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Polyamines in Plant Biotechnology, Food Nutrition and Human Health

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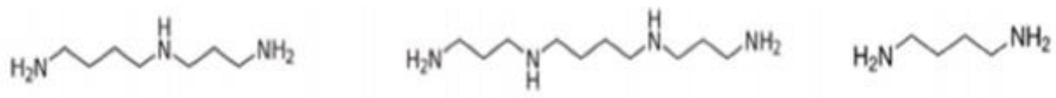
Abstract

Polyamines, spermine, spermidine and putrescine also have antioxidant properties and are involved in a variety of organic processes, particularly cell proliferation and differentiation. Dietary polyamines have important consequences for human health, particularly for intestinal growth and immune system differentiation and development. Polyamine plays an important role in preventing the chronic diseases such as cardiovascular diseases, by delivering antioxidants and anti-inflammatory effects. Food is a significant source of polyamines, in addition to endogenous synthesis. While polyamine intake is not recommended daily, it is well known that polyamine requirements are high during stages of fast cell growth (i.e. during the neonatal period). In humans, a general decrease of PA with ageing occurs in conjunction with the certain human health conditions. In the case of Alzheimer's and Parkinson's diseases, high polyamine dose is also detrimental to cancer patients, aging, innate immunity and cognitive impairment. There is a dichotomy since, while polyamine can increase their lifespan and minimize age-related cardiovascular problems, they have negative consequences in conditions of higher cell proliferation. The amount of polyamine in edible plant products as well as food meats should therefore be rigorously quantified. Any food / meats a patient may eat and which are to be avoided can be a guide for the medical experts. In a variety of concentrations, polyamines can be found in every kind of food. Naturally, spermidine and spermine are found in food, while putrescine may also be of microbial origin.
Key words: Alzheimer's disease, Cardiovascular disease, Chronic diseases, Polyamines, Putrescine, Parkinson's diseases, Spermine, Spermidine

Introduction

In 1678, Antoni van Leeuwenhoek discovered the crystals in the human semen which were called as the spermine, discovered 200 years later (1888). Spermine and spermidine were identified as a chemical structure in 1924. The spermidine polyamines (N-(3-aminopropyl)-1,4-butane diamine), spermine (N,N-bis (3-aminopropyl)-1,4-butane diamine) and putrescine (1,4-butane diamine) are low in molecular weight with two or more amino-groups [1]. They are found in all living cells such as in the microorganisms, plants and animals. Polyamines are relatively stable, resistant to acidic conditions and alkaline, since their structure (Fig. 1) enables them to create hydrogen linkages with hydroxyl solvents such as water and alcohol. Within the cell, the protonated and solid polyanionic macromolecules such as DNA and RNA are fully related to the physiological pH [2]. Polyamines, on the other hand, are also found in animal as well as plant foods. Breast milk and baby formula are an important source of polyamines for the humans.



Spermidine N-(3-aminopropyl)-1,4- butane diamine | Spermine N,N-bis(3-aminopropyl)-1,4-butane diamine | Putrescine 1,4-butane diamine

Fig.1: Chemical structure of polyamines.

Polyamines are aliphatic polycations all over the fabrics and all types of cells studied in animals and plants that are all present. The polyamine functions include apoptosis, cell division, differentiation, cell proliferation, RNA and protein synthesis, gene expression, homeostasis, and signal transduction in various cell processes [3]. Although the biological activity and mechanism of action of the sperm crystals in human semen have been intermittent since their initial discovery, it is now a common knowledge that polyamines and their analogs have practical effects on plant life, as well as in various aspects of human / animal health and diseases. For example, gastroenterology, programmed cell death (PCD); parasitology, brain stroke and other disorders, oxidative stresses are recognized as their role(s). Polyamines also feature in plants in a wide range of processes, including plant growth and development and stress / senescence responses in particular [4]. These findings intensify research into the clarifying functions of polyamines, pre- and post-harvest biology, abiotic and biotic stresses in plants, in Pharmacology and Medicine.

Putrescine (Put), spermidine (Spd) and spermine (Spm) are the key polyamines in mammalian cells and plants, while thermo-Spm (T-Spm) are found to be essential for abiotic stress plants. Other than these floral plants, each cadaverine, 1,3-diaminopropane and other modified formations will also be synthesized. Other amines, which are less common, include cadaverine, homoSpd, norSpm, norSpd, thermoSpm, aminopropyl homoSpd and methyl spd [5]. Branched and long polyamines are normally present in the vegetable seeds and graminae seeds to protect seed from water deficit, while di-, tri-, and tetra-polyamines are considered to control the osmotic stress in aquatic plants during water submergence.

1. Polyamines and Health:

The role of polyamines in cell growth and proliferation, stabilization of negative DNA charges, RNA transcription, protein synthesis, immune response regulation, apoptotic control, regulation of ionic channels, and as antioxidants in particular, is important [6]. Polyamines mainly affect the membrane lipids and nucleic acids through their antioxidant activity. Spermine, which has more positive charges, is the polyamine with the most antioxidative characteristics. Metal chelation inhibits the growth of hydroperoxides and slows down the development of secondary oxidation compound which is the main mechanism for polyamine antioxidant action.

2. Polyamine Homeostasis:

The de novo synthesis of Polyamines starts with the production by the enzyme Ornithine Decarboxylase (ODC) of putrescine of the amino acid ornithine (Fig. 2). Through incorporating the propylamine derived from the decarboxylation of S-adenosyl methionine, Putrescine is converted through spermidine synthase into spermidine. Spermidine is subsequently converted into sperm by spermine synthase, thereby adding a second group of propylamines [7].

Polyamine interconversion is a cyclic process that regulates its turnover and controls the intracellular homeostasis. This process starts with the acetylation of any of the three polyamines, which is catalyzed with the involvement of acetyl coenzymeA with N-acetyltransferase enzyme. The polyamine Oxidase (PAO) enzyme is then extracted from a propylamine group and putrescine comes from a spermidine metabolite or acetylated sperm metabolite. Polyamines are removed from the body by oxidizing a primary amino group, primarily through the action of diamine oxidase (DAO) and PAO. Polyamines and their acetylated derivatives can be affected by both the enzymes. Polyamines also have an exogenous origin, mainly food and breast milk, in addition to the endogenous synthesis. Moreover, intestinal microbiota is also described in the large intestine as the source of polyamines. Some recent studies have linked the synthesis of these compounds to various microbial intestinal organisms. Further knowledge on the capacity of intestinal microbiota polyamines and the corresponding biosynthetic tract is however still required [8]. Eventually, the intestinal and pancreatic secretions as well as the catabolism products from gut cells also support polyamines in the intestines [9]. Different mechanisms, among them transcellular (by passive diffusion and conveyors) and paracellular routes, absorb polyamines in the duodenum and in the first part of jejunum. Polyamins are partly metabolized until they enter in the blood circulation and those that are dispersed throughout the organism are collected by the tissues where they may undergo interconversion reactions. They are also metabolized in the intestinal wall. In the stomach, thymus and liver, the highest concentrations of polyamines are found. A polyamine-enriched diet raises plasma levels within the animals and people [10].

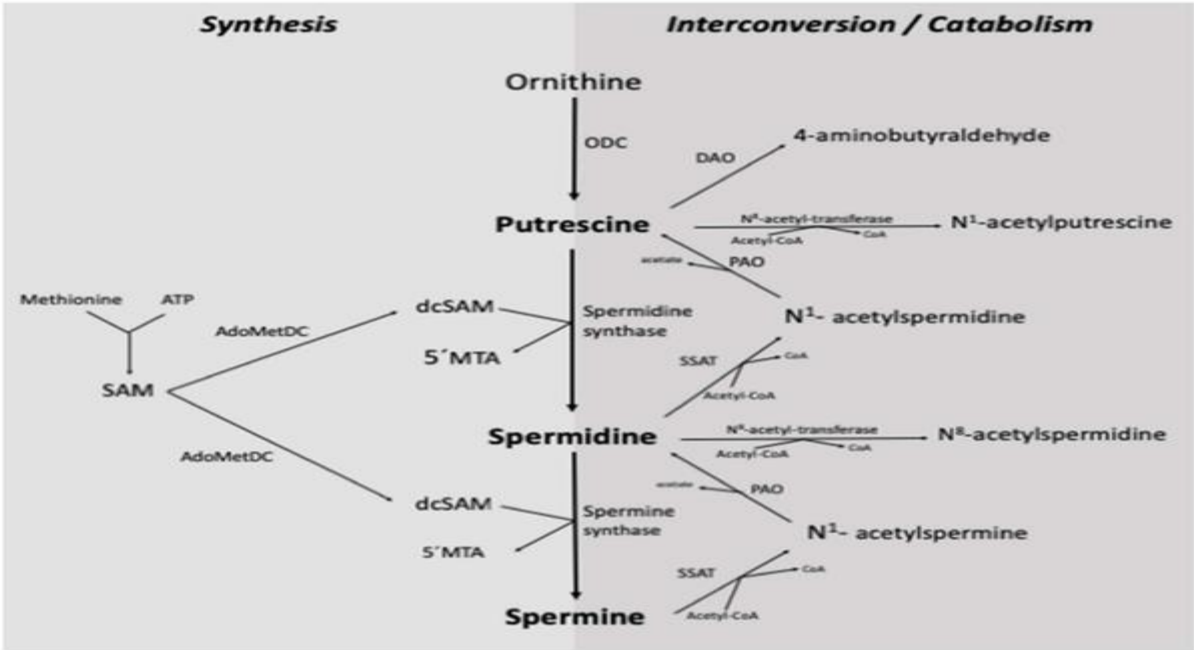


Fig.2: Synthesis and interconversion/catabolism of polyamines in the organism.

3. Potential effects of Polyamines:

a) Postnatal stage:

Several studies explain the importance of polyamines in people, especially in the early life stages. It is recognized that the need for polyamines is growing during the fast cell growth, particularly in the neonatal stage. The requisites for surgery or wound healing and aging are also higher. Polyamines (spermine and spermidine) contribute to the gastrointestinal tract proliferation and maturation, and participate in the immune system differentiation and development [11]. These compounds can also be used to regulate the inflammatory responses due to their antioxidant properties.

Several studies have shown that the oral polyamine in the mice leads to early postnatal intestinal maturation, acts on bowel mucosal reparation, and immune-inflammatory reactions. Modified protein spermine and spermidine and the function of disaccharidases and accelerated postnatal intestinal maturation leads to the morphological epithelial changes and mucosal permeability. The related species such as the liver and pancreas also participate in the maturation. An early maturation of Glycoprotein Fucosylation was observed in another study with mice to facilitate the oral administration of polyamines mainly spermidine. The doses of α-1,2-fucosyl-transferase and α-L-fucosidase increased by 10 μmol / day each polyamine and induced an α-1,2-fucoprotein synthesis. According to a study, the authors suggest the post-natal changes in intestinal glycoprotein fucosylation that mainly relate to the intake of polyamines, in particular spermidine and spermine. Another study showed that the oral administration of spermine in mouse raises alkaline phosphatase and disaccharidase activity and consequently improves the bowel movement. Spermine and spermidine administration in newborn rats has increased the intestinal weight and duration and has improved the maturation [12]. In terms of intestinal immune response, numerous animal studies have demonstrated that the oral spermine and spermidine administration during the postnatal period enhances the maturation of the intestinal immune cells and raises immunoglobulin A rates in villi and bowel crypts.

b) Aging:

Throughout aging, spermine and spermidine cell levels and ODC enzyme activity tend to decrease. During this point, the dietary enhancement with polyamines reduces the risks of age-related diseases and promotes longevity. Diabetic concentrations of these blood compounds increased and pro-industrial markers decreased, age-associated DNA methylation, renal glomerular atrophy and mortality increased in the aged mice (374 and 1540 nmol / g, respectively) in the sample. The autophagy, which includes removal of the damaged proteins and organelles from the cells and thus inhibiting the aging process, was also observed to increase spermidin. Spermidine showed the strongest inversive mortality relationship among 146 nutrients in a follow-up study of a cohort of 829 participants over twenty years [13]. The dose-dependent effect is explained by the authors that spermidine effectively causes autophagy and can reduce the acetylation of histones, which are the essential processes for homeostasis cell during ageing. The diet rich in spermidine was associated with a decrease in the risk of all-cause mortality in the general community, predominantly from plant-based foods (green pepper, wheat grains, mushrooms, etc.).

4. Polyamines in food:

Polyamines are either present in free or conjugated form in foods of both animal and plant origin. In plant-based foods often associated with the phenolic compounds, combined polyamines are present. The main source of the foodstuff is natural spermidine and spermine from raw plant and animal tissues, whereas the presence of fermentative or contaminating microorganisms can also cause putrescine. Spermidine and spermine can be defined, in particular with the fermented products, as a part of their bacterial origin. The overall content of the polyamines can thus be influenced by processing and storage conditions [14].

a) Breast milk and infant formula:

Breast milk is the first dietary exposure to polyamines. The contents and profile of these compounds are appropriate in all the studies which were reviewed according to the factors such as genetics, lactation phase, nutritional status and dietary intake of a mother.

Spermidine and spermine are the major polyamines in the breast milk. They are substantially different in contents with differences of > 68 and 53 percent respectively. Usually spermine values are higher, except in two trials conducted by the same author that have reported higher spermidine values. In the milk of the mothers of preterm infants, in contrast to the full-term, two studies showed the higher polyamine content. In addition, it should be noted, as preliminary information that milk from obese mothers has been shown to contain less polyamines than milk from normal mothers.

b) Food of plant origin:

Polyamines are ubiquitous in plant foods, though the quality and distribution of these items vary depending on the food type. The prevalent polyamine is spermidine in all plant related foods. Cereals, legumes and soy derivatives are the most common food types with the highest protein and semen content. In particular, the values for spermidine are 2,437 and 1,425 nmol / g, 722 nmol / g and 341 nmol / g, respectively, with the soy and wheat germs in their respective spermine levels. The polyamines also have some significant amounts of mushrooms, peas, hazelnuts, lettuce, broccoli, cauliflowers and green beans. In the fruit group, the lowest levels are found. The recorded spermidine values are for example less than 21 nmol / g and < 1.98 nmol / g for spermine in apples, pears, cherries, oranges or tangerines.

Just like spermidine, putrescine can be found in almost any plant food in which fruit and vegetable products, particularly citrus fruit (1,554 nmol / and green peppers (794 nmol / g), are especially abundant. In wheat germs (705 nmol / g) and in soybean sprouts (507 nmol / g) there are also high amounts of putrescine.

Conclusion

The physiological functions and importance of polyamines for human health are of extensive knowledge. Several studies show that the dietary polyamines are important in various stages and life situations such as postnatal aging and in higher demands. Polyamines play an important role in the development of the mammals and plants and in their cell response to biotic and abiotic pressures in a wide range of biochemical and physiological processes. The role of polyamines in sustaining human health is well-known due to their ubiquity and inclusion in a broad range of essential cellular processes. Nonetheless, the basic mechanisms by which polyamines influence human health are less well known, particularly with an increasing age. The role of polyamines in the development of tumors is likely to lead to largely overlooked research into the health benefits of polyamines. The evidence in this chapter shows that polyamines are important molecules to maintain good health at an aging age, while diets may influence overall body polyamine pools.

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