2-Aminobutyrate

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summary

2-Aminobutyrate, also known as dl-2-aminobutyric acid, is a non-proteinogenic amino acid with the molecular formula C4H9NO2 and a molecular weight of 103.1198 g/mol.[1][2] This compound has gained prominence in biochemical research due to its significant roles in various metabolic processes, including its interactions with neurotransmitters such as gamma-aminobutyric acid (GABA), which is crucial for regulating neuronal activity and mitigating stress responses.[3][4][5] 2-Aminobu-

tyrate's involvement in neuroprotection and oxidative stress management has led to investigations into its therapeutic potential for neurological disorders, metabolic health, and cardiovascular function.[6][7][8]

The biosynthesis of 2-aminobutyrate has been achieved through engineered microbial pathways, notably in and , making it a focal point for biotechnological applications.[9][10] Recent studies have demonstrated successful production methods using genetic modifications, which enhance its yield and stability, providing a promising approach for developing sustainable bioprocesses for this compound.[9] Furthermore, its neuroprotective properties and potential anti-diabetic effects have sparked interest in its clinical applications, including treatment strategies for inflammatory bowel disease and stress-related conditions.[11][12][13]

Despite its potential benefits, the safety profile of 2-aminobutyrate necessitates further investigation, as some users may experience side effects such as gastrointestinal discomfort and drowsiness.[14][15] Ongoing research aims to establish standardized dosages and comprehensive treatment protocols to maximize its therapeutic applications while minimizing adverse effects.[16][17] The compound's multifaceted roles in health and disease highlight its significance in both scientific research and potential therapeutic interventions.

Chemical Structure

2-Aminobutyrate, also known as dl-2-Aminobutyric acid, has the molecular formula $C_4H_9NO_2$ and a molecular weight of 103.1198 g/mol[1][2]. The IUPAC Standard InChIKey for this compound is QWCKQJZIFLGMSD-UHFFFAOYSA-N, and its CAS Registry Number is 2835-81-6[1][2].

The chemical structure of 2-Aminobutyrate can be represented in various forms, including two-dimensional (2D) and three-dimensional (3D) models. Its linear formula is $C_2H_5CH(NH_2)CO_2H$, indicating the presence of both an amino group (NH_2) and a carboxylic acid group (COOH)[3][4]. The compound can also be identified by several synonyms, including 2-Aminobutanoate and D,L-alpha-amino-N-butyric acid, among others[1][5].

The stereoisomers of 2-Aminobutyrate, particularly its (S)-form, are relevant in biological contexts due to their varying physiological effects and roles in metabolism[6][4]. The unique structural features of 2-Aminobutyrate enable it to participate in several biochemical processes, thereby playing an important role in amino acid metabolism and related physiological functions[7][8].

Biosynthesis

The biosynthesis of 2-aminobutyrate (2-ABA) can be achieved through engineered microbial pathways, particularly in and . In , the introduction of heterologous enzymatic steps allows for the conversion of l-threonine into 2-ABA via a two-step process. The initial step involves the deamination of l-threonine to form 2-ketobutyric acid, facilitated by threonine deaminases sourced from various organisms, including and .[9] The subsequent step converts the keto acid to 2-ABA through amination, utilizing modified glutamate dehydrogenases and other enzymes derived from different bacteria.[9]

Recent studies have demonstrated that the integration of the complete biosynthetic pathway into a single chromosomal locus significantly enhances the production of (S)-2-aminobutanol and 2-ABA, suggesting that genomic integration provides more stable and effective gene expression compared to episomal systems. In contrast, strains maintaining plasmids for pathway expression exhibited lower growth rates, highlighting the potential trade-offs between plasmid maintenance and metabolic productivity.[9]

In , a synthetic pathway for l-2-ABA production has been developed, directly converting glucose into l-ABA through fermentation processes. This method has shown promising yields, such as 3.60 g/L of l-threonine and 1.42 g/L of 2-ketobutyric acid, demonstrating a simplified production process compared to traditional enzyme-catalyzed methods.[10] This innovation underscores the advantages of using genetically engineered microorganisms for the biosynthesis of valuable non-natural products from renewable resources.[10]

Biological Role

2-Aminobutyrate (2-AB) serves several important functions in biological systems, particularly as a metabolite and an amino acid. As an alpha-aminobutyric acid and a non-proteinogenic L-alpha-amino acid, it plays a role in various metabolic processes, including those involving oxidative stress and neurotransmission[9][11].

Neuroprotective Effects

The compound has also been associated with neuroprotective mechanisms, notably in inhibiting neuroinflammation and repairing oxidative damage in neuronal tissues[12][13]. These properties indicate that 2-AB could play a beneficial role in preventing neurological disorders, enhancing cognitive function, and offering protective effects against neurodegenerative diseases[14].

Metabolic Functions

2-AB is recognized as a human metabolite that may be involved in pathways regulating glutathione homeostasis, which is crucial for maintaining cellular redox balance. Research indicates that 2-AB can influence glutathione levels in the myocardium, suggesting its potential role in cardioprotection against oxidative damage[9][15]. Additionally, it reflects a compensatory response to oxidative stress, highlighting its significance in metabolic health[15][16].

Interaction with Neurotransmitters

Moreover, 2-AB interacts with gamma-aminobutyric acid (GABA), a primary inhibitory neurotransmitter in the central nervous system. This interaction may contribute to its anxiolytic and stress-reducing effects, impacting mental states and sleep quality[16][17][18]. As such, 2-AB might be explored as a potential therapeutic agent in managing anxiety, mood disorders, and other related conditions[19].

Health Implications

2-Aminobutyrate (2-AB), a naturally occurring amino acid, has been investigated for its potential health benefits and implications. Preliminary research suggests that it may have various therapeutic effects, particularly concerning neurological and metabolic health.

Neuroprotective Effects

Research indicates that 2-AB exhibits neuroprotective properties, which may be beneficial in preventing neurological disorders. By modulating neuronal activity and providing a calming effect, 2-AB has been associated with improvements in stress response and mental state, potentially leading to better sleep quality and anxiety reduction[20][21]. Its influence on gamma-aminobutyric acid (GABA) signaling suggests a role in regulating neurotransmission, which is crucial for maintaining neurological health[22].

Anti-Diabetic Effects

Recent studies have explored the role of 2-AB in glucose metabolism and its potential effects on diabetes. Specifically, it has been shown to alter GABA signaling in pancreatic islets, which could impact insulin secretion and glucose homeostasis, providing insights into its anti-diabetic effects[23][24]. In one study, 2-AB administration was linked to increased levels of glutathione, an important antioxidant, which may protect pancreatic beta cells from oxidative stress induced by high glucose levels[25][15].

Cardiovascular Benefits

2-AB has also demonstrated potential cardioprotective effects. It may help mitigate oxidative stress, a contributing factor in cardiovascular diseases. Enhanced glutathione levels associated with 2-AB intake could counteract oxidative damage and improve overall cardiovascular health[26][24]. A study indicated that supplementation with 2-AB may lower blood pressure, further supporting its role in cardiovascular wellness[27].

Safety and Side Effects

While 2-AB appears to offer various health benefits, its safety profile requires further examination. Some amino acid supplements may not be risk-free and could lead to side effects, such as gastrointestinal discomfort, headaches, and drowsiness[28][29]. Consequently, individuals considering 2-AB supplementation should consult healthcare providers to ensure its appropriateness and to discuss any potential interactions with medications or other supplements[19][18].

Research and Applications

Overview of 2-Aminobutyrate

2-Aminobutyrate, specifically (S)-2-aminobutyric acid (GABA), has garnered significant interest in the fields of pharmaceuticals and biotechnology due to its various therapeutic applications. Research has shown that GABA plays a critical role in neuroprotection and has potential benefits in managing conditions such as stress, anxiety, and sleep disorders[7][30]. The compound is recognized for its ability to modulate the central nervous system, leading to reduced stress levels and improved sleep quality, as evidenced by various clinical studies[30][24].

Therapeutic Applications

Treatment of Inflammatory Bowel Disease (IBD)

Recent studies have explored the use of 2-aminobutyrate in the treatment of inflammatory bowel disease (IBD). Conventional therapies, including antibiotics and immunosuppressants, often face challenges due to their long-term side effects and toxic buildup in patients. Researchers are investigating nanoparticle-based drug delivery systems and exosomes derived from mesenchymal stem cells (MSC-EXO) as novel approaches to enhance the efficacy and reduce the side effects of traditional treatments. These methods leverage the low immunogenicity and biocompatibility of exosomes, which may help regulate IBD-related pathways, including immune response and intestinal barrier function[7][30].

GABA in Stress and Sleep Management

A systematic review of studies assessing GABA's effects on stress and sleep has highlighted its potential as a non-pharmacological approach to enhance psychophysiological outcomes. Evidence suggests that GABA intake can reduce sympathetic nervous system activity, which is typically elevated under stress conditions. This reduction is evidenced by decreased levels of markers such as cortisol and CgA, indicating lower stress levels in individuals consuming GABA compared to controls[30][9]. Despite some limitations in the reviewed studies, including methodological variability, the findings underscore GABA's promise in improving sleep and reducing anxiety[30][31].

Limitations and Future Directions

While the therapeutic benefits of 2-aminobutyrate are supported by preliminary studies, further research is essential to establish standardized dosages and treatment protocols. The current literature demonstrates significant heterogeneity in study designs and outcomes, complicating the ability to draw definitive conclusions. Future investigations should focus on conducting larger, more rigorous trials to solidify the role of GABA in clinical applications, particularly in chronic conditions such as IBD and stress-related disorders[30][24].

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