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A review on the potential of bamboo as dietary source of prebiotics and their impact on human health

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Abstract

The prevalence of chronic disease has increased substantially over the last several decades and scientific research has correlated them with the altered food habits accompanied by other lifestyle changes. The consumption of processed foods has negatively influenced the diversity and population of beneficial gut microbiota, which deteriorates our digestive and immune health. Hence, the demand of health food and nutraceuticals that prevents various chronic health problems is increasing among the consumers. Prebiotics are one such promising food nutrients that selectively promote the growth of beneficial microbes belonging to the genera *Lactobacillus, Clostridiales, Ruminococcus*, and *Lachnospiraceae* in the gastro-intestinal tract, enhance the absorption of certain vitamins and minerals, and selectively inhibit the growth of pathogens, thus reduce the risk factors involved in colorectal diseases. Various investigators have reported the potential prebiotic activity of bamboo leaves, shoots and bamboo vinegar. Juvenile bamboo shoots are rich in dietary fibers and polysaccharides that are fermented in the colon by the resident microbes results in yielding energy and short chain fatty acids, which in turn promote their own population. Bamboo vinegar has a low pH that promotes the growth of intestinal lactic acid bacteria, improves digestion and absorption to enhance appetite and reduces abnormal fermentation in the intestinal tract. Supplementation of bamboo leaf flavonoids is known to have improved immune function due to modulation of cecum microbiota. This review emphasizes the potential of naturally occurring components of bamboo in the development of commercial prebiotics and their impact on various biological functions contributing to human health.

Keywords Bamboo; prebiotics; dietary fibers; polysaccharides; gut microbiota; short chain fatty acids

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1. Introduction

In recent decades, enormous amount of scientific research has highlighted the significance of gut microbiota in maintaining human health. The definition a normal 'healthy' gut microbiota in human is not so clear, but they play vital role in inhibiting the progression of chronic diseases including inflammatory bowel diseases, obesity, colorectal cancer, type 2 diabetes and the metabolic syndrome (Alonso and Guarner 2013). These intestinal microbial community also perform functions including colonic fermentation of starches, dietary fibers and other available carbohydrate sources and convert them into short chain fatty acids (SCFA's), along with production of essential nutrients such as vitamins and bioactive components that modulates gastrointestinal epithelium, provide protection against pathogens and immunostimulation (Hillman et al. 2017). SCFAs are simple aliphatic carboxylic acids consists of acetate, propionate, and butyrate that are produced as microbial metabolites in the colonic lumen. The most studied gut microbes belong to six phyla named as *Firmicutes, Bacteroidetes, Actinobacteria, Proteobacteria, Fusobacteria* and *Verrucomicrobia* among which *Firmicutes* and *Bacteroidetes* are the major types (Laterza, et al. 2016). The biochemical profiling of diet plays vital role in maintaining the healthy symbiosis between the gut microbiota and host. Adequate dietary intake of certain food components is essential for maintaining the functional gut microbial environment, which includes fibers, polysaccharides, resistant starch termed as prebiotics. Gut microbiota selectively fermented the dietary prebiotics that cause specific changes in their composition and activity thus conferring various health benefits. There are three requirements for dietary components to act as a prebiotic: 1) resistance to gastric juice hydrolysis and gastrointestinal absorption; 2) ability to be slowly fermented by intestinal microbiota and in turn stimulates their own growth 3) have no negative effects on host's health, such as pathogenic microorganism's growth or abdominal discomfort (Gibson et al. 2004). Besides, for effectiveness prebiotic must be present in a certain amount to maintain target bacteria to the desired level (Lordan et al. 2020).

Plant based diets are rich source of components that can boost the abundance and diversity of beneficial gut bacteria and act as prebiotic (Gibson et al. 2004). Plants based foods with prebiotic properties have been reported as rich source of carbohydrate polymers that are neither digested nor absorbed in the small intestine (Kharuddin et al. 2023). Carbohydrate components in plants with prebiotic potential include non-starch polysaccharides, resistant oligosaccharides and resistant starch, collectively named as fibers. Dietary composition is an important factor affecting intestinal bacteria. The non-starch polysaccharides fibres with 10 or more monomeric units mainly include cellulose, hemicellulose, pectin, inulin, and various hydrocolloids (Kumar et al. 2012). Resistant oligosaccharides consist of 3–9 monosaccharide units, many of which were named after polymerized monosaccharides, such as galacto-oligosaccharides (GOS), fructo-oligosaccharides (FOS), and galactosides (Mussatto and Mancilha 2007). Generally, soluble fibers (oligosaccharides and non-cellulosic polysaccharides) are fermented faster and to a higher extent than insoluble fibers (water-insoluble hemicellulose) (Rezende, et al. 2021). Recent research investigations also suggests that some non-carbohydrate substances, such as phenolic compounds, carotenoids, polyunsaturated fatty acids, and vitamins, stimulates beneficial bacteria and provide good gut health, hence have prebiotic properties (Rodriguez-Daza et al. 2021). Total dietary polyphenols consumed in diet are weakly absorbed in the small intestine (5–10%) and thus reach the colon with the remaining 90–95%, where it is exposed to the enzymatic activity of local microbiota (Frolinger et al. 2019). Alves-Santos et al. (2020) revealed that polyphenols such as catechins, anthocyanins, proanthocyanin and flavanoid can stimulate the growth of microorganisms including *Lactobacillus* spp., *Bifidobacterium* spp., *Akkermansia* spp. and *Roseburia* spp., along with the increased SCFA production such as butyrate.

Health awareness among population has been resulted in the popularity of prebiotic consumption and to fulfil this demand novel, cost-effective sources has been receiving more and more attention. Bamboo is one such fastest growing, renewable natural resources with shoots and leaves being part of traditional food and medicinal system of Asian countries (Lathwal et al. 2023; Rani et al. 2023). Various research investigations reported the anti-carcinogenic, anti-diabetic, anti-inflammatory and immmuno-stimulating properties of bamboo leaves owing to their bioactive compounds including phenols, flavonoid and flavone glycosides (Nirmala et al. 2018; Indira et al. 2022). Consumption of bamboo shoots as fresh or in processed forms such as boiled, soaked, canned and fermented are very popular (Joshi et al. 2023). The nutrient profile of shoots showed that they are rich source of protein, amino acids, carbohydrates, fiber, phenolic compounds, vitamin and minerals (Chongtham and Bisht 2020; Chongtham et al. 2021). Bamboo shoots also possess health benefits including weight loss, lowering of serum cholesterol, cardioprotection, antioxidant and anti-cancer activity (Chongtham and Bisht 2020; Kalyan et al. 2023; Indira et al. 2023a,b). The present review discusses the current state of knowledge about components of bamboo that have positive impact on gut microbiota and host’s health, and their potential as future prebiotics.

2. Bamboo Shoots Dietary Fibers and Polysaccharides

Young juvenile culms of bamboo being low in fat, high in dietary fibre and rich in polyphenol content, are ideal source for extraction of prebiotic components. Sampaio et al (2023) confirms the potential prebiotic activity of young bamboo culm (*Dendrocalamus latiflorus*) flour as when combined with rice flour to produce healthy extruded products improves their physicochemical and technological properties. Supplementation of basal diet of broilers with 1% of micronized bamboo powder improves their caecal chyme microflora and regulates metabolic pathways for intestinal fatty acids, amino acids, and intestinal immune IgA production (Dai et al. 2022). It was rich in bamboo leaf flavonoids and polysaccharides, which can regulate the immunity and anti-oxidant capacity of animals (Ge et al. 2020). Dietary fibers are complex compounds mainly carbohydrates except lignin, that are resistant to digestion in the small intestine but may only be fermented to a limited extent in the colon to have positive impact on gut microbiota (Tejada-Ortigoza et al. 2016). Bamboo shoots being rich in fiber are the potential dietary source for prebiotics. Fang et al. (2020) reported the prebiotic potential of modified dietary fiber from the basal part of bamboo shoot. Bamboo dietary fiber in both cases when modified using enzymatic hydrolysis and dynamic high-pressure micro-fluidization (DHPM) showed improved *in vitro* prebiotic property indicated by positive impact on the growth of *Lactobacillus acidophilus* ATCC 4356 and *Bifidobacterium longum* ATCC 15707. FTIR analysis confirmed the increase in crystallinity of DHPM-modified fibers due to the disruption of lignin and hemicellulose. However, both methods have efficiently reduced the fiber particle size and increased roughness of the fiber surface. The soluble dietary fiber (SDF) and insoluble dietary fiber (IDF) extracted from bamboo shoots of *Phyllostachys praecox*, *P. edulis, Fargesia spathacea*, *P. pubescens*, and *P. iridescens* found highest in *F. spathacea* (1.76%) and *P. pubescensis* (3.41%) while they were lowest in *P. praecox* (0.35%) and *P. iridescens* (2.64%), respectively (Wu et al. 2020). Both SDF and IDF from *F. spathacea* showed higher cholesterol-adsorption capacities than those from other bamboo shoots and has effectively modulated the intestinal microbiota composition by promoting *Lactobacillus* and *Bifidobacterium* population, as well as increasing the SCFAs contents. IDF was more effective in enhancing the production of SCFAs as compared to SDF supplement during *in vitro* fermentation while the promotion of microbiota growth was relatively higher for SDF. In another study, Wu et al. (2023) performed the *in vitro* glycolysis of intestinal microbiota samples in non-targeted colonic fecal fermentation broth to determine the effect of bamboo shoots (*Phyllostachys edulis*) dietary fiber (BSDF) on the intestinal microbiota. The study revealed that population of *Alistipes* and *Lactobacillus* were increased after bamboo shoot dietary fiber fermentation, whereas those of *Escherichia-Shigella*, *Enterococcus*, and *Proteus* significantly decreased. After fermentation for 48 h, BSDF altered the levels of 17 metabolites including cadaverine and regulated the metabolism of the SCFAs, amino acids, and bile acids. The supplementation of high fat diet (HFD) with 10 % bamboo shoot fiber exhibited the lowest weight gain along with increased relative abundance of *Bacteroidetes* among all groups fed with HFD diet supplemented with other fibers (Li et al. 2016). The study also revealed that bamboo shoot fiber effectively suppressed the increased abundance of *Verrucomicrobia*, induced due to high-fat feeding. The characterization of bamboo shoot fiber showed that it is semi-fermentable as it consists both both nonfermentable cellulose (30.8%) and fermentable hemicellulose (41.8%). Ikeyama et al. (2021) evaluated the prebiotic potential of bamboo hemicellulose hydrolysate (BHH) by investigating the correlations between the fecal microbiomes and BHH in mice groups fed either a normal diet, a high-fat diet, or a high-fat diet supplemented with 5% BHH for 5 weeks. Fecal analysis has revealed non-significant alpha diversity (within community) for all groups whereas beta diversity analysis (among communities) showed suppression of high-fat diet induced changes. BHH group showed the amelioration of *Firmicutes/Bacteroidetes* ratio, the family S24-7 of *Bacteroidales, Lachnospiraceae* and several cellulolytic taxa. In addition, BHH significantly improved short-chain fatty acid production for all of the gut bacterial communities as well as lowered the serum cholesterol levels and fecal pH.

Li et al. (2021) investigated the effects of *Phyllostachys edulis* shoot polysaccharides (BSP) on the gastrointestinal health of humans. The study involved *in vitro* fermentation of BSP using human gut microbes and results exhibited the significantly increased concentration of short-chain fatty acids and organic acid while reduction in the pH and ammonia concentrations. The gut microbial community structure of the BSP-treated group showed increased abundance of *Firmicutes*, *Actinobacteria*, and *Proteobacteria* while that of *Bacteroidetes* and *Fusobacteria* decreased significantly. The polysaccharide fractions extracted from bamboo shoots (*Chimonobambusa quadrangularis*), using three different ethanol concentration (70%, 75%, and 80%) for precipitation has a significant impact on the prebiotic activity (Chen et al. 2020a). The three CPS fractions exhibited *in vitro* indigestibility to human gastric juice (>98.5%) and α-amylase hydrolysis (>94.5%). The addition of these polysaccharides as alternative carbon sources to glucose during the *in vitro* fermentation significantly stimulated the proliferation and growth of *B. adolescentis*, *B. infantis*, *B. bifidum*, and *L. acidophilus*, along with the increased production of lactic, acetic, propionic, and butyric acid. In another study, Chen et al. (2020b) showed the impact of different drying methods including hot air-, vacuum-, freeze-, and spray-drying on chemical digestibility and prebiotic potential of polysaccharides from bamboo shoot (*C. quadrangularis*) residues (CPS). The results revealed that all four CPSs fractions have low digestibility to human gastric juice and α-amylase whereas freeze-dried induced strongest proliferation effect of probiotic bacteria and the highest production of total short chain fatty acids. Further physicochemical characteristic of freeze-dried CPSs exhibited the higher solubility and uronic acid content, with smaller particle size when compared to other CPSs that shows freeze-drying method as an effective technique in improving the prebiotic potential of CPSs. In previous study, Chen et al. (2019) prepared five polysaccharide fractions from the shoots of *C. quadrangularis* and added to liquid cultures of *bifidobacteria* and *lactobacilli* strains as alternative carbon sources to glucose for *in vitro* fermentation. The study reported that all five polysaccharides significantly stimulated the growth of the probiotics along with increased production of lactic, acetate, propionate, and butyrate acids during fermentation. However, polysaccharides prepared through ultrasound- and enzyme-assisted extraction methods had higher carbohydrate contents, lower molecular weights, and smaller particle sizes that induced higher levels of proliferation, and stimulated higher SCFA production than the other fractions, indicating ultrasound- and enzyme-assisted extractions as effective techniques for improving the prebiotic potential of CPS. He et al. (2016) isolated two water soluble polysaccharides fractions from *P. praecox* shoots having potential prebiotic properties as they significantly increased the numbers of *Bifidobacterium adolescentis* and *Bifidobacterium bifidum* in *in-vitro* culture in dose dependent manner. The characterisation of both polysaccharides revealed the presence of heteropolysaccharides-protein complexes that were composed of amino acids, rhamnose, arabinose, xylose, mannose, glucose and galactose in different molar ratios, and have positive effects on the acidifying activities of the probiotics. Similar results were obtained for the crude polysaccharides extracted from *Gigantochloa levis* (Buluh beting) shoots (Azmi et al. 2012). Bamboo shoot crude polysaccharides (BSCP) when used as a carbon source showed significant increase in the growth of probiotics including *B. animalis, B. longum* and *L. acidophilus* as compared to the use of fructo-oligosaccharide (FOS). In addition, the growth rate of *Salmonella choleraesuis, a* pathogenic microbe was found to be declined in both BSCP and FOS. FTIR analysis of BSCP revealed the presence of β-glucan, which contributes to its high degree of non-digestibility and hence improves prebiotic potential.

Table 1. Dietary fibers and polysaccharides of several bamboo species and its beneficial effects.

Bamboo species	Part of bamboo plant used or product	In combination	Effect (s)	References
Dendrocalamus latiflorus	Young bamboo culm flour	Rice flour	Produce healthy extruded products; improves physicochemical and technological properties	Sampaio et al (2023)
Unknown species	1% micronized bamboo powder	Supplementation of basal diet of broilers	Improves caecal chyme microflora; regulates metabolic pathways for intestinal fatty acids, amino acids, and intestinal immune IgA production	Dai et al. (2022)
Unknown species	Bamboo leaf flavonoid and polysaccharides	-	Regulate immunity and anti-oxidant capacity of animals	Ge et al. (2020)
Unknown species	Modified dietary fiber from the basal part of bamboo shoot	-	*In vitro* prebiotic property indicated by positive impact on the growth of *Lactobacillus acidophilus* ATCC 4356 and *Bifidobacterium longum* ATCC 15707	Fang et al. (2020)
Fargesia spathacea	Soluble dietary fiber (SDF) and insoluble dietary fiber (IDF)	-	Cholesterol-adsorption capacities and has effectively modulated the intestinal	Wu et al. 2020

			microbiota composition as well as increasing the SCFAs contents	
Unknown species	10 % bamboo shoot fiber	Supplementation of high fat diet (HFD)	Exhibited the lowest weight gain along with increased relative abundance of *Bacteroidetes*	Li et al. 2016
Unknown species	Bamboo hemicellulose hydrolysate	high-fat diet supplemented with 5% BHH	Improved short-chain fatty acid production for all of the gut bacterial communities as well as lowered the serum cholesterol levels and fecal pH	Ikeyama et al. (2021)
Phyllostachys edulis	Bamboo shoot polysaccharides	-	Increase the concentration of short-chain fatty acids and organic acid while reduction in the pH and ammonia concentrations	Li et al. (2021)
Chimonobambusa quadrangularis	Polysaccharide fractions extracted from bamboo shoots	-	*In vitro* indigestibility to human gastric juice (>98.5%) and α-amylase hydrolysis	Chen et al. (2020a)
C. quadrangularis	Polysaccharides from bamboo shoot	-	Proliferation effect of probiotic bacteria and the highest production of total short chain fatty acids	Chen et al. (2020b)

3. Bamboo Leaf Flavonoids

Bamboo leaf flavonoids (BLF) are polyphenolic compounds responsible for plenty of bamboo leaf bioactivities, for instance, antibacterial, anti-inflammatory, antioxidant, antitumor, and anti-aging activities (Indira et al. 2022; Nirmala et al. 2018). Zhang et al. (2022) studied the effect BLF on the growth performance of intestinal microbiota in Chinese mitten crabs and results showed the addition of both 500 and 1000 mg/kg BLF to the diet reduced the abundance of phyla *Bacteroidota* while increased the abundance of *Firmicutes, Candidatus* and *Bacilloplasma* in the crab's intestine. In addition to improve the growth performance of intestinal microflora, dietary BLF also enhanced the non-specific immunity and antioxidant activity in Chinese mitten crabs. BLF extracted from the leaves of *D. membranaceus* when added to the basal diet of *Gallus gallus domesticus* also modulated the gut microbiota of birds as decreased the *Firmicutes:Bacteroidetes* ratio along with increased relative abundance of *Lactobacillus* and *Bacteroides stercoris* (Cao et al. 2022). The caecal acetate and butyrate contents were reported to increase in the BLF group. Ultra-high-performance liquid chromatography triple-quadrupole mass spectrometry analysis indicated that presence of vitexin, fumaric acid, orientin, isoorientin, and p-coumaric acid as predominant components of BLF. Similar results reported by Shu et al. (2020), when investigated the effects of bamboo leaf flavones (BF) on broiler cecal microbiota and related immune function. Arbor Acres broilers (AA) were fed with BF supplemented diet at 200 (Low group, L), 400 (Medial group, M), and 800 mg/(kg d) (High group, H) and all groups showed the presence of greater proportions of bacterial taxa belonging to *Lactobacillus, Clostridiales, Ruminococcus,* and *Lachnospiraceae*. In addition, expression of serum and spleen IL-2 and IFN-γ gene were increased in both medium and high supplemented diets after 28 days. The composition of BF included 85% bamboo leaf favonoids (orientin, homoorientin, vitexin, and isovitexin) and 15% starch and was extracted with the enzyme-assistant method (Li et al. 2010). Wang et al. (2021) proposed the use of BLF as prebiotics in the conservation management of wild animals based upon their investigation showing high flavonoids in the diet, feces, and plasma of both wild and captive giant pandas feeding on bamboo leaves. Fecal analysis also showed increased abundance of microbial diversity during leaf eating stage of pandas when compared with shoot eating stage.

4. Bamboo Charcoal and Vinegar

Bamboo charcoal is activated charcoal with high mineral content, made from the dry distillation of thick bamboo stems. The byproduct of the distillation process is bamboo vinegar, enriched in bioactive components such as organic acids, aldehydes, and ketones (Chen et al. 2010) Its low pH facilitate the growth of intestinal lactic acid bacteria, and promote digestive health of the livestock (Yao et al., 2012). Ju et al. (2023) demonstrate that supplementation of diet of *Paramisgurnus dabryanus* (large-scale loach, a commercial fish species) with 1% and

2% bamboo vinegar and charcoal powder (BVC) resulted in increased proportion of beneficial microbes such as *Lactococus raffinolactis* and *Faecalibacterium prausnitzii* while proportion of pathogenic bacterial species (*Aeromonas veronii* and *Escherichia coli*) decreased significantly. Similarly, feeding betong chickens with BCV supplemented diet at 0.5, 1 and 1.5% level for 16 weeks was resulted in modulation of fecal microflora population and intestinal morphology of chickens (Rattanawut 2014). The colony counts of fecal *Escherichia coli* and *Salmonella* spp. had been effectively reduced in 1 and 5% BVC supplemented groups. In another study, fattening pigs were fed with 0.3% bamboo vinegar (BV) and 0.3% bamboo charcoal supplemented diets to analyse their fecal microflora populations, growth performance and immune responses (Chu et al. 2013). The result of study revealed that in comparison with control, fecal anaerobic total bacteria and lactic acid bacteria counts of were higher while counts of pathogenic coliform bacteria and *Salmonella* spp. were lower in BC and BV supplemented groups. The growth performance and immune responses of BC and BV supplemented groups were also improved significantly that suggested the potential of bamboo charcoal or bamboo vinegar as prebiotic additives in animal diets.

Table 2. Bamboo Leaf Flavonoids, Bamboo Charcoal and Vinegar from several bamboo species and its beneficial effects.

Bamboo species	**Part of bamboo plant used or product**	**In combination**	**Effect (s)**	**References**
Unknown species	Bamboo leaf flavonoids	500 and 1000 mg/kg BLF supplementation to the diet	Improve the growth performance of intestinal microflora, enhanced the non-specific immunity and antioxidant activity in Chinese mitten crabs	Zhang et al. (2022)
D. membranaceus	Bamboo leaf flavonoids	Added to the basal diet	Modulated the gut microbiota	Cao et al. 2022
Unknown species	Bamboo leaf flavones	Supplementation of diet	Improved cecal microbiota and related immune function	Shu et al. (2020)
Unknown species	Bamboo vinegar	-	Growth of intestinal lactic	Chen et al. 2010

			acid bacteria, and promote digestive health	
Unknown species	Bamboo vinegar and charcoal powder	Supplementation of diet	Increased proportion of beneficial microbes	Ju et al. (2023)
Unknown species	0.3% Bamboo vinegar (BV) and 0.3% bamboo charcoal	Supplementation of diet	Improved fecal microflora populations, growth performance and immune responses	Chu et al. (2013)

5. Mechanism of Action for Prebiotic Activity

Dietary fibers, polysaccharides, flavonoids, charcoal and vinegar positively influenced the gut microbiota via modulation, stimulation and inhibition of various metabolites and pathways. The prebiotic activity of bamboo fiber has been extensively studied and reported that microbial fermentation of fiber in gut depends upon physiological characteristics including solubility, types of linkage, degree of polymerization, and transit time (Wu et al. 2023). Although soluble dietary fiber is more effectively fermented in the gut than insoluble dietary fiber, but insoluble bamboo shoot fiber components including cellulose and hemicellulose also fermented anaerobically in ceacum to improve SCFAs production to regulate gut microbiota balance. Fiber modification resulted in cellulose degradation that increases the fermentable saccharide and stimulated the growth of gut bacteria. Structural and chemical properties including monosaccharide composition, molecular weight, glycosidic linkages, water solubility, chain length and type directly contributes to the SCFAs production (Miao et al. 2016). Moreover, the smaller size of the polysaccharides provides larger accessible surface area for the probiotics and low molecular weight assist them to reach more distal regions of gastrointestinal tract, resulting in a better prebiotic activity (Chen et al. 2012).

Bamboo leaf flavonoids may directly metabolize both by intestinal epithelial enzymes and local microbiota to promote the growth of beneficial bacteria (Cao et al. 2022). Microbial interaction also resulted in their conversion to aromatic and phenolic acids, which can be absorbed or exert local effects. The prebiotic effect of bamboo vinegar attributed to its bioactive components such as organic acids, phenols, aldehydes, ketones, furans, heterocyclic aromatic compounds, and alcohols, which modulate the intestinal microenvironment (i.e., pH), inhibits pathogenic bacterial growth and promote the growth of beneficial bacteria (Ju et al. 2023; Watarai and Tana 2005). Bamboo charcoal possess higher absorption capacity compared to general wood charcoal due to special micro-pore structure of bamboo stems, which facilitate the effective removal of toxins and impurities from the gastrointestinal tract along with improved nutrient absorption and utilization across the intestinal cell membranes (Mekbungwan et al. 2004).

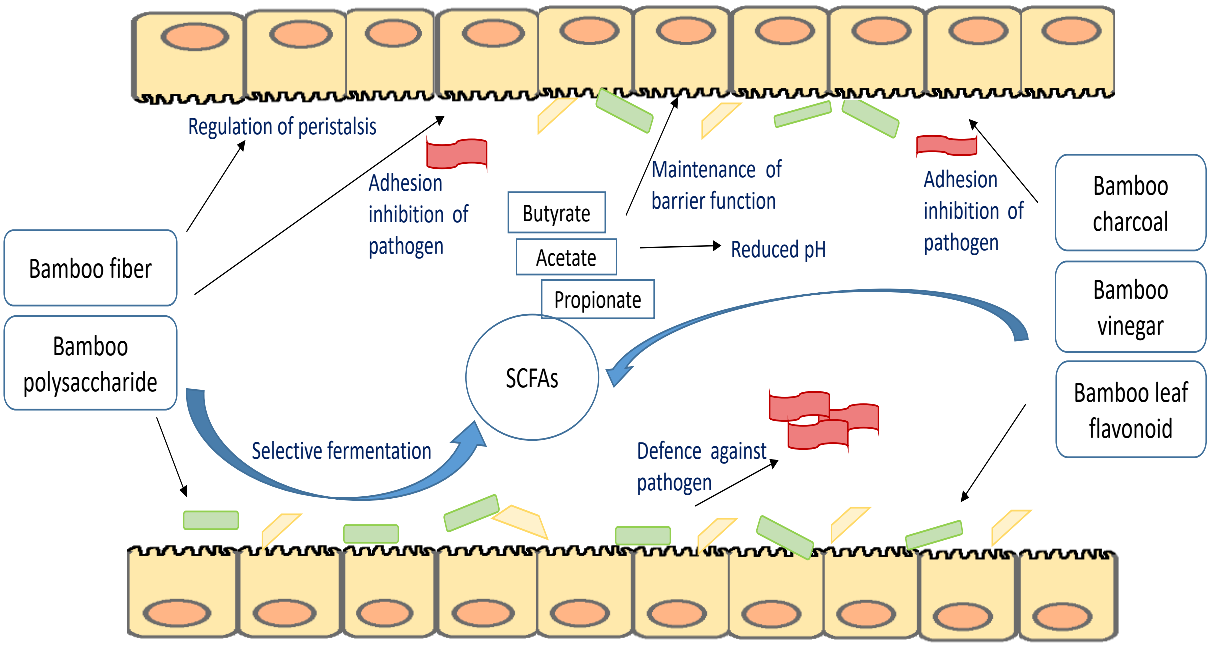

Fig. 1. Mechanism of action of bamboo components as prebiotics.

Conclusion

Prebiotics has been gaining huge interest among masses in recent times as various scientific investigations has reported the influence of gut microbiota on the host's health and well-being. The current ever-increasing demand of prebiotics has resulted in the exploration of new novel sources and compounds, apart from common prebiotic carbohydrates. Bamboo shoots being rich in conventional prebiotic components i.e. dietary fiber and polysaccharides could be considered as ideal source. Recent investigations has shown the positive influence of bamboo vinegar, charcoal and leaf flavonoids on gut microbiota that convey them as potential next generation of prebiotics. Further research studies required to be conducted to study their impact on host's health, detailed mechanism of action and development of effective and economical extraction method for prebiotics.

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Conflict of Interest

The authors declare there is no conflict of interest

Reference

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