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PROBIOTICS AND ITS EFFECT ON HUMAN HEALTH-A REVIEW

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ABSTRACT

Probiotics are live microorganisms that confer health benefits when consumed in adequate amounts. Probiotics have been widely known for its beneficial effects on human health. They consist of different types of foods for many decades. Fermentation, is an old method that has been used to improve nutritional value and food preservation. Fermented dairy products and vegetables have been suitable means for consumption of probiotics. In Africa, many of the seasoning agents are products of alkaline fermentation of plant-seed, legume based products and in some cases, animal proteins and seafood. Consumption of probiotics have shown antimicrobial, anti-inflammatory, and cholesterol-lowering effects due to its symbiotic blend of bacteria and yeast. Probiotics contain antioxidants to protect the body from oxidative stress and chronic diseases. Probiotics support microbial diversity in the gut, enhances lactose digestion, reduce diarrhoea, aids digestion and improves lactose tolerance. Various types of bacteria are generally contained in probiotics, they are Lactobacillus, Streptococcus, Lactococcus, Enterococcus and Bifidobacterium. Although it has seemed that dairy products were the primary source of probiotic bacteria until now, the popularity of fruit and vegetable juices is increasing more rapidly. Previous studies have revealed some indigenous Nigerian local foods, beverages, staples and spices like pap, garri, palm wine, iru, ugba, etc, that we consume are actually excellent sources of probiotics. Probotics have been proposed as preventive and therapuetic measures, in order to restore the healthy composition and function of the gut microbiome. By incorporating probiotics into our diet and lifestyle, we can take a proactive approach to maintaining our health and preventing diseases.

Introduction

The human body is a home to trillions of microorganisms that play a crucial role in maintaining overall health and well-being (Savage, 1977; Hill, 2010). The gut microbiome, in particular, is a complex ecosystem that is composed of a diverse range of microorganisms, including bacteria, viruses, and fungi (Qin *et al.,* 2010). Probiotics are live microorganisms that confer a health benefit on the host, and have been shown to have a positive impact on gut health and immune function (Goldin and Gorbach,1992 ; FAO/WHO, 2002).

The concept of probiotics dates back to the early 20th century, when Russian scientist Elie Metchnikoff proposed that the consumption of live microorganisms could have a positive impact on human health (Metchnikoff, 1907). Since then, numerous studies have demonstrated the potential health benefits of probiotics, including improved digestion, enhanced immune function, and reduced symptoms of irritable bowel syndrome (IBS) (O'Toole and Cooney, 2008; McFarland, 2010; Kondo *et al.,* 2013).

The most commonly used probiotic microorganisms are *Lactobacillus* and *Bifidobacterium* species, which are found in fermented foods and are also available as dietary supplements (FAO/WHO, 2002). Other probiotic microorganisms, such as *Saccharomyces boulardii* and *Streptococcus thermophilus*, are also used in some probiotic products (McFarland, 2010).

Fermentation which is the breaking down of complex organic compounds through biochemical transformations is an old-age food processing technique known to enhance the value of food (Romulo and Surya, 2021). Fermented foods are generally produced using plant or animal ingredients in combination with fungi or bacteria which are either sourced from the environment, or carefully kept in cultures maintained by humans (Chamberlain, G. *et al* 1997). The food delivery vehicles for probiotics are products such as dairy, beverages, meats, and cereals (Aspri *et al.*, 2020). Studies have shown fermented products that contain lactic acid bacteria to include vegetables such as pickled vegetables (Breidt F. *et al*., 2013), kimchi (Oh C. K., *et al.,* 2004) and sauerkraut (Friedman Y *et al*., 2006), fermented cereal-fish-shrimp mixtures and fermented meats (National Academies Press (US). 1992), soy products such as tempeh (Moreno MR *et al*., 2002), miso, (Ehrlich S. D. May 24, 2011), and soy sauce, (Tanasupawat S. *et al*., 2002), dairy products such as yogurt, kefir, (Plessas S, *et al*., 2011) buttermilk (Shiby VK and Mishra HN, 2013).

Although it has seemed that dairy products were the primary source of probiotic bacteria until now, the popularity of fruit and vegetable juices is increasing more rapidly (Mojikon F. D. *et al*., 2022). Fruit and vegetables include polyphenol compounds, which are good providers of vitamins and minerals and have a very appealing profile for people of all ages (Amorim J. C. *et al.*, 2018 and Ilango S. *et al*., 2021). Also, previous studies have revealed some indigenous Nigerian local foods, beverages, staples and spices like pap, *garri*, palm wine, *iru*, etc, that we consume are actually excellent sources of probiotics (Adebolu *et al.,* 2007). This article is aimed at revealing the probiotics contained in the dairy products, fermented foods, fruits and vegetables and other Nigerian indigenous foods and their health benefits.

Probiotics

Probiotics are live microorganisms that confer health benefits when consumed in adequate amounts, particularly by improving or restoring gut flora (Hill *et al*., 2014). Probiotics are available in a variety of forms, including capsules, tablets, powders, and fermented foods such as yogurt and kefir (Goldin and Gorbach, 1992). The most commonly used probiotic microorganisms are *Lactobacillus* and *Bifidobacterium* species, which are frequently found in fermented foods and marketed as dietary supplements (Sanders *et al*., 2013). Additional probiotic strains such as *Saccharomyces boulardii* and *Streptococcus thermophilus* are also utilized in various commercial probiotic products (Hill *et al*., 2014).

Probiotics have been associated with several health benefits, including enhanced gastrointestinal function, modulation of the immune system, and mitigation of irritable bowel syndrome (IBS) symptoms (Ouwehand *et al*., 2002; Gibson *et al.*, 2017; Hemarajata and Versalovic, 2013). They have also been shown to have anti-inflammatory effects, improve mental health, and reduce the risk of certain diseases, such as obesity and type 2 diabetes (Dinan *et al.,* 2013; Slykerman *et al.,* 2017). The mechanisms by which probiotics exert their effects on human health are complex and multifaceted, and involve the modulation of the gut microbiome, the production of antimicrobial peptides, and the modulation of the immune system (Gill *et al.,* 2001; Isolauri *et al.,* 2001).

Prebiotics

Prebiotics are non-digestible food components, primarily fibers, that selectively stimulate the growth and/or activity of beneficial microorganisms in the gut, especially *Bifidobacterium* and *Lactobacillus* species (Slavin, 2013). Unlike probiotics, which are live microorganisms, prebiotics act as substrates to nourish these beneficial bacteria. Common dietary sources include asparagus, bananas, onions, garlic, leeks, and whole grains, particularly inulin, fructooligosaccharides (FOS), and galactooligosaccharides (GOS) (Markowiak & Śliżewska, 2017; Holscher, 2017).

Prebiotics are also available as dietary supplements in the form of powders, tablets, and capsules. These supplements are often incorporated into functional foods and beverages to promote gut health (Davani-Davari *et al*., 2019).

Since the prebiotic concept was first introduced, studies have consistently demonstrated benefits such as enhanced digestion, immune system modulation, and relief of symptoms associated with irritable bowel syndrome (IBS) and other gastrointestinal disorders (Bindels *et al*., 2015). One of the key mechanisms involves the fermentation of prebiotics in the colon, resulting in the production of short-chain fatty acids (SCFAs) like butyrate, acetate, and propionate, which are known to reduce inflammation and support the gut barrier (Morrison and Preston, 2016).

Beyond gut health, prebiotics may positively impact metabolic health, with evidence showing associations with improved lipid metabolism, reduced obesity risk, and even mental health benefits through the gut-brain axis (Cunningham *et al*., 2021). These effects are being actively explored in both healthy individuals and those with chronic conditions.

Types of prebiotics

Prebiotics, offers its own unique characteristics and benefits.

Inulin is one of the most common types of prebiotics which is a fructan that is found in a variety of plants, including chicory, artichokes, and asparagus (Roberfroid, 2007). Inulin has been shown to have a variety of health benefits, including improved gut health, enhanced immune function, and reduced symptoms of irritable bowel syndrome (IBS) (Kolida *et al.,* 2007; Meyer and Stasse-Wolthuis, 2009).

Oligofructose is another type of prebiotic which is a short-chain fructan that is also found in a variety of plants, including chicory and artichokes (Gibson and Roberfroid, 1995). Oligofructose has been shown to have a variety of health benefits, including improved gut health, enhanced immune function, and reduced symptoms of IBS (Kolida *et al.,* 2007; Meyer and Stasse-Wolthuis, 2009)

Galacto-oligosaccharides (GOS), which are found in human milk and have been shown to have a variety of health benefits, including improved gut health and enhanced immune function (Boehm *et al.,* 2004).

Difference between probiotics and prebiotics

Probiotics and prebiotics are two closely related concepts that are often confused with each other. While they are related, they are distinct and have different functions in the body. Probiotics are live microorganisms that are similar to the beneficial microorganisms found in the human gut (FAO/WHO, 2002). They are available in a variety of forms, including capsules, tablets, powders, and fermented foods such as yogurt and kefir (Goldin and Gorbach, 1992). Probiotics have been shown to have a variety of health benefits, including improved gut health, enhanced immune function, and reduced symptoms of irritable bowel syndrome (IBS) (O'Toole and Cooney, 2008; McFarland, 2010; Kondo *et al.,* 2013).

On the other hand, prebiotics are non-digestible carbohydrates that serve as food for beneficial microorganisms in the gut, promoting their growth and activity (Gibson and Roberfroid, 1995). They are found in a variety of foods, including asparagus, bananas, onions, garlic, and whole wheat bread (Roberfroid, 2007). Prebiotics can also be taken as dietary supplements, which are available in various forms, including powders, capsules, and tablets (Macfarlane *et al.,* 2006). Prebiotics have been shown to have a variety of health benefits, including improved gut health, enhanced immune function, and reduced symptoms of IBS (Roberfroid, 2007; Macfarlane *et al.,* 2006).

One of the main differences between probiotics and prebiotics is their mechanism of action. Probiotics work by introducing live microorganisms into the gut, where they can colonize and exert their beneficial effects (FAO/WHO, 2002). Prebiotics, on the other hand, work by providing a food source for beneficial microorganisms that are already present in the gut, promoting their growth and activity (Gibson and Roberfroid, 1995). Another difference between probiotics and prebiotics is their stability and shelf life. Probiotics are live microorganisms that require specific storage and handling conditions to maintain their viability, whereas prebiotics are non-digestible carbohydrates that are more stable and

can be stored for longer periods of time (Macfarlane *et al.,* 2006).

In addition to their different mechanisms of action and stability, probiotics and prebiotics also have different health benefits. Probiotics have been shown to have a variety of health benefits, including improved gut health, enhanced immune function, and reduced symptoms of IBS (Kondo *et al.,* 2013; McFarland, 2010; O'Toole and Cooney, 2008). Prebiotics, on the other hand, have been shown to have health benefits that are more related to the promotion of beneficial microorganisms in the gut, such as improved gut health, enhanced immune function, and reduced symptoms of IBS (Roberfroid, 2007; Macfarlane *et al.,* 2006).

Human microbiome

The human microbiome is a complex ecosystem composed of trillions of microorganisms that live within and on the human body (Qin *et al.,* 2010). These microorganisms, including bacteria, viruses, fungi, and *archaea*, play a crucial role in maintaining human health and well-being (Savage, 1977). The human microbiome is estimated to consist of approximately 100 trillion microorganisms, with the majority residing in the gut (Qin *et al.,* 2010).

The gut microbiome is a diverse and dynamic ecosystem that is influenced by a variety of factors, including diet, lifestyle, and environmental exposures (Sonnenburg and Sonnenburg, 2014). The gut microbiome plays a crucial role in maintaining gut health, including the digestion and absorption of nutrients, the production of certain vitamins, and the maintenance of the gut barrier function (Cummings and Macfarlane, 1997). An imbalance of the gut microbiome, also known as dysbiosis, has been implicated in a variety of diseases, including inflammatory bowel disease, obesity, and mental health disorders (Cani *et al.,* 2012; Cryan and Dinan, 2012).

The human microbiome is not limited to the gut, but is also found on the skin, in the respiratory tract, and in the urogenital tract (Grice *et al.,* 2009). Each of these microbiomes plays a unique role in maintaining human health and preventing disease. For example, the skin microbiome plays a crucial role in maintaining skin health and preventing diseases such as acne and psoriasis (Grice *et al.,* 2009).

Healthy Gut Microbiome

A healthy gut microbiome is essential for maintaining overall health and well-being (Bunesova *et al*., 2023). The gut microbiome is composed of trillions of microorganisms that live in the gastrointestinal tract and play a crucial role in various physiological processes, including digestion, absorption of nutrients, and immune system function (Zhao *et al*., 2023). One of the primary benefits of a healthy gut microbiome is its ability to regulate the immune system and prevent disease (Fan and Pedersen, 2021). A healthy gut microbiome has been shown to stimulate the production of antibodies and activate immune cells, such as macrophages and T-cells, which are essential for fighting off infections (Dong *et al*., 2023).

In addition to its role in immune system function, a healthy gut microbiome has also been shown to play a crucial role in maintaining a healthy weight and preventing metabolic disorders, such as obesity and diabetes (López-Moreno *et al*., 2024). A healthy gut microbiome has been shown to regulate glucose metabolism and improve insulin sensitivity, which can help to prevent the development of metabolic disorders (López-Moreno *et al*., 2024). Furthermore, a healthy gut microbiome has also been shown to produce certain hormones, such as peptide YY and glucagon-like peptide-1, which can help to regulate appetite and satiety (Wang *et al*., 2023).

A healthy gut microbiome has also been shown to play a crucial role in maintaining mental health and preventing neurological disorders, such as anxiety and depression (Zhu *et al*., 2023). A healthy gut microbiome has been shown to produce certain neurotransmitters, such as serotonin and dopamine, which are essential for regulating mood and cognitive function (Zhu *et al*., 2023). Furthermore, a healthy gut microbiome has also been shown to regulate the gut-brain axis,

which is the bidirectional communication network between the gut and the brain (Zhu *et al*., 2023).

Effect of Unhealthy Gut Microbiome

An unhealthy gut microbiome, also known as dysbiosis, can have a profound impact on overall health and well-being (Fan and Pedersen, 2021). When the balance of the gut microbiome is disrupted, it can lead to a variety of negative consequences, including impaired immune function, increased inflammation, and altered metabolism (Dong *et al*., 2023). One of the primary effects of an unhealthy gut microbiome is impaired immune function, which can lead to increased susceptibility to infections and autoimmune diseases (Bunesova *et al*., 2023).

An unhealthy gut microbiome has also been linked to increased inflammation, which can lead to a variety of chronic diseases, including cardiovascular disease, type 2 diabetes, and obesity (López-Moreno *et al*., 2024). The gut microbiome plays a crucial role in regulating inflammation, and when the balance of the microbiome is disrupted, it can lead to increased production of pro-inflammatory cytokines and decreased production of anti-inflammatory cytokines (Wang *et al*., 2023). Furthermore, an unhealthy gut microbiome has also been linked to altered metabolism, which can lead to changes in glucose and lipid metabolism, and increased risk of metabolic disorders (López-Moreno *et al*., 2024).

In addition to its effects on immune function, inflammation, and metabolism, an unhealthy gut microbiome has also been linked to a variety of neurological and psychiatric disorders, including anxiety, depression, and autism spectrum disorder (Zhu *et al*., 2023). The gut-brain axis, which is the bidirectional communication network between the gut and the brain plays a crucial role in regulating mood and cognitive function, and when the balance of the gut microbiome is disrupted, it can lead to changes in brain function and behavior (Zhu *et al*., 2023).

Probiotic bacteria, foods and health benefits

Probiotics bacteria in dairy foods

Fermented dairy products, such as yogurt and kefir, are rich in probiotic bacteria, including *Lactobacillus acidophilus* (*L. acidophilus*), *Bifidobacterium bifidum* (*B. bifidum*), and *Streptococcus thermophilus* (*S. thermophilus*) (Wang *et al.,* 2020). These probiotic bacteria have been shown to have anti-inflammatory properties, reducing inflammation in the gut and promoting immune system function (Liu *et al.,* 2019). In addition to fermented foods, probiotic bacteria can also be found in other dietary foods, such as cheese and buttermilk. Cheese, for example, contains probiotic bacteria such as *Lactobacillus acidophilus* (*L. acidophilus*) and *Bifidobacterium bifidum* (*B. bifidum*) (Wang *et al.,* 2020). Buttermilk also contains probiotic bacteria such as *Lactobacillus acidophilus* (*L. acidophilus*) and *Streptococcus thermophilus* (*S. thermophilus*) (Wang *et al.,* 2020).

A study by Marco *et al*. (2021) emphasized that regular consumption of yogurt and kefir supports microbial diversity in the gut, enhances lactose digestion, and may reduce inflammation.
Kefir, in particular, has shown antimicrobial, anti-inflammatory, and cholesterol-lowering effects due to its symbiotic blend of bacteria and yeast (Leech *et al*., 2020).

Probiotics bacteria in fruits

Research has shown that fruits and vegetables contain probiotic bacteria. One of the most studied fruits in terms of probiotic content is the pomegranate. Pomegranate juice has been found to contain a range of probiotic bacteria, including *Lactobacillus plantarum, Lactobacillus pentosus,* and *Bifidobacterium bifidum* (Bialas *et al.,* 2020). These bacteria have been shown to have anti-inflammatory properties and improve gut health (Liu *et al.,* 2019).

Another fruit that has been found to contain probiotic bacteria is the apple. Apple juice has been found to contain a range of probiotic bacteria, including *Lactobacillus plantarum* and *Bifidobacterium bifidum* (Kumar *et al.,* 2020). These bacteria have been shown to have antimicrobial properties and improve gut health (Wang *et al.,* 2020). Berries, such as blueberries and raspberries, have also been found to contain probiotic bacteria. Berry extracts have been found

to contain a range of probiotic bacteria, including *Lactobacillus plantarum* and *Bifidobacterium bifidum* (Lee *et al.,* 2020). These bacteria have been shown to have anti-inflammatory properties and improve gut health (Liu *et al.,* 2019).

Probiotic bacteria in fermented Vegetables

Vegetables can also act as natural carriers of probiotics when fermented. Popular global examples include sauerkraut (fermented cabbage), kimchi (fermented spicy vegetables), and pickled cucumbers. Recent research showed that fermented vegetables like sauerkraut and kimchi harbor lactic acid bacteria such as *Lactobacillus plantarum* and *Leuconostoc mesenteroides,* which can improve intestinal barrier function and modulate inflammation (Park *et al*., 2021).

Fermented plant-based foods also support a diverse gut microbiome, which is essential for nutrient absorption and immune regulation. These foods serve as excellent non-pharmaceutical strategies for promoting gut health, especially when consumed as part of a balanced diet (Melini *et al*., 2019).

Probiotics bacteria in fermented foods

Another fermented food that is rich in probiotic bacteria is sauerkraut. Sauerkraut contains a range of probiotic bacteria, including L*actobacillus plantarum (L. plantarum), Lactobacillus brevis* (*L. brevis*)*, and Leuconostoc mesenteroides* (*L. mesenteroides*) (Lee *et al.,* 2020). These bacteria have been shown to have antimicrobial properties, inhibiting the growth of pathogens such as *Escherichia coli and Staphylococcus aureus* (Wang *et al.,* 2020).

Kimchi, a fermented Korean dish, is also rich in probiotic bacteria. Kimchi contains a range of probiotic bacteria, including *Lactobacillus plantarum* (*L. plantarum*)*, Lactobacillus brevis* (*L. brevis*)*, and Leuconostoc mesenteroides* (*L. mesenteroides*) (Lee *et al.,* 2020). These bacteria have been shown to have anti-inflammatory properties, reducing inflammation in the gut and promoting immune system function (Liu *et al.,* 2019).

Miso, a fermented Japanese soybean paste, is also a rich source of probiotic bacteria. Miso contains a range of probiotic bacteria, including *Lactobacillus plantarum* (*L. plantarum*) and *Aspergillus oryzae* (*A. oryzae*) (Wang *et al.,* 2020). These bacteria have been shown to have antimicrobial properties, inhibiting the growth of pathogens such as *E. coli* and *S. aureus* (Wang *et al.,* 2020).

Tempeh, a fermented Indonesian soybean product, is also a rich source of probiotic bacteria. Tempeh contains a range of probiotic bacteria, including *Rhizopus oligosporus* (*R. oligosporus*) and *Aspergillus oryzae* (*A. oryzae*) (Wang *et al.,* 2020). These bacteria have been shown to have anti-inflammatory properties, reducing inflammation in the gut and promoting immune system function (Liu *et al.,* 2019).

Probiotics bacteria in Nigeria indigenous foods

Fermented foods can be classified in different ways based on the type of substrate, microorganisms involved in the fermentation and even the processing methods. Based on the substrate or raw material from which they are manufactured (Steinkraus KH., 1997) foods derived by fermentation can be classified into five main categories namely:

Starchy foods such as root tubers (cassava), examples: garri, akpu; cereals (maize, sorghum, millet), examples: Ogi (akamu)

Ogi (akamu)

This is an example of traditional fermented food. It is a staple cereal of Yorubas of Nigeria and is the first native food given to babies at weaning. It is produced generally by soaking corn grains in warm water for one to two days, followed by wet milling and sieving through a screen mesh. The sieved material is allowed to sediment and ferment, and is marketed as wet cake wrapped in leaves. Various food dishes are made from the fermented cakes or ogi. During the steeping corn, *Corynebacterium* spp. become prominent and appears to be responsible for the diastolic action necessary for the growth of yeast and lactic acid bacteria. Along with the corn in bacteria, *S. cerevisiae, Enterobacter cloacae, Candida spp.* and *L. plantarum* have been found to be prominent in traditional ogi fermentation, as associated

potential probiotics (O.K. Achi, 2005; Egwim *et al*., 2013). The presence of lactic acid bacteria like *Lactobacillus fermentum* and has been found to support gut health and reduce diarrhoeal diseases in infants (Awoniyi *et al*., 2021).

Gari is a creamy-white, granular flour with fermented flavour and a slightly sour taste made from fermented, gelatinized fresh cassava tubers. Gari is widely known in Nigeria and other West African countries. It is commonly consumed either by being soaked in cold water with sugar, coconut, roasted groundnuts, dry fish, or boiled cowpea as complements or as a paste made with hot water and eaten with vegetable sauce (Egwim *et al*., 2013). Associated potential probiotics in gari are *Bacillus* spp.*, Streptococcus spp, Leuconostoc, Candida* sp. *Lactobacillus coryniformis*, *L. fermentum,* L. *plantarum, S. cerevisiae* (Obafemi, Y.D. *et al*., 2022).

Fufu is a fermented white paste made from cassava. It is ranked next to gari as an indigenous food of most Nigerians in the South. Fufu is made by steeping whole or cut peeled cassava roots in water to ferment for maximum of three days, during the steeping, fermentation decrease the pH, softens the roots and help to reduce the potentially toxic cyanogenic compound (Agbor-Egbe and Lape Mbome, 2006). Study by Uzogara S.G., 1990, revealed *L. fermentum, Ped. Pentosaceus, Candida tropicalis, Lactobacillus plantarium, Leuconostoc mesenteroides, Lactobacillus cellobiosus* and *Bacillus subtili* as potential probiotics.

Alcoholic and non-alcoholic beverages (palm wine) ngwo, nkwu enu, kunu-zaki, Nunu

Kunun-zaki is a non-alcoholic fermented beverage widely consumed in Northern part of Nigeria. This beverage is however becoming more widely consumed in southern Nigeria owing to its refreshing qualities. Kunun-zaki is consumed anytime of the day by both adult and children as breakfast drink or food supplement. It is a refreshing drink usually used to entertain visitors, appetizers and is commonly used / served at social gathering. The traditional process for the manufacture of kunun-zaki involves the steeping of millet grains, wet milling with spices (ginger, cloves and pepper) ,wet sieving and partial gelatinization of the slurry, followed by the addition of sugar and bottling (Egwim *et al.*, 2013). Studies by Agarry, *et.al*., 2010; Raungrusmee S. *et al* 2022) has revealed the presence of *Lactobacillius plantarum, L. fermentum , Lactococcus lactis, L. pentosus*, *L. celbiosus*, *L. mesenteroides* and *Sacharomyces cerevisae* in Kunun-zaki as potential probiotics. These probiotic strains that may help in maintaining a healthy gut microbiota (Ameh *et al*., 2020).

Ngwo/nkwu enu is an alcoholic fermented wine or palm sap widely consumed in Eastern part of Nigeria, (Franz C.P. *et al.*, 2014). The major organisms involved in this fermentation include *Lactobacillus, Pediococcus, Leuconostoc*, *S. cerevisiae*, *Zygosaccharomyces baili*, *Brevibacterium*, *Bacillus, Streptococcus*, *Candid spp,* and *Pichia* (Bisi-Johnson M. A. *et al.,* 2010; Villarreal-Morales, S. L. *et al*., 2018).

Animal protein based products (milk) example nono

Traditionally, nono is prepared by inoculating freshly drawn cow milk with a little of the leftover as starter and then is allowed to ferment for twenty four hours at room temperature. During fermentation, some of the lactose is converted to the lactic acid. At the end of the fermentation period, the milk butter is removed by churning for further use and the remaining sour milk, nono is a delicious and refreshing beverage. Most of the organisms involved in the fermentation process are usually of three main groups; bacteria, yeast, and mould. Of these, *Lactobacilli* (*L. acidophilus and L.bulgaris*), *Lactococci species* (*L. cremoni, and L.lactis*), *Streptococcus thermophilus, Leuconostoc species and Saccharomyces species* seems to be the most prominent, each giving the product a characteristic flavour (Egwim *et al*., 2013). These probiotic strains aid digestion and improve lactose tolerance (Akindahunsi *et al.*, 2020).

Fish/ sea food based foods examples azu-okpo

Azu-okpo is a fermented fish used as a food condiment in Nigeria. The potential probiotic

bacteria involved in the fermentation has not been identified (Olusupe NA and Okorie PC, 2019).

Plant-seed and legume based products (seasoning agents) (locust-beans, african oil beans, soya beans), including daddawa/ iru, ugba, afiyo (okpeye)

Dadawa/Iru

This is one of the most important food condiments in Nigeria and many countries of West and Central Africa. It is used in much the same way as bouillon cubes are used in the Western world as nutritious flavouring additives along with cereal grains sauce and may serve as meat substitute. Dadawa (Iru) is prepared from the seeds of African locust beans, thus are rich in fat (39 to 40%) and protein (31 to 40%) (Achi, 2005) and contributes significantly to the energy intake, protein and vitamins, especially riboflavin, in many countries of West and Central Africa. Dadawa or iru is made from locust-bean (*Parkia biglobosa*) seed, a leguminous tree found in the Savannah region of Africa, Southeast Asia and South America. Dadawa is produced by a natural un-inoculated solid –substrate fermentation of the boiled and dehaulled cotyledon, the major fermenting organisms are the *Bacillus* and *Staphylococcus* (Egwim *et al*., 2013). Other potential probiotics from Dadawa include *Bacillus subtilis, B. licheniformis, B megaterium, B. coagulans, B. circulans* and *Staphylococcus* sp. (Ojinnaka P.C. and Ojimelukwe C. M., 2013). The beans mass after fermentation is sun-dried and moulded into round balls or flattened cakes. Due to the high protein content, it has a great potential as a key protein source basic ingredient for food supplement (Egwim *et al*., 2013). A fermented seasoning used widely in Yoruba cooking. Contains *Bacillus subtilis* and *Lactobacillus* spp., offering both digestive and nutritional benefits (Adewumi *et al*., 2019).

Fermented African Oil bean seed, (*Panthaclethra macrophylla benth*

Ugba*,* is an indigenous fermented food and a popular staple among the Eastern part of Nigeria. It is rich in protein and other minerals and is obtained by solid-state fermentation of the African Oil bean seed. It is gotten traditionally from the fermentation of oil bean seed. It contains up to 44% protein, which comprise of at least 17 of the 20 amino and protein digestibility and utilization increases with fermentation (Okechukwu *et al*, 2012; Njoku and Okemadu, 2021). The oil bean seeds are boiled for three hours, dehaulled and cooked, the cooked seeds are then sliced (0.5 to 1mm thickness) and boiled again for two hours, drained, rinsed thrice in water and steeped in cold water for four hours so as to eliminate the bitter taste. The sliced beans are wrapped with enough banana leaves (*Musca sapientum*), packed in a clean container and covered to ferment at room temperature (Egwim *et al*., 2013). The potential probiotics are *Bacillus* sp. and *Micrococcus* sp. (Nwagu T. N. *et al*., 2011).

Okpeye prepared from the seeds of *Prosopis africana*, ogiri prepared from melon seeds (*Citrullus vulgaria*) and castor oil bean (*Ricinus cummunis*).

The preparation of these foods are similar to that of Dadawa fermentation (Egwim *et al*., 2013). The potential probiotic organisms involved in the fermentation of these foods condiments have been identified, *Bacillus* spp.*, Pedicoccus, Proteus, Micrococcus, Lactobacillus, Streptococcus* (Uzogara S. G., *et al*., 1990; Nwagu T. N. *et al*., 2011).

Activities of probiotics in the gastrointestinal tract

The gastrointestinal (GI) tract serves as a major site where probiotics carry out their health-promoting functions. This part of the body hosts a diverse community of microorganisms, and probiotics are essential in supporting the balance and stability of this environment (Sokol *et al*., 2019). Once consumed, probiotics make their way to the GI tract, where they begin to function by performing various beneficial tasks. A key role they play is producing substances like antimicrobial peptides and organic acids, which act to suppress the growth of harmful microbes (Wang *et al*., 2020). For instance, *Lactobacillus acidophilus,* a well-known probiotic species, is capable of producing antimicrobial agents that effectively limit the growth

of disease-causing bacteria such as *Escherichia coli and Staphylococcus aureus* (Srivastava *et al*., 2019).

Production of bacteriocins

The mechanisms by which probiotics exert their beneficial effects is through the production of bacteriocins. Bacteriocins are antimicrobial peptides produced by bacteria that inhibit the growth of other bacteria (Cotter *et al.,* 2013). Probiotics, particularly lactic acid bacteria (LAB), are known to produce a wide range of bacteriocins that exhibit antimicrobial activity against pathogenic bacteria (Wang *et al.,* 2020). The production of bacteriocins by probiotics is a complex process that involves the regulation of gene expression, protein synthesis, and secretion (Cotter *et al.,* 2013). Probiotics produce bacteriocins as a means of competing with other bacteria for resources and habitat (Wang *et al.,* 2020). Bacteriocins produced by probiotics have been shown to exhibit antimicrobial activity against a wide range of pathogenic bacteria, including *Escherichia coli, Staphylococcus aureus,* and *Clostridium difficile* (Srivastava *et al.,* 2019). *Lactobacillus acidophilus*, a common probiotic strain, has been shown to produce a bacteriocin called acidophilin, which exhibits antimicrobial activity against *E. coli* and *S. aureus* (Wang *et al.,* 2020). Another probiotic strain, *Bifidobacterium bifidum*, has been shown to produce a bacteriocin called bifidocin, which exhibits antimicrobial activity against *C. difficile* (Srivastava *et al.,* 2019).

The production of bacteriocins by probiotics has several implications for human health. Bacteriocins produced by probiotics can help to inhibit the growth of pathogenic bacteria in the gut, reducing the risk of infection and disease (Wang *et al.,* 2020). Additionally, bacteriocins produced by probiotics can help to modulate the immune system, reducing inflammation and promoting immune homeostasis (Srivastava *et al.,* 2019). Probiotics also play a crucial role in maintaining the integrity of the gut epithelial barrier. The gut epithelial barrier is a complex structure that separates the luminal contents of the GI (Gastrointestinal) tract from the underlying tissues (Sokol *et al*., 2019). Probiotics help to maintain the integrity of this barrier by producing anti-inflammatory cytokines and promoting the expression of tight junction proteins (Wang *et al*., 2020). For example, *Bifidobacterium bifidum*, a common probiotic strain, has been shown to promote the expression of tight junction proteins and reduce inflammation in the gut (Liu *et al*., 2019).

Probiotics impact on gut health

One of the primary functions of probiotics is to maintain a healthy balance of gut microbiota, which is essential for proper digestion, absorption of nutrients, and immune system function (Gibson and Roberfroid, 1995). Probiotics have been shown to have a positive impact on gut health by increasing the production of short-chain fatty acids, which are essential for the health and function of the gut epithelial cells (Cummings and Macfarlane, 1997). Probiotics have also been shown to improve the integrity of the gut epithelial barrier, which is essential for preventing the translocation of toxins and undigested food particles into the bloodstream (Isolauri *et al*., 2001).

Probiotics impact on immune system

The immune system is a complex network of cells, tissues, and organs that work together to defend the body against infection and disease (Abbas *et al*., 2017). Probiotics have been shown to stimulate the immune system by increasing the production of antibodies and activating immune cells, such as macrophages and T-cells (Mazmanian *et al*., 2005). This can help to prevent and treat various diseases and disorders, including infectious diseases, autoimmune diseases, and allergies (Isolauri *et al*., 2001).

One of the primary ways in which probiotics stimulate the immune system is by interacting with immune cells in the gut-associated lymphoid tissue (GALT) (Cebra, 1999). The GALT is a network of immune cells and tissues that line the gut and play a crucial role in immune system function (Cebra, 1999). Probiotics have been shown to interact with immune cells in the GALT, such as dendritic cells and T-cells, and stimulate

the production of cytokines and other immune molecules (Mazmanian *et al.*, 2005).

In addition to their ability to stimulate the immune system, probiotics have also been shown to have anti-inflammatory effects (Cani *et al*., 2012). Chronic inflammation is a major risk factor for various diseases and disorders, including cardiovascular disease, type 2 diabetes, and cancer (Cani *et al*., 2012). Probiotics have been shown to reduce inflammation by inhibiting the production of pro-inflammatory cytokines and increasing the production of anti-inflammatory cytokines (Cani *et al.*, 2012).

Probiotics have also been shown to have a positive impact on immune system function in various populations, including infants, children, and older adults (Isolauri *et al*., 2001). For example, probiotics have been shown to reduce the incidence of respiratory tract infections in infants and children (Hatakka *et al.*, 2001). Probiotics have also been shown to improve immune system function in older adults, who are at increased risk of immune system dysfunction and disease (Ouwehand *et al*., 2002).

Conclusion

The functions of probiotics in humans are numerous and can be broadly categorized into several areas, including gut health, immune system function, and overall health and well-being (Goldin and Gorbach, 1992). Probiotics can help to stimulate the immune system by increasing the production of antibodies and activating immune cells, such as macrophages and T-cells (Mazmanian *et al.,* 2005). This can help to prevent and treat various diseases and disorders, including infectious diseases, autoimmune diseases, and allergies (Isolauri *et al.,* 2001). Probiotics are also recommended for their ability to prevent and treat various gastrointestinal disorders, including irritable bowel syndrome (IBS), inflammatory bowel disease (IBD), and diarrhea (Kondo *et al.,* 2013).

In addition to their ability to promote a healthy gut microbiome, boost the immune system, and prevent and treat various diseases and disorders, probiotics are also recommended for their ability to improve mental health and mood. Probiotics can help to produce certain neurotransmitters, such as serotonin and dopamine, which are essential for regulating mood and cognitive function (Cryan and Dinan, 2012). This can help to prevent and treat various mental health disorders, including depression and anxiety.

The mechanisms by which probiotics exert their effects on human health are complex and multifaceted, and are thought to involve the modulation of the gut-brain axis, the enhancement of immune system function, and the production of bioactive compounds, such as short-chain fatty acids and neurotransmitters (Cryan and Dinan, 2012).

Probiotics have potential therapeutic applications in the prevention and treatment of diseases such as inflammatory bowel disease, obesity, and mental health disorders. By incorporating probiotics into our diet and lifestyle, we can take a proactive approach to maintaining our health and preventing disease. It is recommended that individuals consume probiotic-rich foods, such as yogurt and kefir, and consider using probiotic supplements. Further research is needed to fully understand the mechanisms by which probiotics exert their effects on human health and to explore their potential therapeutic applications.

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