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Effects of Polyunsaturated Fatty Acids on Human Health Through Intestinal Microbiota

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Abstract. Unsaturated fatty acids act a necessary part in the intestinal health of the host microbiota environment and immune ability by being transformed by intestinal microorganisms. Polyunsaturated fatty acids (PUFAs) are very important to the host body, also they influence many physiological activities of the body. The amount of polyunsaturated fatty acids synthesized by the human body cannot meet the daily needs of the human body, and it is necessary to obtain some essential fatty acids (EFA) from food. At the same time, some intestinal microorganisms can also synthesize and convert polyunsaturated fatty acids, which contribute to the regulation and control of host immunity. In addition, PUFAs are also beneficial to humans. They are critical in sustaining a healthy and stable gut microbiota environment and regulating and controlling host immunity. This paper summarized the conversion mechanism and effect of intestinal microbiota on polyunsaturated fatty acids, discussed whether polyunsaturated fatty acids can regulate human diseases and microbiota as health products, and determined the regulatory mechanism of polyunsaturated fatty acids.

Keywords: unsaturated fatty acids, gut microbiota, polyunsaturated fatty acids

1. Introduction

When the molecule contains unsaturated bonds and is liquid at room temperature, the substance is called an unsaturated fatty acid. Depending on how many double bonds there are in the carbon chain, fatty acids can be categorized as monounsaturated or polyunsaturated. Not all carbon bonds in fatty acids are occupied by hydrogen bonds; In other words, unsaturated fatty acids are molecules that are fluid at room temperature and have unsaturated bonds. The synthesized amount of various polyunsaturated fatty acids found in the human body cannot meet the needs of human daily life, and the unsaturated fatty acids that must be ingested from food are called essential fatty acids (EFA). For example, linoleic acid and arachidonic acid are all EFA. A variety of polyunsaturated fatty acids are present in the gut, these fatty acids also have corresponding physiological functions, such as preventing various diseases. At the same time, the proportion of these fatty acids in the intestine directly or indirectly affects intestinal microecology. Some microbes in the gut can synthesize and convert polyunsaturated fatty acids. Bifidobacteria, Lactobacillus, and Lactococcus, for example, create omega-3, omega-6 fatty acid synthesis, convert them to specific fatty acids like conjugated linoleic acid and linoleic acid. They are

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considered the most beneficial polyunsaturated fatty acids. At the same time, polyunsaturated fatty acids have certain benefits for the human body. They are essential for the control and regulation of host immunity, including anti-cancer, prevention of dementia, prevention of cardiovascular diseases, anti-inflammatory, and antioxidant activities. At the same time, the proportion of these fatty acids in the intestine directly or indirectly affects the intestinal microecology, which can change the quantity and composition of the intestinal microbiota, and affect the physiological properties and function of the intestinal mucosal barrier. Studies have found that the imbalance of intestinal microbiota is closely related to metabolic disorders, cancer, and other diseases.

2. Definition and classification of polyunsaturated fatty acids

Fatty acids can be divided into saturated and unsaturated fatty acids. Unsaturated fatty acids are straight-chain fatty acids with at least two double bonds and a carbon chain length of 18 to 22 carbon atoms. The more double bonds, the higher the degree of unsaturation n-6, n-3 two categories. Linoleic acid, linolenic acid, arachidonic acid, and other n-6 PUFAs are examples. Long-chain PUFAs such as eicosapentaenoic acid (EPA), as well as linolenic acid, make up the majority of n-3 PUFAs [14].

According to the position of the first double bond at the methyl end of fatty acids, long-chain PUFA (LC-PUFA) can be separated into two main families: n-6 PUFA and n-3 PUFA. N-3 is prevalent in food sources. The LC-PUFA consists of EPA, and docosahexaenoic acid (DHA), as well as n-6 linoleic acid (LA), arachidonic acid (AA), and α-linolenic acid (ALA). In the process of making LC-PUFA, a number of intermediates are created, including double-high gamma linolenic acid (DHGLA), gamma linolenic acid (GLA), stearidonic acid (SDA), and eicosapentaenoic acid (ETA), which Figure 1 depicts the molecular makeup of the fatty acids mentioned above.

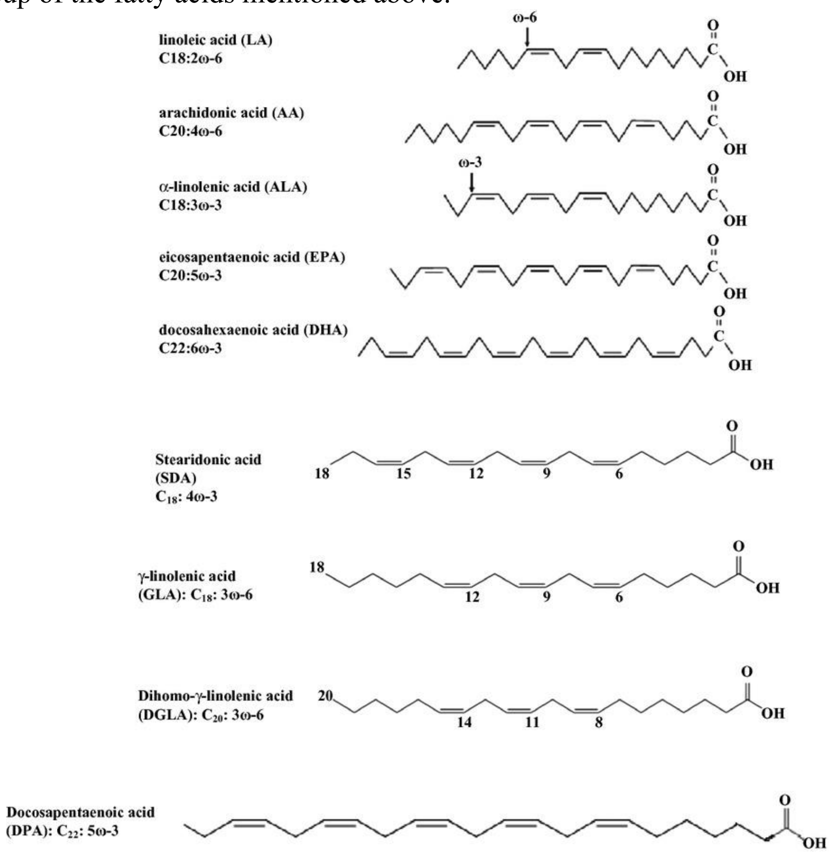

Figure 1. Several structure of polyunsaturated fatty acids.

3. Conversion mechanism of unsaturated fatty acids in intestine

Microbes in the gastrointestinal tract metabolize fat and produce numerous fatty acids, including conjugated fatty acids and trans fatty acids [1]. These produced fatty acids also act on host lipid metabolism. PUFAs saturated metabolism is an example of fat metabolism by gastrointestinal microorganisms, which specifically refers to the detoxification metabolism of anaerobic bacteria present in the gut, such as lactic acid bacteria. This metabolic reaction can be used to convert free polyunsaturated fatty acids that inhibit host growth into free saturated fatty acids that are less inhibitory [2]. The majority of fatty acids are now thought to be taken on the apical membrane of enterocytes by membrane-associated fatty acid binding proteins, also known as transporters of fatty acids, through a protein-mediated fatty acid absorption pathway. The small intestine contains fatty acid binding protein (FABP), which may be crucial for the intracellular transit of the absorbed fatty acids. According to the widely held belief, these transporters could serve as fatty acids acceptors, and as a result, the fatty acids may enter the cell membrane through simple diffusion. The prevailing theory holds that these fatty acids—possibly go through the phospholipid bilayer just by enhanced diffusion—after being accepted by these acceptors. The primary biological role of -linolenic acid (LNA; 18:3n-3) appears to be that it serves as a precursor for the synthesis of longer chain n-3 PUFAs [3]. Figure2 depicts a pathway for the conversion of the essential fatty acids ALA (n-3) and LA (n-6) to longer-chain PUFA, except for the final reaction that results in DHA formation, which occurs in the endoplasmic reticulum [4]. Recent work is accepted that some bacteria do have the metabolic capacity to make EPA, as well as docosahexaenoic acid (DHA; 22:6n3)or arachidonic acid (AA;20:4n6) [5]. In the human body, these fatty acids (FAs) generate arachidonic acid (ARA, n-6), eicosapentaenoic acid (EPA, n-3), and docosahexaenoic acid (DHA, n-3).

4. Function of unsaturated fatty acids in intestine

4.1. Function of maintaining intestinal homeostasis

N-3 PUFA suppresses the synthesis of lipoprotein B in very low-density lipoprotein, accelerates the clearance of VLDL residues in surrounding tissues and the liver, and prevents VLDL conversion [6]. There is strong scientific evidence that the composition of dietary fatty acids plays a role in the etiology of many diseases. Increasing n-3 PUFA intake may lower the risk of CHD. Several scientific bodies have published recommendations for n-3 PUFA (See, for example, the Departments of Health in 1991 and 1994; the British Nutrition Foundation in 1992; the Scientific Committee for Food in 1993; and the FAO/WHO in 1998). Platelet, Plasma, and erythrocyte phospholipid n-3 PUFA levels are functional biomarkers of n-3 PUFAs. Because n-3 PUFA has a consistent and long-lasting hypotriacylglycerolaemic effect, plasma triacylglycerol concentrations are also a functional indicator of n-3 PUFA [7].

Furthermore, Omega-3 PUFAs have the potential to directly influence the validness and plenty of gut bacteria. Fish oil is rich in omega-3 PUFAs, which has a much greater impact on the diversity of gut microbiota than sunflower oil, and consuming fish oil is of great benefit to people's health [8-9]. Omega-3 PUFAs have certain inhibitory effects on a great diversity of destructive bacteria. Omega-3 PUFAs reduce the growth of E. coli, which in turn reduces competition from bifidobacteria and increases the amount of bifidobacteria in the human gut. In turn, it can effectively inhibit the inflammatory response related to metabolic endotoxemia and produce beneficial changes in intestinal flora [10]. ω-3 PUFAs can also regulate the abundance of intestinal Akk, and inhibit liver inflammation, which can alleviate hepatitis caused by high fat. Akk is a weight loss bacterium that decomposes bacteria for mucins residing in the mucus layer and is the dominant bacterial species in humans. Akk can increase the content of endocannabinoids in the ileum during metabolic disorders in the human gut, thereby reducing the effects of obesity on the human body, such as the dysfunction of the colonic mucosal barrier due to an unhealthy diet. In other words, Omega-3 PUFAs can control the gut microbiota of human and increase the thickness of intestinal mucosa, thereby reducing the harm of obesity.

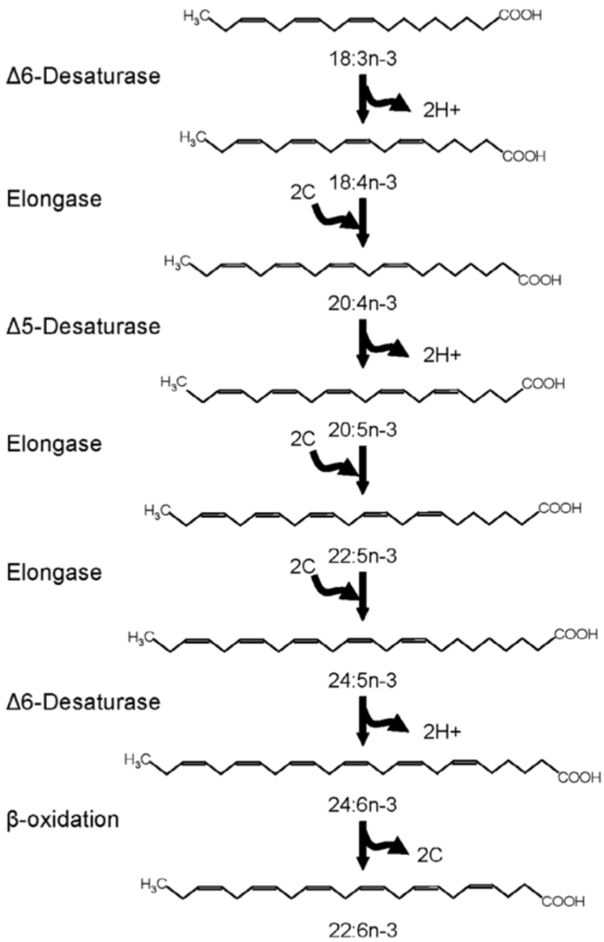

Figure 2. A broad pathway for converting-linolenic acid to longer-chain n-3 polyunsaturated fatty acids [11].

4.2. Health functions of PUFAs

4.2.1. Preventing colorectal cancer. Many pieces of literature point out that high-fat and high-calorie foods may lead to an increase in tumor incidence rate: however, the cancer incidence rate of Greenland Eskimos whose main fat source is marine fish oil is significantly lower than that of other populations, which is thought to be related to the amount of n-3 and n-6 polyunsaturated fatty acids in food. Noguchi et al. believe that n-6 polyunsaturated fatty acids, mainly linoleic acid, can improve the occurrence of breast cancer and the proliferation and metastasis of cancer cells by increasing the catalysis of cyclooxygenase and lipoxygenase. Animal experiments show that corn oil rich in n-6PUFAS can promote the occurrence of breast cancer and colon cancer [12]. N-3 polyunsaturated fatty acids, mainly EPA and DHA, can inhibit the occurrence of breast cancer and the proliferation of cancer cells. Both have the effect of inhibiting rectal cancer, and DHA has a stronger anti-cancer effect [12]. Studies have proved that after the treatment of mice with eicosapentaenoic acid, the number of beneficial bacteria in the intestine increased, as a result, the number of proliferative cells decreases, the number of tumor cells increases, and apoptosis occurs, and a reduction in the volume of colon tumors [13]. In addition, according to the study yang et al., it was discovered that the composition of PUFAs differed between normal and cancer tissues of colorectal cancer patients. This indicates that PUFA metabolism plays an important role in the process of tumor formation in colorectal cancer [14]. Both EPA and EHA can reduce the resistance to anti-tumor drugs such as gastric cancer, bladder cancer, and uterine cancer. At

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high concentrations, they can inhibit the production of abnormal glands on the large intestine membrane and inhibit their growth. It can be seen that DHA and EPA are effective in inhibiting the occurrence and transformation of swelling and pain Migration and decrease of its growth rate. N-3 PUFA may indirectly change the production of intracellular lipid second messengers by changing the composition of tumor cell membrane phospholipids, and inhibiting the metabolism of n-6 PUFA in vivo: at the same time, it changes the antigenicity of the cell surface, so that tumor cells lose the immune escape mechanism; and it makes chemotherapy drugs easy to accumulate in tumor cells, playing a role of chemotherapy sensitization, and then inhibiting tumor cell proliferation. Whether n-3 PUFA regulates the transcription and expression of tumor-related genes through the second messenger pathway or other pathways remains to be studied.

4.2.2. Protect vision. PUFA is an important component of the cell membrane, which determines cell structure and function. Studies have shown that DHA plays an important role in the function of membrane, especially in retinal and neuronal tissues. Loss of n-3 PUFA results in the loss of DHA from the outer laminar phospholipids of the brain and retina, which is replaced by 22:5 n-6 PUFA. This small change in phospholipid structure is sufficient to cause loss of memory, loss of learning ability, and destruction of vision. Eileen Birch of the Southwest Texas Retinal Foundation found that infants and young children who were fed with the DHA formula had a significantly better vision after one year of age than those who were fed without it.

4.2.3. Anti-inflammatory effect. Inflammation is a non-specific response to trauma and microbial infection, resulting in symptoms such as redness, swelling, pain, and so on. This is due to the activation of macrophages and leukocytes. Activated macrophages produce a range of cytokines such as tumor necrosis factor (TNF) and interleukin (IL). This process is mediated by eicosanoids such as prostaglandin E2 and leukotrienes produced by AA metabolism. Eicosanoids derived from n-3 series can reduce the inflammatory response. At the same time, EPA and DHA could inhibit the production of interleukins, IL and TNF. Therefore, n-3 series PUFAs play an anti-inflammatory role by inhibiting AA metabolism and scavenging eicosanoid products of AA.

4.2.4. Reduces the effect of cholesterol. The elevation of serum cholesterol and triglycerides is one of the important factors that induce cardiovascular diseases. N-3 PUFA can reduce serum cholesterols and triglycerides, but n-6PUFA has no such function. This effect was dose dependent. Daily intake of EPA 0.21 g and DHA 0.12 g significantly reduced serum triglycerides in patients with hyperlipidemia [15]. This may be due to the inhibition of the synthesis of fatty acids and triglycerides in the liver by n-3 PUFA: inhibition of hepatic very low overall density lipoprotein secretion and synthesis; n-3 PUFA suppresses the synthesis of lipoprotein B in a less density lipoprotein, accelerates the clearance of VLDL residues in surrounding tissues and the liver, and prevents VLDL conversion [16].

4.2.5. Regulate enzyme transcription. N-3 PUFA can regulate the transcription and expression of some enzymes related to fat metabolism. Animal studies showed that feeding PUFAs enriched with 20C and 22C significantly increased the expression of genes involved in higher rate of fat oxidation. Previously, the expression of several genes has been found to be regulated by PUFA, such as p-coding fatty acid synthase, glycolytic enzyme, L. The expression of pyruvate kinase, interleukin and other genes was inhibited, and the expression of genes encoding fatty acid oxidase was induced [16].

4.2.6. Prevention and treatment of heart disease. A growing body of evidence suggests that n-3 PUFA has a significant protective effect against fatal cardiovascular disease. This is because n-3 PUFA can prevent platelet agglutination and anti-arrhythmia, reduce the tendency of blood clot formation, prevent vascular embolism, and greatly reduce the risk of heart disease caused by myocardial infarction. A low dose of n-3 PUFA(20mg/kg/d) per day can be used as a preventive measure [17].

5. Conclusion

Polyunsaturated fatty acids and their own derivatives play a very significant role in maintaining intestinal health, especially in fighting gut-related diseases and improving intestinal health and directly or indirectly affecting the balance of intestinal microecology. In the gut, not only polyunsaturated fatty acids derived from food intake, but the majority of the gut microbes also have synthetic polyunsaturated fatty acid metabolic pathways, and part of the gut microbes can through a series of transformation mechanisms polyunsaturated fatty acids be converted to have special structure and physiological function of rare fatty acids, such as hydroxy fatty acids, etc. These fatty acids play a variety of functions in the body including anti-cancer, anti-inflammatory, immune regulation, and metabolic regulation. This article elucidates the mechanism and function of fatty acid transformation, and also describes the diseases treatment executed by fatty acids, which provides new ideas for future research on the mechanism of intestinal diseases and new methods for the prevention and treatment of related diseases.

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