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REVIEW ARTICLE

Alliicin: A Chemical Compound

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Abstract

Garlic is known for its beneficial effects in literature. Alliicin which is a component of garlic extract is majorly responsible for it. Alliicin is a hydrophobic compound that is formed by alliin by the enzyme alliinase. Alliicin is known to have antimicrobial activity like antifungal, antiviral and antibacterial properties. Alliicin is also known to have inhibitory effects on tumors. It also provides protection against cardiovascular diseases. In this review, we have covered biosynthesis, production and the beneficial effects of alliicin.

Keywords: Ammonia, Allyl sulfenic acid, Alliin

Introduction

Natural compounds present in the organic products can be potential source for new drugs (Newman et al., 2000). Aspirin is an example of biological compound that has medicinal properties which been turned into a FDA approved drug (Jeffreys 2008). Similarly, other compounds like caffeine, morphine and morphine are also known to have medicinal uses. Alliicin is the active biological compound in garlic that accounts for 70% of thiosulfinate in garlic (Kubec et al., 2000). It is formed by the catalytic action of alliinase using alliin as a substrate (Granroth 1970; Stoll & Seebeck, 1949). Alliicin is known to have antibacterial, antifungal and antiviral properties. Alliicin has been used in the treatment of soldiers during World War II. It is also known to have antioxidant properties. Alliicin is found to be effective against both Gram negative and Gram-positive bacteria. It is also effective against some drug resistant bacteria *Staphylococcus aureus* (Cutler, 2004). Many sulphur containing compounds in garlic including alliicin have anti-cancerous properties. Garlic consumption is correlated with anti tumor properties like skin, uterus, colon and breasts. This review covers the synthesis, benefits and mechanism of action of alliicin against bacterial and fungi. It also includes the benefit of alliicin in cardiovascular system and immune system.

Biosynthesis of Alliicin

Alliin ((+)-(S)-allyl-L-cysteine-sulfoxide) is converted into Alliicin by alliinase enzyme only after garlic clove is crushed. It is so because the alliinase enzyme and its substrate are found in different compartments. Alliinase first converts alliin into an intermediate compound known as allyl sulfenic acid, ammonia and pyruvic acid as shown in figure. Allyl sulfenic acid is unstable and reactive and therefore 2 molecules of allyl sulfenic acid together form alliicin with the release of a water molecule as shown in (Fig. 1).

Synthesis of Alliicin

Industrial production and isolation of alliicin is tedious task because of the instability and volatile nature of alliicin. For the industrial production of alliicin, diallyl disulphide is taken as a substrate. Along with diallyl disulphide, hydrogen peroxide and acetic acid are added. Here, acetic acid act as a catalyst to catalyse the reaction between diallyl disulphide and hydrogen peroxide. Acetic acid reacts with peroxide and form peracetic acid. Peracetic acid reacts with diallyl disulphide to form allyl sulfenic acid and allyl radicals. Allyl radicals reacts with peroxide to form allyl sulfenic acid. Two molecules of allyl sulfenic acid reacts to form alliicin (Villalon, 2001). Alliicin can be synthesized using diallyl disulphide and chloroperbenzoic acid (Cellini, 1996).

Pharmacology of Alliicin

Antibacterial properties of alliicin

The antibacterial properties of garlic are due to alliicin was first demonstrated by Cavallito and Bailey. Alliicin also has antifungal

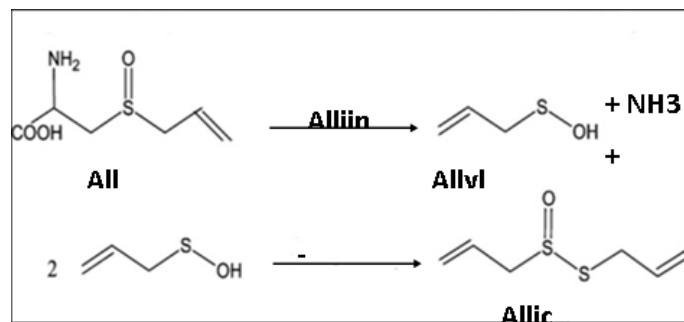


Figure 1. Mechanism of formation of alliin

Table 1. Alliin sensitivity of various bacterial species.

Bacteria	LD50 Value of Alliin(ug/ml)
<i>Staphylococcus aureus</i>	12
<i>Escherichia coli</i>	15
<i>Streptococcus pyogenes</i>	3
<i>Streptococcus hemolyticus</i>	>100
<i>Proteus mirabilis</i>	15
<i>Pseudomonas aeruginosa</i>	15
<i>Acinetobacter baumannii</i>	15
<i>Klebsiella pneumoniae</i>	8
<i>Enterococcus faecium</i>	>100

and antiviral properties. Alliin is found to be effective against many Gram positive and Gram-negative bacteria like *Escherichia*, *Clostridium*, *Bacillus*, *Staphylococcus*, *Streptococcus*, *Proteus*. List of bacteria that are susceptible to alliin are listed in table 1. Alliin is found to be effective against ulcer causing bacteria *Helicobacter pylori* (Cellini, 1996). It is also effective against some enterotoxin producing bacteria like *Staphylococcus* (Gonzalez, 1194). Have demonstrated that alliin targets the DNA gyrase enzyme in the bacteria and hence preventing the proliferation of the bacteria (Reiter, 2020).

Most of the bacteria have developed antibacterial resistance against several drugs. One of the reasons for the development of this resistance is that bacteria form biofilm that is difficult to be penetrated by antibiotics. But alliin prevent the formation of biofilm which makes it effective against antibiotic resistant bacteria. Bacteria like *Mycobacteria tuberculosis* which is known to develop quick antibiotic resistance is found sensitive for alliin. Therefore, use of alliin in combination with already prescribed drugs can be very useful.

Antifungal properties of alliin

Garlic is known to be effective against the fungal infections. The main component of the extract that prevent the fungal growth was found to be alliin (Lawson, 1996). Alliin has been shown to be effective against *Candida*, *Trichophyton* and *Cryptococcus* species. It is effective against *Candida* at minimum IC (inhibitory concentration) of 7 microgram/mL.

Antiviral property of alliin

Alliin is found to have antiviral property as well. It is found effective against some viruses like *Influenza B*, *Herpes simplex virus type 1* and *type 2*, *Human Rhinovirus type 2*, *Vaccinia virus* and *vascular stomatitis virus* (Tsai, 1985). The mechanism by which alliin inhibits viruses is not yet explored.

Health benefits of Alliin Anticancer

Properties of Alliin

Alliin has been demonstrated to have antitumor effects. In a study it was shown that a tumor explant treated with alliin did not show proliferative properties when grafted onto mice in comparison to untreated control (DiPaolo & Christopher, 1960). Alliin is found play precautious role again liver cancer, colorectal cancer and stomach cancer. Anti-cancerous property of alliin is due to its ability to induce apoptosis by altering the redox potential in the cell. Therefore, it induces apoptosis in both caspase dependent and independent manner (Oommen, 2004; Park, 2005). Alliin has been demonstrated to prevent stomach cancer by arresting cells in G₂/M phase and by apoptosis induction by ER stress and mitochondrial damage (Luo, 2016). Alliin also has inhibitory effects against liver cancer. Yun- Lin Chu et al have demonstrated that alliin induces p53 mediated autophagy in hepatic cells and hence preventing the proliferation of liver cancer (Chu, 2012; Chu et al., 2013). Alliin sensitises hepatic carcinoma cells by ROS mediated mitochondrial pathway and enhances cytotoxic activity of 5- fluorouracil against these hepatic carcinogenic cells (Zou et al., 2016). Alliin has also been demonstrated effective against treatment of glioma tumor. Treatment of Hepatic cells with alliin increases caspases activity and the expression of Fas/FasL. Hence, indicating that alliin inhibit hepatic cancer cells by inducing apoptosis of these cells (Li et al., 2018).

Benefits of Allicin in Cardiovascular Diseases

Cardiovascular disease is a chronic disease related to heart that is a major reason of mortality in world. Allicin has been found to provide protection against cardiovascular diseases. Allicin induces vasodilation and increases angiogenesis, platelet aggregation, hence preventing cardiovascular diseases. Allicin bring about the dilation of vessels by Nitric oxide (Ku, 2002). Since, allicin is hydrophobic in nature so it can easily permeabilize through the lipid bilayer and carry out its effects required for protection against cardiovascular diseases. Allicin has been shown to be effective against hyperlipidaemia which is a condition where the amount of low-density lipids exceeds the healthy limits (Ghorai et al., 2000; Gonen et al., 2005). Allicin is also known to prevent cardiac hypertrophy where the cardiac cells increase in size (Sun & David 2005; Liu et al., 2010). Allicin inhibits angiogenesis (increase in the number of blood vessels) which is a key factor that play role in tumorigenesis (Sela et al., 2008). Allicin has shown to have antithrombic activity. Therefore, it prevents blood coagulation and hence, atherosclerosis. Allicin act as an antioxidant and prevent the reactive oxygen species and hence protect against the cardiovascular diseases.

Conclusion

Allicin is one of the components of garlic extract that is formed from alliin by alliinase enzyme. Allicin is known to have antibacterial, antifungal and antiviral properties. It is also shown to be protective against cardiovascular diseases. There are many benefits of allicin that have been reported in literature. It will be beneficial to find out the mechanism of action of allicin against bacteria, viruses and other pathogen. Its antitumor property is worth exploring and it can a potential drug that can be used in cancer treatment. It can be concluded that allicin has many benefits that can explored to develop potential health product.

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