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Short Communication

Carbon 60: Vision for the Future

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Preface

Carbon 60, or C60 is one of the most interesting and potentially useful molecules discovered in recent decades. It has the potential to enhance the health of people and animals, extending longevity, while reducing the impact of pain and disease. We have not yet begun to realize the many opportunities to apply C60 to treat and prevent disease conditions in humans and animals.

What is carbon 60?

Carbon 60, also known as C60, C_{60}, fullerene, buckminsterfullerene, and buckyballs, is composed entirely of carbon; 60 carbon atoms, bonded in the shape of a soccer ball. It was named in honor of Buckminster Fuller, the inventor of the geodesic dome, because it has a geodesic structure. This shape gives it many unique and potentially useful properties. The 60 carbon atoms are bonded with alternating double and single bonds: 30 double bonds and 20 single bonds in all. The structure created is made up of hexagons and pentagons, making it resilient and extremely strong.

Unique properties of C60

C60 has several unique properties that make it a powerful antioxidant, capable of neutralizing highly reactive free radical molecules. No other antioxidant molecule has these properties or can neutralize as many free radical molecules.

- Small size (0.72 nm diameter)
- Hydrophobicity (solubility in water 1.0 X 10^{-11} gm/ml)
- Ability to donate 24 electrons to neutralize unstable free radical molecules
- Ability to absorb 6 protons to irreversibly neutralize unstable free radical molecules
- No exhibited toxicity at any level tested – composed only of carbon

C60- Macromolecule not nanomaterial

C60 has been called a nanoparticle but it is actually a macromolecule. At 0.72 nanometers in diameter, it is below the defined size of a nanoparticle of 1 nanometer. That may be a matter of definition, however, it is meaningful that a free C60 molecule is not a finely divided solid particle, as is true of nanoparticles. The chemistry of a macromolecule is drastically different from a nanoparticle. The surface area of a nanoparticle is large, increasing the chemical reactivity, but still only the exposed surface is reactive. In solubilized C60 all of the carbon atoms in the macromolecule are capable of reaction. The space between the carbon atoms in C60 allow them to behave differently than if aligned in a tight crystalline structure, as in nanoparticles. And, most importantly, the carbon atoms in C60 form a hollow macromolecular structure with a comparatively huge empty space inside. The open spacing of the carbon atoms in C60 gives it a chemistry unlike any nanoparticle. Electrical charge flows freely around the carbon cage.

C60 is not a nanoparticle. It is a unique and highly bioactive carbon macromolecule.

Dissolving C60

Until recently, the only solvents that were known to dissolve C60 at useful concentrations were toxic materials such as toluene. In order for C60 to be fully active in biological systems it must be solubilized. Solubilized C60 molecules are able to pass through membranes in the intestines and liver and enter the bloodstream. Unlike many other materials, including antioxidants such as melatonin, the liver does not remove C60. C60 molecules pass through cell walls and mitochondrial walls to get to the places in the body where most free radical molecules are formed.

Most of the research on C60 to date has been done using either dispersed crystalline forms, with limited solubility, or derivatized forms with enhanced solubility but markedly different, even toxic, chemistry. Only a few studies have properly recognized and quantified the solubility of the C60 used. Therefore, most of the existing studies are inaccurate at best or wrong at worst.

A fully solubilized and bioactive C60 enables the development of many applications that were impossible before. There is a lot of work to do using properly and safely solubilized C60.

Free radical molecules

Free radical molecules are molecules that have an unpaired electron or proton (hydrogen atom) [1]. Stable molecules have electrons in pairs with opposite spin. A molecule with an unpaired electron is highly reactive and will react quickly with a neighboring molecule to take an electron to satisfy its need. This often creates another molecule with an unpaired electron, which is now an unstable free radical molecule, causing a chain of free radical generation. C60 can donate up to 24 electrons to needy free radical molecules, neutralizing them without causing any instability in the C60 molecule, thereby terminating the chain of free radical generation.

Free radicals are different from ions, which are charged atoms. For example, in sodium chloride, sodium atoms have 23 protons and 23 electrons, a stable atom but in order to have a full outer electron shell it needs to give up an electron. Chlorine has the opposite issue. It has 35 protons and 35 electrons, again a stable configuration, but in order to fill up the outer electron shell it needs another electron. In an aqueous solution the Sodium and Chlorine atoms dissociate, with the Sodium atom giving up an electron creating an Na^+ ion, while the Chlorine atom picks up an electron creating a Cl^- ion. All electrons are paired and electron shells are full, so the resulting ions are very stable. Ions are not free radicals.

Free radical production during respiration

Adults take in approximately 250 grams of oxygen each day by breathing. The process of respiration takes place inside the mitochondria, reacting glucose with oxygen to produce ATP. The process is about 98% efficient, resulting in harmless water and carbon dioxide as reaction products. The other 2% (about 5 grams daily) is converted into $\bullet OH^-$ hydroxyl free radical molecules. Each molecule of glucose produces 24 $\bullet OH^-$ hydroxyl free radical molecules. The result is the production of 1.88×10^{23} hydroxyl free radical molecules per day, or 188 million quadrillion free radicals. The hydroxyl free radical is highly reactive, with a half-life of 1 ten billionth of a second [2]. It reacts quickly with a fat, protein or DNA molecule nearby inside the mitochondria, causing damage. Fats are oxidized to peroxide molecules that are unstable, initiating a chain of oxidative reactions. Intercellular proteins are often enzymes, and when damaged at the functional site, can be rendered nonfunctional. DNA can also be damaged, causing mutations, some of which will be corrected by mechanisms in the cell. Other damage accumulates and can impair the function of the gene impacted, ultimately leading to inactivity or cancer.

Free radicals from environmental sources

Free radicals are produced in the body due to many other causes, including

- Some antioxidants can become prooxidants, creating a chain of free radical production. C-60 is stable and does not become a prooxidant.
- Cigarette smoke contains 10^{15} to 10^{17} free radical molecules per puff as H_2O_2 and $\bullet O2^-$ free radicals.
- The presence of heavy metals in the body (mercury, chromium, aluminum, lead, iron and cadmium) greatly increase the formation of free radicals.
- Oxidized (rancid) fats in the diet have unstable, oxidized double bonds that create free radicals.
- Environmental contaminants such as air pollution, pesticides, herbicides and smoke greatly increase free radical formation in the body.
- Ionizing radiation from UV light or x-rays create free radicals [3].
- Cosmic radiation from high altitude and space flight generates free radicals.
- High intensity exercise increases the rate of free radical [4] production from respiration.
- Petroleum based solvents such as toluene, benzene, carbon tetrachloride and formaldehyde are pro-oxidants, generating free radicals. These can be found in furniture polish, nail polish and paints [5].
- Stress enhances the formation of free radicals [6].
- The immune system produces free radical molecules to destroy pathogens and foreign material in the body.

Antioxidants

Antioxidants are molecules that react with oxygen or the products created by the metabolism of oxygen. It is a fascinating fact that oxygen is actually toxic. The early atmosphere on earth contained very little oxygen, so the first forms of life on earth were anaerobic bacteria. These bacteria require no oxygen. In fact, oxygen kills them. These bacteria still exist in large numbers in the soil and deep ocean where oxygen is limited. As evolution progressed, green algae used photosynthesis to create glucose from sunlight, water and carbon dioxide, which were abundant. Water and carbon dioxide both contain oxygen and in the process of producing a glucose molecule, six oxygen molecules are released into the atmosphere. After a few hundred million years, the oxygen concentration in the atmosphere became high enough to be toxic to anaerobic bacteria and they literally went underground. Meanwhile, life did what life does-it evolved to use the abundant oxygen now present in the atmosphere as a resource to increase the efficiency of energy storage and use. Fungi evolved with the ability to use the abundant glucose stored in dead plant material, combining it with oxygen to reverse the process of energy storage that takes place in photosynthesis. Plants and green algae are glucose producers. Fungi and animals are glucose consumers. It created a beautiful and balanced system of life on earth-glucose producers and glucose consumers all driven by photosynthesis.

How did life manage to survive and even use the toxic oxygen? Aerobic bacteria and green algae produced antioxidants to manage and control the toxicity of oxygen. Anaerobic bacteria never developed antioxidant chemistry and therefore cannot tolerate oxygen, even today.

Oxygen has become an important component of life, enabled by the production of antioxidants. Glucose is reacted with oxygen to create energy inside the mitochondria. Mitochondria are tiny organelles inside of our cells. A single cell can contain 100 mitochondria. The mitochondria are thought to be an early form of cell that at one time was an independent life form. Since then, glucose-consuming cells have made the mitochondria part of their cellular components.

Oxidative stress

Free radicals are produced in the body as a result of respiration, exposure to environmental factors such as air pollution, toxicants, UV radiation, cosmic radiation and immune system overreaction. Inadequate production and dietary intake of antioxidants put most people into a state of oxidative stress-too many free radicals and too few antioxidants to neutralize them. In advanced cases, oxidative stress visibly manifests as inflamed, swollen tissues often in extremities of the body such as feet, ankles and fingers, but internal organs may also be inflamed as well. Our bodies naturally produce antioxidants such as glutathione, melatonin and uric acid. As we age, antioxidant production declines [7]. Many studies show the benefits of antioxidant supplementation to compensate. There are dozens of antioxidants, with differing properties: C60, melatonin, uric acid, Vitamin C, Vitamin E, Vitamin A, Vitamin D, glutathione, astaxanthin, curcumin, lutein, luteolin, selenium, manganese, flavonoids, to name a few. All are valuable, but function differently.

Prevention of damage due to toxins

C60 has been shown to prevent damage to liver tissue caused by the biotransformation of carbon tetrachloride [8]. C60 protected the liver from damage, penetrating liver tissues and neutralizing free radicals [9]. In another study C60 protected the liver against free radicals produced by the biotransformation of other toxic materials [10].

Prevention of damage due to radiation

C60 has been shown effective in preventing damage from free radical molecules produced by exposure to nuclear radiation, space travel, cancer treatment and exposure to X-Rays. The radioprotective possibilities of C60 were reviewed by the department of Radiobiology University of Defense, Faculty of Military Health Sciences, Czech Republic [11]. They concluded "fullerenes offer a great potential to become radioprotectants with a possibility of repeated administration". Another study compared C60 to amifostine, a commonly used radioprotective agent with significant adverse side effects and concluded that C60 was effective and exhibited no toxicity [12]. Hydrated C60 has been shown to protect DNA from ionizing radiation *in-vitro* and *in-vivo* by decreasing reactive species generated by exposure to X-rays [13].

Prevention of damage due to UV exposure - sunburn

C60 has been shown to penetrate skin cells [14] where it neutralizes free radicals caused by exposure to UV radiation from sunlight [15-18]. Applying or ingesting solubilized C60 can prevent sunburn systemically, avoiding the risk of missing an exposed area. It also eliminates the need for sun-blocking agents, allowing the skin to produce Vitamin D. This is especially relevant as many of the traditional sun-blocking and sunscreen agents are coming under safety scrutiny by FDA and may be banned from use, as PABA has been.

Anti-aging

C60 improves longevity by reducing oxidative free radical damage to DNA, fats and enzymes that accumulates over time [19]. Baati., *et al*. "showed significant prolongation of the lifespan of Wistar rats by repeated oral administration of C60 dissolved in olive oil [20]. The study was designed to determine the toxicity of C60, but no toxicity was found at any level. Most interestingly, the rats taking C60 did not develop cancer as occurred in the control animals. A study in mice showed similar results [21]. Another study focuses on mTOR signaling pathways and antioxidant capabilities to explain how C60 slows aging [22].

Prevention of damage caused by oxidative stress

Other potential applications for solubilized C60 are human diseases involving Immunoglobulin E (IgE) and mast cell release. The ability of solubilized C60 to reduce free radicals will enable treatment of a wide variety of diseases that involve oxidative stress, inflammation and immune system dysfunction [23]. Nebulization of solubilized C60 directly into the lungs and nasal passages can moderate respiratory distress syndromes such as the cytokine storm as occurs in COVID-19, asthma [24,25], allergic rhinitis and urticaria. Delivering solubilized C60 into the mouth can mitigate oral conditions such as periodontitis and gingivitis [26]. Internal delivery of solubilized C60 orally can mitigate free radical damage caused by autoimmune diseases such as rheumatoid arthritis [26]. and scleroderma; and allergic responses such as celiac disease [28]. Inflammatory responses in the skin and adjacent tissues such as rosacea [28], poison ivy, Atopic dermatitis [30], chronic wounds [31], gout and varicose veins can benefit from a powerful antioxidant anti-inflammatory applied topically. The common factor in all of these conditions is inflammation [32] accompanied by excess free radical production.

Prevention and treatment of cancer

C60 has been studied, along with other antioxidants in the prevention and treatment of cancers of various types [33,34]. Dr. Shilpa Sharma at the All-India Institute of Medical Sciences has studied the impact of antioxidants on hepatocellular cancers [35,36].

The future for C60

The ability of C60 to diffuse across cell and mitochondrial membranes to irreversibly neutralize free radical molecules before damaging reactions can occur makes it uniquely capable of reducing damage caused by free radical molecules and the associated inflammation. Over one hundred disease conditions have been identified to involve an excess of free radical molecules [37].

Many studies have been performed with no evidence of toxicity observed at any level of pristine C60 administered. Unfortunately, these studies are not sufficiently conclusive to support a GRAS status. Further, controlled safety and efficacy studies need to be performed. A non-toxic process for solubilizing C60 enables a wide range of new applications. The vision for the future is bright.

Bibliography

1. Slater Trevor F. "Free-Radical Mechanisms in Tissue Injury". *Biochemical Journal* 222 (1984): 1-15.
2. Naidu AS. "Redox Life". Bio-Rep Network (2013).
3. Beranova Eva. "Radioprotective Properties and a Toxicity Test of C60 Fullerene Derivative in Vivo and *in Vitro". Nanocon* 2013 (2010).
4. Belviranlt Muaz. "Acute Exercise Induced Oxidative Stress and Antioxidant Changes". *European Journal of General Medicine* 3.3 (2006): 126-131.
5. Manibusan Mary K. "Postulated Carbon Tetrachloride Mode of Action: A Review". *Journal of Environmental Science and Health, Part C* 25.3 (2007): 185-209.
6. Gonchar Olga O. "C60 Fullerene Prevents Restraint Stress-Induced Oxidative Disorders in Rat Tissues: Possible Involvement of the Nrf2/ARE-Antioxidant Pathway". *Oxidative Medicine and Cellular Longevity* 2518676 (2018): 17.
7. Warraich Umm-e-Ammara. "Aging - Oxidative Stress, Antioxidants and Computational Modeling". *Heliyon* 6.e04107 (2020).
8. Muriel Pablo. "Role of Free Radicals in Liver Disease". *Hepatology International* 2009.3 (2009): 526-536.
9. Manibusan Mary K. "Postulated Carbon Tetrachloride Mode of Action: A Review". *Journal of Environmental Science and Health, Part C* 25.3 (2007): 185-209.
10. Durasevic Sinisa. "Effects of C60 Fullerene on Thioacetamide-Induced Rat Liver Toxicity and Gut Microbiome Changes". *Antioxidants* 10.911 (2021): 1-19.
11. Rezacova Martina. "Fullerene Nano Particles and Their Anti-Oxidative Effects: A Comparison to Other Radio Protective Agents". *Journal of Applied Biomedicine* (2012).
12. Vavrova Jirina. "Fullerene Nanoparticles and Their Anti-Oxidative Effects: A Comparison to Other Radioprotective Agents". *Journal of Applied Biomedicine* 10.1 (2012): 1-8.
13. Andrievsky Grigory V. "Peculiarities of the Antioxidant and Radioprotective Effects of Hydrated C60 Fullerene Nanostructures *in Vitro* and *in Vivo". Free Radical Biology and Medicine* 47.6 (2009): 786-793.
14. Kato Shinya. "Defensive Effects of Fullerene-C60/Liposome Complex against UVA-Induced Intracellular Reactive Oxygen Species Generation and Cell Death in Human Skin Keratinocytes HaCaT, Associated with Intracellular Uptake and Extracellular Excretion of Fullerene-C60". *Journal of Photochemistry and Photobiology B: Biology* 98 (2010): 144-151.
15. Kato Shinya. "Fullerene-C60/Liposome Complex: Defensive Effects against UVA-Induced Damages in Skin Structure, Nucleus and Collagen Type I/IV Fibrils, and the Permeability into Human Skin Tissue". *Journal of Photochemistry and Photobiology B: Biology* 98 (2010): 99-105.
16. Mousavi S Zeinab. "Fullerene Nanoparticle in Dermatological and Cosmetic Applications". *Nanomedicine: Nanotechnology, Biology and Medicine* 13.3 (2017): 1071-1087.
17. Krusic PJ. "Radical Reactions of C60". *Science* 254.5035 (1991): 1183-1185.
18. Lin Qianyu. "UV Protection and Antioxidant Activity of Nanodiamonds and Fullerenes for Sunscreen Formulations". *Applied Nanomaterials* 2.12 (2019): 7604-7616.
19. Alperovich IG., *et al*. "Fullerenes as Anti-Aging Antioxidants". *Current Aging Science* (2016).
20. Baati Tarek., *et al*. "The Prolongation of the Lifespan of Rats by Repeated Oral Administration of [60] Fullerene". *Biomaterials* (2012): 1-11.
21. Shytikov Dmytro. "Effect of Long-Term Treatment with C60 Fullerenes on the Lifespan and Health Status of CBA/Ca Mice". *Rejuvenation Research* (2021).
22. Turner Ashley R. "Studies Examining the Anti-Aging Effects of Fullerenes". *Dissertation Submitted to the Graduate School at the University of North Carolina at Greensboro* (2017).
23. Hirai Toshiro. "Potential Suppressive Effects of Two C60 Fullerene Derivatives on Acquired Immunity". *Nanoscale Research Letters* 2016.11 (2016): 449.
24. Shershakova Nedezda., *et al*. "Anti-Inflammatory Effect of Fullerene C60 in a Mice Model of Atopic Dermatitis". *Journal of Nanobiotechnology* 14 (2016).
25. Ryan John J., *et al*. "Fullerene Nanomaterials Inhibit the Allergic Response". *The Journal of Immunology* 179 (2007): 665-672.
26. Hans Mayank. "Toll-like Receptors and Their Dual Role in Periodontitis: A Review". *Journal of Oral Science* 53.3 (2011): 263-271.
27. Liu Qihai. "The Applications of Buckerminsterfullerene C60 and Derivatives in Orthopaedic Research". *Connective Tissue Research* 55.2 (2014): 71-79.
28. Bouziat Romain. "Reovirus Infection Triggers Inflammatory Responses to Dietary Antigens and Development of Celiac Disease". *Science* 356.6333 (2017).
29. Jones D. "Reactive Oxygen Species and Rosacea". *Cutis* 74.3 (2004): 17-20.

30. Bertino Lucrezia. “Oxidative Stress and Atopic Dermatitis”. *Antioxidants* 9 (2020).

31. Soriano Jose L. “Endogenous Antioxidant Cocktail Loaded Hydrogel for Topical Wound Healing of Burns”. *Pharmaceutics* 13.8 (2021).

32. Oyinloye Babatunji Emmanuel. “Reactive Oxygen Species, Apoptosis, Antimicrobial Peptides and Human Inflammatory Diseases”. *Pharmaceuticals* 2015.8 (2015): 151-175.

33. Fernandes Neha Benedicta. “Fullerenes for the Treatment of Cancer: An Emerging Tool”. *Environmental Science and Pollution Research* 29 (2022): 58607-58627.

34. Chen Virginia. “How Curcumin Targets Cancer”. *Life Extension Magazine* (2016).

35. Sharma Shilpa., *et al*. “Curcumin: An Adjuvant Therapeutic Remedy for Liver Cancer”. *Hepatoma Research* 2 (2016): 62-70.

36. Locatelli Claudriana. “Role of Antioxidants in the Treatment of Hepatocellular Carcinoma: Integrative Review”. *Research, Society and Development* 10.1 (2021).

37. Poljsak Borut. “Achieving the Balance between ROS and Antioxidants: When to Use Synthetic Antioxidants”. *Oxidative Medicine and Cellular Longevity* (2013): 956792.