

# Development of Functional Probiotics Candy Using Dark Chocolate

Arti S. Shinde <sup>1</sup>, *Shraddha institute of Pharmacy, Kondala Zambre, Washim 444505.*

Dr. Swati P. Deshmukh <sup>2</sup>, *Principal, Department of Pharmacology Shraddha Institute of Pharmacy, Kondala Zambre, Washim 444505.*

Mr. Aditya P. Bhise <sup>3</sup>, *Lecturer, Shraddha Institute of Pharmacy, Kondala Zambre, Washim 444505.*

\*Corresponding Author - Arti S. Shinde

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**Abstract:** This study looks into making a probiotic candy that works well using dark chocolate as a way to deliver the probiotics. The digestive system is key for breaking down food, supporting the immune system, and controlling metabolism. Keeping a healthy balance of gut bacteria is important for overall health. Probiotics are good bacteria that help restore that balance and improve health. However, keeping these probiotics alive during processing and storage is difficult. This study uses dark chocolate as a non-dairy option to carry probiotics because it has plenty of polyphenols, fats, and antioxidants that help protect the probiotics. A mix was made with cocoa powder, cocoa butter, oats powder, milk powder, honey, a sugar substitute, salt, and probiotic capsules. The candy was tested for its physical and chemical properties, taste, and how well it stays stable. The results showed it was well-liked, stable, and had good potential for keeping the probiotics alive. The study says that a probiotic candy made with dark chocolate could be a good functional food for better gut health.

**Keywords:** Probiotics, dark chocolate, functional food, gut microbiota, probiotic stability, nutraceuticals, and sensory evaluation

## 1.Introduction

The gastrointestinal tract is a complex system that not only helps with digestion but also plays a role in immune regulation and metabolic processes. It is home to a diverse community of microorganisms known as the gut microbiota, which is essential for nutrient absorption, immune support, and defense against harmful pathogens. When this microbial balance is disrupted, it can lead to various health issues such as obesity, inflammatory bowel disease, and metabolic disorders. Probiotics are live microorganisms that offer health benefits when consumed in sufficient amounts. Common probiotic strains include Lactobacillus, Bifidobacterium, and Bacillus. These beneficial bacteria help improve gut health, strengthen the immune system, and support metabolic functions. Traditional methods of delivering probiotics, such as capsules and tablets, often struggle to maintain the viability of the live microorganisms. As a result, researchers are looking for alternative delivery methods, such as functional foods. Dark chocolate has shown potential as a suitable carrier for probiotics due to its high antioxidant content, protective lipid matrix, and prebiotic-like properties. This study aims to develop a probiotic-enriched dark chocolate candy.

## Gut Anatomy and Physiology

The gastrointestinal tract is a complex system that helps with digestion, absorbing nutrients, producing substances, and supporting the immune system, all of which are essential for overall health [1]. Structurally, it starts at the mouth and ends at the anus, consisting of several parts like the esophagus, stomach, small intestine, and large intestine. Each

part has its own unique structure and function [2,3]. Together, these sections work well with each other to break down food, take in nutrients, manage interactions with bacteria, and keep a balance between the body and the microbes living inside it [4].

## 1. Structural Organization of the Gastrointestinal Tract

The gastrointestinal tract is structured into four main layers, the mucosa, submucosa, muscularis externa, and serosa [5,6]. The mucosa is the innermost layer, made up of epithelial cells, lamina propria, and muscularis mucosae. Its main job is to absorb nutrients and secrete substances, and it's crucial for keeping harmful microbes from entering the body [7,8]. The submucosa is made of connective tissue, blood vessels, lymphatic vessels, and the submucosal (Meissner's) nerve plexus, which helps control secretion and blood flow [9]. The muscularis externa has two layers of muscle circular and longitudinal that help push food through the intestines with peristaltic movements [10]. The outer layer, called the serosa or adventitia, acts as a protective covering that connects the gut to nearby tissues [11].

## 2. The Small and Large Intestine

The small intestine is about six to seven meters long and is split into three parts: the duodenum, jejunum, and ileum [12]. It's the main place where food is broken down and nutrients are taken in. The inside has folds, villi, and microvilli, collectively called the brush border, which greatly increases the surface area for absorption [13,14]. There are different types of specialized cells in the small intestine, such as enterocytes for absorbing nutrients, goblet cells that produce mucus, enteroendocrine cells that release hormones, and Paneth cells that secrete antimicrobial peptides [15]. Tight junctions between the epithelial cells help control what can pass through, allowing nutrients to be absorbed while keeping harmful pathogens out [16,17]. The large intestine, which is about 1.5 meters long, is made up of three main parts: the cecum, colon, and rectum [18]. Its main job is to reabsorb water and electrolytes, break down any leftover carbohydrates using gut microbes, and produce short-chain fatty acids (SCFAs) [19,20]. The colon has deep pockets called crypts that contain a lot of goblet cells. These cells make mucus, which forms two layers an outer layer that helps support good bacteria and an inner layer that is mostly free of microbes [21,22]. This mucus layer acts as the first defense against harmful bacteria in the gut [23].

## 3. Physiological Functions

The functioning of the gastrointestinal system combines mechanical, chemical, nerve, and microbial activities. In the stomach, special glands produce hydrochloric acid and pepsinogen, which start breaking down proteins and kill bacteria [24]. The highly acidic environment in the stomach (pH 1.5–3.5) changes the structure of proteins and activates pepsin, while also stopping most of the bacteria you eat from surviving [25]. When the partly digested food, called chyme, enters the duodenum, bile from the liver helps break down fats, and enzymes from the pancreas continue digesting proteins, carbohydrates, and fats [26]. Peristalsis, controlled by the enteric nervous system (ENS), moves food through the intestines smoothly and effectively [27]. In the small intestine, nutrients are absorbed using different transport methods, while the colon mainly recovers water, salts, and helps break down undigested foods [28]. The fermentation of dietary fibers by gut bacteria produces SCFAs like acetate, propionate, and butyrate. These SCFAs provide energy for the cells in the colon and help control how the body uses fats and sugars [29,30]. Butyrate, especially, helps keep the lining of the colon healthy by encouraging new cell growth and keeping the connections between cells strong [31].

## 4. Gut-Associated Lymphoid Tissue and Immune Function

The gut is the body's largest immune organ, containing nearly 70% of all immune cells [32]. The gut-associated lymphoid tissue (GALT) includes parts like Peyer's patches, mesenteric lymph nodes, and isolated lymphoid follicles, which are key to mucosal immunity [33]. Specialized cells called microfold (M) cells collect antigens from the gut lumen

and pass them to antigen-presenting cells such as dendritic cells and macrophages located in the lamina propria [34]. These cells help coordinate immune responses by encouraging the production of immunoglobulin A (IgA) and by activating regulatory T cells (Tregs), which help the body tolerate harmless bacteria and food antigens [35].

## 2. Aim and Objectives

**Aim :** To create a functional probiotic candy made with dark chocolate.

### Objectives :

- To choose the right probiotic strain
- To make a probiotic dark chocolate candy
- To check the physical and chemical properties
- To compare it with regular probiotic products

## 3. Materials and Methods

### 3. Materials :

- Cocoa powder
- Cocoa butter
- Milk powder
- Oats powder (prebiotic source)
- Honey
- Sugar-free sweetener
- Sodium chloride
- Probiotic capsule (VIBACI)

## 4. Drug profile :

**Coco powder:** Cocoa powder comes from the seeds of the *Theobroma cacao* plant, after the cocoa butter has been removed. It is part of the Malvaceae plant family. It is also known by other names like cocoa, cacao, chocolate powder, and cocoa mass. The main areas where cocoa is grown are in West Africa, especially Ghana and the Ivory Coast, as well as in parts of South America and certain regions of India, such as Kerala, Karnataka, and Tamil Nadu. Chemically, cocoa powder includes important substances like alkaloids, with theobromine being the main one, along with a small amount of caffeine.

It also contains flavonoids such as catechins and epicatechins, which give it antioxidant qualities. It also has a little bit of fat in the form of cocoa butter, along with proteins, carbohydrates, and essential minerals like magnesium and iron.

In terms of appearance, cocoa powder is a fine, dark brown powder that has a nice chocolate smell and a bitter taste.

From a medical point of view, cocoa has several benefits.

It acts as an antioxidant, helps protect the heart, works as a mild stimulant because of the alkaloids it contains, and can also improve mood.

Cocoa powder is often used as a flavoring in many foods and is a key ingredient in making sweets. It is also appreciated for its health benefits, especially for supporting heart health and acting as a natural antioxidant.

**Oats powder :** Oats powder comes from the dried seeds of the plant *Avena sativa*, which is part of the grass family called Poaceae. It's also known by names like oat, oatmeal, oat flour, and common oat. Oats are grown in many places, including Europe, North America, and parts of India such as Punjab, Haryana, and Himachal Pradesh.

From a chemical point of view, oats are mostly made up of carbohydrates, especially starch, and have a lot of dietary fiber, mainly beta-glucan.

This fiber is important for many of the health benefits oats provide. They also contain proteins like avenin, fats in the form of fatty acids, and essential vitamins from the B-complex group. Oats also have important minerals such as iron, magnesium, and zinc.

In terms of appearance, oats powder is a fine, light brown or cream-colored powder.

It has a mild smell and a slightly sweet, bland taste.

When it comes to health benefits, oats have properties that help lower cholesterol levels.

They also support gut health by acting as a prebiotic, which means they help good bacteria in the intestines grow. Oats are also rich in antioxidants and help with digestion.

Because of these health benefits, oats powder is often used to improve digestion, lower cholesterol, and support a healthy gut.

It is also used in various dietary supplements and health-related food products.

**Milk powder:** Milk powder is made by evaporating and drying milk from cows (*Bos taurus*) or buffaloes. It is considered a dairy product since it comes from animals. People also call it dried milk, powdered milk, or dehydrated milk. It is produced in many countries around the world, with big amounts made in places like India, the United States, Europe, and Australia.

On the chemical side, milk powder has important nutrients like proteins, which include casein and whey, carbohydrates mainly in the form of lactose, and fats known as milk fat.

It is also rich in vitamins such as A, D, and B-complex, along with minerals like calcium and phosphorus.

In terms of appearance, milk powder looks like a fine, white or cream-colored powder.

It has a smell that is similar to milk and a slightly sweet taste.

From a nutrition and health standpoint, milk powder gives the body energy and essential nutrients.

It is especially good for bone health because of its high calcium content and also helps with growth and development.

Milk powder is used as a supplement for nutrition and is included in many food products.

It is often found in baby foods and other dietary items because of its high nutritional value.

**Honey:** Honey is a natural sweet substance made by honeybees, especially the *Apis mellifera* species, from the nectar of flowers. It is considered an animal-origin product and is known by many names such as Madhu, bee honey, *Apis* honey, and honeydew. It is produced in many parts of the world, with large amounts coming from countries like India, China, the USA, and various parts of Europe.

Chemically, honey is mostly made up of sugars, especially fructose and glucose.

It also includes important enzymes like invertase and diastase, organic acids like gluconic acid, and vitamins such as the B-complex group and vitamin C. It also contains essential minerals like calcium and potassium, along with antioxidants like flavonoids, which help give it its health benefits.

In terms of appearance, honey is a thick liquid that can range in color from light yellow to dark brown.

It has a pleasant smell and a sweet taste that is unique to it.

In terms of its medicinal properties, honey has several helpful effects.

It has antimicrobial, antioxidant, and anti-inflammatory qualities and is well-known for its role in helping wounds heal.

Honey is often used as a natural sweetener and is also a popular remedy for coughs and colds.

It can provide a quick burst of energy and is used in treating wounds because of its soothing and protective qualities.

**Sugar free:** Sugar-free sweeteners can be derived from natural plant sources or man-made chemical compounds. Common natural sources include the stevia plant, while widely used synthetic options are aspartame, saccharin, and sucralose. These sweeteners are classified as non-nutritive or low-calorie and are often called artificial sweeteners, sugar

substitutes, or low-calorie sweeteners. Stevia is mainly grown in regions like South America and India, while synthetic sweeteners are produced around the world.

Chemically, natural sweeteners like stevia contain compounds called steviol glycosides as their active components, while synthetic sweeteners consist of aspartame, saccharin, and sucralose.

These sweeteners have very little or no carbohydrates, making them good alternatives to sugar.

In terms of appearance, sugar-free sweeteners are usually available in the form of white powders, granules, or tablets.

They are generally odorless and have a sweet taste that is often stronger than sugar.

From a pharmacological perspective, these sweeteners are non-glycemic, meaning they do not significantly raise blood sugar levels.

They are also low in calories, making them especially suitable for people with diabetes or those watching their calorie intake.

Sugar-free sweeteners are commonly used as sugar substitutes in a variety of food and beverage products.

They are often included in diabetic diets and are also used in food and pharmaceutical products to add sweetness without adding calories.

**NaCl:** Sodium chloride is an inorganic compound found in nature, such as in seawater and rock salt deposits, and is commonly known as halite. It is considered a mineral formed from non-living sources and is also referred to by names like common salt, table salt, rock salt, and sodium chloride. This compound is obtained from coastal areas by evaporating seawater and is also extracted from rock salt mines in places like India, the United States, and various European countries.

From a chemical perspective, sodium chloride is made up of sodium ions ( $\text{Na}^+$ ) and chloride ions ( $\text{Cl}^-$ ), which are important for several functions in the human body.

In terms of appearance, sodium chloride forms white or colorless crystals.

It has no smell, a distinct salty taste, and is typically found as a crystalline powder.

In terms of its medical importance, sodium chloride helps maintain the balance of electrolytes in the body and controls the pressure of fluids.

It is also necessary for proper nerve function and muscle movement.

Sodium chloride is frequently used in oral rehydration solutions to help restore fluids and electrolytes.

It is also used as a flavor booster in food and is essential for keeping the body's fluid levels balanced.

**Probiotics capsule VIBACI:** This product is a type of probiotic and prebiotic mix, also called a probiotic capsule, gut health supplement, or live microbial formula. It's made by USV Pvt. Ltd. And includes helpful probiotic bacteria along with prebiotics that help these microbes grow. The mix has different types of bacteria, like *Lactobacillus sporogenes*, which is also called *Bacillus coagulans*, *Streptococcus faecalis*, now known as *Enterococcus faecalis*, *Clostridium butyricum*, and *Bacillus mesentericus*.

The product comes from live good bacteria, mostly ones that can form spores.

These spores make the bacteria stronger and able to survive heat and harsh conditions. The product is in capsule form, and the inside is a pale white or light cream-colored powder made up of live bacterial cells.

When it comes to its health benefits, this probiotic helps bring back the right balance of bacteria in the gut, aids digestion, and boosts the immune system.

It also helps make helpful substances like short-chain fatty acids, which are important for gut health.

Doctors use this product to help with issues like diarrhea, especially when it happens after taking antibiotics, irritable bowel syndrome, other digestion problems, and when gut bacteria are out of balance.

There are some things to keep in mind when using this product.

It should be stored away from high temperatures, especially above  $40^\circ\text{C}$ , to keep the bacteria alive. People with weak immune systems should use it carefully.

**Cocoa butter:** Cocoa butter is derived from the seeds of the *Theobroma cacao* plant, which is part of the Malvaceae family. It is also known by other names such as cocoa butter and *Theobroma* oil. Chemically, it is mainly composed of triglycerides, which include fatty acids like oleic acid, stearic acid, and palmitic acid, giving it its distinct characteristics. Physically, cocoa butter is a pale yellow, smooth substance with a melting point between 30 and 34 degrees Celsius, which means it melts at body temperature.

From a pharmacological standpoint, cocoa butter functions as an emollient and protective agent, helping to soften and shield the skin.

It is widely used in the production of chocolate, cosmetics, and as a base for suppository preparations.

In both pharmaceutical and food applications, cocoa butter is important because it provides structure, gives a smooth texture, and helps in the solidification of the final product.

## **5. Formulation :**

The formulation table is central to the research because it shows how each ingredient contributes to the overall makeup and function of the probiotic chocolate candy.

### **1. Cocoa Powder (6 g)**

Cocoa powder serves as the main flavor and functional component.

#### **It gives:**

A strong chocolate flavor

Antioxidants (like polyphenols)

A gentle stimulant effect

It also adds to the health benefits by supporting heart health and helping to neutralize harmful free radicals.

### **2. Cocoa Butter (9 g)**

Cocoa butter is the main fat used, which helps in:

Creating the right texture and structure of the chocolate

Providing a smooth and pleasant mouthfeel

Ensuring the chocolate sets properly with a satisfying snap

It also forms a protective layer of fat, which helps in:

Keeping the probiotics safe from heat, moisture, and air

This protection helps the probiotics stay alive and effective.

### **3. Milk Powder (6 g)**

Milk powder helps improve:

Nutritional value (like proteins and calcium)

Creamy texture

Taste

It also supports the growth of probiotics because of lactose and proteins, which help them grow.

### **4. Oats Powder (3 g)**

Oats powder works as a prebiotic because of its  $\beta$ -glucan content.

#### **Functions:**

Helps probiotics grow

Improves gut health

Adds more fiber

This combination of probiotics and prebiotics creates a synbiotic effect, making the product more effective overall.

### **5. Honey (2.4 g)**

Honey serves as:

A natural sweetener

A binding agent

An antimicrobial and antioxidant

It also improves:

Taste

Texture

Shelf life

Honey also has some prebiotic properties that support probiotic activity.

#### **6.Sugar-Free (0.6 g)**

Sugar-free sweetener is used to:

Add sweetness without increasing sugar levels

Make the product safe for people with diabetes

It improves how people like the product without harming the probiotics.

#### **7.Sodium Chloride (0.15 g)**

A small amount of NaCl is added to:

Enhance flavor

Balance out sweetness

It also helps keep the body's electrolyte levels steady, though it has little effect on the product's stability.

#### **8.Probiotic Capsule (0.3 g)**

This is the main active ingredient in the product.

It contains beneficial bacteria like:

Lactobacillus

Bacillus coagulans

#### **Functions:**

Improves gut health

Boosts immunity

Helps restore balance in the gut microbiome

Probiotics are added at a low temperature (<40°C) to keep them alive and effective.

#### **6. Conclusion**

This study successfully created a functional probiotic candy using dark chocolate as a new way to deliver probiotics.

The candy was made with cocoa powder, cocoa butter, milk powder, oats powder, honey, a sugar substitute, sodium chloride, and probiotic bacteria. The choice of these ingredients was based on their nutritional benefits, how well they work together, and their ability to support probiotic survival. The final product had good physical and chemical properties, including a smooth look, pleasant texture, tasty flavor, and proper melting point. People who tasted it found it enjoyable and acceptable. The product stayed stable when stored properly, without major changes in quality. The probiotics were kept alive through controlled temperature conditions, ensuring they remained effective. The dark chocolate's high fat content helped protect the probiotics from environmental stress. Also, the oats powder added prebiotic benefits, making the candy more nutritious and functional.

In conclusion, dark chocolate is a good non-dairy option for carrying probiotics, offering both health benefits and therapeutic value. This probiotic candy is a promising functional food that could help improve gut health and make it easier for people to take probiotics regularly.

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**7.References**

- [1] Hemarajata H, Versalovic J. Effects of probiotics on gut microbiota: mechanisms of intestinal immunomodulation and health benefits. *Clin Microbiol Rev.* 2012;25(4):655–670.
- [2] Hill C, Guarner F, Reid G, et al. A review of dose-responses of probiotics in human studies. *Benef Microbes.* 2017;8(2):143–161.
- [3] Cristofori F, Dargenio VN, Dargenio C, Miniello VL, Barone M, Francavilla R. The role of probiotics and prebiotics in inducing gut immunity. *Front Immunol.* 2021;12:578386.
- [4] Collado MC, Isolauri E, Laitinen K, Salminen S. Influence of mother’s intestinal microbiota on gut colonization in the infant. *J Pediatr Gastroenterol Nutr.* 2010;51(5):507–512.
- [5] Kumar M, Salminen S. Immune-boosting functional foods and their mechanisms: a critical evaluation of probiotics and prebiotics. *Food Sci Technol.* 2019;116:108641.
- [6] Heczko PB, Strus M, Kochan P. Analyzing ordered responses: A review of probiotic clinical trials. *J Physiol Pharmacol.* 2006;57(Suppl 9):5–12.
- [7] Wang Y, Wu Y, Wang Y, Xu H, Mei X, Yu D, Wang Y, Li W. Probiotics regulate gut microbiota: An effective method to improve immunity. *Molecules.* 2020;25(4):830.
- [8] Sharma M, Shukla G, Chauhan M. Probiotics: Sources, isolation, and industrial application. *Food Biotechnol.* 2022;36(3):189–203.
- [9] Azad MAK, Sarker M, Li T, Yin J. Probiotic species in the modulation of gut microbiota: An overview. *BioMed Res Int.* 2018;2018:9478630.
- [10] Chawla S, Saxena V, Sharma A. Functional food applications of probiotics: A review. *J Food Sci Technol.* 2020;57:3613–3625.
- [11] Forssten SD, Sindelar CW, Ouwehand AC. The role of probiotics in intestinal barrier function and host health. *Curr Opin Clin Nutr Metab Care.* 2011;14(6):586–591.
- [12] Li Y, Dong J, Qiu Z, et al. Probiotics and mucosal immunity. *Front Cell Infect Microbiol.* 2021;11:609722.
- [13] Markowiak-Kopec P, Śliżewska K. Probiotics and prebiotics in human nutrition and health. *Nutrients.* 2021;13(3):933.
- [14] Wendel M. *Frontiers in Microbiology: Gut microbiota modulation through functional foods.* *Front Microbiol.* 2022;12:818468.
- [15] Sušković J, Kos B, Beganović J, Pavunc AL, Habjanič K, Matošić S. Sources, isolation, characterization and evaluation of probiotics. *Food Technol Biotechnol.* 2010;48(3):217–227.
- [16] D’Argenio V, Salvatore F. The role of the gut microbiota in human health: an overview. *Front Microbiol.* 2015;6:163.
- [17] Papadimitriou K, Zoumpopoulou G, Foligné B, et al. Discovering probiotic microorganisms: in vitro, in vivo, genetic and omics approaches. *Front Microbiol.* 2015;6:58.
- [18] Antinozzi C, et al. A review of the relationship between probiotics and human gut health. *Nutrients.* 2022;14(9):3323.
- [19] Fredua-Agyeman M, Gaisford S. Probiotics and prebiotics in mucosal immunity. *Front Microbiol.* 2016;7:684.
- [20] Grönlund MM, Arvilommi H, Kero P, Lehtonen OP, Isolauri E. Influence of early gut microbiota on infant immune development. *J Pediatr Gastroenterol Nutr.* 2000;31(1):21–26.
- [21] Laitinen K, Poussa T, Isolauri E. Probiotics in maternal and infant health. *J Nutr.* 2010;140(11):2081–2088.
- [22] Lahtinen SJ, Gueimonde M, Ouwehand AC, Reinikainen JP, Salminen SJ. Mechanisms of intestinal colonization by probiotics. *Curr Opin Biotechnol.* 2009;20(2):190–196.
- [23] Mikami K, Takahashi H, Kimura M. Bifidobacterium and the gut ecosystem. *Int J Food Microbiol.* 2009;132(1):79–88.
- [24] Zuccotti GV, Meneghin F, Aceti A, Barone G, Callegari ML, et al. Revisione sui probiotici: use in pediatric health. *Ital J Pediatr.* 2011;37:45.
- [25] *Biomedicines Review. Biomedicines-10-00510: Probiotics and human health. Biomedicines.* 2022;10(5):510.

- [26] Informit Report. Functional evaluation of probiotic species. Informit Health Database. 2019.
- [27] Probiotics from an Industrial Perspective. Industrial production and application of probiotics. 2011.
- [28] Yogurt as Probiotic Carrier Food. Use of yogurt as a carrier for probiotics. Dairy Sci Technol. 2020;100(2):85–97.
- [29] 1-s2.0-S0362028X22015629-main. Functional probiotic formulations and dose response. Food Chem. 2022.
- [30] MCOES Article. Immune boosting effects of probiotics. Med Chem Open Educ Sci. 2018;5(11):S9.
- [31] Christensen HR, Frokiaer H, Pestka JJ. Probiotic function and intestinal adhesion. Am J Clin Nutr. 2006;83(6):1036–1044.
- [32] 2441-Sušković J, et al. Characterisation of lactic acid bacteria for probiotic use. Food Technol Biotechnol. 2010;48(3):217–227.
- [33] Bernatek M, et al. Factors determining effective probiotic activity: Evaluation of survival and antibacterial activity of selected probiotic products using an in vitro study. Nutrients. 2022;14(3323).
- [34] El Far M, et al. Characterization of probiotics isolated from dietary supplements and evaluation of metabiotic-antibiotic combinations against antibiotic-resistant pathogens. BMC Complement Med Ther. 2024;24:303.
- [35] Sekirov I, Russell SL, Antunes LCM, Finlay BB. Gut microbiota in health and disease. Physiol Rev. 2010;90(3):859–904.
- [36] Zhang YJ, Li S, Gan RY, Zhou T, Xu DP, Li HB. Impacts of gut bacteria on human health and diseases. Int J Mol Sci. 2015;16(4):7493–7519.
- [37] Afzaal M, Saeed F, Shah YA, Hussain M, Rabail R, Socol CT, Hassoun A, Pateiro M, Lorenzo JM, Rusu AV, Aadil RM. Human gut microbiota in health and disease: Unveiling the relationship. Front Microbiol. 2022;13:999001.
- [38] Antinozzi C, et al. Functional modulation of gut ecosystem through probiotics and diet. Nutrients. 2022;14(3323).
- [39] Papadimitriou K, et al. Frontiers in Microbiology: Probiotics and immunity. Front Microbiol. 2015;6:58.
- [40] Wendel M, et al. Frontiers: Gut microbiota modulation through functional foods. Front Microbiol. 2022;12:818468