

Role of Guava-Derived Dietary Fiber in Gut Microbiota Modulation and Constipation Management

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ABSTRACT

Constipation is one of the most common FIDs globally. It has been linked to low dietary fiber intake and unhealthy dietary patterns, as well as changes in gut microbiota composition. There is growing scientific evidence that dietary fiber has more than mechanical effects on bowel functioning, such as bulking stool, retaining water in the gut, and promoting intestinal transit, but also exerts important biological effects by modulating gut microbial communities and stimulating the production of short-chain fatty acids (SCFA). Guava (*Psidium guajava*) is one of the natural fiber-rich foods that has been identified as a potential functional food because it contains high levels of soluble and insoluble dietary fiber, polyphenols, flavonoids, antioxidants, and other bioactive compounds. This paper examines the possible use of the guava fruit based dietary fiber in modulating gut microbiota and managing constipation by reviewing and analyzing the evidence from nutritional, microbiological and gastrointestinal studies. The literature shows that dietary fibre can be a fermentable source for the beneficial bacteria on the gut, increasing the diversity of microorganisms, increase production of SCFA, improve intestinal barrier function and support bowel regularity. Besides that, fibers from fruits, especially when used in conjunction with phytochemicals, have prebiotic properties which positively influence the functioning of the digestive system and the balance of microorganisms. While guava has a distinct nutritional profile that

may have a beneficial effect on bowel function and microbial fermentation, there is currently limited scientific evidence on the direct effects of guava on gut microbiota composition, microbial metabolites and outcomes of constipation. The review points out that there is a huge gap in research regarding the mechanistic, microbiological, and clinical aspects of guava derived dietary fibre and the need for proper human trials for establishing its therapeutic potential. In summary, the study indicates that guava could be a low cost, readily available functional food with multiple mechanisms of action (mechanical and micro biome-mediated) to support gastrointestinal health. Further studies are needed to confirm its effectiveness, identify the best dosage, and elucidate the role of guava as a dietary fiber for gut microbiota regulation and constipation alleviation.

Keywords— Psidium guajava, Dietary Fiber, Gut Microbiota, Gastrointestinal Health, Functional Foods.

1. Introduction

Constipation is among the most common functional gastrointestinal disorders globally and a significant clinical and public health problem (Bharucha & Lacy, 2020; Drossman, 2016). It is characterized by a set of symptoms such as infrequent bowel movements, constipation, excessive straining during defecation, hard or lumpy stools, and the feeling that stools have not been completely evacuated (Bharucha et al., 2013; Lacy et al., 2016). From the Rome IV diagnostic criteria, functional constipation is a disorder of gut–brain interaction and is often chronic, meaning that the treatment should be long-term and aimed at the underlying mechanism, not just providing symptomatic relief (Drossman, 2016). The prevalence of constipation is different among populations around the world, depending on the definition used, but epidemiological studies have reported that there is widespread prevalence of constipation in adults and children throughout the world (Barberio et al., 2021; Suares & Ford, 2011). The disease is more prevalent in older people, women, and in people with low levels of physical activity and/or dietary fiber (Mugie et al., 2011; Wald et al., 2016). Constipation does not typically pose a life-threatening risk, but is strongly linked to diminished health-related quality of life, psychological distress, and impairment of daily functioning (Bharucha & Lacy, 2020; Wald et al., 2016). Patients often experience abdominal discomfort, bloating, loss of appetite, and social embarrassment, which all affect productivity and lead to increased healthcare utilization (Ford et al., 2014).

From a public health perspective, constipation is a burgeoning problem because of its chronicity and high recurrence rate. Research shows that people who have chronic constipation tend to need multiple consultations with their doctors and also take laxatives for longer periods of time, which can cause side effects or dependency issues (Camilleri et al., 2017; Rao & Camilleri, 2010). Furthermore, the prevalence of constipation has surged across the world, due to the modern lifestyle changes, including decreased physical activity, increased stress, irregular eating habits, and reduced natural dietary fiber intake (Mugie et al., 2011; Bharucha et al., 2013).

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Furthermore, dietary patterns in current societies have become more Western with an increasing intake of highly processed foods low in fibre and essential nutrients, which further contributes to bowel dysfunction and slow intestinal transit time (Slavin, 2013; Anderson et al., 2009). This has led to a greater focus on dietary and lifestyle changes as a first-line option for both prevention and treatment of constipation (Ford et al., 2014; Camilleri et al., 2017). Of all these interventions, the consumption of dietary fiber has consistently been shown as one of the most effective and evidence-based interventions for bowel regularity and for overall gastrointestinal function (McRorie & McKeown, 2017; Slavin, 2013).

Dietary fiber has long been known to be one of the most important factors of the diet that can affect gastrointestinal function and bowel regularity. Fiber is a type of carbohydrate that is not broken down in the upper gastrointestinal tract and is instead delivered to the colon, where it has mechanical and biochemical effects on bowel function (Slavin, 2013; Anderson et al., 2009). Dietary fibers can be generally classified as soluble or insoluble, according to their solubility and fermentability, and each type plays a role in intestinal physiology (McRorie & McKeown, 2017). Insoluble fibre promotes gastrointestinal (GI) motility by increasing stool volume and peristalsis, which increases stool bulk, decreases stool hardness, and improves stool evacuation efficiency (Slavin, 2013). Soluble fibre, on the other hand, can help to keep stools hydrated, soften stool consistency, and make bowel movements easier by forming viscous gels that swell when they absorb water (McRorie & McKeown, 2017). With all populations studied, adequate fibre intake has been consistently correlated with increased bowel frequency, less straining, and lower risk of chronic constipation, supporting these complementary mechanisms (Yang et al., 2012; Eswaran et al., 2013). In addition to its mechanical properties, dietary fibre also has a significant role in the modulation of the gut microbiota, which is now well known to be a major contributor to the regulation of gastrointestinal health. Trillions of microorganisms reside within the human gut, working in concert with one another to affect digestion, immune regulation, metabolic activity, and intestinal homeostasis (Valdes et al., 2018; Holscher, 2017). Dietary fibre is not broken down by intestinal enzyme digestion processes in humans and is delivered to the colon, where it undergoes fermentation by the gut microorganisms, resulting in the production of beneficial metabolites called short-chain fatty acids (SCFAs) including acetate, propionate, and butyrate (Koh et al., 2016; Makki et al., 2018).

These SCFAs also have important roles in gut health by supporting gut barrier function and controlling inflammatory responses as well as colonic motility (Koh et al., 2016). In terms of gastrointestinal health, butyrate – especially – is the main fuel source for colonocytes and plays a role in the health of epithelial cells and in lowering inflammation in the colon (Makki et al., 2018). Dietary fiber has a systemic effect in addition to its gastrointestinal tract function in providing glucose and lipid metabolism regulation and maintenance of metabolic status, which is a result of systemically absorbed acetate and propionate (Valdes et al., 2018). Recent studies have found a close relationship between the pathophysiological mechanisms of chronic constipation and the composition of gut flora. There is growing evidence that disturbances of the composition of gut flora (dysbiosis) are associated with the biology of chronic

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constipation. Several studies have shown that the patients who suffer from constipation have a decline in microbial diversity and a change in bacterial composition alongside a decrease in the production of SCFAs that lead to reduced intestinal motility and stool consistency (Ohkusa et al., 2019; Zhao & Yu, 2016). Thus, dietary strategies aimed at improving microbial diversity and fermentation capacity are regarded as beneficial approaches that can normalize bowel function and promote bowel long-term health.

Recent studies have clearly demonstrated the involvement of alteration of gut microbiota composition, or dysbiosis, in chronic constipation (Gharber et al., 2019; Valdes et al., 2018). The intestinal microbiota is composed of many different microorganisms and is a very complex ecosystem that helps the body with digestion and related functions, such as the upkeep of gastrointestinal homeostasis and modulation of the immune system. Microbial disruption has been linked to decreased intestinal motility and stool consistency and is believed to create imbalances in microbial production of metabolites that are essential to health (Zhao & Yu, 2016; Holscher, 2017). Chronic constipation patients tend to have less diversity of microbes, coupled with a dysbalance in beneficial bacterial species, including Bifidobacteria and Lactobacilli species (Ohkusa et al., 2019). Calamitous changes are clinically significant due to the important contribution of the beneficial microbes to the breakdown of dietary fiber and the production of a group of fatty acids known as short-chain fatty acids (SCFAs), key for a normal working colon (Makki et al., 2018). This decreased diversity is, therefore, well associated with lower fermentative potential, and this could be responsible for slowing intestinal transit and adhesion of more compact feces.

The metabolic products of bacterial fermentation of non-absorbable carbohydrates in the colon, such as SCFA (acetate, propionate, butyrate), play an important role (Koh et al., 2016). The metabolites play several physiological roles, such as the regulation of the integrity of the colonic epithelium, modulation of immune responses, and stimulation of intestinal motility (Valdes et al., 2018). Butyrate has a special significance, being the main source of energy for colonocytes and a modulator of gut–brain axis signaling pathways and metabolic regulation in the systemic system, as is acetate and propionate (Makki et al., 2018; Koh et al., 2016). It has also been recently proposed that this class of metabolites, the SCFAs, is a communication signal between the enteric nervous system (EN) and the intestine. This lower concentration of SCFAs in people who are constipated could then compromise the colon's neuromuscular coordination, which would result in slower transit time and stool evacuation. However, dysbiosis-induced alterations in bile acid metabolism and microbial enzyme activity may be additional modulations that lead to altered stool disinfiltrative and motility (Valdes et al., 2018).

Besides microbial imbalance, a dysfunction in the gut – brain axis has been recognized as an important contributing factor in functional constipation. For instance, metabolites generated by microorganisms (SCFAs) can regulate intestinal function by altering the pathways of vagal signaling or the release of neurotransmitters, connecting gut microbiota activity to the regulation of intestinal function by the central nervous system (Koh et al., 2016; Valdes et al., 2018). This bi-directional communication indicates the significance of maintaining a balance of microbes for gastrointestinal and systemic well-being. Based on these results, there has been an increased interest in

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dietary-based restoration of the balance of the gut flora in today's nutritional gastroenterology. Foods with prebiotics and fiber are especially relevant as they selectively support rather than shrink the positive bacteria, which in turn increases SCFA production and improves stool consistency and bowel movements (Holscher, 2017; Erhardt et al., 2023). In recent years, there has been a shift toward dietary fibre consumption from whole food products, among which fruit is especially receiving the spotlight, due to its ability to provide food for faecal microflora and bioactive molecules, with multiple benefits that can act synergistically for gut health.

Fruits are considered to be one of the most studied natural fibers for both their fermentable carbohydrate content and the bioactive compounds that they contain, which affect gastrointestinal function (Katsirma et al., 2021; Gill et al., 2021). As opposed to individual fibre supplements, whole fruits are rich in a collection of fatty-soluble and insoluble fibres, polyphenols, organic acids, and natural sugars that work together to promote gut motility and microbial modulation (Katsirma et al., 2021). Fruit has been shown to positively correlate with bowel function and a diminished risk of constipation thanks to its effects on intestinal stimulation, fecal bulking, and increasing stool hydration (Huo et al., 2022; Slavin, 2013). Pectin, a soluble fibre present in fruits like apples, pears, citrus fruits and berries, is responsible for creating viscous gels in the intestine, due to which stool consistency is softened, resulting in defecation becoming easier (Gill et al., 2021). Furthermore, some fruits can also be osmotically active in the colon, which thus facilitates bowel movement and helps to soften the stool (Katsirma et al., 2021). In addition to their fiber content, fruits also affect gut bacteria with polyphenols and phytochemicals that coordinate and regulate bacteria. These compounds have been demonstrated to selectively boost good bacteria over bad bacteria, thereby creating increased microbial diversity and production of beneficial short-chain fatty acids (SCFAs) (Valdes et al., 2018; Jin et al., 2023). Fruit nutrient-gut microbiota interactions demonstrate potential implications for gastrointestinal homeostasis with whole-food strategies. For stool regulation, systematic reviews and meta-analyses have shown that higher fruit consumption has a positive effect on stool frequency and severity of functional constipation, which highlights the potential role of fruits as a first-line dietary therapy for bowel regulation (Huo et al. 2022). Besides, fruits are a source of hydration and electrolytes, which also help to create soft stools and promote colonic transit time, making them especially helpful for people with a lower fiber intake or who are constipated due to dehydration.

Guava (*Psidium guajava*) is a fruit that has had special interest as a functional food because of its high amount of phytochemicals and high fiber content. The functional properties of the nutrients present in guava are essential to maintain good digestive function as they contain both soluble fiber and insoluble fiber, vitamin C, carotenoids, flavonoids, and polyphenolic compounds (Naseer et al., 2018). The intestinal luminal bulk enhancing and motility promoting effect of its high fibre density is related to a high potential for improvement, and its bioactive compounds are expected to provide for enhanced gut microflora activity and SCFA production. Guava is still under-explored in relation to gut microbiota modulation coupled with constipation treatment in comparison with other fruits. The evidence available, however, suggests that the guava has the potential to have both mechanical and microbiological effects on

bowel function, and therefore the fruit is a suitable candidate for research in functional gastrointestinal studies (Joseph & Priya, 2011; Naseer et al., 2018). However, though there is substantial evidence for the health-promoting effects of dietary fibre on the gastrointestinal tract in both its nutritional benefits and impacts on bowel function, constipation is a very common and very frequent functional gastrointestinal disorder globally (Bharucha & Lacy, 2020; Barberio et al., 2021). Most research has focused on individual fibers or on commonly studied fruits, e.g., citrus fruits, prunes, or kiwi, while regionally available fiber-rich fruits, such as guava (*Psidium guajava*) fruit, have received relatively little attention (Huo et al., 2022; Gill et al., 2021).

Besides their fibre content, several whole fruits' beneficial effects on bowel function are also attributed to their complex phytochemical composition, such as polyphenols, flavonoids, natural sugars, etc., which can modulate intestinal motility and microbial fermentation; emerging evidence supports this (Katsirma et al., 2021). These compounds have a synergistic effect to increase stool hydration, increase intestinal transit time, and help stimulate gut microbial populations that produce short-chain fatty acids (SCFA) (Makki et al., 2018; Valdes et al., 2018). The intensity of these effects, however, differs according to the type of fruit, and some fruits have not been examined consistently and exhaustively in clinical or experimental research. Guava (*Psidium guajava*) is one of the richest kinds of tropical fruit with a high soluble to insoluble dietary fiber ratio, which possesses enormous nutritional and medicinal value containing abundant amounts of vitamin C, carotenoids, flavonoids, and polyphenolic compounds (Naseer et al., 2018). Include guava in your diet because the fibers it has can lead to bulkier stools, as well as water retention and increased bowel movement. Furthermore, polyphenolic compounds might help to influence the composition of gut microbiota by increasing beneficial bacteria concentrations while reducing concentrations of harmful bacteria (Slavin, 2013; Holscher, 2017).

Although these are certain characteristics that promote beneficial effects, there remains a great deal of research needed to elucidate the specific mechanism of action of the dietary fibre derived from guava in regulating gut flora and treating constipation. The beneficial effects of fruit consumption have mostly been studied as part of the diet in general, and the study of guava is weak in the area of mechanisms for its influence on gastrointestinal health (Huo et al., 2022). In addition, the effects of guava fiber, microbial fermentation, SCFA production, and intestinal motility in human clinical trials have not been sufficiently studied. Hence, this study aims to provide a critical review of the literature on existing research on the moment of dietary fibre obtained from guava and its potential to modulate gut microbiota and the effect of its use in the treatment of constipation. This review aims to highlight the existing evidence on dietary fiber, gut microbial health, and fruit-based functional foods; pinpoint mechanisms of action; pinpoint significant gaps in the literature; and lay the groundwork for future experiments and research on guava as a functional food for digestive health.

Significance

Table: Guava is a food with dietary fibre and the present study about role of dietary fibre extract from guava in the regulation of gut microbiota and constipation is important because digestive system disorders in the world are rising, and there is a great need to use digestive system regulating foods that are free from side effects, safe,

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natural, and botanical foods. Constipation is a regular occurrence throughout the world, and when it happens regularly or becomes a chronic issue, it can cause discomfort, bloating, abdominal pain, and limit an individual's enjoyment of life. While highly popular, laxatives can be transient and even have side effects and dependency effects, making it all the more important to find long-term diet solutions. The spiny guava, *Psidium guajava* L. In this particular case, the factor of being so readily available and being eaten in various parts of the region, combined with its low cost and allying with the locals, is why (guava) is really so significant. So it can be used as a functional food for digestive health, which is feasible. Apart from the fact that it is a motility-related disorder, it is becoming evident that constipation conditions are linked to gut microbiota imbalance and associated with the production of short-chain fatty acids (SCFAs), regulation of gut microbiota, and the role of dietary fibre in gut microbiota fermentation. Also, guava contains both soluble and insoluble fibre that could potentially encourage the growth of “good” bacteria within the gastrointestinal tract, though the impact of these is not fully understood. This study hence fills an important gap regarding the convergence of traditional dietary knowledge with current knowledge of the microbiome and may contribute to public health in the development of better dietary strategies. It could also help in clinical trials, nutritional recommendations, and natural & sustainable remedies for constipation in the future.

Literature review

One of the main reasons dietary fibre is recognized as an important part of a healthy diet is because of its large role in the function of the gastrointestinal tract and digestive health. With a rise in prevalence, reduction of fiber intakes and dependency of highly processed foods have been associated with constipation and other FGIDs. As prevalence rises, decreases in fiber intake and reliance on highly processed foods have been correlated with increased constipation and other functional gastrointestinal disorders. The beneficial effect of dietary fiber on the health of the intestine is mediated by a number of physiological effects: increased faecal bulk, increased water content in the intestinal lumen and stimulation of intestinal transit. Further, fiber is used as a fermentable substrate by gut bacteria, which consequently affects the constituents and activity of gut bacteria in the colon. Dietary fibre has been reported to have multiple physiological effects, which depend on the solubility, viscosity, and fermentability properties (Gill et al., 2021). Likewise, Makki et al. (2018) pointed out that dietary fiber has multiple roles in the control of gut microbial ecology and host health. These observations are in line with the theories that Gropper and Smith (2021) presented, that dietary fibre is an important nutritional component that affects digestive physiology and metabolic regulation in the body.

Constipation is one of the most frequent gastrointestinal complaints worldwide that is manifested by infrequent evacuation of bowels, excessive straining, hard stool, and sensation of incomplete evacuation. The role of dietary fiber as a first-line nutrition intervention to change stool consistency and bowel movements has been advocated since long. Fiber increases the mass of stool, decreases colonic transit time, and enhances water absorption, which leads to easier movement of stool. Slavin (2013) went on to state that dietary fibre is still one of the top dietary recommendations for bowel regularity and preventing constipation. Moreover, So et al. (2018) found that

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dietary fiber is a beneficial factor affecting gut microbial composition, which helps gut function better. "Fiber's role in managing constipation is also addressed in Krause's Food and the Nutrition Care Process (Mahan and Raymond 2020), which recognizes an adequate level of fiber as key to promoting a healthy digestive system." With the rise of microbiome science, understanding of the interactions between dietary fibre and gut health has broadened. The gastrointestinal system inhabits trillions of microbes that aid in digestion, metabolism of nutrients, immune regulation and intestinal homeostasis. Dietary fibre is indigestible in the upper gut and finds its way into the colon, where it can be broken down by the bacteria. The procedure selectively encourages good microorganisms and microbial diversity. Makki et al (2018) had reported that microbial responses to various types of dietary fibre vary between them due to structural properties and fermentation. Similarly, Gill et al. (2021) reported that the microbial interactions in the gastrointestinal tract in response to dietary fiber has a significant effect on the digestion and overall health of the host. Therefore, the importance of a good amount of dietary fiber is gradually gaining considerable recognition in terms of microbial balance as well as digestive health.

The most critical benefit of microbial fibre fermentation is the production of short-chain fatty acids or SCFAs, such as acetate, propionate, and butyrate. The metabolites play essential roles in maintaining physiological functions such as supplying the Epithelium with energy, improving the function of the barrier, inducing immune modulation, and facilitating the activity of the intestine. Moreover, SCFAs provide an environment that is optimal for the colonization of the intestines by decreasing the pH of the lumen and reducing the growth of pathogenic microorganisms. Increased fiber intake was also found to promote gut health and metabolism by increasing SCFA production when the diets are fermented by the gut microbiota, as reported by Makki et al. (2018). Dietary fibre interventions also appeared to increase the populations of microbes involved in the production of SCFAs, similar to So et al. (2018). The results suggest a potential mechanism for the positive action of dietary fiber on gut health: its action on microbial fermentation. What is also becoming evident is the role that changes in the bacterial makeup of the gut, or "gut dysbiosis," play a role in chronic constipation. People with constipation tend to have less diverse microbes, lower levels of beneficial microorganisms, and lower fermentation activity. These changes can have a negative impact on bowel movements, moisture, and bowel function. Gill et al. 2021 found that microflora alterations directly affect bowel function by altering intestinal signaling pathways or microbial metabolites. Similarly, Makki et al. (2018) reported that diets low in fibre cause damage to beneficial strains of microbes and reduce the activities of colonic microbiota. Based on these results, it can be concluded that dietary intervention for restoring the balance of the microbiome can have a sustainable therapeutic effect in the treatment of constipation.

In general, the evidence available shows that there is a good relationship between dietary fiber intake, modulation of gut microbiota, fermentation, and bowel function. In addition to mechanical functions, dietary fiber has also been shown to promote gastrointestinal health in microbiological ways, such as increasing stool bulk, accelerating intestinal transit, boosting the diversity of gut microbes and raising the levels of beneficial metabolites. Gill et al(2021) concluded that dietary fibre plays an

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essential role in gastrointestinal integrity and helps to prevent digestive disorders. Similarly, Slavin (2013) also highlighted the need for proper fiber intake in maintaining bowel movement and sustaining a good digestive system for good long-term health. In summary, the results obtained in this study offer a solid scientific foundation for the study of the modulatory effect of gut microbiota in the management of constipation using fibers sourced from fruits, especially guava (*Psidium guajava*).

Three fibre types are derived from fruit, which have attracted much interest in the context of nutritional gastroenterology and for their role in manipulating bowel physiology and gut microbial ecology. Fruits also include the complex matrix of soluble and insoluble fibres, polyphenols, vitamins, and bioactive elements which act synergistically to fight gastrointestinal diseases. Soluble fibre can be easily eaten away by the bacteria in the gut; insoluble fibre will bulk the stool and stimulate the movement of the gut. Holscher (2017) states that dietary fibres from whole foods selectively ferment useful microbial species and play a role in the production of metabolites for intestinal well-being. Similarly, Valdés et al. (2018) stated that diets with high fruits/vegetable content showed increased diversity of microbes, especially in the gastrointestinal tract, and better gastrointestinal outcomes. The principles from Human Nutrition by Mann and Truswell (2017) reinforce these observations and the significance of the fruit-based dietary components in ensuring a healthy digestive system and preventing gastrointestinal disorders.

Healthy case-control and clinical studies have shown that eating fruit has significant beneficial effects for bowel regularity. The dietary fiber content of fruits, combined with their naturally occurring water and phytochemicals, helps to keep everything hydrated and hydrating – helping to make bowel movements easier! Fruits have been linked to increased stool frequency, decreased straining and increased comfort in the digestive system. Riezzo et al. (2012) showed that intake of fruits high in fibre dramatically enhances the frequency of bowel movements and minimizes bowel disturbances associated with functional constipation. Likewise, Slavin and Lloyd (2012) noted that whole fruits offer greater physiological effects than whole fibre supplements, and that's because of their complex nutritive profile. The results suggest that there is a potential use of these types of dietary fibre as a good intervention in the management of constipation due to their dietary source. Dietary fiber has been identified as a key factor in the structure of gastrointestinal microflora in recent research on the microbiome. Many plant fibres go through the small intestine undigested and enter the colon, where they react with microbes. It has the capacity to selectively promote desired bacteria and spread diversity. Holscher et al. (2017) found fermentable fibres to be important for the development of gut microbes, in particular short-chain fatty acid-producing microbes. Moreover, Louis and Flint (2017) described fiber degradation and fermentation as being performed by specific groups of microorganisms belonging to different phyla, such as Firmicutes and Bacteroidetes. These are usually the microbial interactions that aid in sustaining the health of the small bowel as well as intestinal homeostasis. The results of microbial fiber fermentation are especially considered as the production of butyrate, propionate, and acetate (SCFA). These metabolites play strategic roles in gut health as a source of energy for intestinal cell function in the colon, supporting epithelial barrier integrity, and modulating immune

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function. Furthermore, these SHFAs affect the gut conformation and consistency of stool, promoting the prevention of constipation. Valdés et al. (2018) highlighted that high SCFA-producing diets are strongly correlated with enhancing gut function. Similarly, Louis & Flint, 2017 noted the crucial function of microbial fermentation pathways in maintaining digestive stability and metabolic health. Thus, feeding of fermentable fiber from fruits can have significant effects on bowel function and gut health.

The effect of long-term dietary options on microbial adaptability is another important aspect. Shape – Dietary changes of low fibre consumption could result in loss of fibre-degrading populations of bacteria, which decreases the efficiency of the bacterial fermentation processes. Sonnenburg and Sonnenburg (2014) suggested that a continued decrease in dietary fibre consumption can lead to a loss of microbial diversity and decreased ability to metabolize carbohydrates in the gut microbiome. This decrease could lead to constipation and other gastrointestinal diseases due to the inability to produce fermentation activity and metabolites. Therefore, increasing dietary sources rich in fibre, such as fruit, can re-establish the microbiology and optimize normal digestion. At this time, there is a compelling link between fruit-based dietary fibre, modulation of gut microbiota, and bowel health. Fruit fibers play a crucial role in gastrointestinal regulation and preventing constipation due to their microbiota fermentation and generation of SCFA, as well as the increase of intestinal movements. In addition, some of the components of whole fruits can boost microbial activity and contribute to the maintenance of intestinal homeostasis. As Mann and Truswell (2017) pointed out, the concepts outlined from the fruit-based dietary approach and strategies are important as a dietary option for digestive health promotion. The results in this study give good justification to investigate guava (*Psidium guajava*) as a natural functional food that is rich in dietary fiber and phytochemical compounds for gut microbiota modulation and constipation management.

Given the close relation between prebiotics and gut microbiota, gastrointestinal health has become an important concept associated with prebiotics in nutrition. Prebiotics are substrates that are selectively used by the beneficial microorganisms in the gastrointestinal tract, which are beneficial to health. Fruits are a major source of dietary fibers, which are natural prebiotic as it cannot be digested by upper gastrointestinal enzymes and are fermented in the colon. Gibson et al. (2017) stressed the selective ability of prebiotic fibres to feed specific species of beneficial microorganisms, such as *Bifidobacterium* spp. and *Lactobacillus* spp., which help maintain healthy gut bacteria and metabolic control. In the same way, mounting evidence emerged suggesting that dietary fibers also have biological functions that can affect the gut microbial ecology and fermentation process (Cho & Samuel, 2009). The results indicate that fibers obtained from fruits can act as important gut microbes modulators. Dietary fiber-gut microbiota interactions are largely explained by microbe-derived fermentation processes. Arrived at the colon, the fermentable fibers are fermented by the resident microorganisms, the metabolites created being beneficial, and the microbial community structure changes. Another study by Holscher (2017) found that a high dietary fibre intake has a significant effect on microbial diversity and the growth of beneficial bacterial taxonomic groups. A healthy and resilient gastrointestinal

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environment is typically accompanied by an increase in microbial diversity. Eating fruit rich in fibre can therefore help maintain the stability of the flora and improve gastrointestinal function outcomes, especially when a person is constipated or has dysmotility of some other functional bowel disorder.

Production of short-chain fatty acids (SCFAs), such as acetate, propionate, and butyrate, is one of the most important outcomes of microbial fermentation. These metabolites are essential to maintain intestinal homeostasis through their energy provision for colonocytes, reinforcement of the epithelial barrier, and control of inflammation. Koh et al (2016) proved that dietary fiber consumption and its effect on the host can be connected to key signaling molecules, known as SCFAs. In addition, Louis and Flint (2017) showed that pathways for the production of SCFA are essential processes in colonic fermentation by bacteria, which play an important role in maintaining colonic health and normal bowel motility. The increased production of SCFAs during the consumption of dietary fibre is therefore of great significance in the potential influence of dietary fibre on gastrointestinal well-being and constipation relief. Besides their apparent effects on microbial metabolism, dietary fibres also shape the long-term composition and functional capacity of gut microbiota. However, modern diets with a lower intake of plant foods are linked with decreases in microbial diversity and that of fiber-degrading bacteria. According to Sonnenburg and Sonnenburg (2014), a lower intake of MICC in the human diet could be responsible for reduced microbial diversity and efficiency of fermentation. Any changes may have an adverse impact on the function of the bowel and make it more prone to gastrointestinal diseases such as constipation. So, diets rich in fiber-containing fruits could be beneficial in restoring microbial diversity and beneficial fermentation routes within the gut.

Recent studies have also shown that metabolites of microbes are important seed regulators of communication between the gut and other physiological systems. Agus et al. (2018) described that microbes affect many gut biochemical pathways that regulate host health, function, and the immune system. Reactive metabolites from the fermentation have a signaling role for their effect on intestinal motility/integrity and metabolism. These results indicate that the beneficial effects of dietary fibres are not merely related to their combination of bulk and solution promoting properties in stool formation but also to complex interactions with the metabolic actions of the microbes and the physiology of the host. These mechanisms could be especially interesting in the context of the role of fibers from fruits in constipation treatment. Overall, available data show that dietary fibers are good regulators of gut microbiota composition, gut fermentation, and metabolite production. Dietary fibers have prebiotic effects that favor the proliferation of microbial diversity, increase the production of SCFA, and maintain intestinal homeostasis. In line with the above, as attributed by Marriott et al. (2020), nutrition-based strategies that contribute to the creation of healthy microbial environments are becoming increasingly important strategies in gastrointestinal health. The results of this study lay a solid scientific foundation for the study of guava (*Psidium guajava*) as a dietary fibre and bioactive-rich potential functional food for its beneficial effect on gut microbiota in the management of cases of constipation.

Guava (*Psidium guajava*), with its nutritious composition and promises of health attributes, is increasingly coming to the fore as a functional fruit. Fruit is rich in

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dietary fiber, vitamin C, polyphenols, flavonoids, carotenoids, and many other bioactive compounds that can help with gastrointestinal and metabolic health. Guava is endowed with both soluble and insoluble dietary fibers that allow it to have an effect on bowel function in a number of different ways when compared to many of the commercially consumed fruits. Jiménez-Escrig and Sánchez-Muniz (2000) stated that the dietary fiber content in fruits, when supplemented with antioxidants, provides extra biological advantages, such as protection against oxidative stress and intestinal health effects, in addition to the bulking agents it contains. Such attributes render guava a prospective dietary ingredient for enhancing gastrointestinal activities and keeping microbial equilibrium in the gut. Acid-soluble fibre fraction from guava is especially effective in the physiology of the digestive system. Soluble fiber, present in guava, can absorb water and can gel in the lumen of the intestine, which increases the hydration of the stools and assists in eliminating stools. However, when the fibres are inaccessible to the digestive enzymes, they tend to swell in the gut and push the bowels into action, called insoluble fibre. These mechanisms, combined, help people have more regular bowel movements and less risk of constipation. Cho and Samuel (2009) cited that dietary fibres are biologically different in terms of chemical composition and fermentability properties in dietary fibrous foods. Hence, the combination of fiber in guava might offer potential for both mechanical and fermentative action, including gastrointestinal health.

In addition to the fibres, guava is rich in phytochemicals that could have an impact on the composition and operation of microflora in the gut. Polyphenols are one such type of compound that has received the maximum attention in terms of interaction with the microbes in the intestine. Since many polyphenols are not absorbed in the upper gastrointestinal tract, they are metabolised in the colon by bacteria, and increase the growth of beneficial bacteria. Cardona et al. (2013) have reported that polyphenols from food have a strong modulatory effect on the composition of gut microbiota and also on the metabolic activity of the microbes. These interactions can have a beneficial effect on the health of the gut microbiome, thus benefiting digestive health. The synergy between fruit polyphenols and microbial fermentation takes special importance when considering gastrointestinal function. Many food products contain both polyphenols and dietary fibre components and, in some cases, there may be synergetic interaction between these components, affecting microbial ecology. The results of Tzounis et al. (2011) showed that polyphenols from fruits can have a positive effect on the growth populations of beneficial microorganisms, making them more numerous, and have a negative effect on the population of potentially harmful bacteria species, reducing their numbers. This change in the microorganism creates a better fermentation efficiency and boosts the production of some metabolites. With its rich content in both dietary fiber and polyphenols, guava could have a comparable microbiota-modulating effect beneficial for intestinal health and bowel regulation.

Some recent research also indicates that fibers found in fruits can increase the metabolic activity of microbes and boost the production of short-chain fatty acids (SCFAs). The metabolites play a role in the maintenance of the intestinal barrier, immune regulation, and colonic motility. Holgerson et al. (2017) highlighted the ability of fermentable dietary fibers to selectively stimulate beneficial bacteria associated with

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the biosynthesis of SCFA, which offers gut health benefits. The intake of guava could lead to increased production of SCFAs and promote digestive benefits due to the presence of fiber fractions, which can be fermented by microbes. The mechanisms can be considered a biologically plausible explanation for the potential effect of guava in managing constipation and modulating gut microbiota. Overall, the available evidence suggests that guava has some properties fitting the functional food definition. It has a number of ways it could affect gut health, as a result of its blend of dietary fibre, antioxidant components, and microbiota accessible substrates. The synergy between guava fiber, polyphenols, and gut microbes can lead to an increase in microbial diversity, gut fermentation, and overall bowel health. While a more general study of the role of fruit fibre has confirmed these mechanisms in many different fruits, the fruit-specific study is generally limited to guava. The effects of the gut microbiota profile and the resolution of constipation with guava extruded dietary fibres remain to be fully understood in human cases, warranting further research.

With a growing interest in the field of functional foods, guava (*Psidium guajava*) has come into focus for its potential as dietary fiber and functional substance (s) with health-promoting properties, notably to gastrointestinal organs. The fruit exhibits a combination of soluble and insoluble dietary fibre, vitamin C, polyphenols, flavonoids, and other antioxidant compounds, which could have a synergistic effect on the digestive physiology and microbial ecology. It has been established in previous nutritional studies that fruits with more fermentable fiber (FF) ameliorate bowel regularity. Promote the development of good bacterial populations and increase the production of metabolites by helpful bacteria. Due to its nutritional profile, guava is a fruit that is being regarded as a potent functional food that could help to promote the health of the intestine from several bio-pathways. Of all its constituents, the dietary fibre of guava is of special importance in the management of constipation, as it displays a combination of mechanical AND microbiological mechanisms of action. The soluble fiber for hydration of stool and soluble fiber for substrate of microbial fermentation are beneficial, as is the insoluble fiber for bulking stool and for accelerating intestinal transit. This is because this dual activity can be beneficial compared to fibre supplements that have single physiological effects. The health benefits of fibrous dietary components are not only related to the quantity of fiber, but also related to its physicochemical properties and fermentability (Cho and Samuel, 2009). So, the blended fiber content in guava could yield a beneficial impact on gastrointestinal well-being and functionality.

Apart from the major presence of fibre, guava is also rich in polyphenols and antioxidant metabolites, which might have implications for the composition of gut microorganisms. Polyphenols are increasingly being seen as important modulators of the gut microbiota due to their modulating action along the gut, where they play a role in the metabolic function of microorganisms. Cardona et al. (2013) reported selective stimulation of beneficial species of bacteria in the gastrointestinal tract via polyphenol-rich foods with reported reduction of potentially harmful microorganisms. The quality and quantity of fiber might go hand in hand with polyphenolic compounds in guava, thus increasing its beneficial impact on gut health may have more complex microbiota-mediated mechanisms. Some emerging evidence also indicates that specific diets rich

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in fermentable fibre and phytochemicals may increase the production of short-chain fatty acids (SCFAs), such as acetate, propionate, and butyrate. These metabolites are critical to the normal functioning of the intestine and to keeping the cells that make up the lining of the colon impervious to the outside environment and to inflammation. These metabolites are essential for a healthy intestine, as they help maintain the integrity of the cells that form the lining, control immune responses, and facilitate normal way of going to the bathroom. Koh et al. (2016) showed that dietary fibre consumption is associated with changes in the host's physiology through an indirect pathway involving the production of SCFAs. This is also true for microbial fermentation of complex carbohydrates, which is said to be critical to maintain the intestinal homeostasis, which in turn, Louis and Flint (2017) stated that this is essential. Because of the fermentable fiber content, guava could be useful to increase the production of SCFA levels and thus enhance the bowel function in constipated patients.

Although the available evidence suggests that dietary fibre, fibre from fruits, and microbiota-targeted nutritional interventions play a role, so far, research has been very limited and does not specifically focus on guava. Many of the studies so far have explored the dietary fiber content of fruit in general or other fruits, including kiwifruit, apples, berries, and citrus fruits. Few studies have investigated the impact of guava fibre on the human gut diversity, activity of human gut microbes, SCFA levels, and bowel issues such as constipation. Moreover, few reports exist on the mechanisms by which guava exerts its effects on the intestinal microbiome and its effects on gastrointestinal physiology. This paucity of specifically targeted evidence is a significant gap in the scientific literature. Hence, studies are needed to investigate the effect of the dietary fiber derived from guava as a gut microbiota modifier and treatment for constipation. The association of guava consumption with microbial communities, metabolites of fermentation, and bowel functions could help to gain insights into its applications as a functional food. This study may help to design evidence-based dietary interventions to promote gastrointestinal health and provide a natural and sustainable way to manage constipation. Thus, in the present study, we aim to fill this knowledge gap by studying the effect of *Psidium guajava* dietary fiber on gut microbiota and constipation relief, contributing to the expanding niche of nutritional gastroenterology and microbiome studies.

Although numerous publications have demonstrated the beneficial effects of dietary fibre on gastrointestinal health, gut biota composition, short-chain fatty acid (SCFA) production and the treatment of constipation, there is still not sufficient research to confirm the specific effect of the fibre from guava fruit (*Psidium guajava*) on these processes. Although dietary fibre has been studied as a whole, in isolation, and as prebiotic feeding, there has been relatively little research that has examined the use of guava as a functional dietary intervention. However, there remains unresolved mechanistic, microbiological, and clinical data regarding the effects of the guava-derived fibre in influencing the composition of gut bacteria, benefiting bacterial population growth, gut microbial flooding, or boosting the production of SCFAs in the context of constipation. Moreover, most studies available in the literature on guava focus on its nutritional content, antioxidant capacity, or overall health effects and have largely neglected individual aspects related to gut microbial diversity, intestinal

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metabolism, and bowel physiology. There are also a few human clinical trials using a well-designed design that explore the link between guava consumption, changes in the gut flora, stool properties, frequency of bowel movements, and long-term gastrointestinal health. Furthermore, the differences in the variety of the guava, in processing technology, in the ripeness stage, in the diet, and in the composition of the microbiota of the individual with which they are administered make it harder to draw any definitive conclusions as to their therapeutic effect. Based on this, the present study aims to bridge this gap by identifying the specific microbiota modulating potential of guava-derived dietary fibre in the alleviation of constipation and thereby provide scientific evidence on its use as a natural, affordable and sustainable source of functional food for gut health and as a part of microbiome-mediated nutritional interventions.

Discussion

Dietary fiber is a well-known and basic component of gastrointestinal health through its ability to help prevent or manage constipation (Slavin, 2013; Anderson et al., 2009). Results from the literature reviewed consistently showed that low fiber intake is one of the most significant dietary factors associated with the development of constipation in all age groups and populations. In the present days, people have an imbalance in eating habits where they have low fiber intake and end up consuming an excess of refined and processed foods that cause diminished stool size, a slower transit, and irregular bowel habits (Rao & Camilleri, 2010). Therefore, one of the most common non-drug recommendations to reduce the occurrence of constipation is to increase dietary fibre. The mechanical action of the dietary fiber just in the GIT provides an explanation for the effectiveness of the dietary fibre. Insoluble fiber is water soluble, which increases water consumption and evokes the stimulation of mechanoreceptors in the wall of the intestine, which stimulates peristaltic activity and accelerates colonic transit (McRorie & McKeown, 2017). Meanwhile, soluble fiber generates viscous gel-like complexes that bind water, facilitate ease of stool movement, and make stool consistency more relaxed, allowing for more pain-free defecation (Yang et al., 2012). All these physiological benefits together alleviate constipation, the straining provoking bowel movement, and enhance bowel function. Evidence through the meta-analysis shows that both men and women who eat sufficient amounts of dietary fiber tend to have much more regular bowel movements than their counterparts who follow a low-fiber diet (Yang et al., 2012). Hence, the present findings suggest that dietary fibre could be a key intervention to normalize bowel function.

Other health benefits exist beyond this "bulking" effect, however. Over the past few years, research into the microbiome has altered the science of the roles of fibre in gastrointestinal health. Fiber is not just required as a substrate for stool formation, but it is also an important source of nutrients for gut microbes (Holscher, 2017). Digestive enzymes from the human gastrointestinal tract are less effective on many fiber components, and so the undigested material leads to the colon, where it is fermented by the intestinal flora present there (Makki et al., 2018). The interaction points indicate the close relationship between dietary habits and the microbial environment and suggest that the effects of fiber may occur via both intestinal mechanics and more complex processes of host-microbe interaction. An important

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product of microbial fermentation is short-chain fatty acids (SCFAs: acetate, propionate, and butyrate), which are produced by microbial fermentation following the digestion of complex nutrients (Koh et al., 2016). These metabolites are of great importance for the connection between dietary fibre intake and gut health. Nevertheless, butyrate is the main energy source in the colonocytes, and it is essential to maintain epithelial barrier integrity. A healthy intestinal barrier will keep this from becoming too permeable and will limit inflammatory responses that could adversely affect gastrointestinal motility. Furthermore, SCFAs act on enteric (bowel) neurons and smooth muscle cells promoting gut motility and thus improving bowel movements (Valdes et al., 2018). Hence, the positive role of dietary fibre on improving constipation may be attributed to the production of SCFA and the improvement of optimum function of microorganisms.

The evidence reviewed also reveals that these people with chronic constipation may have dysregulated gut microbiota, including a decrease in microbial diversity and fewer species of beneficial bacteria, including *Bifidobacterium* and various *Lactobacillus* species (Ohkusa et al., 2019). Often, these microbial changes are accompanied by diminished fermentation activity and diminished generation of SCFA that could also directly lead to impaired bowel function. Thus, increased consumption of dietary fibre could be used to achieve both therapeutic effects: mechanical (e.g., stool characteristics) and fermentational (e.g. microbial balance and metabolism). The dual action sets apart dietary fiber from most traditional products on the market that target only symptomology rather than physiological or microbial causes of constipation. These studies collectively suggest that dietary fibre should not be viewed as a 'stool-bulking agent'. Rather, it plays an all-rounded role as a dietary fibre that can act on intestinal motility, microbial flora, metabolic activity, and gastrointestinal homeostasis as all-inclusive (Slavin, 2013; Makki et al., 2018). These interdependent mechanisms serve as scientific justification for recommending a long-term answer for constipation, which is to eat foods that are good sources of dietary fiber. Moreover, they provide a conceptual approach for further research into a specific class of fruits rich in dietary fiber, such as guava (*Psidium guajava*), which can provide further benefits due to its exclusive dietary fiber and bioactive composition.

In addition to its direct influence on the characteristics of the stool, research interest has been focused to date on the way through which dietary fibre influences the makeup of the gut microbiota and the interactions between the microbiota and the host's metabolic machinery. The human gastrointestinal tract contains an incredibly complex microbial community with trillions of microorganisms that play a role in metabolism, immune system function, regulation of lamina propria barrier integrity and gastrointestinal motility (Valdes et al., 2018). There is emerging evidence suggesting disturbances in this microbial ecosystem, known as dysbiosis, closely relate to the development of chronic constipation (Ohkusa et al., 2019; Zhao and Yu, 2016). Considering the beneficial effects of dietary fibre, however, in both a nutritional and a microbiological and metabolic contexts should be taken. The fermentation of the dietary fibre by intestinal microorganisms is one of the most important abilities to change bowel function. Many dietary fibres escape digestion in the upper gastrointestinal tract and enter the colon in an undigested form, where it acts as substrate

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for colonic bacterial fermentation (Makki et al., 2018). It helps to selectively promote the growth of certain bacterial groups, including *Bifidobacterium* and *Lactobacillus* species, which are often recognized to support digestive health, its benefits, and improve intestinal function (Holscher, 2017). For this reason, people who eat high-fibre foods tend to have higher levels of microbial diversity and a supposedly more balanced microbial makeup than those who eat fibre-deficient foods.

When dietary fibre is fermented, short-chain fatty acids (SCFAs), especially acetate, propionate, and butyrate, are produced, which are considered to be important factors that mediate gut health (Koh et al., 2016). These metabolites have various physiological roles in addition to their roles within the gastrointestinal tract. Butyrate acts as the main energy source for colonocytes, plays a major role in the maintenance of the intestinal barrier, and plays an important anti-inflammatory role. These acetate and propionate interact with metabolic signaling networks, which affect glucose control, lipid metabolism, and immune function (Valdes et al., 2018). These metabolites show a direct link between the consumption of dietary fibre, the activity of the microbes, and gastrointestinal health. SCFAs are of particular importance from the constipation management point of view since these factors impact intestinal motility and colonic transit time. Experimental research has shown that SCFAs help to enhance the efficiency of movement in the bowels by promoting proper entero-bowel signalling together with the stimulation of the smooth muscles (Koh et al., 2016). Decreased intestinal transit and constipation may thus occur due to a decrease in SCFA production (often seen in dietary low-fibre subjects and people with microbial dysbiosis). It's a new mechanistic explanation for the link between low-fibre diets and chronic constipation, which has been frequently seen before.

One more key finding from recent microbiome research is the correlation of lower levels of beneficial microorganisms and changes in the microbes' metabolism when constipation occurs (Ohkusa et al., 2019). There have been several investigations reporting decreased counts of *Bifidobacterium* species and *Lactobacillus* species in constipated people compared with healthy people. Such microbial alterations can result in suboptimal intestinal fermentation, reduced production of SCFA, and disturbance of intestinal pathways of signaling for bowel control. Thus, constipation should be treated not only as a dysfunction of the passage of stools but as a phenomenon that develops in the context of interactions between nutrition, intestinal flora, and the physiology of the intestines. The literature surveyed also indicated that a high intake of dietary fiber may have a beneficial effect on reversing these disturbances in the microflora. Fiber promotes microbial diversity and facilitates the generation of some metabolites from beneficial microbes as fermentable substrates in the gut, which are important for normal bowel function (Holscher, 2017; Makki et al., 2018). However, unlike stimulant laxatives, which produce short-term relief for symptoms, dietary fibre exerts a feedback effect on underlying physiological reasons as it works through improving the quality of the stool as well as the microorganisms involved. It is this dual action that could account for the reason why interventions based on fiber are often suggested as long-term effective interventions for the prevention of constipation and constipation management.

The prevailing body of evidence favours a multifactorial mechanism through which dietary fibre has beneficial effects, which involves mechanical, microbial, and

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metabolic pathways. Besides improving stool bulk, it also works to improve hydration. Also, it has important implications for bacterial ecology, SCFA formation, intestinal signaling, and epithelial health. The data suggest that an adequate diet of fibre can play a crucial role in gastrointestinal health within a broader healthier lifestyle. Moreover, they have a scientific justification for further investigation on particular fruits that are rich in fiber, such as guava fruit (*Psidium guajava*), which has a fiber profile and high bioactive compounds that could exhibit other focused microbiota-mediated benefits in managing constipation. The beneficial effects of dietary fiber as a laxative on constipation are undisputed, but there is increasing evidence that the source of fiber could have a significant impact on the physiological and microbiological effects it has when eaten. The benefits of fiber from whole foods over fiber supplements used alone have received greater attention over the past few years (Gill et al., 2021). While purified fibre preparations might increase stool bulk and bowel frequency, they are not as rich in bioactive compounds as fruits and vegetables. It is a reasonable assumption, therefore, that dietary fibers from whole foods might offer greater and longer-lasting benefits to gastrointestinal well-being in a variety of complementary ways.

Fruity fibers, with their balanced supply of soluble and insoluble fiber, are types of dietary fibers of special importance. Soluble fibers add water to stools, encourage bacteria growth in the bowel, while insoluble fibers increase stool bulk and bowel movement (Slavin, 2013). This synergy helps to promote bowel regularity better than some fiber supplements, which contain just one type of fiber. Moreover, fruits are naturally packed with water, which can further help to make stools soft and so ease bowel movements. So, the advantage of the fruit is not just the amount of fibre, but the quality of fibre in relation to the fruit's other nutritional components. One key difference between fruits and purified fiber supplements is polyphenols, flavonoids, vitamins, and antioxidants. Increasingly, these compounds are known to play a key role in modulating the gut microbiota, both in terms of their overall composition and function (Valdes et al., 2018). Polyphenols can have bidirectional interactions with intestinal microorganisms, especially. Probiotics convert polyphenols to bioactive compounds, and polyphenols can selectively enhance beneficial microbes and inhibit harmful microbes (Jin et al., 2023). As a result of this interaction, enhanced microbial diversity and a healthier gut environment may even result in benefits to bowel functioning and alleviate the symptoms of constipation.

There has been much research done in the past few years linking bioactive compounds in fruits with gut microbiota. Specific studies also show polyphenol-rich foods can contribute to the growth of beneficial bacteria (*Bifidobacterium* spp. and *Lactobacillus* spp.), and inhibit inflammatory and metabolic dysfunction linked to microbial communities (Jin et al., 2023; Holscher, 2017). The changes in microorganisms could enhance fermentation efficiency and boost short-chain fatty acid (SCFA) production, which would improve intestinal motility and epithelial health. Fruit-based diet interventions thus have the potential to have both physiological and indirect gut microbiota-related benefits. Another factor to keep in mind is the fruits' antioxidant properties. Having an imbalance of Reactive Oxygen Species (ROS) and antioxidant molecules has been linked with some gastrointestinal diseases, including disorders of compromised intestinal function and inflammation. The antioxidants

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contained in fruits are believed to help neutralize the ROS and maintain the integrity of the intestinal barrier (Gill et al., 2021). The antioxidant action of fruits and a positive effect on the intestinal environment could help in keeping the gastrointestinal system in a healthier condition earlier and also in the long run. The effects further reinforce the importance of dietary recommendations based on whole fruits instead of individual nutrients. Epidemiological and clinical studies have all consistently linked the intake of fruits with abdominal regularity. People who have fruits in their diet regularly have a lower rate of constipation and better stool frequency than people with low-fruit diets (Huo et al., 2022). Based on these observations, it is tempting to conclude that it is the combination of these reputedly effective components in the pads that makes them such an effective treatment, more effective than fiber alone. Fruits, therefore, should not be considered only as a fibre source, but have the potential to positively impact some pathways in gastrointestinal health.

The current evidence demonstrates that dietary fibers from fruits hold promises for treating constipation due to their diverse effects on stool properties, the composition of intestinal microbes, the production of SCFAs, and intestinal homeostasis. The findings offer a sound scientific foundation to pursue detailed studies on specific fruits that have a very high level of fiber and phytochemical content. Being one of the above-mentioned fruits, guava (*Psidium guajava*) has gained growing interest based on its nutritional profile, greater concentration of dietary fiber, and higher proportion of biologically active compounds. Hence, guava is seen as a potential candidate for further investigation as a functional food to be used for the modulation and improvement of the gut microbiome and constipation. Among the different fruit fibre sources, guava (*Psidium guajava*) has proved to be an interesting candidate for use in developing a functional food because of its high nutritional value and gastrointestinal properties. It is widely grown in tropical and subtropical areas and is not just popular for its delicious taste, but also for its nutritional value, which includes a rich network of phytochemicals including polyphenols, flavonoids, carotenes, and many more, with particularly high amounts of dietary fibre and vitamin C (Naseer et al., 2018; Joseph & Priya 2011). The nutritional properties indicate that guava could offer direct physiological functions as well as indirect functions mediated by microbiota, which might enhance gastrointestinal well-being. The content of dietary fibre is one of the most important properties of guava. Guavas are one of the few fruits that are both rich in soluble and the rich in insoluble fibre. Insoluble fiber will increase intestinal peristalsis and fecal bulk to push the contents through the colon (Slavin, 2013). Concurrently, soluble fiber becomes gel-like with water, which makes stools softer and easier to hydrate, alleviating pain during bowel movements and hard stools. Since guavas have both these types of fiber, they might offer a synergistic effect which would make them a more potent aid to bowel regularity than foods that contain just one of the dominant fiber fractions.

In addition to its fiber content, guava is a fruit with a very high amount of vitamin C, even more than that of most of the other commonly consumed citrus fruits (Naseer et al., 2018). Vitamin C acts as a powerful antioxidant, which is important for the protection of the internal tissues of the intestine from oxidative stress, as well as for immune function in the gastrointestinal tract. Chronic gastrointestinal dysfunction can

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also be linked with low grade inflammation and oxidative damage, so the antioxidant action of guava can be beneficial to hold the intestinal lining together and keep a healthier digestive system. This indicates that guava has benefits other than fiber-mediated. The other pivotal factor of the guava nutritional profile is its rich content of polyphenols and flavonoids. These chemicals boast antioxidant, anti-inflammatory, and antimicrobial attributes that can have a beneficial effect on the composition of gut microorganisms (Joseph & Priya, 2011). Polyphenols can be utilized by microbes, and metabolites beneficial to gut health can be generated. At the same time, they can cause beneficial bacteria to grow, but potentially harmful bacteria to be inhibited. The synergistic relationship between polyphenols and gut microbiota has been gaining momentum in recent years as it is a further mechanism by which the consumption of fruits could act as a beneficial effect on gastrointestinal function. The ability of guava to show prebiotic activity is significant for constipation treatment. Prebiotics are substances in the diet that selectively help 'friendly gut bacteria' grow and work in the gut. The fiber content and phytochemical composition of guava could render it a natural prebiotic, which will make it a natural prebiotic by increasing the microbial diversity and stimulate the fermentation process of the colon (Holscher, 2017). With an increase in fermentation activity, more short-chain fatty acids (SCFAs) can be made, seen as helpful to enhance intestinal motility, strengthen the intestinal barrier, and manage inflammatory responses. While the effects of guava on the production of SCFAs have not been directly studied in humans, the current data support this idea, and this likely is one of the pathways involved in the potential therapeutic benefits of guava.

Some of guava's attractive qualities are compared to other fruits that are regularly advised for individuals having bowel problems. Guava is compared to other fruits that are typically suggested for bowel issues, like prunes, apples, pears, and kiwifruit. These fruits have high dietary fibre content as well as retention of water, much like guava. The rich polyphenolic content and high vitamin C content may provide some other health benefits associated with it, in addition to bowel regulation (Naseer et al., 2018). The functional effects of guava components have established it as a nutritional asset that affects multiple physiological pathways with its fiber and bioactive contents. Although the above-mentioned properties are promising, there is a limited number of scientific studies specifically focusing on guava for gut microbiota modulation and constipation. Very few studies exist in terms of the impact it has on bowel function and the microbes. The available studies are mostly focused on its nutrients, antioxidant content, and overall health benefits. Therefore, it is not well understood how the dietary fibre content of guava directly affects the diversity of microbes, promotes SCFA production, affects the motility of the intestine, and affects constipation. This is why it is important to fill this gap: it may be possible to use the information in the development of a cost-effective, food-based intervention that can be applied in clinical and community settings. The literature reviewed on guava shows that it has several properties that make it a functional food for digestive health. It has been well documented from a scientific point of view that the use of it in constipation is related to its presence of soluble and insoluble fibre, as well as antioxidants, polyphenols, flavonoids, and vitamin C. The evidence presented, though promising, still needs to be further complemented by controlled evaluation in humans, microbiome

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analyses, and mechanistic studies to definitely prove its efficacy and elucidate the specific biological mechanisms. This study could contribute to the scientific basis for including guava in a dietary approach to balance the gut microbiota and reduce constipation in the population.

While there's plenty of evidence that dietary fiber has positive effects on the health of the gut and the treatment of constipation, there are several points to consider. An important conclusion that came out of this review is that several studies focused on the effect of dietary fiber, not specifically fiber-containing foods, and the downstream physiological effects thereof. Although the overall trend between consumption of fibre and its effects on bowel activity is known, the mechanisms by which the specific effects of each type of fruit occur are not known to be the same between fruits. This is especially true for guava (*Psidium guajava*), which has an exclusive nutritional profile and has been poorly studied in relation to constipation. Another limitation is the fact that much of the evidence for the efficacy of guava fibre comes from observational studies, laboratory investigations, or experimental studies on dietary fibre in general rather than on guava fibre specifically (Bharucha & Lacy, 2020). Observational studies can give us important information about people's diets and bowel health, but do not prove causal links. Like so many mechanistic studies considering gut microbiota and short-chain fatty acid (SCFA) production, research models that do not necessarily represent the physiology of the human gastrointestinal tract are used. Consequently, the clinical impact of some of the findings is still inconclusive and needs to be confirmed in adequately designed human intervention studies.

There is also a wide variety of study populations, diets evaluated, microbiome analysis techniques, definitions of constipation, and outcome measures among published studies, which makes it difficult to provide comparisons among them (Ford et al., 2014). Moreover, there are many factors affecting the composition of gut microbiota: use of medication, age, geographical location, lifestyle, and dietary habits. These factors can affect the outcome of studies and partly account for the opposing findings of some studies. Therefore, a standardized approach is required to make dietary interventions for constipation more comparable and in line with the actions of dietary intervention. One of the key unmet research needs of this review is that only a small number of studies have directly assessed the effect of guava on gut microbiota modulation. Although it is known that guava contains great amounts of dietary fibre, Vitamin C content, flavonoids, and polyphenolic compounds, there were limited studies focusing on the effects of these compounds on microbial diversity, fermentation activity, and SCFA production in human populations. Current literature emphasizes most of the antioxidant, antimicrobial, and antidiabetic activity and nutritional profiles of guava fruit, but its digestibility has not been widely studied (Naseer et al., 2018; Joseph & Priya, 2011). All the mechanisms by which guava can relieve constipation are therefore only speculative, but mostly identified from the surrounding research on dietary fibre and not through clinical evidence.

Recent studies indicate that gut microbiota is a key player in gastrointestinal health, and more specific investigations are needed. Future experiments should incorporate high-throughput sequencing methods of the microbiome, metabolomics analyses, and controlled dietary intervention designs to better understand the impact of

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guava fiber on microbiome composition and activity. Specific attention must be paid to changes in beneficial bacteria, like *Bifidobacterium* and *Lactobacillus*, changes in the concentration of SCFA, and intestinal transit time. Such studies should help in defining the mode of action of guava's therapeutic actions on the biological systems. Besides, further RCTs need to be conducted on the efficacy of guava as a functional dietary intervention for managing constipation. These trials should aim to make comparisons with other fiber-rich fruits commonly recommended to see if there are unique or better advantages of eating guava as compared to conventional fiber supplements. Long-term studies are also warranted to determine the impact of its use on gastrointestinal and other health effects, as well as compliance. Long-term studies are also necessary to evaluate the sustainability, safety, and effect on gastrointestinal health. The scientific basis for the intake of guava in advice and clinical practice guidelines would be further strengthened with such evidence. In addition, these conclusions from this review have significant implications for public health. Constipation is a condition that impacts millions of people in the world and thereby impacts quality of life, healthcare use, and has a significant economic impact. The potential of changing diet as a low-cost, readily available, non-drug strategy for management makes the need for its identification a priority. The availability of guavas in many tropical and subtropical countries throughout the world makes this fruit a promising edible food item for promoting bowel health, given its ease of availability and low cost. Therefore, guava may be a valuable addition to the indications for nutrition recommendations in the future if its microbiota-modulating and constipation-relieving effects are found to be sustained in further studies.

The evidence reviewed here overall indicates that dietary fibre offers a powerful core support of the concept that it is a result of both the mechanical, microbial, and metabolic activity, and that it improves constipation. Fiber adds bulk and hydration to stools, fosters good bacteria colonization, stimulates production of SCFA, and aids in gut function. Fibers from fruit also seem to have added value, as they add other bioactive components that also play a beneficial role in gut health. In these fruits, guava (*Psidium guajava*) is very promising because of its rich fiber composition and phytochemical diversity. While the potential of this is sound, substantial gaps in the available evidence exist, however. Thus, further clinical, microbiological and mechanistic studies are needed to determine its ability to properly function as a gut microbiota modulating functional food in the treatment of constipation.

Limitations

The limitation of this study is that there are no specific scientific studies that have focused on the direct action of guava fibre on gut microbiota modulation and application for the alleviation of constipation. While there are several studies which validate the positive impact of dietary fibre consumption on digestive health, the majority of the studies have focused on dietary fibre, fibre supplements, or other fruits and not on guava specifically. Therefore, the exact biological mechanisms by which guava fiber has an anti-microbial effect, enhances the diversity of intestinal bacteria, and regulates bowel movement functions are still not completely understood. Furthermore, guava contains several nutritive and bioactive elements (including soluble fibre, insoluble fibre, polyphenols, antioxidants, and flavonoids), making it challenging

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to determine which of these elements might be responsible for digestive effects. Another constraint is that the guava variety, ripeness stage, growing practices, processing methods, and consumption habits vary, which can lead to different results of the research. Additionally, other parameters such as age, water consumption, feeding and eating habits, activity level, metabolism, and differences in the baseline gut microbiota composition will influence the effect of guava consumption, which may constrain these findings to other demographics. Only a few long-term human clinical trials with guava are available, and currently published studies are mostly related to observations, laboratory studies, or theoretical. Further, constipation is a complex problem related to the functioning of the digestive tract along with various physiological, psychological, and lifestyle factors, making the assignment of the dietary fibre from guava fruits alone in causing constipation very difficult. Despite these encouraging results on the possible benefits of guava for digestive health and constipation, more experimental, microbiological, and clinical studies are required on a larger scale to validate its effectiveness and provide a better understanding of long-term effects, the recommended dose for consumption, and its effects on gut microbiota.

Conclusion

In conclusion, the present work highlights that the anti-constipation, mechanical, and microbiological activities of the dietary fibre extracted from guava fruit have immense potential in the pharmaceutical domain to overcome the issue affecting the gastrointestinal tract, which is constipation. The soluble and insoluble dietary fibers found in guava help to increase stool bulk, increase water retention, soften the stool, and improve the intestinal transit, which is critical to keep bowel movements regular and reduce the common symptoms of constipation. Guava fiber is not only physically beneficial, it is also a fermentable fiber for gut microbiota that helps keep the gut balanced and produces the short-chain fatty acids that are essential to gut health, inflammation regulation, and colon function. This is believed to extend the functions of dietary fibre beyond simply digestion to cover a wider range of involvement with intestinal microbes and intestinal homeostasis. Further, the property of promotion of probiotics and suppressing oxidative stress in the gastrointestinal system could be the additional protective and functional properties of the gastrointestinal system provided by antioxidants, polyphenols, and other phytochemical properties contained in guava. The authors also highlight the role of disruption of the gut microbiota, reduction in dietary fibre intake, and unhealthy nutritional practices as the main factors causing constipation and its poor clinical results. Hence, intake of the natural guava can be regarded as a promising dietary habit for digestive health and chronic constipation, as it is an affordable and eco-friendly diet choice. In addition, numerous parts of the world have ready access to guava; it is cheap and very popular culturally, thereby providing guava with great potential in the area of public health nutrition as a functional food, and as a food for digestive health over an extended period of time. Despite this encouraging evidence, the current study shows that there are very few detailed clinical and mechanistic studies focusing on guava-based dietary fiber, specifically on the effect of gut microbiota composition and outcome on constipation. The key point is that there are, at the present time, no specific investigations or studies of dietary fibre for guava and only generalized ones. Hence, more experimental, microbiological, and long-term

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clinical studies are required to get scientific evidence of dose recommendation standardization, study long-term safety and efficacy, and better understand how guava works to maintain proper bowel and gut flora. Overall, this study has presented convincing data on the potential of this natural dietary fiber as an alternative source for alleviating constipation and possibly other gastrointestinal conditions and its association with the human gut microbiome.

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Author Contributions

Muhammad Waqas conceived and designed the study, supervised the research, and wrote and finalized the manuscript. Hazrat Anas contributed to data collection, experimental work, and initial data analysis. Abd Ullah Shah assisted in laboratory analyses, data interpretation, and validation of results. Khushdil Khan contributed to statistical analysis, visualization of data, and critical revision of the manuscript. All authors read and approved the final version of the manuscript.

References

1. Agus, A., Planchais, J., & Sokol, H. (2018). Gut microbiota regulation of tryptophan metabolism in health and disease. *Cell Host & Microbe*, 23(6), 716–724. <https://doi.org/10.1016/j.chom.2018.05.003>
2. Anderson, J. W., Baird, P., Davis, R. H., Ferreri, S., Knudtson, M., Koraym, A., Waters, V., & Williams, C. L. (2009). Health benefits of dietary fiber. *Nutrition Reviews*, 67(4), 188–205. <https://doi.org/10.1111/j.1753-4887.2009.00189.x>
3. Barberio, B., Judge, C., Savarino, E. V., & Ford, A. C. (2021). Global prevalence of functional constipation according to the Rome criteria: A systematic review and meta-analysis. *The Lancet Gastroenterology & Hepatology*, 6(8), 638–648. [https://doi.org/10.1016/S2468-1253\(21\)00161-0](https://doi.org/10.1016/S2468-1253(21)00161-0)
4. Bharucha, A. E., & Lacy, B. E. (2020). Mechanisms, evaluation, and management of chronic constipation. *Gastroenterology*, 158(5), 1232–1249. <https://doi.org/10.1053/j.gastro.2019.12.034>
5. Bharucha, A. E., Pemberton, J. H., & Locke, G. R. (2013). American Gastroenterological Association technical review on constipation. *Gastroenterology*, 144(1), 218–238. <https://doi.org/10.1053/j.gastro.2012.10.028>
6. Camilleri, M., Ford, A. C., Mawe, G. M., Dinning, P. G., Rao, S. S. C., Chey, W. D., Simrén, M., Lembo, A., & Young-Fadok, T. M. (2017). Chronic constipation. *Nature Reviews Disease Primers*, 3, 17095. <https://doi.org/10.1038/nrdp.2017.95>
7. Cardona, F., Andrés-Lacueva, C., Tulipani, S., Tinahones, F. J., & Queipo-Ortuño, M. I. (2013). Benefits of polyphenols on gut microbiota and implications in

Online ISSN

3007-3197

Print ISSN

3007-3189

<http://amresearchreview.com/index.php/Journal/about>

- human health. *Journal of Nutritional Biochemistry*, 24(8), 1415–1422. <https://doi.org/10.1016/j.jnutbio.2013.05.001>
8. Cho, S. S., & Samuel, P. (2009). *Fiber Ingredients: Food Applications and Health Benefits*. CRC Press. <https://www.routledge.com/Fiber-Ingredients-Food-Applications-and-Health-Benefits/Cho-Samuel/p/book/9781420043842>
9. Drossman, D. A. (2016). Functional gastrointestinal disorders: History, pathophysiology, clinical features and Rome IV. *Gastroenterology*, 150(6), 1262–1279. <https://doi.org/10.1053/j.gastro.2016.02.032>
10. Eswaran, S., Muir, J., & Chey, W. D. (2013). Fiber and functional gastrointestinal disorders. *American Journal of Gastroenterology*, 108(5), 718–727. <https://doi.org/10.1038/ajg.2013.63>
11. Ford, A. C., Suares, N. C., et al. (2014). Effect of laxatives and pharmacological therapies in chronic idiopathic constipation: Systematic review and meta-analysis. *Gut*, 63(6), 1000–1009. <https://doi.org/10.1136/gutjnl-2013-304947>
12. Gibson, G. R., Hutkins, R., Sanders, M. E., et al. (2017). The International Scientific Association for Probiotics and Prebiotics consensus statement on the definition and scope of prebiotics. *Nature Reviews Gastroenterology & Hepatology*, 14, 491–502. <https://doi.org/10.1038/nrgastro.2017.75>
13. Gill, S. K., Rossi, M., Bajka, B., & Whelan, K. (2021). Dietary fibre in gastrointestinal health and disease. *Nature Reviews Gastroenterology & Hepatology*, 18, 101–116. <https://doi.org/10.1038/s41575-020-00375-4>
14. Holscher, H. D. (2017). Dietary fiber and prebiotics and the gastrointestinal microbiota. *Gut Microbes*, 8(2), 172–184. <https://doi.org/10.1080/19490976.2017.1290756>
15. Jin, Y., Wu, S., Zeng, Z., & Fu, Z. (2023). Effects of polyphenols on gut microbiota and human health. *Nutrients*, 15(3). <https://doi.org/10.3390/nu15030666>
16. Joseph, B., & Priya, R. M. (2011). Review on nutritional, medicinal and pharmacological properties of guava (*Psidium guajava* Linn.). *International Journal of Pharma and Bio Sciences*, 2(1), 53–69. <https://www.researchgate.net/publication/266888728>
17. Koh, A., De Vadder, F., Kovatcheva-Datchary, P., & Bäckhed, F. (2016). From dietary fiber to host physiology: Short-chain fatty acids as key bacterial metabolites. *Cell*, 165(6), 1332–1345. <https://doi.org/10.1016/j.cell.2016.05.041>
18. Lacy, B. E., Mearin, F., Chang, L., et al. (2016). Bowel disorders. *Gastroenterology*, 150(6), 1393–1407. <https://doi.org/10.1053/j.gastro.2016.02.031>
19. Louis, P., & Flint, H. J. (2017). Formation of propionate and butyrate by the human colonic microbiota. *Environmental Microbiology*, 19(1), 29–41. <https://doi.org/10.1111/1462-2920.13589>
20. Makki, K., Deehan, E. C., Walter, J., & Bäckhed, F. (2018). The impact of dietary fiber on gut microbiota in host health and disease. *Cell Host & Microbe*, 23(6), 705–715. <https://doi.org/10.1016/j.chom.2018.05.012>
21. McRorie, J. W., & McKeown, N. M. (2017). Understanding the physics of functional fibers in the gastrointestinal tract. *Journal of the Academy of Nutrition and Dietetics*, 117(2), 251–264. <https://doi.org/10.1016/j.jand.2016.09.021>

Online ISSN

3007-3197

Print ISSN

3007-3189

<http://amresearchreview.com/index.php/Journal/about>

22. Naseer, S., Hussain, S., Naeem, N., Pervaiz, M., & Rahman, M. (2018). The phytochemistry and medicinal value of Psidium guajava. *Biomedicine & Pharmacotherapy*, 95, 32–44. <https://doi.org/10.1016/j.biopha.2017.07.119>
23. Krause's Food & the Nutrition Care Process (13th Edition) - Elsevier^[OBJ]
24. Rao, S. S. C., & Camilleri, M. (2010). Metabolic and functional causes of constipation. *Alimentary Pharmacology & Therapeutics*, 31(7), 775–785. <https://doi.org/10.1111/j.1365-2036.2010.04253.x>
25. Slavin, J. L. (2013). Fiber and prebiotics: Mechanisms and health benefits. *Nutrients*, 5(4), 1417–1435. <https://doi.org/10.3390/nu5041417>
26. Sonnenburg, E. D., & Sonnenburg, J. L. (2014). Starving our microbial self: The deleterious consequences of a diet deficient in microbiota-accessible carbohydrates. *Cell Metabolism*, 20(5), 779–786. <https://doi.org/10.1016/j.cmet.2014.07.003>
27. Soares, N. C., & Ford, A. C. (2011). Prevalence of, and risk factors for, chronic idiopathic constipation in the community. *American Journal of Gastroenterology*, 106(9), 1582–1591. <https://doi.org/10.1038/ajg.2011.164>
28. Tzounis, X., Rodriguez-Mateos, A., Vulevic, J., Gibson, G. R., Kwik-Urbe, C., & Spencer, J. P. E. (2008). Prebiotic evaluation of cocoa-derived flavanols. *Journal of Agricultural and Food Chemistry*, 56(20), 9780–9786. <https://doi.org/10.1021/jf801675e>
29. Valdes, A. M., Walter, J., Segal, E., & Spector, T. D. (2018). Role of the gut microbiota in nutrition and health. *BMJ*, 361, k2179. <https://doi.org/10.1136/bmj.k2179>
30. Wald, A., Scarpignato, C., Kamm, M. A., et al. (2016). The burden of constipation on quality of life. *Alimentary Pharmacology & Therapeutics*, 44(3), 227–238. <https://doi.org/10.1111/apt.13620>
31. Yang, J., Wang, H. P., Zhou, L., & Xu, C. F. (2012). Effect of dietary fiber on constipation: A meta-analysis. *World Journal of Gastroenterology*, 18(48), 7378–7383. <https://doi.org/10.3748/wjg.v18.i48.7378>
32. Zhao, Y., & Yu, Y. B. (2016). Intestinal microbiota and chronic constipation. *SpringerPlus*, 5, 1130. <https://doi.org/10.1186/s40064-016-2821-1>