

Tyrosine

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summary

Tyrosine, an aromatic amino acid with the chemical formula $C_9H_9NO_3$, is a vital compound in human physiology, primarily functioning as a precursor for essential neurotransmitters and hormones, including dopamine, norepinephrine, and thyroid hormones.^{[1][2]} It is synthesized in the body from phenylalanine through the action of the enzyme phenylalanine hydroxylase, highlighting its significance in metabolic pathways crucial for cognitive function, stress response, and overall hormonal balance.^{[3][4]} As a non-essential amino acid, tyrosine can be obtained through dietary sources such as meats, dairy products, and certain plant-based foods, making it widely accessible for various populations.^{[5][6][7]}

Tyrosine's role in neurotransmitter synthesis makes it particularly notable in the context of mental health and cognitive performance. Supplementation with L-tyrosine has been studied for its potential benefits in enhancing cognitive function during stress, with some evidence suggesting improvements in working memory and task performance under challenging conditions.^{[8][9][10]} However, research findings are mixed, with varying results regarding its efficacy in alleviating symptoms of mood disorders and its impact on individuals under chronic stress.^{[11][12]} Additionally, while tyrosine is generally considered safe, its supplementation may pose risks for individuals on certain medications, necessitating caution and professional guidance.^{[5][9]}

Beyond its cognitive benefits, tyrosine is also essential for thyroid hormone production, influencing metabolic regulation and energy balance in the body. The interaction of tyrosine with other metabolic processes underscores its multifaceted role in maintaining health and well-being.^{[13][14][15]} As research continues to explore its therapeutic potential, tyrosine remains a compound of interest, particularly in the fields of nutrition, mental health, and metabolic disorders.

Structure and Properties

Tyrosine, with the chemical formula $C_9H_9NO_3$ and CAS number 60-18-4, is classified as an aromatic amino acid. It plays a critical role in various biological processes and is synthesized from phenylalanine through hydroxylation at the para position[1][16]. The compound has a nonpolar nature, although it is more soluble in water than its precursor, phenylalanine, due to the presence of a phenolic hydroxyl group, which imparts some degree of polarity[16].

Chemical Structure

The molecular structure of tyrosine features a central α -carbon atom bonded to four distinct groups: an amino group (NH_2), a carboxyl group ($COOH$), a hydrogen atom, and a unique side chain known as the R-group, which is a phenolic ring containing a hydroxyl group[16][2]. The presence of the aromatic ring contributes to the molecule's stability and reactivity, particularly its ability to absorb ultraviolet light, which is significant in the context of protein spectroscopy[16].

Acid-Base Properties

Tyrosine exhibits distinct acid-base characteristics due to its ionizable hydroxyl group. The pK_a of the hydroxyl group in tyrosine is approximately 9.8 when part of a polypeptide chain, indicating that it can act as both a weak acid and a base under physiological conditions[16][2]. The exact pK_a can vary depending on the local environment within a protein; for instance, tyrosines located on the surface of proteins generally have lower pK_a values compared to those buried within the hydrophobic core[16]. This property is crucial for the function of many enzymes and proteins where tyrosine residues participate in critical interactions or modifications.

Physical Properties

Tyrosine is known for its role in the biosynthesis of neurotransmitters and hormones, including dopamine and thyroid hormones. Its solubility and hydrophobicity, combined with its ability to participate in hydrogen bonding and π -stacking interactions, enhance its functional versatility in biological systems[1][16]. Furthermore, tyrosine can undergo post-translational modifications, such as phosphorylation, which can significantly alter protein activity and function[2].

Biosynthesis

Tyrosine is a non-essential amino acid that is primarily synthesized from phenylalanine through a hydroxylation reaction. This reaction is catalyzed by the enzyme phenylalanine hydroxylase (PAH), which requires tetrahydrobiopterin (BH_4) as a cofactor and is significant for converting phenylalanine into tyrosine[3][4].

Pathways of Tyrosine Synthesis

In mammals, the conversion of phenylalanine to tyrosine occurs in the liver and is essential for the production of various neurotransmitters and hormones. Phenylala-

nine, derived from dietary protein, is oxidized to tyrosine through the action of PAH, utilizing oxygen and tetrahydrobiopterin[3][17].

In certain plants and microorganisms, an alternative pathway known as the Aro-genate pathway can also facilitate the synthesis of tyrosine. This pathway is regulated by the enzyme arogenate dehydrogenase (ADH) and is an important route for aromatic amino acid biosynthesis in these organisms[3].

Role of Tyrosine in Metabolism

Once synthesized, tyrosine serves as a precursor for several important compounds, including neurotransmitters like dopamine, norepinephrine, and epinephrine. Tyrosine can undergo further transformations, such as phosphorylation and sulfation, which are crucial for its role in signal transduction and other biological functions[18-][4]. The regulation of tyrosine metabolism is vital for maintaining neurotransmitter levels, impacting cognitive functions and mood regulation[19][4].

Functions in the Body

L-tyrosine plays a crucial role in various physiological processes within the body, primarily as a precursor for essential neurotransmitters and hormones. As a non-essential amino acid, L-tyrosine can be synthesized from phenylalanine and is involved in the synthesis of catecholamines, including dopamine, norepinephrine, and epinephrine, which are vital for stress response and mood regulation[8][13].

Neurotransmitter Synthesis

One of the most significant functions of L-tyrosine is its contribution to the synthesis of neurotransmitters. Upon absorption, L-tyrosine is transported to neuroendocrine cells where it undergoes enzymatic conversion to L-DOPA through the action of tyrosine hydroxylase. This conversion is considered the rate-limiting step in catecholamine synthesis. L-DOPA is subsequently transformed into dopamine, which is pivotal for regulating mood, reward mechanisms, and motor control. Dopamine can further be converted into norepinephrine and epinephrine, which are critical in the body's stress response and overall physiological function[15][14].

Cognitive Function and Stress Response

L-tyrosine supplementation has been shown to support cognitive function during periods of stress. Research indicates that acute doses of L-tyrosine can alleviate declines in working memory and information processing that arise from situational stressors, such as intense mental tasks or extreme environmental conditions. This suggests that L-tyrosine may help maintain cognitive performance under challenging circumstances by replenishing dopamine levels that tend to drop during prolonged stress[8][13].

Thyroid Hormone Production

In addition to its role in neurotransmitter synthesis, L-tyrosine is integral to the production of thyroid hormones. The thyroid gland utilizes L-tyrosine, along with iodine, to synthesize thyroxine (T4) and triiodothyronine (T3). The enzyme thyroid peroxidase facilitates the incorporation of iodine into tyrosine residues within thyroglobulin, leading to the formation of these hormones. Proper thyroid function, which is heavily reliant on L-tyrosine, is essential for regulating metabolism, energy production, and overall growth and development[\[13\]\[14\]](#).

Overall Health and Well-being

Due to its multifaceted roles, L-tyrosine has been proposed as a supportive nutrient for both adrenal and thyroid health. By serving as a precursor for catecholamines and thyroid hormones, L-tyrosine supplementation may contribute to enhanced energy regulation, improved stress response, and overall hormonal balance, thereby promoting homeostasis within the body[\[15\]\[20\]](#).

Dietary Sources

Tyrosine is classified as a conditionally essential amino acid, meaning that while the body can synthesize it from phenylalanine, it may require additional intake during certain metabolic states or under specific health conditions[\[15\]\[21\]](#). The recommended intake for adults is approximately 13.7 mg/kg of body weight daily, with infants requiring significantly more at 68 mg/kg[\[15\]\[22\]](#).

Food Sources

A variety of high-protein foods are rich in tyrosine.

Animal Products: These are some of the richest sources of tyrosine. Beef, pork, lamb, and poultry (chicken and turkey) provide substantial amounts, with 500 to 1000 mg per 3-ounce (85 g) serving[\[5\]\[6\]](#). Fish, such as tuna and salmon, also contribute significantly to dietary tyrosine intake[\[22\]\[21\]](#).

Dairy: Cheese and other dairy products like yogurt and cottage cheese are excellent sources. For instance, the white of an egg contains about 250 mg of tyrosine, while cheese can sometimes present tyrosine crystals on aged surfaces, indicating its richness in this amino acid[\[7\]\[21\]\[23\]](#).

Plant-Based Sources: Soy products, including soybeans, tofu, and soy milk, contain considerable amounts of tyrosine and also include phenylalanine, its precursor[\[6\]\[24\]](#). Nuts and seeds, particularly sesame seeds, peanuts, and pumpkin seeds, are also good sources[\[7\]\[25\]](#).

Legumes and Whole Grains: Beans, such as lentils and kidney beans, and whole grains provide additional sources of tyrosine, making them important for those on vegetarian or vegan diets[\[21\]\[26\]](#).

Health Benefits

L-tyrosine is an amino acid that plays a critical role in the production of important neurotransmitters, including dopamine, adrenaline, and norepinephrine, which are essential for regulating mood and stress responses[\[11\]\[9\]](#). Supplementing with L-tyrosine has been associated with several health benefits, particularly in contexts of stress and cognitive demand.

Cognitive Function

Research indicates that L-tyrosine supplementation may enhance cognitive performance, especially in stressful situations. For instance, studies have demonstrated improvements in working memory among individuals engaged in mentally demanding tasks when supplemented with L-tyrosine[\[10\]\[27\]](#). In one notable study involving 22 women, participants showed significant enhancements in working memory during high-stress activities compared to those receiving a placebo[\[10\]](#). Additionally, cognitive flexibility—the ability to adapt and switch between tasks—has also been positively influenced by L-tyrosine supplementation, further suggesting its potential benefits for mental agility under pressure[\[28\]\[27\]](#).

Physical Performance

Supplementing with L-tyrosine might also benefit physical performance, particularly in situations of sleep deprivation or extreme exertion. Studies have suggested that L-tyrosine can help maintain alertness and performance levels when individuals are sleep-deprived, with some findings indicating that it extends the time one can perform physical tasks without significant declines in performance[\[10\]\[28\]](#). Moreover, early research hints at its potential to enhance endurance during physical activity, though more studies are needed to solidify these claims[\[9\]](#).

Mood and Mental Health

L-tyrosine may provide therapeutic effects for individuals experiencing mood disorders, such as depression. This amino acid is believed to alleviate symptoms by replenishing depleted neurotransmitters associated with mood regulation[\[11\]\[9\]](#). While some research indicates that L-tyrosine can improve mood and cognitive function in individuals under chronic stress or facing depressive episodes, the evidence remains mixed, warranting further investigation into its efficacy[\[9\]\[28\]](#).

Additional Benefits

Beyond cognitive and physical performance, L-tyrosine has been suggested to aid in the management of certain medical conditions. For instance, individuals with phenylketonuria (PKU), a genetic disorder that impairs the body's ability to metabolize phenylalanine, may require L-tyrosine supplementation to prevent deficiencies[\[28\]](#). Additionally, there are indications that L-tyrosine could support immune function by increasing the production of red and white blood cells[\[28\]](#).

While L-tyrosine is generally considered safe, individuals should be cautious about potential interactions with certain medications, such as those for hyperthyroidism[\[9\]](#).

Despite the growing interest in L-tyrosine as a nootropic and health supplement, more comprehensive research is necessary to confirm its benefits and establish optimal dosing[9][29].

Deficiency and Disorders

Tyrosine is a nonessential amino acid, meaning the body can synthesize it from phenylalanine. However, certain conditions can lead to a deficiency in tyrosine, particularly in individuals with phenylketonuria (PKU), a genetic disorder that impairs the conversion of phenylalanine to tyrosine, resulting in low levels of this amino acid in the body[22][28].

Symptoms of Deficiency

A deficiency in tyrosine can manifest in various symptoms that affect general well-being and specific bodily functions. Common symptoms include diminished stress resistance, depressive moods, and overall weakness[15]. Neurologically, a lack of tyrosine can disrupt neurotransmitter synthesis, particularly dopamine, which may lead to reduced cognitive performance and mood disturbances[15][28].

Impact on Health Conditions

Stress and Cognitive Performance

Supplementation of tyrosine has been studied for its potential benefits in managing stress and improving cognitive performance under pressure. Some research suggests that tyrosine may enhance memory and task performance in stressful situations[28][12]. However, the effects may not be as pronounced in older adults, indicating variability in response based on age[28].

Psychological Disorders

While some studies have investigated the role of tyrosine in the treatment of psychological disorders such as depression, results remain inconclusive. Preliminary studies indicate potential cognitive benefits under stress, but evidence supporting its effectiveness for mood disorders is limited[12]. Additional research is needed to better understand the role of tyrosine in mental health.

Physical Health

Tyrosine deficiency can also impact physical health, as it is associated with low blood pressure and body temperature, which are critical for maintaining homeostasis[22]. Moreover, individuals with PKU are at an increased risk of tyrosine deficiency due to their inability to convert phenylalanine, which may necessitate dietary adjustments or supplementation to mitigate these risks[28].

Supplementation

Tyrosine supplementation is often explored for various health benefits, although evidence supporting its efficacy remains limited.

Potential Uses

There is ongoing interest in using tyrosine supplements to enhance athletic performance, alleviate symptoms of depression, and manage conditions like chronic fatigue and attention-deficit hyperactivity disorder (ADHD). However, current scientific evidence does not substantiate these claims for healthy adults[\[5\]\[9\]](#). Some studies suggest that tyrosine may have a positive impact on physical endurance during exercise, but further research is necessary to confirm these benefits[\[9\]](#).

Dosage Recommendations

For adults, the typical dosage of tyrosine supplements ranges from 500 to 2,000 milligrams per day. It is recommended to take these supplements on an empty stomach, ideally 30 to 60 minutes before meals, to optimize absorption[\[9\]\[28\]](#). Individuals considering supplementation should consult with a healthcare provider, especially if they are on medications for conditions such as hyperthyroidism or Parkinson's disease, due to potential interactions[\[9\]](#).

Safety and Risks

Generally, L-tyrosine supplements are regarded as safe for short-term use in most adults, though they may pose risks for individuals taking certain medications, particularly monoamine oxidase inhibitors (MAOIs) and other antidepressants, which can lead to dangerous increases in blood pressure known as hypertensive crises[\[5\]\[9\]\[30\]](#). Additionally, people with phenylketonuria (PKU) may require supplemental L-tyrosine to maintain normal levels, as they cannot consume phenylalanine, another essential amino acid[\[9\]](#).

Side Effects

Users of tyrosine supplements may experience a range of side effects, including digestive issues, headaches, sleep disturbances, and heart palpitations[\[30\]\[24\]](#). To mitigate these risks, it is advisable to start with a lower dose and monitor for any adverse reactions[\[30\]](#). Furthermore, the quality and purity of tyrosine supplements can vary; therefore, selecting reputable brands that undergo third-party testing is crucial to ensure safety and efficacy[\[30\]](#).

Research and Studies

Cognitive Effects of Tyrosine

Numerous studies have explored the effects of L-tyrosine (TYR) on cognitive performance, particularly in healthy individuals. Research indicates that TYR supplementation can alleviate stress-induced impairments in working memory and attentional tasks, especially in those who are more sensitive to stressors[29]. For example, TYR has been found to have acute benefits on task performance related to dopamine (DA), enhancing the ability to perform multiple tasks simultaneously, as well as improving the updating and monitoring of working memory and inhibitory control[29][8].

However, it is important to note that individual responses to TYR supplementation can vary significantly. Future research is encouraged to take into account individual differences that may influence the efficacy of TYR, as these variations could affect the generalizability of study results[29][27].

Tyrosine and Dopamine Function

The relationship between TYR supplementation and dopamine function is a critical area of study. Some research suggests that individuals with low dopamine levels may experience significant cognitive benefits from TYR supplementation, while other studies indicate no substantial antidepressant effects from TYR alone[27]. Understanding the nuances of this relationship is essential, as it suggests that TYR's effects may not be universally applicable across different populations.

Safety and Regulation

TYR supplements are generally recognized as safe by the U.S. Food and Drug Administration (FDA). However, they may interact with certain medications, necessitating caution when used in conjunction with other treatments[27][10]. Additionally, conditions such as phenylketonuria (PKU), a rare genetic disorder that affects TYR production, present unique challenges in determining the effectiveness of TYR supplementation[27]. Research regarding the impact of TYR on symptoms of PKU is ongoing, with mixed results reported[27].

Recommendations for Future Research

To enhance the understanding of TYR's cognitive effects and its relationship with dopamine, future studies should incorporate diverse measures of DA function and consider individual differences among participants. By doing so, researchers can provide more comprehensive insights into how TYR supplementation might optimize cognitive control and performance across various populations[29].

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