

Review on application of one of the most valuable players of amino acids: L-Lysine

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Submitted: 07-04-2024

Accepted: 17-04-2024

ABSTRACT

Amino acids are an important component of our daily nutrients. They are the building blocks for proteins. These are essential and non-essential amino acids. L-lysine is one of the essential amino acids widely used in our day-to-day supplements. Lysine hydrochloride is the salt form of the amino acid used in the formulations. The objective of this paper is to review various applications of lysine monohydrochloride. Lysine is used in health nutrition where it plays a role of protein synthesis, tissue repair, skin care, hair care, and immune function. It also has a role in collagen synthesis, neurotransmitter regulation, and calcium absorption. It has also found to have therapeutic application in treatment of conditions like herpes simplex virus infections, hypertension, diabetes, osteoporosis, anxiety, and colon cancer. It also has unique applications in material science like hydrogel formation and nanoparticle synthesis. Thus, lysine stands as an essential player in human health and becomes the most valuable players of amino acids.

Keywords: Amino acids; L-Lysine monohydrochloride; Lysine; Alanine;

bonds serving as the building blocks of proteins, crucial for the structure and function of cells. Comprising a central carbon atom, an amino group (NH₂), a carboxyl group (COOH), and a variable side chain, amino acids exhibit diverse structures and properties. The general molecular formula is NH₂-CR-COOH, where "R" represents the side chain that differentiates each amino acid[1]. There are 20 standard amino acids, classified based on the nature of their side chains: essential amino acids must be obtained through diet, while non-essential amino acids can be synthesized within the body. This classification underscores their pivotal role in protein synthesis, which, in turn, contributes to the formation of enzymes, hormones, and structural tissues[2, 3]. Beyond protein synthesis, amino acids play crucial roles in neurotransmitter production, immune system function, and energy metabolism[4]. Their significance extends to various sectors, including medicine, nutrition, and biotechnology[5]. Understanding amino acids' structure and function is integral to advancing fields like biochemistry and molecular biology, contributing to advancements in drug development, nutritional science, and the broader understanding of life processes[6]. All these 20 amino acids are categorized into essential, non-essential and conditionally essential amino acids. These are mentioned in table 1.

I. INTRODUCTION

Amino acids are fundamental molecules essential for life. At its simplest a protein is a chain of amino acids bound to one another by peptide

Table 1: Amino acids into essential and non essential categories.

Category	Amino Acids
Essential Amino Acids	Histidine, Isoleucine, Leucine, Lysine, Methionine, Phenylalanine, Threonine, Tryptophan, Valine
Non-Essential Amino Acids	Alanine, Arginine, Asparagine, Aspartic Acid, Cysteine, Glutamic Acid, Glutamine, Glycine, Proline, Serine, Tyrosine
Conditionally Essential Amino Acids	Arginine (During Periods Of Rapid Growth Or Stress), Cysteine (If There Is A Deficiency In Methionine), Tyrosine (If Phenylalanine Intake Is Insufficient)

All these amino acids are important but there is a wide application of one of the amino acid – Lysine. This amino acid has application in various industries like healthcare, pharmaceutical, nutraceutical, cosmetics, food and poultry to name a few. To the best of our knowledge there is no single article reflecting all the applications of this essential amino acid. This article focuses on describing various applications of lysine. It involves application of salt form of this amino acid like lysine monohydrochloride.

Salt form of lysine – lysine monohydrochloride

Lysine monohydrochloride is the hydrochloride salt form of lysine, an essential amino acid crucial for protein synthesis and various physiological functions in the body [7]. Its molecular structure consists of a central carbon atom bonded to an amino group (NH₂), a carboxyl group (COOH), a hydrogen atom, and a unique side chain containing four carbon atoms. This side chain is where lysine differentiates itself from other amino acids. Additionally, lysine contains a positively charged ε-amino group, making it basic at physiological pH [8]. The molecular structure is shown in fig 1. The molecular weight is 182.65 g and the CAS number is 657-27-2

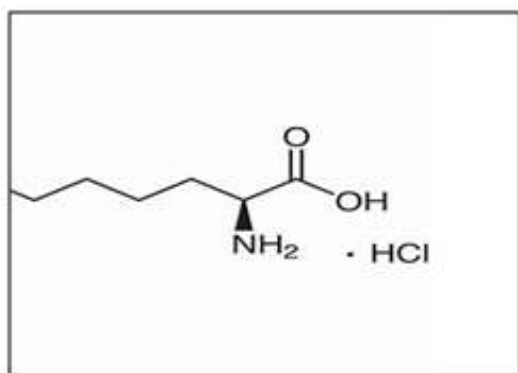


Figure 1: Structure of L-lysine monohydrochloride

As an overview, Lysine Monohydrochloride (LYS) is an essential amino acid, vital for protein synthesis and various metabolic functions in the human body [9]. It is classified as an essential amino acid because the body cannot produce it naturally, necessitating its intake through diet or supplements. Lysine is particularly important for the growth and maintenance of body tissues, as well as the production of enzymes and hormones [10]. Lysine is often recognized for its importance in supporting immune function and aiding in the prevention of herpes simplex virus infections. Lysine is commonly found in protein-rich foods such as meat, fish, dairy, and legumes [11].

Thus, lysine monohydrochloride distinguishes itself as an essential amino acid with a unique set of biological roles, emphasizing its significance in maintaining overall health. Its structural importance, coupled with its involvement in various physiological functions, makes lysine a key player in the intricate orchestra of amino acids within the human body.

Comparing with another widely used amino acid - alanine:

Alanine is a non-essential amino acid, meaning it can be synthesized by the human body. It is an amino acid used in the biosynthesis of proteins [12]. Structurally, alanine also contains a central carbon atom bonded to an amino group, a carboxyl group, a hydrogen atom, and a methyl group in its side chain. Unlike lysine, alanine is nonpolar and aliphatic, meaning its side chain is non-reactive and does not carry a charge [13]. These two amino acids – Alanin and Lysine are compared on certain paramters as described in table 2[13–15].

Table 2: Comparison between Alanine and Lysine amino acids

Sr. No.	Parameter	Alanine	Lysine
1	Category	Non - essential	Essential
2	Function	Glucose production and energy metabolism	Protein synthesis, tissue repair, and enzyme production
3	Charge	Neutral	Positively charged side chain, making it basic
4	Structure	Alanine has a shorter, nonpolar, and uncharged side chain.	Lysine has a longer, polar, and positively charged side chain
5	Dietary sources	Alanine is found in a variety of protein-rich foods	Commonly found in meat, fish, eggs, and some plant sources

Applications of lysine monohydrochloride

Lysine being an essential amino acids it is majorly consumed in salt form of hydrochloride.

Lysine has shown significant presence in various aspects, majorly in our everyday use items. Some of them are listed in table 3.

Table 3: Example of products containing lysine monohydrochloride

Product Category	Examples Of Products
Dietary Supplements	Amino Acid Supplements
Animal Feed Additives	Livestock And Poultry Feed
Pharmaceuticals	Medications And Nutritional Supplements
Cosmetics And Skincare	Hair And Skincare Products
Pet Food	Cat And Dog Food
Food And Beverages	Processed Foods, Sports Drinks, Protein Bars
Personal Care Products	Shampoos, Conditioners

The above mentioned uses are generic to lysine monohydrochloride. They are also basic applications of amino acids. Lysine distinguishes itself from other amino acids as it has applicability in various facets of health care. The unique applications of this amino acid is detailed in this paper.

1) Lysine For Treating Herpes Simplex Virus (HSV)

Lysine supplements may reduce the number and frequency of cold sore outbreaks, because of the herpes simplex type 1 virus. 1,000 milligrams of lysine supplements a day is shown to be effective. Lysine has antagonist action as arginine which is an amino acid which promotes replication of herpes simplex virus (HSV) so lysine act by blocking the absorption of arginine so inhibiting the growth of herpes simplex virus (HSV) [16][17]

2) Lysine For Lowering Blood Pressure

Lysine plays a key role in linus pauling's approach to managing heart diseases. Pauling's study suggests that elevated levels of lysine and proline in the blood can obstruct lipoprotein attachment sites, forming a protective coating around lipoprotein particles. This process prevents lipoprotein from binding to arterial walls, ultimately inhibiting plaque buildup, promoting the regression of existing deposits, and reducing arterial pressure to reduce the hypertension [18].

3) Lysine For Treating Diabetes

As the body does not store amino acids so they undergo catabolism after exerting their biological or pharmacological effects. In the liver,

L-lysine is catabolized using α -ketoglutarate (α -kg) as both acceptor and co-substrate thus increasing glucose entry into the liver through insulin-dependent mechanisms to generate more α -kg for L-lysine catabolism leads to a reduction in blood glucose levels. Insulin secretion is stimulated by lysine and arginine through a process of direct membrane depolarization. Positively charged amino acids are transported into β cells, inducing cell membrane depolarization and this depolarization opens voltage-dependent calcium channels, resulting in calcium influx and subsequent insulin secretion [19]

4) Lysine In Osteoporosis

Lysine helps the body absorb calcium and reduces the amount of calcium that is lost in urine and lysine in combination with arginine (another amino acid) makes bone building cells more active and enhances production of collagen thus they could help in prevent osteoporosis in humans [20]

5) Lysine in Reducing Anxiety

Low levels of L-lysine can disturb the regular release of serotonin, a neurotransmitter associated with feelings of happiness. A research shows the promising result in suggesting that L-lysine supplements may effectively decrease anxiety by supplementing with lysine, serotonin levels are elevated, cortisol levels (stress hormone) are reduced which ultimately contributing to lowering of stress and a potentially reducing the anxiety [21]

6) Lysine as Immunity Booster

A dietary deficiency of lysine limits the synthesis of protein, proliferation of lymphocytes, impairs immune responses and increases susceptibility to infections in the body. As lysine helps in

- regulating t-lymphocytes,natural b-killer cells and macrophages, lymphocytes
- facilitates absorption of zinc, which is the most essential micronutrient that helps boosting the cell mediated immune system of the body
- also regulates production of antibodies, cytokines and other cytotoxic substances which help in building immune response
- lysine supplementation may increase transferrin and prealbumin serum, which reflects the improvement of protein status[22][23]

7) Lysine beneficial for skin

Lysine serves as a crucial component in the construction of collagen protein, forming the base layer of the skin and is responsible for its elasticity and the development of fine lines. While lysine is only obtained from dietary sources, the demand for it also increases with age and factors such as exposure to uv light and other elements can reduce the collagen formation so we need it.

Supplement of lysine gives us

- May improve skin elasticity and firmness
- Heals wounds faster
- Encourages skin renewal
- May prevent age related conditions like wrinkles and fine lines [24]

8) Lysine for Supporting Hair Growth

- **Collagen production** :- collagen is a structural protein vital for strengthening the body parts like the scalp and hair follicles which relies on l-lysine for its synthesis. This essential nutrient is important to maintaining the healthy hair, preventing breakage, enhancing volume, and promoting thickness through adequate collagen production
- **Enhancing hair texture**:- lysine plays a crucial role in shaping the texture of hair by contributing in collagen production and this contribution helps maintain the integrity of the hair shaft, resulting in smoother, shinier, and more manageable hair.
- **Iron absorption**:- hair loss and thinning have been associated with iron deficiency. Lysine, particularly in plant-based foods, facilitates the absorption of nonheme iron by forming a complex that enhances its uptake in the

intestine and maintaining sufficient iron levels through enhanced absorption and can positively influence hair growth and prevent excessive shedding [25]

9) L-lysine α -oxidase in the treatment of colon cancer

Colon cancer cells exhibit a dependency on cationic amino acids, particularly l-arginine, for their growth. The increased demand for amino acids prompts increased regulation of amino acid transporters to fulfill these needs. In colon cancer cells, there's a reported 70% increase in the expression of the slc7a1 gene, responsible for the cationic amino acid transporter cat1. Deprivation of arginine resulted in g0/g1 phase arrest and cell death in colon cancer cells. Furthermore, it reduces the levels of l-lysine, l-arginine and l-ornithine and induced inhibition of cell viability and apoptosis. Therefore, targeting cationic amino acids may be effective in colon cancer treatment [26]

10) Lysine as Injectable Hydrogels

Lysine can be a new alternative for potential tissue bone applications that are a lot of problems in bone and tissue transplant like finding a property doughnut also transparent digestion for one and tissue transported this important for the tissue to make expressed activity in a preferred due to the availability to make a cell and a matrix similar to tissues in the body [27]

11) Lysine Coated Magnetic Core Particles For Removal Of Acetylsalicylic Acid From Aqueous Solutions

Magnetic core particles are useful for removal of all waste from water also pharmaceutical and biochemical waste from hospitals farms incorrect disposable of bandages and other hazardous waste. Magnetic core particles are used because of their magnetization properties (80 emu/g) can easily remove pollution from water but these particles react easily with atmosphere affecting their chemical and physical properties which is why lysine coated magnetic core particles are used for removal of acetylsalicylic acid from aqueous solutions. Lysine moieties enhance adsorption capacity which is also a reason for the modification in magnetic core particles [28]

12) New Bio Renewable Polyester With Rich Amino Groups With L-Lysine

To make lysine based bio renewable polyester ring opening polymerization method is

used, in this method lysine was simply converted to its corresponding alpha-hydroxy acids and cyclized to give to 0-carboxyanhydride monomer, and on this monomer then ring opening reaction using (dmap) dimethylaminopyridine as a catalyst in CH_2Cl_2 . This new bio renewable polyesters had an excellent compatibility and showed a tunable glass transition temperature [29]

13) Lysine Sulphate – A Novel Versatile Salt

L-lysine is obtained from fermentation of *Corynebacterium glutamicum* in different forms like sulfate salts or monohydrochloride. L-lysine sulphate is generally considered safe for non-ruminant animals but safe for ruminant animals. Drawback- but the biggest drawback L-lysine sulphate salt has is it easily catches fire and is explosive. Therefore it needs a green inhibitor like sodium phytate to prevent the same and to prevent any accidents [30][31]

14) New Chemosynthetic Route Linear ϵ -Poly-Lysine

Linear ϵ -poly-lysine is non-toxic and safe for human consumption which makes it a suitable additive in the food industry. Lysine can be obtained with high purity with a low price due to recent advances in aerobic fermentation it's a suitable biorenewable source and the homopolymer of lysine has even more features due to its chirality, biodegradability and reactive amino groups resulting in polycationic applications. Separation of complex mixtures of amino acids for biorefinery applications using electrodialysis [32, 33][34]

15) Nitrogen And Sulfur Doped Carbon Dots From Amino Acids For Potential Biomedical Applications

Nitrogen and sulfur doped carbon dots can be synthesized using microwave technique from amino acids like lysine. They have properties like high fluorescence and most importantly low toxicity along with biocompatibility and tunable properties. These nitrogen and sulphur doped carbon dots can be useful in biomedical applications like sensing, bioimaging, medical diagnostics and as antimicrobial agents [35]

16) Separation Of High Performance Liquid Chromatography(Hplc) Of Alpha And Beta Amino Acids Like Lysine

Lysine 2,3 amino mutase and leucine 2,3 aminomutase separation was done through separation by hplc they were well separated as ortho phthalaldehyde derivatives by reversed phase hplc. High performance liquid chromatography is used to identify separate and quantify specific components in mixtures[36].

II. CONCLUSION

L-lysine emerges as a pivotal amino acid with diverse applications across various domains, ranging from healthcare to industrial processes. Its essentiality underscores its importance in human nutrition, where it plays crucial roles in protein synthesis, tissue repair, and immune function. Lysine's involvement in numerous physiological processes, such as collagen synthesis, neurotransmitter regulation, and calcium absorption, highlights its multifaceted significance in maintaining overall health and well-being.

Furthermore, research indicates lysine's potential therapeutic benefits in managing conditions like herpes simplex virus infections, hypertension, diabetes, osteoporosis, anxiety, and even colon cancer. Its role in supporting skin health, hair growth, and immune function further accentuates its utility in cosmetic and pharmaceutical applications.

Moreover, recent advancements have extended lysine's utility to areas such as material science, with applications in hydrogel formation and nanoparticle synthesis, showcasing its versatility beyond biological contexts. However, it is crucial to note potential adverse effects associated with lysine supplementation, including gastrointestinal distress, allergic reactions, and interactions with medications or other amino acids. In conclusion, lysine stands as an essential player in human health and beyond, offering a myriad of benefits across diverse fields, while prudent consideration of its potential drawbacks is necessary for its safe and effective utilization.

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