



Research Article

Arabinoxylan as Prebiotic Improves Mental Health: Importance of Gut Brain Axis

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ABSTRACT

One of the main causes of disability in the world is mental health illnesses, which are becoming more common as a result of stress, dietary changes, and modern lifestyles. Through the gut– brain axis (GBA), a two-way communication pathway that links intestinal physiology and brain function, the gut microbiota has recently become a crucial regulator of neurological health. Prebiotics are vital for regulating the microbiome because they are dietary fibers that are specifically broken down by good bacteria. Among these, the non-starch polysaccharide arabinoxylan, which is found in cereals including wheat, rye, and barley, has drawn attention due to its potential prebiotic qualities. There is evidence that Arabinoxylan and its derivative arabinoxylan-oligosaccharides (AXOS) promote the growth of *Lactobacillus* and *Bifidobacterium*, boost the synthesis of short-chain fatty acids (SCFAs), control systemic inflammation, and affect neurotransmitter pathways. These outcomes are consistent with processes linked to a decrease in anxiety, depression, and cognitive deterioration. The chemical makeup and origins of arabinoxylan, its function as a prebiotic, and its ability to alter the gut-brain axis to enhance mental health are all examined in this review paper. Critical analysis of clinical and experimental data is also included, along with a discussion of its drawbacks and potential future developments

Keywords: Arabinoxylan, prebiotic, gut–brain axis, short-chain fatty acids, mental health, microbiome

INTRODUCTION

Anxiety, depression, and cognitive deficits are among the mental health conditions that greatly increase the worldwide burden of disease. More than 264 million people worldwide suffer from depression alone, according to the World Health Organization (2021), and mental health issues are predicted to increase as a result of sedentary lifestyles, chronic stress, and nutritional imbalances.

The importance of the gut microbiota in determining brain health has come to light in recent years. The human gut's trillions of bacteria affect immunological, neuroendocrine, and metabolic functions; dysbiosis, or imbalances, has been connected to mental health disorders (Cryan et al., 2019). The gut–brain axis (GBA) is the term for this communication between the gut and the brain, which is mediated by immunological signaling molecules, neurotransmitters, microbial metabolites, and neuronal circuits, particularly the vagus nerve (Foster & McVey Neufeld, 2013).

The gut microbiota is significantly impacted by diet. Prebiotics, which are substrates that host bacteria preferentially use to provide health advantages (Gibson et al., 2017), have become potential agents for microbial balance restoration. Inulin, fructo-oligosaccharides, galacto-oligosaccharides, and, more recently, fibers derived from cereals like arabinoxylan are examples of common prebiotics.

Whole grains are rich in arabinoxylan, which has special structural and functional qualities. It ferments in the colon to form SCFAs like butyrate, which have neuroprotective properties and can pass through the blood–brain barrier (Dalile et al., 2019). Arabinoxylan may be used as a dietary intervention to enhance mental health by affecting immunological regulation, neurotransmitter pathways, and microbial diversity.

The potential of arabinoxylan as a prebiotic in relation to mental health is summarized in this review, with a focus on its function within the framework of the gut-brain axis.

A. Research Objective

The primary objectives of this review are to:

1. To Study the biochemical composition and prebiotic properties of arabinoxylan.
2. To evaluate how arabinoxylan modulates gut microbiota and SCFA production.
3. To explore the mechanisms of the gut-brain axis in mental health regulation.
4. To analyze recent evidence linking arabinoxylan supplementation with improved cognitive function reduced anxiety, and depression.

LITERATURE REVIEW

According to Rajanala, Kumar, and Chamallamudi (2021), trillions of microorganisms from different species and genera are entrenched in the human digestive system. These organisms live in symbiosis with the host and fulfill a variety of functions in the human body. Their primary function is to aid in the breakdown and transformation of food into a variety of beneficial substrates for the human body. In addition to this, the gut bacteria keeps the brain and other body organs in good communication. The gut-brain axis (GBA) refers to the relationship between gut microbiota and the brain, which is mediated via immunological, endocrine, and neurological pathways. They therefore play a role in the neurophysiology and neuropathology of a number of illnesses, including autism, depression, Parkinson's disease (PD), and Alzheimer's disease (AD). Numerous dietary supplements, including probiotics and prebiotics, can alter the makeup of the gut microbiota. The gut microbiota's role in depression and the benefits of probiotics and other supplements for treating depression are reviewed in this article.

According to Marcel et al. (2017), the gut is home to a vast array of microorganisms that are critical to maintaining homeostasis in both health and illness. The idea that this microbiome influences host appetite and food consumption is becoming more and more supported by data. The presence of other bacterial species and the nutrients that are available to them exert selective pressure on individual species within the gut microbiota. Through the specific fermentation of dietary nutrients and the secretion of metabolites, each species of bacteria in the gut seeks to improve its own fitness, habitat, and survival. Many of these metabolites have the ability to directly impact nutrient sensing, appetite, and satiety-regulating systems, thereby influencing host appetite and eating behavior. These include short-chain fatty acids and neuroactives generated by the microbiome. Furthermore, the gut microbiota can affect host antigen production, modify the immune system, interact with bile acid metabolism, and alter intestinal barrier integrity, all of which have an indirect impact on eating habits. An increasing amount of data suggests that the microbiota plays a critical role in controlling various facets of eating-related behavior as well as the behavioral comorbidities of metabolic and eating disorders. Obesity, anorexia nervosa, and severe acute malnutrition have all been linked to the composition of the gut microbiota. Novel biotherapeutic approaches will result from a better understanding of the ways in which the gut microbiota can affect host appetite and metabolism. This understanding will help address illnesses like obesity and other metabolic or eating disorders where hunger is dysregulated.

According to research by Appleton (2018), the gut-brain axis is a network of two-way communication that connects the central nervous system and the gastrointestinal system. This network encompasses not just anatomical pathways but also humoral, immunological, metabolic, and endocrine pathways. The gut can affect mood, cognition, and mental health, while the brain can affect intestinal activities, including the activity of functional immune effector cells, thanks to the autonomic nervous system, the hypothalamic-pituitary-adrenal (HPA) axis, and nerves in the gastrointestinal tract.

Probiotics and prebiotics have been shown to alter the gut-brain axis, which supports central nervous systems and reduces or manages the prevalence of mental illnesses such as depression, anxiety, autism, schizophrenia, and Alzheimer's disease (Ansari et al., 2023). Complex interactions between the gut, brain, and microbiota have been covered in this review, along with new research on the effects and potential mechanisms of action of probiotics and prebiotics on mental illnesses. According to the results, probiotics and prebiotics can enhance central nervous system function and are useful in the prevention and treatment of certain brain disorders. However, more research is required, particularly in the form of human studies and clinical trials, to substantiate these effects definitively and to use these substances in a supportive and therapeutic manner.

According to Berding et al. (2021), the gut microbiota has become increasingly important in controlling behavior and brain functions throughout the last ten years. One of the main elements influencing the composition of the gut microbiota during life is diet. However, research is just now starting to look at if and how nutrition can impact the brain through its effects on the microbiota. There are a number of known gut-to-brain communication channels, such as immunological, neuronal, metabolic, and microbial metabolites, some of which may be susceptible to dietary modification. Our knowledge of the role of diet in this reciprocal communication has advanced as a result of animal studies examining the effects of dietary treatments on the microbiota–gut–brain axis. In this review, we examine possible underlying mechanisms and provide an overview of the present status of the literature that triangulates host behavior/brain processes, microbiome, and nutrition. Evidence supporting the microbiome as an underlying modulator of the impact of nutrition on brain health is also presented, along with factors that influence response to dietary interventions. We also highlight the need for more evidence from clinical populations and the understudied application of whole-dietary techniques in this attempt. Although encouraging findings have been published, more information— particularly from clinical cohorts—is needed to support evidence-based suggestions for the creation of whole-dietary, microbiota-targeted interventions to enhance mental and cognitive health.

ARABINOXYLAN: STRUCTURE AND SOURCES

Structural Composition

Hemicellulosic polysaccharides called arabinoxylans are mostly found in wheat grain cell walls. At positions 2 and/or 3, arabinofuranosyl residues are substituted for the β -(1→4)-linked xylopyranosyl residues that make up their backbone (Izydorczyk & Biliaderis, 1995). In certain instances, arabinoxylans are cross-linked by ferulic acid residues via ester linkages, which affects their solubility and fermentability.

The physiological characteristics of arabinoxylans are strongly influenced by the degree of substitution and the ratio of arabinose to xylose (A/X ratio). While insoluble fractions are frequently associated with the bulking effect of dietary fiber, a high A/X ratio improves solubility. The profile of metabolites produced and the pace of fermentation in the colon are determined by these anatomical differences.

Dietary Sources

Arabinoxylan is present in the **bran and endosperm** of cereal grains. Wheat bran is the richest source, containing 20–30% arabinoxylan by weight (Courtin & Delcour, 2002). Other sources include:

- **Rye** – contains both soluble and insoluble arabinoxylan.
- **Barley** – lower content but important due to soluble fractions.
- **Corn fiber** – used industrially for AXOS production.

Whole-grain products, particularly wheat bran supplements, are therefore practical dietary sources of arabinoxylan.

Arabinoxylan-Oligosaccharides (AXOS)

Arabinoxylan can be enzymatically hydrolyzed into **arabinoxylan-oligosaccharides (AXOS)**, which are shorter, more soluble chains with enhanced prebiotic potential. AXOS are more readily fermented by *Bifidobacteria* and *Lactobacilli*, compared to native arabinoxylan, making them ideal for functional foods and dietary supplements (Swennen et al., 2006).

PREBIOTIC ROLE OF ARABINOXYLAN

Mechanistic Basis of Prebiotic Action

To qualify as a prebiotic, a compound must resist digestion in the upper gastrointestinal tract, reach the colon intact, and be selectively fermented by beneficial microbes. Arabinoxylan fulfills these criteria. Upon reaching the colon, it undergoes fermentation by bacteria that release SCFAs, influencing both gut and systemic health.

Microbiota Modulation

Numerous studies show that arabinoxylan and AXOS selectively enhance the growth of beneficial bacteria. Neyrinck et al. (2011) demonstrated that wheat-derived AXOS increased *Bifidobacteria* while reducing pathogenic species such as *Clostridium perfringens*. Walton et al. (2012) confirmed similar bifidogenic effects in human trials.

Metabolite Production

Arabinoxylan fermentation leads to **SCFA production**:

- **Acetate** – influences cholesterol metabolism.
- **Propionate** – involved in gluconeogenesis.

- **Butyrate** – enhances gut barrier integrity, exerts anti-inflammatory effects, and acts as a signaling molecule for brain function (Dalile et al., 2019).

Together, these SCFAs modulate metabolic health while directly impacting brain processes.

GUT–BRAIN AXIS: A BIDIRECTIONAL COMMUNICATION SYSTEM

Overview of the Gut–Brain Axis

The GBA integrates communication between the central nervous system (CNS) and the enteric nervous system. The primary mechanisms include:

- **Neural pathways:** Microbial signals are transmitted via the vagus nerve.
- **Immune pathways:** Cytokines produced in the gut influence neuroinflammation.
- **Endocrine pathways:** Gut microbes modulate stress hormones through the hypothalamic–pituitary–adrenal (HPA) axis.
- **Metabolic pathways:** Microbial metabolites, particularly SCFAs, cross into circulation and affect brain activity.

Dysbiosis and Mental Health

Dysbiosis disrupts these communication channels, leading to psychiatric outcomes. For example, patients with major depressive disorder often exhibit reduced microbial diversity and lower abundance of butyrate-producing bacteria (Jiang et al., 2015). Restoring microbial balance with prebiotics such as arabinoxylan may normalize these pathways, improving mood and cognition.

MECHANISMS LINKING ARABINOXYLAN TO MENTAL HEALTH

Microbiota Modulation and Behavior

AXOS supplementation not only increases beneficial bacteria but also correlates with behavioral improvements. Liu et al. (2020) reported that mice receiving AXOS showed reduced anxiety-like behavior and improved spatial memory.

SCFA-Mediated Neuroprotection

Butyrate is particularly relevant for mental health. It serves as a histone deacetylase inhibitor, enhancing expression of **brain-derived neurotrophic factor (BDNF)**, a protein critical for neuroplasticity and resilience to stress (Dalile et al., 2019).

Neurotransmitter Regulation

Gut microbes affected by arabinoxylan can produce or influence the availability of neurotransmitters:

- **Serotonin (5-HT):** About 90% is produced in the gut. Modulation of serotonin precursors impacts mood regulation.
- **Dopamine:** Influences motivation and reward pathways.
- **GABA:** Plays a role in reducing neuronal excitability, linked to anxiolytic effects (Strandwitz, 2018).

EXPERIMENTAL AND CLINICAL EVIDENCE

Animal Studies

- Liu et al. (2020) found that AXOS supplementation improved gut microbiota composition, reduced anxiety-like behavior, and increased hippocampal plasticity in mice.
- Other rodent studies have demonstrated enhanced SCFA levels and improved learning behaviors, linking AXOS to neurodevelopmental benefits.

Human Studies

Walton et al. (2012) conducted a randomized, crossover human trial where arabinoxylan supplementation significantly increased bifidobacteria populations, elevated SCFA levels, and improved gastrointestinal comfort. While mental health parameters were not primary outcomes, participants reported improved well-being and reduced stress symptoms.

Comparative Studies

Compared to inulin and galacto-oligosaccharides, arabinoxylan offers unique antioxidant and immune-regulatory properties. This makes it particularly promising as a dietary intervention for long-term brain health (Broekaert et al., 2011).

Clinical Evidence and Human Trials

Table 1: Summary of Key Studies on Arabinoxylan, Gut Microbiota, and Mental Health

Author & Year	Study Type	Model / Participants	Intervention	Key Findings	Relevance to Mental Health
Swennen et al., 2006	In vitro study	Fermentation assays with human gut microbiota	Arabinoxylan supplementation	Enhanced growth of <i>Bifidobacterium</i> and <i>Lactobacillus</i> ; increased SCFA production	Indicates arabinoxylan has strong prebiotic potential, essential for gut-brain axis signaling
Broekaert et al., 2011	Review & mechanistic	Various studies on cereal arabinoxylans	Wheat bran arabinoxylan	Improved bowel function, modulation of immune responses	Suggests indirect mental health benefits via immune regulation
Vulevic et al., 2013	Human trial	Elderly participants	Wheat bran arabinoxylan-rich diet	Increased bifidobacteria, improved immune markers, reduced fatigue	Positive correlation between prebiotic intake and mood improvements
Chen et al., 2020	Animal study	Mice	Arabinoxylan supplementation	Reduced oxidative stress, improved gut barrier function	Neuroprotection via lowered inflammation and improved barrier integrity
Tengeler et al., 2020	Animal & review	Rodents + literature	Prebiotic supplementation including arabinoxylan	Reduced anxiety- and depression-like behaviors; improved synaptic plasticity	Highlights the role of arabinoxylan in regulating mood disorders
Hao et al., 2021	Review & mechanistic	Human and animal studies	Dietary fibers including arabinoxylan	Promoted hippocampal neurogenesis, enhanced memory and learning	Strong link to cognitive health via gut-brain axis

Immune Modulation

Chronic systemic inflammation is a key feature of depression and anxiety. Arabinoxylan reduces inflammatory markers such as IL-6 and TNF- α , thereby lowering neuroinflammation (Neyrinck et al., 2011).

Stress Response and HPA Axis

By improving microbial diversity and reducing systemic stress responses, arabinoxylan indirectly regulates cortisol levels via the HPA axis (Cryan et al., 2019). This stabilizes emotional responses and enhances stress resilience.

FUTURE PERSPECTIVES AND CHALLENGES

Need for Clinical Validation

Most evidence linking arabinoxylan to mental health benefits comes from preclinical and pilot studies. Larger, longer human trials are needed to establish causal effects.

Personalized Nutrition

Individual responses to prebiotics depend on baseline microbiota composition. Personalized dietary interventions may be more effective than generalized recommendations.

Dosage and Delivery Optimization

Further research is needed to determine optimal daily intake of arabinoxylan and whether whole grains or purified AXOS supplements are more effective.

Integration into Psychiatry

Arabinoxylan-based interventions could complement existing treatments for depression and anxiety, potentially reducing drug dependence. However, interdisciplinary collaboration is necessary to integrate such dietary strategies into clinical practice.

CONCLUSION

According to the reviewed research, arabinoxylan is a promising prebiotic that can alter the gut-brain axis to enhance mental health. Arabinoxylan targets several pathways linked to mental illnesses by boosting the creation of SCFA, improving the good bacteria in the stomach, controlling immunological responses, and promoting the synthesis of neurotransmitters. More thorough clinical research is needed to convert findings into useful dietary recommendations, even if existing animal and early human studies corroborate these advantages. In the context of a comprehensive nutritional psychiatry approach, meals or supplements high in arabinoxylan may offer a secure, affordable, and long-lasting means of promoting mental health.

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