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Common bean (*Phaseolus vulgaris L.*) A Source of Essential Amino Acid: Lysine

Farah Anjum[1], Reetika Mahajan[2], Muslima Nazir[1], Tanveer Ali Dar[3], Parvaze Ahmad Sofi[4], Imtiyaz Murtaza[5], Khalid Z Masoodi[1], Asif B Shikari[1], Shafiq A Wani[1], Sajad Majeed Zargar[1*]

[1]Division of Biotechnology, Sher-e-Kashmir University of Agricultural Science and Technology of Kashmir, Shalimar, Srinagar, J&K, India

[2]School of Biotechnology, Sher-e-Kashmir University of Agricultural Science and Technology of Jammu, Chatha, Jammu, J&K, India

[3]Department of Clinical Biochemistry, University of Kashmir, Hazratbal, Srinagar, J&K, India

[4]Division of Genetics and Plant Breeding, Sher-e-Kashmir University of Agricultural Science and Technology of Kashmir, Shalimar, Srinagar, J&K, India

[5]Division of Post-Harvest Technology, Sher-e-Kashmir University of Agricultural Science and Technology of Kashmir, Shalimar, Srinagar, J&K, India

[*]**Corresponding author:** Sajad Majeed Zargar, Division of Biotechnology, Sher-e-Kashmir University of Agricultural Science and Technology of Kashmir, Shalimar, Srinagar, J&K, India-190025,Tel: 94195-80509; Email: smzargar@gmail.com

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Abstract

Common bean (*Phaseolus vulgaris L.*) is a legume crop, and its seed is rich in various essentialamino acids.It can be used as a source of protein, folic acid, dietary fiber, and complex carbohydrates and is one of the plant foods that provide significant amounts of the indispensable amino acid viz lysine.This amino acid is a key component for proper growth and development of animals and plays a critical role in various plant and animal biological and metabolic processes.The amount and proportion of amino acids in the diet is very important as they are the building blocks of proteins and have fundamental role in the formation, stability and function of proteins. As such there is need to look look for the sources of this essential amino acid in various food and the role of lysine in animal, humans and plant growth and development and its involvement in variousbiological processes. Keeping this in mind, we are in process of screening common bean germplasm for theseed lysine content. In the present mini review we highlight the importance of common bean as a source of lysine and its role in various biological process in the human and plants.

Keywords: Amino Bcid; Biological Process; Common Bean; Lysine.

Introduction

Common bean (*Phaseolusvulgaris L.*) is an important grain legume with small genomeof 473 Mb and a self-pollinating diploid genus with most species having 2n = 2x = 22 chromosomes (some species have 2n = 2x = 20) [1]. In terms of its cultivation and nutritional aspects itis third in its importance after soyabean and peanut [2].It is also rich in lysine and is a major source that provides quality protein therefore complements most cereals [3]. Beans are also rich source of fiber, and minerals like calcium,potassium, phosphorus, iron, zinc and magnesium [1]. Being a rich source of protein, folic acid, dietary fiber, and complex carbohydrates, commonbeans are considered nutritionally rich. Common beans are also a good non-meat source of iron, providing 23-30% of the daily recommended levels of this important element [4]. A diet including beans provides substantial health benefits, decreasing the risk of heart and renal diseases, protecting against several cancer types and helping in the control of obesity [5].

Lysine: An Essential Amino Acid

Certain organisms like fungi, plant and bacteria can synthesize all 20 amino acids on their own whereas monogastric animals including humanscan only synthesis 11 amino acids and the remaining nine amino acidswhich are described as essential are obtained from diet. Lysine is one of the most important essential amino acid and limiting amino acid in different diets [6]. The daily recommended allowance of lysine content varies from infant to adult.As recommended by WHO, an infant of the age 2-3 months requires 103 mg/kg per day, children of the age 2 years requires 64 mg/kg per day, individual of 10-12 years age group requires 44 mg/kg per day and an adult human being requires 12 mg/kg per day of lysine content in the diet for proper growth and development. The difference in the concentrations of lysine depends on the intake capacity of nitrogen in the body [7-9]. L-Lysineis beneficial for the body in terms of calcium absorption, building muscle protein, recovering from surgery or sports injuries and the body's production of hormones, enzymes, and antibodies. L-Lysine helps in the treatment of various pathological conditions like Herpes Simplex Virus (HSV) infection, osteoporosis, anxiety and mood disturbances, migraine [10], thus playing a pivotal role for overall growth and protection of body against various diseases.However, deficiency of this essential amino acid may lead to anemia, blood shoot eyes, enzyme problems, hair loss, inability to concentrate, irritability, lack of energy, poor appetite, reproductive problems, retarded growth and weight loss [11] (Figure 1). Keeping in view the importance of lysine in humans and as it cannot be synthesized in the body on its own, there is an urgent need to provide adequate amount of this essential amino acid through diet. For this purpose scientists are trying to find out the ways for accumulation of more lysine content in food crops. Researchfor biofortification of essential amino acids have been done in various crops (maize, wheat, barley) [12,13] and among them Quality Protein Maize (QPM) is one of the successfulexamples of bio fortified crop, in which, the protein content is double than the ordinary maize. In QPM, amino acid (lysine and tryptophan) content is higher. It is worth to mentioningthat such efforts must be done for enhancing lysine content in other crops. Moreover, there is need to screen the germplasm of various crops for identifying genotypes mainly landraces with high lysine content, and the genes responsible for accumulation of lysine must be mined or the linked QTLs be identified.

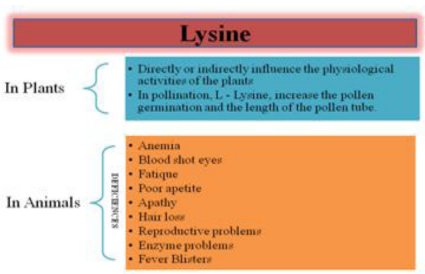

Figure 1: Role of lysine in plants and animals

Role of Lysine in Humans

L-Lysine hydrochloride is mainly used for cereal fortification for human consumption and feed formulation for animals in developing countries. In mammals, the prime center for lysine catabolism is the liver and its main role is to participate in protein synthesis.In the human body, Lysine is catabolized through the saccharopine pathway resulting in the irreversible formation of glutamate and α-aminoadipate, which are then subjected to deamination andoxidation.Two enzymes namely Lysine-Oxoglutarate Reductase (LOR) and Saccharopine Dehydrogenase (SDH) catalyse the first two steps of lysine degradation through the saccharopine pathway. The saccharopine pathway is involved in growth and development in mammals.Lysine requirement by the body is based on the determination of the quantity of dietary lysine necessary to equilibrate nitrogen balance [14]. Lysine can be used for the treatment of herpes virus. A rationale for lysine therapy was based on the fact that tissue replication of the herpes virus is enhanced when the ratio of arginine to lysine is high. When the host cell containsmore lysine than arginine. Thus lysine is thought to be detrimental to herpes virus by depriving it of arginine. The activity of enzymes LKR-SDH involved in lysine degradation pathway has been detected during embryonic central nervous system development in rat [15] and mutations in genes encoding LKR-SDH are associated with a metabolic disorder known as familial hyper-lysinemia. This metabolic disorder may lead to severe developmental abnormalities, such as mental retardation [16]. It is believed that many biochemical abnormalities of depression or mania caused by some small irregularity in the membrane of nerve cells. These membranes are made up of molecules containing amino acids like arginine and lysine, among others. Arginine is required for proper growth in infants whereas lysine is one of the essential amino acids. It is reported that increased dietary lysine causes decreased gastrointestinal absorption and decreased kidney resorption of arginine. Thus there is a need to make balance between lysine and arginine. Beside lysine catabolism the saccharopine pathway is important in stress responses in animals.As such, the role of lysine in proper human growth and development is must.

Role and Synthesis of Lysine in Plants

Cereal crops that are the major source of food for human and animals have limited concentration of essential amino acids. In plants, lysine is synthesized by dihydrodipicolinate branch of aspartate-family pathway [17]. However, this is regulated by a feedback mechanism which ultimately restricts the accumulation of lysine in the seeds [18]. In this pathway, lysine and threonine inhibit Aspartate Kinase (AK), the first enzyme in the pathway whereas Dihydrodipicolinate Synthase (DHDPS), the first enzyme in the dihydrodipicolinate branch is inhibited by lysine only [19,20]. The amount of soluble lysine accumulated in the seeds is regulated in this pathway two key enzymes [19,21,22]. It is reported that aspartate kinase enzyme is less sensitive to feedback inhibition by lysine which leads to higher accumulation of free threonine in mutant plants without affecting the free lysine levels [23].

Lysine accumulation in the seeds can also be restricted by saccharopine pathway that is generally a lysine degradation pathway. In the saccharopine pathway, the first two reactions are catalyzed by bifunctional enzyme Lysine Ketoglutarate Reductase/Saccharopine Dehydrogenase (LKR/SDH) [24]. Here LKR condenses lysine and α-ketoglutaric acid to form saccharopine, which is then hydrolyzed by SDH, leading to the formation of α-Aminoadipic-Δ-Semialdehyde (AASA) and glutamic acid. These two enzymatic steps catalize the transamination step in which the ε-amino group of lysine is transferred to α-ketoglutaric acid to form glutamic acid. A second glutamic acid is generated in a reaction catalyzed by α-aminoadipic acid aminotransferase (AAA), in which the α-amino group of lysine is transferred from α-aminoadipic acid to α-ketoglutaric acid. Over expressing bacterial DHDPS is less sensitive to feedback inhibition by lysine in Genetically Modified (GM) plants this leads to the overproduction of threonine and lysine but accumulation of more saccharopine, indicates higher lysine degradation through the saccharopine pathway [25]. Thus, lysine catabolism plays an indispensible role in free lysine level regulation in plant seeds.The downregulation of LKR/SDH enzyme may lead to the increase in the levelof free lysine in seeds by engineering plants so to meet requirement of lysine in human and animals. AK and DHDPS feedback inhibition insensitive enclosing genes are overexpressed by lysine degradation through the saccharopine pathway. This study was done in transgenic canola (*Brassica napus*) and soybean plants [25]. In soybean, binding of lysine to active site of LKR enzyme favors dephosphorylation, resulting in lysine depletion prevention from the tissue [26]. In *Arabidopsis*, LKR-SDH is expressed in actively dividing cells of reproductive organs and tissues [27]. Saccharopine pathway also helps the plant in withstanding the biotic and abiotic stress. During salt or osmotic stress, the expression of LKR/SDH is increased in plant [28]. However, the role of the LKR/SDH enzyme has not yet been elucidated in stress response. Upregulation of α-Aminoadipic-Δ-Semialdehyde Dehydrogenase (AASADH) third enzyme insaccharopinehas been observed in the tissues or cells when subjected to osmotic treatments, confirmthe role of the enzyme to stress response [29,30]. The saccharopine pathway has been studied in *Silicibacter pomeroyi*, bacteria living in highsalt environments like seawater recently [31]. There is an increase in levels of compatible solutes like pipecolic acid in *Corynebacterium ammoniagenes* under osmotic stress. The increase in the compatible solute is associated with lysine degradation [32]. Lysine content has been estimated in both wild and cultivated genotypes of Phaseolus species, with a view to investigate possibilities of genetic improvement in seed nutritional quality. Table 1 represents details of lysine content in various *Phaseolus* species.

S.No	Variety	No. of genotypes	Lysine content (%)	Reference
1	*P. vulgaris L*(c.v)	14	7.00-7.43%	[33]
2	*P. lunatus*(c.v)	10	6.81-7.12%	
3	*P. coccineus*(c.v)	13	7.40-7.94%	
4	*P. coccineus*(wild)	3	7.31-7.59%	
5	*P. polyanthus*(c.v)	4	7.47–7.65%	
6	Faba bean	random	19.8 g/kg	[34]

Table 1: Lysine content in various wild and cultivated genotypes of *Phaseolus*species

Our Vision for Future Research Work

Lysine, an essential amino acid is provided to humans via diet. Common bean,which is an easily available diet canprovide the required content of lysine in human body (essential amino acid). As common bean is affordable cropfor everyone thereforeit can be used as high quality food for fighting many diseases and providing benefits like reduction in heart and renal diseases, obesity, enzyme problems, hair loss, inability to concentrate, irritability, lack of energy, poor appetite, reproductive problems, retarded growth and weight loss.Thus there is need to improve or develop new varieties or to identify genotypes of common bean that can serve as major source of lysine for the masses. Moreover, there is need to understandthe role of various key enzymes of saccharopine pathway to design new strategies for enhancing accumulation of lysine in seeds. Identifying key regulators or the QTLs linked to lysine accumulation in common bean will help in overcoming lysine deficiency related problems.

References

1. Perseguini JM, Oblessuc RP, Rosa JR, Gomes KA, Chiorato AF, et al.(2016) Genome Wide Association Studies of Anthracnose and Angular Leaf Spot Resistance in Common Bean. PLoSOne 11: 1-19.

2. Broughton WJ, Hernandez G, Blair MW, Beebe SE, Gepts P, et al. (2003) Beans (Phaseolus spp.), Model Food Legumes. Plant and Soil 252: 55-128.

3. Messina V (2014) Nutritional and health benefits of dried beans. American Society for Nutrition 100: 437S-442S.

4. Cladas DG,KonzenER, Recchia GH,Peeira AC, Tsai SM (2016) Functional Genomics of Biotic and Abiotic Stresses in Phaseolus vulgaris, Abiotic and Biotic Stress in Plants - Recent Advances and Future Perspectives.

5. Mariana SL and Sumalan R (2014) Amino acid composition of some common bean landraces from Caraş-Severin country, of Romania. JHFB 18: 208- 210.

6. Fornazier R, Azevedo RA, Ferreira RR, Varisi VA (2003) Lysine catabolism: flow, metabolic role and regulation. Braz J Plant Physiol15: 9-18.

7. FAO/WHO (Food and Agriculture Organization/World Health Organization)(1973) Energy and Protein Requirements. Report of a Joint FAO/WHO Ad Hoc Expert Committee. World Health Organization, Rome,118 pp.

8. NRC (National Research Council)(1974) Improvement of Protein Nutriture. Report of the Committee on Amino Acids, Food and Nutrition Board. National Academy of Sciences, Washington, DC, 201 pp.

9. WHO (World Health Organization). (1985) Energy and Protein Requirements. Report of a Joint FAO/WHO/UNU Expert Consultation. World Health Organization, Geneva, 206 pp.

10. Singh M, Roa DM, Pande S, Battu S, Mahalakshmi K, et al. (2011) Medicinal Uses of L-Lysine. Past and Future. International Journal of Research in Pharmaceutical Sciences 2: 637-642.

11. BhandareP,Madhavan P, Roa BM,Roa NS (2010) Determination of arginine, lysine and histidine in drug substance and drugproduct without derivatisation by using HILIC column LC technique. J Chem Pharm Res2:580-586.

12. Brandt AB (1975) In vivo incorporation of lysine-C14 into the endosperm proteins of wild type and high lysine barley. FEBS Lett52: 288-291.

13. Sodek L, Wilson CM (1970) Incorporation of leucine-C14 into protein in the developing of normal and opaque-2 corn. Arch BiochemBiophys 140: 29-38.

14. Tome D, Bos C (2007) Lysine Requirement through the Human Life Cycle. J Nutr137: 1642S-1645S.

15. Rao VV, Pan X, Chang YF (1992) Developmental changes of L-lysine–ketoglutaric acid reductase in rat brain and liver. Comp BiochemPhysiol b BiochemMolBiol 103: 221-224.

16. Markovitz PJ, Chuang DT, Cox RP (1984) Familial hyperlysinemias. J BiolChem 259:11643-11646.

17. Azevedo RA, Arruda P, Turner WL, Lea PJ (1999) The biosynthesis and metabolism of the aspartate derived amino acids in higher plants. Phytochem 46: 395-419.

18. Azevedo RA, Arruda P (2010) High-lysine maize: the key discoveries that have made it possible. Amino Acids 39:979-989.

19. Galili G (1995) Regulation of lysine and threonine synthesis. Plant Cell 7: 899-906.

20. Avin-Wittenberg T, Galili G (2012) Metabolism: amino acid regulatory wisdom. Nat ChemBiol 8: 23-24.

21. Angelovici R, Fait A, Zhu X, Szymanski J, Feldmesser E, Fernie AR, et al. (2009) Deciphering transcriptional and metabolic networks associated with lysine metabolism during Arabidopsis seed development. Plant Physiol 151:2058-2072.

22. Angelovici R, Aaron F, Fernie AR, Galili G(2011) A seed high-lysine trait is negatively associated with the TCA cycle and slows down Arabidopsis seed germination. New Phytol 189: 148-159.

23. Bright SWJ, Kueh JSH, Franklin J, Rognes SE,Miflin BJ (1982) Two genes for threonine accumulation in barley seeds. Nature 299: 278-279.

24. Gonçalves-Butruille M,Szajner P, Torigoi E, Leite A, Arruda P (1996) Purification and characterization of the bifunctional enzyme lysine–ketoglutarate reductase–saccharopine dehydrogenase from maize. Plant Physiol 110: 765-771.

25. Falco SC,Guida T, Locke M,Mauvais J, Sanders C,et al. (1995) Transgenic canola and soybean seeds with increased lysine. Biotechnology (NY) 13: 577-582.

26. Miron D, Ben-Yaacov S, Karchi H, GaliliG (1997) In vitro dephosphorylation inhibits the activity of soybean lysine–ketoglutaric acid reductase in a lysine-regulated manner. Plant J 12: 1453-1458.

27. Tang G, Zhu-Shimoni J X, Galili G (1997) Regulation of lysine catabolism through lysine–ketoglutaric acid reductase and saccharopine dehydrogenase in Arabidopsis. Plant Cell 9: 1305-1316.

28. Deleu C, Coustaut M, Niogert MF, Larpher F (1999) Three new osmotic stress-regulated cDNAs identified by differential display polymerase chain reaction in rapeseed leaf discs. Plant Cell Environ 22: 979-988.

29. Rodrigues SM, Andrade MO, Gomes APS, DaMatta FM, Baracat-Pereira MC, et al. (2006) Arabidopsis and tobacco plants ectopically expressing the soybean antiquitin-like ALDH7 gene display enhanced tolerance to drought, salinity, and oxidative stress. J Exp Bot 57: 1909-1918.

30. Brocker C, Lassen N, Estey T, Pappa A, Cantore M., Orlova VV, et al. (2010) Aldehyde dehydrogenase 7A1 (ALDH7A1) is a novel enzyme involved in cellular defense against hyperosmotic stress. J BiolChem 285: 18452-18463.

31. Serrano GC, Silva-Figueira TR, Kiyota E, Zanata N, Arruda P (2012) Lysine degradation through the saccharopine pathway in bacteria: LKR and SDH in bacteria and its relationship to the plant and animal enzymes. FEBS Lett 586: 905-911.

32. Gouesbet G, Blanco C, Hamelin J, Bernard T (1992) Osmotic adjustment in Brevibacteriumammonkgenes: pipecolic acid accumulation at elevated osmolalities. Microbiol138: 959-965.

33. Baudoin JP,Maquet A (1999) Improvement of protein and amino acid contents in seeds of food legumes. A case study in Phaseolus.BiotechnolAgronomic Soc. Environ 3: 220-224.

34. Crepon K,MargetP, Corinne P, Carrouee B, Arese P, et al. (2010)Nutritional value of faba bean (Viciafaba L.) seeds for feed and food. Field Crops Res 115: 329-339.