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Mini Review

The Application of Fullerene Materials in Agriculture

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Received: August 04, 2020; **Published:** July 31, 2020

DOI: 10.31080/ecag.2020.06.00324

Abstract

Carbon fullerene materials have been investigated for applications in humans, animals, and plants for decades. Fullerene materials are composed of carbon atoms and are compatible with specific biological systems, while showing little to no toxicity. They reduce the number of free radicals in cells, provide anti-inflammatory effects, and inhibit tumor growth. However, the primary antioxidant benefit of fullerene materials seems to be the activation of nuclear factor (erythroid-derived 2) factor 2 (Nrf2). Their application can enhance productivity and improve crop yield by stimulating water retention and fighting specific disease organisms in agriculture. Their application in husbandry can enhance productivity and profitability, in part, by stimulating metabolism and immunity. Nanocarbon onion-like fullerene (NOLF) materials have a high surface area to volume ratio, making them viable for transportation within biologic systems. However, NOLFs safety, manufacture, and dosage should be further evaluated for consistency and toxicity, and established for the safe use in humans, animals, and plants.

Keywords: *Agriculture; Biocompatibility; Biomass; Free Radical; Fullerene; Husbandry; Nanocarbon; Shungite*

Abbreviations

C60 Carbon 60; CNO: Carbon Nano-Onion; NOLF: Nanocarbon Onion-Like Fullerene; Nrf2: Nuclear Factor (Erythroid-Derived 2) Factor 2; OLC: Onion-Like Carbon; MWCNO: Multi-Walled Carbon Nano-Onion

Introduction

Fullerene is one of the allotropes of carbon characterized by a non-graphitized physical structure with a unique shape. Fullerenes have vast applications in the agriculture field. The allotrope's unique features allow for various applications in medicine, biology, and agriculture practices [1]. Fullerene was discovered by scientists in Russia as a component in shungite rock. Fullerene substances have an amorphous shape and form about 5% to 95% of the natural shungite [2,3].

In the 1970s, scientists from Japan investigated the properties of the allotrope; however, the results of their studies were not published. Subsequently, in 1985, James Heath, Richard Smalley, Harold Kroto, and Robert Curl published their findings at Rice University on the fundamental properties of the fullerene allotrope [3–5]. Further studies led to the descriptive name, buckminsterfullerene. after the allotrope was discovered to have a soccer-ball-like shape, similar to the geodesic dome structure popularized by American architect Buckminster Fuller [6]. Over subsequent decades, studies on the physical and chemical properties of fullerene advanced, resulting in a wide range of medicine, veterinary medicine, and agriculture and husbandry applications.

The physical structure of carbon fullerene was shown to assume distinct shapes while retaining similar chemical properties [7]. Thus, fullerene materials became a subject of interest for many scientists who studied its various physical structures. As the most stable allotrope, carbon-60 (C_{60}) displayed a complex physical structure but with similar chemical properties. In particular, C_{60} is comprised of twelve rings in pentagonal shape integrated into sixty molecules around its lattice. These pentagonal rings and carbon molecules form a truncated, icosahedral shape with covalent bonds between single atoms [4,5,7].

Over time, scientists proposed various shapes for C_{60}. In 1980, Sumio Ijima offered the onion-like structure of the carbon allotrope [8]. From investigations of black carbon, Ijima discovered that this allotrope formed an onion-like shape. Subsequently, in 1992, David Urgate published the nanocarbon onion-like structure of the fullerene material [9].

Discussion

Nanocarbon onion-like fullerene (NOLF) materials have a wide range of applications in medicine and agriculture owing to the carbon atoms and various shapes of fullerene. Multi-layered forms of the substance have been discovered, and named carbon nano-onions (CNOs), multi-walled carbon nano-onions (MWCNOs), and onion-like carbon (OLC) [10]. These allotropes have different physical properties; however, their chemical features remain similar, e.g. the fullerenes' inherent energies. Also, the many carbon atoms present in the structure create the ability of fullerene to participate in cellular biologic systems of plants and animals [11]. The cellular targeting ability associated with the allotrope allows for the integration of the substance into biologic systems.

NOLFs, being compatible with animal cells and tissues, led to their application in agriculture. Nanocarbon fullerenes have been shown to increase the fruit yield in plants [12] significantly. Also, NOLFs improve water-retaining capacity, which aids in continuous productivity. Nanocarbon fullerenes demonstrate antifungal properties in plants and help eliminate or ameliorate specific plant diseases [13]. Fullerene materials have been introduced in plants and animals, increasing the biomass of such organisms. The application of fullerene materials has shown to increase the yield of tomatoes and many citrus fruits. These findings have provided insights into the fast growth of plants and, by extension, animals to increase productivity and yield in farming and husbandry. Also, their application in horticulture has increased revenues in this area [14].

The administration of nanocarbon fullerene materials in plants is accomplished by applying carbon nanotubes at the base of the organisms. As a result, the total yield of such plants is increased over time as the nanocarbon fullerene materials are compatible with the cells and show no toxicity. These materials boost cellular functions in plants, supporting metabolic processes without interfering with biological processes [15].

Nanocarbon fullerenes have been applied in animals to enhance longevity, eliminate tumors, and improve fertility, increasing productivity and profits over time [16]. They reduce the number of free radicals in cells [17–20], provide anti-inflammatory effects [17,19], and inhibit tumor growth [21–24]. However, the primary antioxidant benefit of fullerene materials seems to be the activation of nuclear factor (erythroid-derived 2) factor 2 (Nrf2) [25,26]. Fullerenes can be used in plant growth through nanotechnology to boost yields and eliminate diseases. The application of NOLF materials in animals increases metabolism and enhances the immune system of such organisms.

Further research is warranted on the beneficial effects of fullerenes on specific crops and animals , as well as any long-term adverse effects or toxicity to the plants, animals, or environment [27–29].

Conclusion

Nanocarbon fullerene materials are being applied in agriculture and husbandry widely. Their application has shown to increase yield, biomass, and eliminate specific diseases that can reduce productivity. In animals, fullerene materials boost the immune system and counter cellular diseases. However, in some ways, the application of nanocarbon fullerene materials in agriculture and husbandry is still in its infancy. Much more needs to be investigated and learned about the application of fullerene materials, including any long-term adverse effects or toxicity to the plants, animals, or environment.

Conflict of Interest Statement

The authors declare that this paper was written in the absence of any commercial or financial relationship that could be construed as a potential conflict of interest.

Supplementary Note

This paper, as a mini-review, is designed as a brief introduction to fullerene materials, regarding their application in agriculture. Other articles have been or will be published on the application of specific fullerenes in the human respiratory system, cardiovascular system, digestive system, neurological system, orthopaedics, dentistry, veterinary medicine, pharmacology and toxicology, and other topics. These distinct mini-review articles could have been combined into a much lengthier review or research article. However, to have done so, the subject matter would have resulted in only one publication in one journal, excluding other medical specialties. The purpose of these papers is to disseminate the purported biocompatibility and beneficial effects of NOLFs to the broadest audience of students, researchers, and medical practitioners as possible. The authors hope that the introduction to fullerenes' application in various and diverse disciplines spawns curiosity and further research regarding NOLFs and fullerene materials. Fullerene materials seem poised to become a vital part of the future of medicine, veterinary medicine, and agriculture. However, more research is needed to determine any adverse effects of their long-term use. Also, the NOLF manufacturing process requires standardization to provide consistent quality and batch samples. Dosage and duration of treatment with fullerene materials for specific conditions need to be established by evidence-based research.

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