, chitin, chitosan, gelatins, hyaluronic acid, cyclodextrins, *etc*., are used (Jampilek and Kralova, 2018). This review presents a compilation of nutraceuticals formulated using nanotechnology with potential to strengthen immunity.

2. Some nanonutraceuticals

2.1 Vitamin C

Ascorbic acid is a potent antioxidant and is popular as 'scavenger molecule', as it has strong potential to scavenge free radicals generated during cell metabolism (Carita *et al.*, 2020; Moser *et al*., 2016). Vitamin C is an immunomodulator and affects both innate (Franz *et al*.., 2011) and acquired immune responses (Molina *et al*., 2014)**.** Studies reveal that NK cells are activated, proliferation of lymphocytes is enhanced and chemotaxis is promoted and enhanced when vitamin C is supplemented in healthy subjects (Heuser and Vojdani, 1997). High vit. C dose also stimulates dendritic cells with boosted interleukin -12 secretion (Jeong *et al*., 2011), as well as activation of T and B population (Woo *et al*., 2010; Maeng *et al*., 2009).

Vitamin encapsulated within liposomes in *ex vivo* studies showed higher antioxidant activity with reduction of malondialdehyde level in comparision to free vitamin C. The release of vitamin C from liposomes was almost 90% within 2 h (Parhizkar *et al*., 2018). Co-encapsulation with folic acid in fatty acid co-loaded liposomes showed good stability and higher encapsulation efficiency with higher antioxidant activity than liposomes loaded with individual vitamins (Jiao *et al*., 2019). Use of nanotechnology has shown to enhance vitamin C delivery along with improved intracellular Fenton reaction-based oxidative stress and found to be useful for Ferroptosis therapy (Pal and Jana, 2022). In combination with vitamin D and zinc, the immunomodulatory effects of vitamin C is boosted (Gautam and Santhiya, 2019). Vitamin C nanoparticles in conjugation with zinc oxide was found to improve the functioning of immune system of heat stressed broiler chickens (Bahrampour *et al*., 2021).

2.2 Curcumin

Rhizomes of *Curcuma longa* (Gingiberaceae) has a yellow to orange natural dye termed curcumin, a derivative of 1,7-bis (4-hydroxy-3-methoxyphenyl) hepta-1,6-diene-3,5-dione. Literature cites that in all forms of ancient medicines, curcumin has been used as antimicrobial (Manoharan *et al*., 2020), anti-inflammatory (Fadus *et al*., 2017) and antitumor (Hewlings and Kalman, 2017) as well as an antioxidant and hypolipedemic (Zahedipour *et al*., 2020). It is used for menstrual arrest, postpartum abdominal pain and GI disorders (Lopresti, 2018). For Alzheimer's, nanoformulations have shown prophylactic effect (Tsuda , 2018). Curcumin is known to inhibit inflammation in animal models. It has been found to inhibit inflammatory signalling molecules as NF-κB, JAKs/STATs and MAPKs (Kahkhaie *et al*., 2019).

On nanoencapsulation of curcumin around zein, an increase in oral bioavailability was seen by Ipar *et al.* (2019). Curcumin nanoparticles were synthesised with surface-charged surfactants and its antimicrobial activity against *Listeria monocytogenes*, was evaluated. Highest antimicrobial activity was demonstrated with nanoparticles formed from positively charged surfactants (No *et al*., 2017).

Treatment with curcumin nanoparticles has led to change of faecal fatty acid level towards short-chain ones and can be a therapeutic modality for IBD diseases (Ohno *et al*., 2017). Curcumin nanoparticles were prepared by Manjili *et al.* (2016) using poly (caprolactone)–poly (ethylene glycol)-poly (caprolactone). These curcumin nanoparticles significantly inhibited proliferation of cells, induced apoptosis and boosted antitumor immunity. Adjuvant therapy with nanoformulations having curcumin-Meriva® has been found to suppress systemic inflammation in cases of solid tumors for patients under standard chemotherapy (Belcaro *et al*., 2014).

2.3 Resveratrol

A natural polyphenolic antioxidant, resveratrol is derived from stilbene. It possesses antiplatelet, anticarcinogenic, antioxidant, anti-inflammatory, cardioprotective, and immunomodulatory activity (Mehrotra, 2020). Resveratrol is an immunomodulatory and induces lymphocyte proliferation, as well as stimulates natural killer cell cytotoxicity. Gianchecchi *et al.* (2020), have also suggested that reservatol plays a regulatory role in apoptosis. Resveratrol can suppress the toll-like receptor (TLR) and pro-inflammatory genes expression.

Resveratrol is an effective antioxidant as it possesses ability to inhibit the eicosanoids production. These eicosanoids contribute anti-inflammatory properties and are beneficial in different autoimmune and for other chronic inflammatory diseases (Malaguarnera, 2019). Resveratrol niosomes have immense anti-inflammatory action. RES-loaded niosomal hydrogel was found to enhance the biological half-life, which is a challenge if resveratrol is given *via* conventional routes of drug delivery. In paw edema model, the anti-inflammatory activity was measured and it was found to reduce the edema and its therapeutic action lasted for longer time (Negi *et al*., 2017).

2.4 Selenium

Selenoproteins the metalloprotein with selenium play a very important physiological functions and thus exemplifies the significance of this trace element (Zhang *et al*., 2020). Literature cites that around 30 genes are present in human genome which transcribe and translate to produce selenoproteins which play a significant role as anti-inflammatory agents as well as antioxidants (Labunskyy *et al*., 2014). Rayman (2012) observed that in HIV, as the concentration of selenium supplementation was increased mortality rate reduced.

Nanoformulations of selenium are advantageous as the selenium is in zero oxidation state, thereby lowering the toxicity and enhancing the bioavailability though it is unstable as it easily transforms into an inactive form (Zhai *et al*., 2017). Although, its stabilization can be achieved by encapsulation into suitable nanovehicles, for

example, chitosan (CS). Nanoformulations of selenium have potential immunomodulatory activity as they affect the functioning of granulocytes (Khabatova *et al*., 2022). A study to assess the effects of selenium nanoparticles as feed additives for goldfish (*Carassius auratus*) was undertaken by Jahanbakhshi (2021). They found that the nanoparticles promoted growth, biochemical metabolic process, hepatic enzymes activities, and enhanced gene expression of ghrelin and IGF-1.

2.5 Zinc

Zinc as a mineral for maintaining immune health is significant as it is a component of thymulin, the thymus hormone associated with T-cell maturation and differentiation. It also stimulates the production of IL-12 by macrophages, and this cytokine further activates natural killer and T cytotoxic cells (Prasad, 2008). Thus, Zn deficiency affects immunity due to degeneration of thymus, by interfering with important cellular functions such as phagocytosis (Fukada *et al.*, 2019). Improved immunity against viruses as well as its antioxidant activity was observed with zinc supplementation as it maintains membrane integrity and prevents inflammation (Read *et al.*, 2019).

Zinc oxide quantum dot powder bound on ZnO polystyrene film as well as suspended in a poly vinyl prolidone gel, are very efficient as antimicrobial packaging against *Listeria monocytogenes*, *Salmonella enteritidis*, and *Escherichia coli* O157:H7 (Sun *et al.*, 2009).

Dietary supplementation of selenium and zinc oxide nanoparticles has been found to stimulate immunity and resist bacterial infection in *L. rohita*. Down regulation of serum lactate dehydrogenase and alkaline phosphatase with upregulation of SOD and acetylcholine esterase was found, thus increasing percentage survival (El-Katcha *et al*., 2017).

3. Conclusion

Industrial revolution, information technology and associated improvisation of economy has led to a trend wherein lifestyle today has moved to being unhealthy, lacking physical exercise with an increase in consumption of fast foods. A balanced diet comprising of major nutrients, *viz*., carbohydrates, proteins and lipids along with micronutrients as vitamins, antioxidants, and minerals in the amount needed is unarguable the key for maintaining homeostasis and functionality of the organism as a whole. Good health is at times synonymous to good immunity and in recent times the emphasis on these has increased.

Thus, the need of nutraceuticals to not only maintain health but also to enhance immunity has been escalated. Theses nutraceuticals however at times have poor bioavailability and poor stability and so the combination with nanotechnology has proved to be highly beneficial. Thus, nutraceuticals so termed as smartfoods, are seeing a makeover to nanonutraceuticals. However, it should also be considered that these nanonutraceuticals, still need to prove their utility to cure an already proven disease. Thus, in conclusion nanonutraceuticals surely can be the key to improve immunity, thereby contributing to holistic wellness as it is well said that 'A healthy mind stays in a healthy body'.

Conflict of interest

The author declares no conflicts of interest relevant to this article.

References

Bahrampour, K.; Ziaei, N. and Esmaeilipour, O. (2021). Feeding nano particles of vitamin C and zinc oxide: Effect on growth performance, immune response, intestinal morphology and blood constituents in heat stressed broiler chickens Livest. Sci., 253, Article 104719

Belcaro, G.; Hosoi, M. and Pellegrini, L. (2014). A controlled study of a lecithinized delivery system of curcumin (Meriva®) to alleviate the adverse effects of cancer treatment. Phytother Res., **28**:444-450.

Calder, P.C. and Yaqoob, P. (2020). Nutrient regulation of the immune response. In Present Knowledge in Nutrition, 11th ed.; Marriott, B.P., Birt, D.F., Stallings, V.A., Yates, A.A., Eds.; Academic Press: Cambridge, MA, USA; pp:625-664.

Carita, A.C.; Fonseca-Santos, B.; Shultz, J.D.; Michniak-Kohn, B.; Chorilli, M. and Leonardi, G.R. (2020). Vitamin C: One compound, several uses. Advances for delivery, efficiency and stability. Nanomedicine, **24**:102-117.

Cena, H. and Chieppa, M. (2020). Coronavirus disease (COVID-19–SARS-CoV-2) and nutrition: Is infection in Italy suggesting a connection? Front. Immunol., 1(11):944.

El-Katcha, M.; Soltan, M. A. and El-Badry, M. (2017). Effect of dietary replacement of inorganic zinc by organic or nanoparticles sources on growth performance, immune response and intestinal histopathology of broiler chicken. Alexandria Journal for Veterinary Sciences, **55**(2):19-25.

Fadus, M. C.; Lau, C.; Bikhchandani, J. and Lynch, H.T. (2017). Curcumin: Anage-old anti-inflammatory and anti-neoplastic agent. Journal of Traditional and Complementary Medicine, **7**(3):339-346.

Franz, S., Rammelt, S.; Scharnweber, D. and Simon, J.C.(2011). Immune responsesto implants: A review of the implications for the design of immunomodulatory biomaterials. Biomaterials, **32**(28):6692-6709.

Fukada, T.; Hojyo, S. and Hara, T., (2019). Revisiting the old and learning the new of zinc in immunity. Nat. Immunol., **20**:248-250

Gautam, M. and Santhiya, D. (2019). Pectin/PEG food grade hydrogel blend for the targeted oral co-delivery of nutrients Colloids Surf. A: Physicochem. Eng. Asp., **577**:637-644

Gombart, A.F.; Pierre, A. and Maggini, S. (2020). A review of micronutrients and the immune System, working in harmony to reduce the risk of infection. Nutrients, **12**:E236.

Heuser, G. and Vojdani, A., (1997). Enhancement of natural killer cell activity and T and B cell function by buffered vitamin C in patients exposed to toxic chemicals: the role of protein kinase-C. Immuno-pharmacol Immunotoxicol., **19**(3):291-312

Hewlings, S. J. and Kalman, D. S. (2017). Curcumin: A review of its effects on human health. Foods, **6**(10):92.

Hewlings, S.J. and Kalman, D.S., (2017). Curcumin: A review of its effects on human health. Foods, **6**:92

Ipar, V.S.; Dsouza, A. and Devarajan, P.V. (2019) Enhancing curcumin oral bioavailability through nanoformulations. Eur. J. Drug Metab. Pharmacokinet., **44**:459-480.

Jahanbakhshi, A.; Pourmozaffar, S.; Adeshina, I.; Mahmoudi, R.; Erfanifar, E.; and Ajdari, A. (2021). Selenium nanoparticle and selenomethionine as feed additives: Effects on growth performance, hepatic enzymes' activity, mucosal immune parameters, liver histology, and appetite-related gene transcript in goldfish (*Carassius auratus*). Fish Physiology and Biochemistry, **47**(2):639-652.

Jampilek, J. and Kralova, K. (2018). Application of nanobioformulations for controlled release and targeted biodistribution of drugs. In Nanobiomaterials: Applications in Drug Delivery; Sharma, A.K., Keservani, R.K., Kesharwani, R.K., Eds.; CRC Press: Warentown, NJ, USA, **pp**:131-208.

Jampilek, J. and Kralova, K. (2019). Nanotechnology based formulations for drug targeting to central nervous system. In Nanoparticulate Drug Delivery Systems; Keservani, R.K., Sharma, A.K., Eds.; Apple Academic Press and CRC Press: Warentown, NJ, USA, pp:151-220.

Jampilek, J. and Kralova, K. (2020). Potential of nanonutraceuticals in increasing immunity. Nanomaterials (Basel), **10**(11):2224.

Jampilek, J.; Kralova, K.; Campos, E.V.R. and Fraceto, L.F. (2019/). Bio-based nanoemulsion formulations applicable in agriculture, medicine and food industry. In nanobiotechnology in bioformulations; Prasad, R., Kumar, V., Kumar, M., Choudhary, D.K., Eds.; Springer: Cham, Switzerland pp:33-84.

Jeong, Y.J.; Hong, S.W.; Kim, J.H.; Jin, D.H.; Kang, J.S.; and Lee, W.J., (2011). Vitamin C-treated murine bone marrow-derived dendritic cells preferentially drive naive T cells into Th1 cells by increased IL-12 secretions. Cell Immunol., **266**(2):192-9.

Jiao, Z., Wang, X.D., Yin, Y.T. and Xia, J.X., (2019). Preparation and evaluation of vitamin C and folic acid-coloaded antioxidant liposomes. Particul. Sci. Technol., **37**:449-455.

Kahkhaie, K.R.; Mirhosseini, A. and Aliabadi, A. (2019). Curcumin: A modulator of inflammatory signaling pathways in the immune system. Inflammopharmacol., **27**:885-900.

Khabatova, V. V.; Serov, D. A.; Tikhonova, I. V.; Astashev, M. E.; Nagaev, E. I.; Sarimov, R. M., and Gudkov, S. V. (2022). Selenium nanoparticles can influence the immune response due to interactions with antibo-dies and modulation of the physiological State of Granulocytes. Pharmaceutics, **14**(12):2772.

Labunskyy, V. M.; Hatfield, D. L. and Gladyshev, V. N. (2014). Selenoproteins: molecular pathways and physiological roles. Physiological Reviews, **94**(3):739-777.

Lopresti, A.L. (2018). The problem of curcumin and its bioavailability: Could its gastrointestinal influence contribute to its overall health-enhancing effects? Adv. Nutr., **9**:41-50

Maeng, H.G.; Lim, H.; Jeong, Y.J.; Woo, A.; Kang, J.S. and Lee, W.J. (2009). Vitamin C enters mouse T cells as dehydroascorbic acid *in vitro* and does not recapitulate *in vivo* vitamin C effects. Immunobiology, **214**(4):311-20.

Maggini, S.; Pierre, A. and Calder, P.C. (2018). Immune function and micronutrient requirements change over the life course. Nutrients, **10**:1531.

Malaguarnera, L. (2019). Influence of resveratrol on the immune response. Nutrients, **11**(5):946.

Manjili, H.K.; Sharafi, A. and Danafar, H. (2016). Poly(caprolactone) - poly (ethylene glycol) - poly(caprolactone) (PCL–PEG–PCL) nanoparti-cles: A valuable and efficient system for *in vitro* and *in vivo* delivery of curcumin. RSC Adv., **6**:14403-14415.

Manoharan, Y.; Haridas, V.; Vasanthakumar, K. C.; Muthu, S.; Thavoorullah, F. F. and Shetty, P. (2020). Curcumin: A wonder drug as a preventive measurefor COVID-19 management. Ind. Journ. Clin. Biochem., **35**(3):373-375.

Molina, N.; Morandi, A.C.; Bolin, A.P. and Otton, R. (2014). Comparative effectof fucoxanthin and vitamin C on oxidative and functionalparameters of human lymphocytes. Int. Immunopharmacol., **22**:41-50.

Moser, M.A. and Chun, O.K. (2016). Vitamin C and heart health: A reviewbased on findings from epidemiologic studies. Int. J. Mol. Sci., **17**:1328-38.

No, Da Som.; Algburi, A.; Huynh, P.; Moret, A.; Ringard, M.; Comito, N.; Drider, D.; Takhistov, P. and Chikindas, M.L. (2017). Antimicrobial efficacy of curcumin nanoparticles against *Listeria monocytogenes* is mediated by surface charge. Journal of Food Safety, **37**(4):e12353.

Nupur Mehrotra and Kaustubh Jadhav (2021). Nutraceuticals: Potential prospect for COVID-19 management. Ann. Phytomed., Volume10, Special Issue1 (COVID-19):S85-S102.

Ohno, M.; Nishida, A.; Sugitani, Y.; Nishino, K.; Inatomi, O. and Sugimoto, M. (2017). Nanoparticle curcumin ameliorates experimental colitis *via* modulation of gut microbiota and induction of regulatory T cells. PLoS ONE, **134**:329-337.

P. Negi, P.; Aggarwal, M. and Sharma, G. (2017). Niosome-based hydrogel of resveratrol for topical applications: An effective therapy for pain related disorder(s)," Biomedicine and Pharmacotherapy, **88**:480-487.

Pal, S. and Jana, N.R. (2022). Enhanced therapeutic applications of vitamin C *via* nanotechnology-Based Pro-Oxidant Properties: A review. ACS Appl. Nano Mater., **5**(4):4583-4596

Parhizkar, E.; Rashedinia, M.; Karimi, M. and Alipour, S. (2018). Design and development of vitamin C-encapsulated proliposome with improved *in vitro* and *ex vivo* antioxidant efficacy. J. Microencapsul., **35**:301-311.

Pentak, D.; Kozik, V.; Bak, A.; Dybal, P.; Sochanik, A. and Jampilek, J. (2016). Methotrexate and cytarabine: Loaded nanocarriers for multidrug cancer therapy. Spectroscopic study. Molecules, **21**:1689.

Placha, D. and Jampilek, J. (2019). Graphenic materials for biomedical applications. Nanomaterials, **9**:1758.

Prasad, A.S. (2008). Clinical, immunological, anti-inflammatory and antioxidant roles of zinc. Exp. Gerontol., **43**(5):370-377. https://doi.org/10.1016/j.exger.2007.10.013

Quantum Dots against *Listeria monocytogenes*, *Salmonella enteritidis*, and *Escherichia coli* O157:H7. J. Food Sci., **74**(1):M46-M52

Rayman, M.P. (2012). Selenium and human health. The Lancet, **379**(9822):1256-1268.

Read, S.A.; Obeid, S.; Ahlenstiel, C. and Ahlenstiel, G. (2019). The role of zinc in antiviral immunity. Adv. Nutr., **10**(4):696-710. https://doi.org/10.1093/advances/nmz013.

Seidelmann, S.B.; Claggett, B.; Cheng, S.; Henglin, M.; Shah, A.; Steffen, L.M.; Folsom, A.R.; Rimm, E.B.; Willett, W.C. and Solomon, S.D. (2018). Dietary carbohydrate intake and mortality: A prospective cohort study and meta-analysis. Lancet Public Health, **3**:e419-e428.

Sun, D.; T. Jin, J. Y. Su, H. Zhang and H. J. Sue. (2009). Antimicrobial efficacy of zinc oxide. Reviews, **29**:110-129.

Tsuda, T. (2018). Curcumin as a functional food-derived factor: Degradation products, metabolites, bioactivity, and future perspectives. Food Funct., **9**:705-714

Woo, A.; Kim, J.H.; Jeong, Y.J.; Maeng, H.G; Lee, Y.T. and Kang, J.S. (2010). Vitamin C acts indirectly to modulate isotype switching in mouse B cells. Anat. Cell Biol., **43**(1):25-35.

Yahfoufi, N.; Alsadi, N.; Jambi, M. and Matar, C. (2018). The immunomodulatory and anti-inflammatory role of polyphenols. Nutrients, **10**:16-18.

Zahedipour, F.; Hosseini, S. A.; Sathyapalan, T.; Majeed, M.; Jamialahmadi, T.; Al Rasadi, K. and Sahebkar, A. (2020). Potential effects of curcumin in the treatment of COVID 19 infection. Phytotherapy Research, **34**(11):2911-2920.

Zhai, X.; Zhang, C.; Zhao, G.; Stoll, S, Ren F. and Leng X (2017). Antioxidant capacities of the selenium nanoparticles stabilized by chitosan. J Nanobiotechnology, **15**(1):4.

Zhang, J.; Saad, R.; Taylor, E.W. and Rayman, M.P.; (2020). Selenium and selenoproteins in viral infection with potential relevance to COVID-19. Redox Biology, **37**:1017.

Citation **Nupur Mehrotra (2022). Nanoencapsulated nutraceuticals: Potential drug delivery systems for immune health. J. Phytonanotech. Pharmaceut. Sci., 2(4):1-5. http://dx.doi.org/10.54085/jpps.2022.2.4.1**