International Journal of Biotechnology and Microbiology
www.biotechnologyjournals.com
Online ISSN: 2664-7680, Print ISSN: 2664-7672
Received: 03-03-2024, Accepted: 26-03-2024, Published: 17-04-2024
Volume 6, Issue 2, 2024, Page No. 5-8

Phytochemicals Activity of *Bacopa monnieri* (L.) pennel.- A brief review

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Abstract
This review brings out research with phytochemicals associated with low-toxic cognitive enhancing actions of *Bacopa monnieri*, a medicinal Ayurvedic herb. *Bacopa monnieri* is traditionally used for a variety of ailments, but is best known as a nerve tonic and memory enhancer. Several animal and in *vitro* studies have been conducted, which have found evidence of several potential medicinal properties. Several randomized, double-blind, placebo-controlled trials have confirmed *Bacopa monnieri* nootropic utility in humans. There is also evidence of possible attenuation of dementia, Parkinson's disease, and epilepsy. Current evidence suggests that *Bacopa monnieri* acts through the following mechanisms—anti-oxidant neuroprotection (via redox and enzyme induction), acetylcholinesterase inhibition and/or choline acetyltransferase activation, β-amyloid reduction, in cerebral blood flow growth, and neurotransmitter modulation (acetylcholine [ACh], 5-hydroxytryptamine [5-HT], dopamine [DA]). *Bacopa monnieri* appears to exhibit low toxicity in model organisms and humans; However, long-term studies of toxicity in humans have not yet been conducted. This review will integrate phytochemicals in neuroscience with behavioral research.

Keywords: *Bacopa monnieri* (L.), phytochemicals, Cognitive Enhancement

Introduction

The milieu of nootropic phytochemicals found within *Bacopa monnieri*, primarily triperpenoid saponins called bacosides, exhibit minimal observable adverse effects at standard dosages. *Bacopa monnieri* demonstrates anti-oxidant, (Tripathi *et al.*, 1996) hepatoprotective, (Ghosh *et al.*, 2007) and neuroprotective activity. Emerging research demonstrates several mechanisms of action—acetylcholinesterase inhibition, choline acetyltransferase activation, β-amyloid reduction, increased cerebral blood flow, and monoamine potentiation.

Bacopa monnieri, commonly known as Brahmi or water hyssop, is a perennial herb native to wetlands in Asia, particularly in India, Nepal, Sri Lanka, and China. It has a long history of use in traditional Ayurvedic medicine for enhancing cognitive function, improving memory, and promoting longevity. The herb is characterized by its succulent leaves and small white flowers and typically grows in marshy areas, along the edges of ponds, and in damp soil. Here are some key points about *Bacopa monnieri*.

In a 90-day oral administration trial in rats, *Bacopa monnieri* exhibited a no-observed adverse effect level (NOAEL) of 500 mg/kg and a median lethal dose (LD50) of 2400 mg/kg (Tripathi *et al.*, 1996). The standard experimental human dose is between 150 and 3000 mg equivalent per day. The most common clinical side effect of *Bacopa monnieri* is mild gastrointestinal upset, but long-term clinical trials are lacking. Several research groups formulate bacoside-standardized *Bacopa monnieri* extract for clinical use, and the herb is widely used in India, the United States, and Australia. *Bacopa monnieri* has been applied in rodents and cell culture for the following uses, which will not be detailed in this review: anti-convulsant (Mathew *et al.*, 2010 [16], 2011 [15]; Khan, Krishnakumar and Paulose, 2008), anti-depressant (Sairam *et al.*, 2002), analgesic (Abbas *et al.*, 2011 [1]; Vohora *et al.*, 2012; Afjalus *et al.*, 2012) [2], anti-inflamatory (Jain *et al.*, 1994), anti-microbial (Azad *et al.*, 2012) [4], anti-ulcerogenic (Sairam *et al.*, 2001) /anti-H. Pylori (Goel *et al.*, 2003), anxiolytic (Bhattacharya and Ghosal, 2001), adaptogenic (Bhatia *et al.*, 2003; Chowdhuri *et al.*, 2002), anti-neoplastic (Deb *et al.*, 2008; Elangovan *et al.*, 1995), hepatoprotective (Ghosh *et al.*, 2007), immunostimulatory (Yamada *et al.*, 2011; Samiulla, Prashanth and Amit 2001; Russo and Borrelli, 2005) Past reviews have focused on the broad therapeutic uses of *Bacopa monnieri*, including the above uses. This review will elucidate the neuropharmacological mechanisms underlying the nootropic effects of the herb, summarize pre-clinical and clinical studies, outline putative mechanisms of action, and address issues of toxicity.

Chemical Constituents

Bacopa monnieri contains a variety of bioactive compounds, including alkaloids (such as brahmine and herpestine), saponins (including bacosides A and B), flavonoids, triterpenoid saponins, betulinic acid derivatives, polyphenols, sterols, and others (Sivaramakrishna *et al.*, 2005; Garai *et al.*, 2009; Chakravarty *et al.*, 2003; Chakravarty *et al.*, 2008; Deepak *et al.*, 2007). , Rastogi *et al.* 2012 [28, 29] found this bacoside profile—bacopaside I (5.37%), bacoside A3 (5.59%), bacopaside II (6.9%), bacopasaponin C isomer (7.08%), and bacopasaponin C These compounds are responsible for its pharmacological activities.

Cognitive Enhancement: *Bacopa monnieri* is renowned for its cognitive-enhancing properties. It has been traditionally used to improve memory, concentration, learning, and overall cognitive function. Clinical studies have demonstrated its effectiveness in enhancing memory retention, speed of information processing, and cognitive performance, particularly in elderly individuals (Munch *et al.*, 2002, Pratico D. Delanty, 2000; Reddy, 2007, Shankar

et al., 2008, Francis *et al.*, 1999). Despite some controversy, cigarette smoking appears to increase dementia risk (Rusanen *et al.*, 2011 [31]; Cataldo, Prochaska and Glantz, 2010) [5].

Neuroprotective Effects: The herb exhibits neuroprotective effects by reducing oxidative stress, inflammation, and neuronal damage in the brain. It may help protect against neurodegenerative diseases such as Alzheimer's and Parkinson's by preserving neuronal function and promoting nerve cell regeneration. Adaptogens enable the body to better cope with the deleterious mental and physical consequences of stress. *Eleutherococcus senticosus* (Siberian ginseng), *Rhodiola rosea*, and *Panax ginseng* are classic adaptogens. Others include *Ocimum sanctum* (Sweet Holy Basil or Tulsi), *Withania somnifera* (Ashwaghanda), Astragalus propinquus, Ganoderma lucidum (Reishi mushroom), and many others (Winston and Maimes, 2007). Sheikh *et al.*, 2007 evaluated *Bacopa monnieri* adaptogenic effect in acute stress and chronic unpredictable stress-induced fluctuations of plasma corticosterone and monoamines in the rat cortex and hippocampus. Charles *et al.*, 1999 found *Bacopa monnieri* extract up-regulated tryptophan hydroxylase (TPH2) and serotonin transporter (SERT) expression in rats.

Antioxidant and Anti-inflammatory Properties: *Bacopa monnieri* possesses potent antioxidant and anti-inflammatory properties, which contribute to its neuroprotective effects and overall health benefits. It scavenges free radicals, reduces oxidative damage to cells, and alleviates inflammation, thereby protecting against various chronic diseases and promoting longevity.

Anxiolytic and Antidepressant Effects: *Bacopa monnieri* has been reported to have anxiolytic and antidepressant properties, helping to reduce anxiety, stress, and depression. It may modulate neurotransmitter levels in the brain and promote feelings of calmness and well-being.

Other Health Benefits: In addition to its cognitive and neurological effects, *Bacopa monnieri* is also believed to have various other health benefits, including improving cardiovascular health, enhancing digestive function, and boosting immunity.

Bacopa monnieri is available in various forms, including capsules, tablets, powders, and liquid extracts. It is often used as a dietary supplement for cognitive support and overall well-being. However, as with any herbal supplement, it's essential to consult with a healthcare professional before starting *Bacopa monnieri*, especially if you have any underlying medical conditions or are taking medications.

A review of phytochemicals and activity of *Bacopa monnieri* Linn. would likely delve into the diverse array of bioactive compounds found within this medicinal herb and their associated biological activities. *Bacopa monnieri*, also known as Brahmi or water hyssop, is a traditional Ayurvedic herb renowned for its cognitive-enhancing properties. Here's an overview:

Alkaloids: *Bacopa monnieri* contains alkaloids such as brahmine and herpestine, which have been found to possess neuroprotective and memory-enhancing effects. These alkaloids are believed to play a role in improving cognitive function and protecting against neurodegenerative diseases.

Saponins: The herb contains saponins, including bacosides A and B, which are considered the primary active compounds responsible for its cognitive benefits. Bacosides have been shown to enhance neuronal communication, improve memory formation, and exhibit antioxidant properties, thus protecting against oxidative stress-induced neuronal damage.

Flavonoids: *Bacopa monnieri* is rich in flavonoids, such as apigenin and luteolin, which possess antioxidant and anti-inflammatory properties. These compounds may contribute to the herb's neuroprotective effects by reducing inflammation and oxidative stress in the brain.

Triterpenoid saponins: These compounds are also present in *Bacopa monnieri* and have been found to exhibit various pharmacological activities, including anti-inflammatory, antioxidant, and neuroprotective effects.

Betulinic acid derivatives: Recent studies have identified betulinic acid derivatives in *Bacopa monnieri* with potential neuroprotective and antidepressant properties.

Polyphenols: *Bacopa monnieri* contains polyphenolic compounds like catechins and epicatechins, which have antioxidant properties and may contribute to the herb's overall neuroprotective effects.

Other compounds: *Bacopa monnieri* also contains other phytochemicals such as sterols, triterpenoids, and betulic acid, which may contribute to its pharmacological activities.

In terms of activities, *Bacopa monnieri* has been extensively studied for its various biological effects, including:

Cognitive enhancement: *Bacopa monnieri* has been traditionally used to improve memory, concentration, and learning abilities. Clinical studies have supported its efficacy in enhancing cognitive function, particularly memory and attention.

Neuroprotection: The herb exhibits neuroprotective effects by reducing oxidative stress, inflammation, and neuronal damage. It may help protect against neurodegenerative diseases such as Alzheimer's and Parkinson's. (De Grey, 1999) by degrading ligands, peroxidizing lipids, disrupting metabolic pathways, denaturing proteins, and breaking DNA strands (Maxwell, 1995). The brain is especially susceptible to OS because it is metabolically active, possesses high levels of pro-oxidant iron, and is composed of unsaturated lipids (prone to lipid peroxidation). (Arivazhagan *et al.*, 2002) Furthermore, the blood–brain barrier prevents many exogenous anti-oxidants from quenching reactive oxygen species (ROS) in the brain (Gilgun-Sherki, Melamed and Offen, 2001).

Antioxidant activity: *Bacopa monnieri* is a potent antioxidant, scavenging free radicals and protecting cells from oxidative damage (Kregel and Zhang, 2007). This antioxidant activity contributes to its neuroprotective effects and overall health benefits (Valko *et al.*, 2007).

Anti-inflammatory properties: The herb has been shown to possess anti-inflammatory effects, which may help alleviate

inflammation in the brain and reduce the risk of neurodegenerative diseases.

Anxiolytic and antidepressant effects: *Bacopa monnieri* has been reported to have anxiolytic and antidepressant properties, which may be attributed to its ability to modulate neurotransmitter levels and reduce stress and anxiety.

Overall, *Bacopa monnieri* is a rich source of phytochemicals with diverse pharmacological activities, particularly in improving cognitive function and protecting against neurodegenerative diseases. Its traditional use in Ayurvedic medicine is supported by modern scientific research, making it a promising candidate for further investigation and development as a natural remedy for cognitive disorders and neurodegenerative conditions.

Anbarasi *et al.*, 2006 assessed the neuroprotective role of bacoside A against OS in the brains of rats exposed to cigarette smoke by measuring concentrations of enzymatic and non-enzymatic anti-oxidants as well as trace elements. The researchers administered 10 mg/kg aqueous bacoside A gavage daily and found that *Bacopa monnieri* significantly increased brain levels of glutathione, vitamin C, vitamin E, and vitamin A in rats exposed to cigarette smoke (perhaps an anti-oxidant conservation effect). Bacoside A administration increased the activities of superoxide dismutase (SOD), catalase, GPx, and GSR. As a result, the levels of glutathione (primary endogenous anti-oxidant conjugate) in the brain were significantly increased as well. The researchers found that cigarette smoke depletes zinc and selenium levels in the brain, which is especially problematic because zinc is a SOD co-factor and selenium is a GPx co-factor. Administration of bacoside A also restored zinc and selenium levels. In a related study, Anbarasi *et al.*, 2005 also showed that 10 mg/kg aqueous gavage administration of bacoside A inhibited lipid peroxidation, improved the activities of adenosine triphosphatases (ATPases), and maintained ionic equilibrium in the brains of cigarette smoke–exposed rats.

Conclusion

Bacopa monnieri demonstrates immense potential in the amelioration of cognitive disorders, as well as prophylactic reduction of oxidative damage, NT modulation, and cognitive enhancement in healthy people. Biomedical research on *Bacopa monnieri* is still in its infancy, but preliminary results such as these have begun to open the research floodgates. It is critical that much longer-term studies be conducted *Bacopa monnieri* in combination with other substances, as is prescribed by the Ayurvedic system, may result in synergistic effects and should also be investigated. The social implications of cognition-enhancing drugs are promising but must be appropriately tempered with ethical consideration as researchers enter the brave new world of neural enhancement.

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