REVIEW ARTICLE Agricultural Reviews, Volume 47 Issue 2: 216-226 (April 2026)

Relevance of Buckwheat in Gastrointestinal Health Modulation: A Review

Jyoti Arora[1], Luxita Sharma[2], Kanwalpreet Kochhar[3]

10.18805/ag.R-2808

ABSTRACT

The potential health benefits of buckwheat are ascribed to bioactive compounds that possess anti-inflammatory, antihypertensive, antioxidant and antidiabetic properties. Owing to its gluten-free and low-FODMAP composition, it attracts individuals who have sensitive gastrointestinal (GI) tracts, specifically those who are sensitive to gluten. In contrast, additional research is required to determine the impact of buckwheat-wheat hybridization in food preparations, which aims to improve texture and flavor, on the production of short-chain fatty acids (SCFAs) *via in vitro* fermentation and its impact on intestinal microbiota. Amidst the prevailing global food crisis, it is critical to prioritize the establishment of food security measures for an expanding population. To enhance the availability and quality of food, an interdisciplinary strategy that may involve enrichment, biofortification and botanical supplements is required. This review evaluates the impact of buckwheat on GI health outcomes and regulation of the gut microbiome, addressing critical health concerns in the midst of evolving food crises. Buckwheat supports gastrointestinal health due to its high nutritional content and possible therapeutic attributes. Comprehending its application is crucial for advancing therapeutic interventions for gastrointestinal issues and mitigating potential food shortages.

Key words: Alternative supplement, Buckwheat, Gastrointestinal health, GI health supplements, Gut-microbiome, Pseudocereal.

Common buckwheat (*Fagopyrum esculentum*) and tartary buckwheat (*F. tataricum*) are currently grown as crops in different regions of the world. Buckwheat, both as a plant and a seed, is a highly nutritious food that is abundant in proteins, fibers, polyphenols, flavonoids and minerals. It is frequently taken as a substitute for cereals and other starchy meals (Giménez-Bastida and Zieliński, 2015).

Buckwheat is associated with possible health advantages owing to the presence of bioactive chemicals that have antioxidant, antihypertensive, anti-inflammatory and antidiabetic effects. this plant is an appealing alternative for people with a sensitive gastrointestinal (gi) tract, especially those with gluten-sensitivity, due to its gluten-free nature and low levels of fermentable oligosaccharides, disaccharides, monosaccharides and polyols (FODMAP) (Fig 1).

Additionally, it contains numerous phyto-active compounds. Dietary fiber present in sweet and tartary buckwheat can enhance the variety of microorganisms in the gut, stimulate the growth of bacteria that produce short-chain fatty acids (SCFAs) and preserve the overall structure of the gut microbiome. Despite the fact that sweet and tartary buckwheat have high usage value, their rough taste and low palatability prevent them from being able to replace staple cereals (Zhou *et al.,* 2019; Zhu, 2016) (Sharma and Singh, 2022).

However, the positive impact of buckwheat on human digestive health is frequently enhanced by combining buckwheat with wheat to create meals. This necessitates further examination of the impact of a combination of cereals and buckwheat to assess their stimulatory effects on gut microorganisms and to justify the production of short-chain fatty acids (SCFAs) using *in vitro* fermentation.

[1]All India Institute of Ayurveda, Delhi-110 076, India.
[2]Amity Medical School, Manesar, Gurugram-122 413, Haryana, India.
[3]All India Institute of Medical Sciences, Delhi-110 029, India.

Corresponding Author: Luxita Sharma, Amity Medical School, Manesar, Gurugram-122 413, Haryana, India.
Email: lshrama@ggn.amity.edu
ORCIDs: https://orcid.org/0000-0003-0688-7733; https://orcid.org/0000-0002-4700-4792; https://orcid.org/0000-0003-3458-3657.

How to cite this article: Arora, J., Sharma, L. and Kochhar, K. (2026). Relevance of Buckwheat in Gastrointestinal Health Modulation: A Review. *Agricultural Reviews*. **47(2):** 216-226. doi: 10.18805/ag. R-2808.

Submitted: 29-05-2025 **Accepted:** 13-08-2025 **Online:** 09-10-2025

Coming to the problem of global food crises, currently it is estimated that amid a worldwide population of 7 billion, the agricultural industry is encountering significant challenges in ensuring sufficient food supply, while simultaneously upholding high levels of productivity and quality standards. Furthermore, the task of addressing the impending food crisis will be highly demanding in the coming years, as the global population is estimated to exceed 10.9 billion by 2050.

To address this issue, it is necessary to adopt an interdisciplinary strategy that not only improves the availability of food but also ensures access to high-quality food through enrichment, biofortification and nutritional supplements. This is crucial to ensure access to nutritious food, which is a key aspect of food security (Wieser, 2007).

Based on these concerns, this review is planned and composed to extract evidence and assess and justify the role of buckwheat in its capacity to regulate the gut

microbiome and hence modify GI health outcomes. The study is based on data and findings of scholarly works published in the period-2017-2025.

This review analyzes buckwheat's potential as a dietary intervention for gastrointestinal disorders and future food security challenges.

Conceptualization and framework development of the review

This review work was carried out at the All India Institute of Ayurveda, New Delhi, India.

The review was conducted based on literature published from 2017 to 2025, with institutional affiliation and analytical work carried out at the All India Institute of Ayurveda, New Delhi, India.

To guarantee openness and consistency in reporting, this study followed the strict methodological framework specified by the preferred reporting items for systematic reviews and meta-analyses statement (prisma) guidelines to clarify the literature search process, we strictly adhered to the prisma statement for reporting literature searches in systematic reviews (Fig 2).

The review process strictly adhered to the established protocol. Public repositories, such as Science Direct, Elsevier, Cochrane Central (Wiley) and Web of Science (Clarivate), were used to collect relevant scholarly articles.

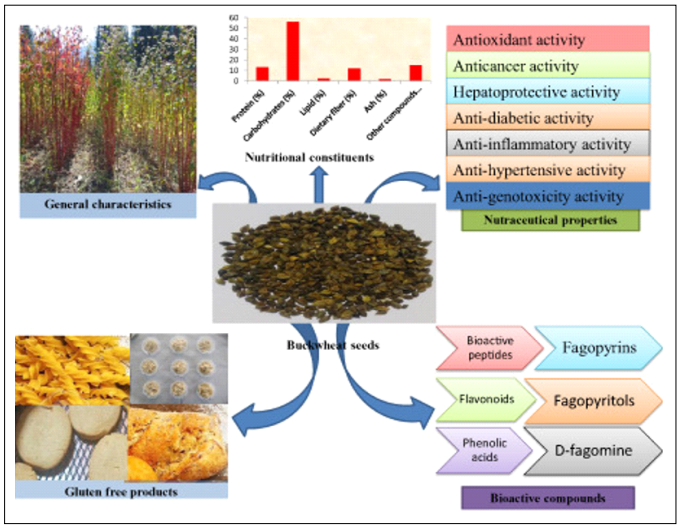


Fig 1: The nutraceutical and pharmacological overview of buckwheat.

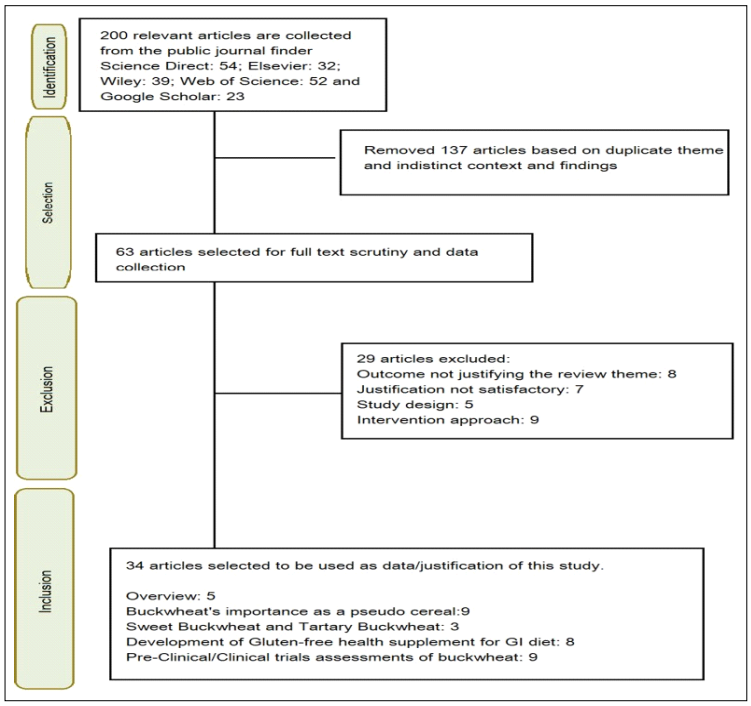


Fig 2: Prisma scheme.

To guarantee reproducibility and allow for adaptation, a single standardized search term was used across the databases. To broaden the scope of the search, we also used Google Scholar to find the 200 most relevant references, which were then extracted using the Publish or Perish program.

A broad variety of phrases relating to buckwheat, including its scientific nomenclature, as well as terms relating to gastrointestinal (GI) issues, outcomes and symptoms were included in the search method. A few examples are given here: "gastrointestinal sensitive buckwheat," "buckwheat pseudocereal," "tartary sweet buckwheat," "assessment buckwheat GI microbiome control". This all-encompassing method sought to gather a wide range of literature relevant to the therapeutic possibilities of buckwheat in reducing gastrointestinal problems.

This study aimed to justify and evaluate the following:

Buckwheat is a potential pseudocereal and an effective substitute for conventional cereals that can be used in the diets of GI-sensitive patients to help them in their recovery.

Furthermore, the study attempts locating the best fit Buckwheat variety that can be utilized as a diet for GI sensitivity problems based on their control capacity on gut-microbiome.

Finally, the study finds the pathways to overcome the existing challenges.

Therefore, the PICO scheme was adopted in this study (Table 1). The inclusion criteria for this review center were studies that compared the effects of sweet and tart buckwheat on the regulation of gut flora. inclusion criteria for gastrointestinal tumor studies included the absence of pre-existing gi disorders in both humans and animals, as well as inflammatory bowel disease (IBD), irritable bowel syndrome (IBS), celiac disease (CED), or IBD. one of the main outcomes that researchers are interested in is the relationship between buckwheat and gastrointestinal symptoms, such as gas, bloating, abdominal pain, diarrhea, constipation, bowel inflammation and damage to the mucosa.

In addition, studies have examined how buckwheat consumption affects inflammatory bowel disease (ibd), irritable bowel syndrome (IBS), celiac disease (CED), or gastrointestinal tumors (GI tumors). changes or variations in gastrointestinal permeability, bacterial diversity, dysbiosis, microbiome metabolites and indicators are also part of the GI microbiome and can be included in future studies. research on the effects of buckwheat on inflammation, antioxidants, or cancer in the gastrointestinal system is equally relevant. We will also consider research that examines the possibility of creating GI health supplements with buckwheat and grains.

However, research that does not address alterations to GI health and focuses only on buckwheat components will not be included. The review will not include studies that do not fulfill the inclusion criteria or concentrate on unrelated outcomes. Through the establishment of precise inclusion criteria, this framework guarantees a concentrated and exhaustive examination of the literature on the therapeutic potential of buckwheat in regulating GI health. This study emphasizes the significance of this research on nutritional supplements and management approaches.

Buckwheat: Pseudocereal crop, its availability and nutritional characteristics

The adaptability, nutritional richness and potential health benefits of buckwheat, a pseudocereal crop, have attracted substantial interest. The table below shows the scientific classification of common buckwheat (Table 2).

This is especially true when it comes to managing gastrointestinal sensitivity. Because of its high protein and fiber content, abundant vitamins and minerals and lack of gluten, buckwheat is quickly becoming a popular gluten-free alternative (Zhu, 2016). Note that grains such as wheat, barley and rye tend to contain gluten, a protein composite composed of gliadins and glutenins that are rich in glutamines and prolines (Prakash and Yadav, 2016; Sapone *et al.,* 2012). It can be used in a variety of culinary products owing to its unique features, such as its high water-binding capacity and elasticity, which allow it to create viscoelastic membranes that are essential for dough consistency.

Nevertheless, gluten is difficult to digest and remains in the GI tract, because gliadins are resistant to proteolytic enzymes (Pirzadah and Malik, 2020). There has been an upsurge in symptoms associated with extensive gluten exposure over the last several decades and the average Western diet contains 5-20 g of gluten per day. Conditions such as non-celiac gluten sensitivity (NCGS), celiac disease (CD) and IgE-mediated wheat allergy are symptoms of these reactions; they affect as much as 10% of the population (Pietzak, 2012). Gluten may affect gastrointestinal health because, according to new research, it can trigger an immunological response, which in turn causes inflammation in the intestines.

Buckwheat is a great tool for combating nutritional deficiencies and encouraging dietary diversity because of

Table 1: PICO scheme.

P Population	I Intervention	C Comparison	O Outcome
Buckwheat classes: Sweet buckwheat and tartary buckwheat.	Availability as pseudocereal and nutritional value justifiable as a diet for GI sensitive patients and their gut micro-biome control mechanism.	Comparative study of (a) Buckwheat with conventional diet for GI sensitive patients (b) Comparative studies between buckwheat classes.	Identification of buckwheat efficacy and existing limitations in their utilization to modify GI health profile and gut-microbiome control.

its unusual nutritional profile, which is achieved by growing buckwheat in a variety of climates and using sustainable farming techniques. the table given below shows a comparative nutritional value of buckwheat with conventional cereals like, rice, wheat and maize (Table 3).

While cereals such as rice, corn and wheat are monocots and members of the poaceae family, the dicots amaranthus, quinoa, buckwheat and chia are classified as pseudocereals. due to their strong nutritional profile as given in the table below, pseudocereals are now commercialized in a wide variety of goods, including noodles, cakes, pancakes, tea, drinks, cookies and other sweets. neglected crops have a high caloric value because of their enhanced protein and lipid content, even though they have less or the same amount of starch as cereal crops (Patel and Meena, 2020; Morales *et al.,* 2021).

A food system in a rich country may find high-energy content problematic, but in a developing country where calorie deficiencies are widespread, it is a blessing. Furthermore, these underappreciated grains have a more balanced amino acid profile and high protein concentration, both of which are beneficial. For instance, quinoa and amaranth have bioactive peptide and amino acid profiles similar to those of caseins and eggs, respectively. On top of that, pseudocereals are great for people with celiac disease because they don't contain gluten.

The importance of buckwheat in dietary and therapeutic supplements is highlighted by the increasing knowledge of gastrointestinal sensitivity disorders such as celiac disease, inflammatory bowel disease (IBD) and irritable bowel syndrome (IBS). Buckwheat is a promising ingredient for gastrointestinal (gi) discomfort relief and gut health products because of its low allergenic potential and ability to regulate the gut flora. because of its soluble fiber content, it aids digestion and may be useful for symptom management, such as gas, indigestion and constipation.

Table 2: Scientific classification of common buckwheat.

Taxonomic rank	Classification
Kingdom	Plantae
Division	Magnoliophyta
Class	Magnoliopsida
Order	Caryophyllales
Family	Polygonaceae
Genus	*Fagopyrum*
Species	*F. esculentum*

Table 3: Comparison of nutritional composition of common buckwheat with grains (per 100 gms).

Nutrients	Buckwheat	Rice	Wheat	Maize
Proximate composition				
Energy (Kcal)	355	345	346	365
Crude protein (%)	12.0	6.8	11.8	9.4
Total carbohydrates (g)	72.9	78.2	71.2	74.3
Total fiber (%)	17.8	4.5	12.5	7.5
Fat (g)	7.4	1.5	2.5	4.7
Moisture (%)	11.0	13.7	12.8	10.4
Minerals and trace elements (mg/100 g)				
Calcium	110	10	30	7
Iron	4.0	0.7	3.5	2.7
Magnesium	390	65	138	127
Phosphorus	330	160	298	210
Manganese	3.4	0.5	2.3	1.9
Zinc	0.8	1.3	2.7	2.3
Potassium	450	268	284	287
Essential amino acids (% of protein)				
Lysine	5.9	3.8	2.6	1.9
Methionine	3.7	3.0	3.5	3.2
Tryptophan	1.4	1.0	1.2	0.6
Leucine	6.7	8.2	6.3	13.0
Vitamins (mg/100 g grain)				
Thiamine	3.3	0.06	0.5	0.4
Riboflavin	10.6	0.06	0.2	0.2
Niacin	18.0	1.9	5.5	3.6
Tocopherol	40.0	-	-	-
Pantothenic acid	11.0	-	-	-
Choline	440	-	-	-

Table 4: Potency of buckwheat as a pseudocereal and health supplement in GI-sensitive patients.

Author(s)	Objective	Outcome
(Shewry, 2009)	Buckwheat nutraceutical study as pseudocereal.	Justified that buckwheat as serve as functional food with nutraceutical benefits.
(Venegas *et al.,* 2019)	Buckwheat use in NCGS control.	Showed that buckwheat controlled NCGS symptoms, reduces inflammation.
(Morrison and Preston, 2016)	Buckwheat pseudocereal starch regulates lipid profile, gut microbiota.	Inferred that tartary buckwheat may be advantageous for lipid metabolism.
(Wieser, 2007)	Assessing pseudocereals' (Buckwheat in particular) nutritional value.	Highlighted pseudocereals' role as superfoods.
(Giménez-Bastida and Zieliński, 2015)	Buckwheat's impact on GI health.	Showed that buckwheat supported gastrointestinal health.
(Zhou *et al.,* 2019)	Impact of buckwheat on microbiome when taken as diet supplement alternative.	Showed Buckwheat's potential benefits for intestinal health
(Dinu *et al.,* 2017)	Assess buckwheat benefits on cereals for gluten-free products.	Proved buckwheat's bioactive potential for gluten-free products.

Table 5: Comparison between sweet buckwheat and tartary buckwheat.

Nutrient content (per 100 g)	Sweet buckwheat	Tartary buckwheat
Calories	~343 kcal	~343 kcal
Protein	~13.25 g	~11-14 g
Carbohydrates	~71.5 g	~70-75 g
Dietary fiber	~10 g	~10-15 g
Fat	~3.4 g	~3-4 g
Vitamins (B1, B2, B3, B5, B6, E)	Varied	Varied
Minerals (Calcium, Iron, *etc.*)	Varied	Varied

Buckwheat has many different uses, from old-fashioned cooking methods to cutting-edge food and medicine creations. Various types of buckwheat, such as flour, groats, bran and extracts, can be used as therapeutic and nutritional supplements to create functional foods, dietary supplements and pharmaceutical formulations that target specific gastrointestinal issues. Various items can integrate buckwheat-derived ingredients, such as starch, buckwheat flour, protein isolates and rutin extracts.

They include gluten-free baked goods, cereals, snacks, drinks and nutritional supplements. in addition, pharmaceutical formulations aimed at improving gastrointestinal health, inflammation and oxidative stress may benefit from buckwheat hull extracts, which are abundant in bioactive components. the use of buckwheat in the production of dietary and medicinal supplements for gastrointestinal sensitivity is set to increase as more and more of its therapeutic properties are discovered, which bodes well for the promotion of digestive health and general well-being (Table 4).

The table shows that buckwheat, a potent pseudocereal, indeed exhibits potential as a health supplement and nutritional powerhouse for those who experience gastrointestinal sensitivity.

A comparison between sweet buckwheat and tartary buckwheat in terms of their gi regulation and gut-microbiome control

Although both sweet and tart buckwheat are members of the genus fagopyrum, their nutritional and phytochemical profiles are distinct. The dietary profiles of sweet and tartary buckwheat are shown in Table 5.

The soluble fiber included in both sweet and tart buckwheat helps keep the digestive tract regular and healthy by encouraging the growth of beneficial bacteria. They may also indirectly affect the composition of the gut microbiota because of the presence of vitamins and minerals, which are crucial for general health.

Buckwheat contains bioactive substances such as flavonoids and phenolic compounds, which may have prebiotic qualities. This means that they can preferentially promote the growth and activity of beneficial bacteria in the gut, according to previous research. Processing techniques, farming practices and individual variability are some of the variables that could affect the precise effects of sweet and tart buckwheat on the management of the gut flora and GI health (Dinu *et al.,* 2017).

High concentrations of flavonoids, fibers and other bioactive chemicals with antioxidant and anti-inflammatory potential are present in both types. These characteristics indicate a possible beneficial effect on microbial composition and gut health. Melini and Melini investigated the prebiotic potential of tartary buckwheat flour in a human intervention experiment and found that the composition of the gut microbiota improved with an increase in beneficial bacteria such as Bifidobacteria (Melini and Melini, 2019). Similarly Ludvigsson *et al.* (2013) studied the gut microbiome in rats with hypercholesterolemia and found that supple-menting with sweet buckwheat improved metabolic parameters and microbial diversity (Ludvigsson *et al.,* 2013).

Modifying GI health and controlling the microbiome are two areas in which short-chain fatty acids (SCFAs) are

crucial control agents. The fermentation of resistant starch and dietary fiber in the colon by the gut microbiota produces organic acids, mainly acetate, propionate and butyrate. In addition to supplying energy to colonocytes, SCFAs regulate immunological function, modulate intestinal motility and preserve mucosal integrity, among their many other physiological effects on the host. Therefore, they play a pivotal role in determining the general health outcomes and sustaining a balanced intestinal environment.

Research has demonstrated that buckwheat, especially the sweet and tartary types, can help regulate the microbiome and alter gastrointestinal health by influencing the formation of short-chain fatty acids (SCFAs) through its metabolic pathways. Buckwheat is high in resistant starch and dietary fiber and eating it encourages the growth of good bacteria in the stomach that make short-chain fatty acids (SCFAs), according to the research. These short-chain fatty acids (SCFAs) have several positive effects on the gastrointestinal tract, such as lowering inflammation, improving barrier integrity and regulating immunological responses.

Another study investigated the effect of cereal mixtures, specifically wheat combined with tartary buckwheat (WT) and sweet buckwheat (WE), on gut microbial composition and short-chain fatty acid (SCFAs) production *via in vitro* fermentation. The results revealed that the WT mixture led to higher levels of lactate and acetate production, whereas the WE mixture resulted in increased levels of propionate and butyrate compared to wheat alone (WA) (Zhou *et al.,* 2019).

Moreover, the relative abundance of certain beneficial bacteria, such as sutterella in wt and faecalibacterium in we, significantly increased with consumption of the cereal mixture, indicating potential beneficial effects on intestinal health. these findings highlight the potential of incorporating buckwheat into cereal mixtures to modulate the gut microbial composition and scfas production, thereby promoting gastrointestinal health (Table 6).

A thorough understanding of the metabolic pathways involving short-chain fatty acids (SCFAs) and their critical role in determining host physiology and gastrointestinal health can be obtained from literature. Both (Lebwohl *et al.,* 2017) and (Yilmaz *et al.,* 2018) investigated the microbiological fermentation process that produces SCFAs from dietary fibers and shed light on the various physiological impacts

Table 6: The summarized outcome of the research.

Aspect	Sweet buckwheat (WT)	Tartary buckwheat (WE)	Common buckwheat (WA)
Increase in beneficial flora	Yes	Yes	No
Beneficial flora species (*e.g.*, Faecalibacterium, Ruminococcus)	Faecalibacterium, Ruminococcus	Faecalibacterium, Ruminococcus	Not mentioned
Higher content of starch and dietary fiber	Yes	Yes	No
Impact on intestinal flora composition	Change observed	Change observed	Not mentioned
Promotion of intestinal health	Yes	Yes	Not mentioned
Production of short-chain fatty acids (SCFAs)	More lactate and acetate	More propionate and butyrate	Not mentioned
Metabolic pathways involved in SCFA production	Pyruvate, acetate and butyrate metabolism	Pyruvate, acetate and butyrate metabolism	Not mentioned
Key enzymes involved	EC 1.1.1.27 (lactic dehydrogenase) and EC 1.2.7.11 (2-oxoacid ferredoxin oxidoreductase subunit alpha)	EC 1.1.1.27 (lactic dehydrogenase) and EC 1.2.7.11 (2-oxoacid ferredoxin oxidoreductase subunit alpha)	Not mentioned

Table 7: Comparative analysis of efficacies of sweet and tartary buckwheat.

Author(s)	Objective	Outcome
(Zhou *et al.,* 2019)	Impact of wheat-buckwheat mix on gut microbiome (sweet and tartary buckwheat).	Proved the effects of sweet and tartary buckwheats as diet supplements in terms of how these pseudocereal mixture impacts gut microbiota, SCFAs.
(Ludvigsson *et al.,* 2013)	Sweet buckwheat's dietary impact on rats.	Presented scope of further trials to validate the impacts on GI problems reductions.
(Melini and Melini, 2019)	Nutritional comparison of tartary and common buckwheat.	Did comparison of nutritional properties in buckwheat flour.
(Valido *et al.,* 2023)	Enhancing buckwheat flour (sweet and tartary buckwheat) nutritional profile.	Showed nutrition sufficiency to be used for GI diet.

of these metabolites. Another study delved deeper into the ways in which SCFAs regulate the gut epithelium and immunological function (Koh *et al.,* 2016).

This is particularly relevant when considering disorders such as inflammatory bowel disease (IBD). An overview of precision nutrition and the microbiome is given in, which highlights the complex relationship between food, the make-up of the microbiota and health results. These studies highlight the importance of short-chain fatty acids (SCFAs) as potential therapeutic targets for inflammatory conditions and gastrointestinal health promotion, because they mediate the relationship between dietary fiber intake, gut microbiota metabolism and host physiology.

Table 7 provides substantiating evidence for the nutritional advantages of both sweet and tartary buckwheat varieties, indicating that they may enhance the nutritional composition and digestive health of gastrointestinal diets.

Development of gluten-free product from buckwheat

Supplemental buckwheat may be helpful for patients with gastrointestinal (GI) sensitivity, including celiac disease. For people who are gluten-intolerant or sensitive, buckwheat products are a great grain substitution that is both healthy and fit their nutritional needs. Buckwheat flour is an option for producing gluten-free baked goods. Pancakes, muffins and bread are all part of this category. Without compromising the flavor or nutritional value, patients can choose from a range of alternatives to meet their dietary needs (Melini and Melini, 2019). Additionally, the high fiber content of buckwheat promotes regular bowel movements and growth of beneficial bacteria, making it an excellent food choice for digestive health. The anti-inflammatory and antioxidant properties of the bioactive components of buckwheat, such as polyphenols and flavonoids, can aid sensitive individuals in managing inflammation and the gastrointestinal tract (Ludvigsson *et al.,* 2013). In addition to assisting GI-sensitive patients in maintaining their dietary restrictions, buckwheat also has positive effects on gut health.

Gluten intolerance, an immunological response to cereal gluten proteins that can harm the mucosa of the small intestine and lead to nutritional loss, is more common in individuals with celiac disease. When intestinal villi fall off and nutrients are only partially digested, they have systemic effects on the body.

As the number of people diagnosed with celiac disease continues to rise, there is a need for gluten-free products worldwide. Celiac disease has a different frequency in different parts of the world; however, according to studies, the combined worldwide prevalence is 1.4% (Dinu *et al.,* 2017; King *et al.,* 2020) and the increasing demand for gluten-free buckwheat products, as well as the health benefits they offer to celiac patients, is driving the market for these products to reach significant valuations by 2027. People with celiac disease benefit from wheat-enriched goods owing to their nutritional profile and nutraceutical potential, which is becoming increasingly obvious. These products include antioxidants, peptides, polyphenols and flavonoids, all of which work together to improve health. Consumers have used methods such as enzymatic treatment, germination, roasting and fermentation of buckwheat flour to increase the bioavailability of these beneficial components.

Consumers who value their health are more likely to purchase buckwheat products enhanced with other grains, pulses, fruits and vegetables. This fortification process stabilizes the product and increases the amount of essential nutrients it contains. Several strategies can be employed to enhance the bioactive components in buckwheat-based productsby utilizing these strategies, both the nutritional value and overall acceptability of food can be enhanced. consumer interest in health-promoting foods is driving the demand for nutritious and functional foods. The use of buckwheat in gluten-free diets and other food formulations is a promising solution for this problem. the top of Table 8 emphasizes the increasing recognition of health concerns associated with gluten and showcases buckwheat as a potentially advantageous gluten-free substitute that may positively impact gastrointestinal well-being (Kumar *et al.,* 2021; Singh *et al.,* 2018).

Clinical validation of buckwheat products on gi health modification

A dietary intervention study was conducted to evaluate the clinical validity of buckwheat in regulating gastrointestinal (gi) health and controlling the gut microbiome of patients with non-celiac gluten sensitivity (ncgs)the investigations were conducted under the condition of ingesting buckwheat products where patients showed a notable reduction in the severity of their most prevalent gastrointestinal symptoms, specifically bloating and stomach discomfort, compared to when they returned to their conventional gluten-free diet (GFD). with the exception of elevated blood magnesium levels, the biochemical markers showed minimal variation after buckwheat intervention.

Significantly, the levels of inflammatory cytokines such as interferon gamma and monocyte chemotactic protein-1 decreased after the intervention. This indicates that buckwheat may have a potential function in regulating the inflammatory processes linked to non-celiac gluten sensitivity (NCGS) (Dinu *et al.,* 2017). Nevertheless, additional research is necessary to confirm these findings. Although the study showed positive outcomes, the limited number of participants emphasized the necessity for more extensive and carefully planned experiments to confirm the effectiveness of buckwheat in treating symptoms of non-celiac gluten sensitivity (NCGS).

From the investigation results, the advantages of Buckwheat in Regulating Gastrointestinal Health Results and Gut Microbiome for Patients with Gastrointestinal Sensitivity are as follows:

The research analysis demonstrated that the inclusion of buckwheat products in the dietary regimen of individuals with non-celiac gluten sensitivity (NCGS) can result in

notable enhancements in gastrointestinal (GI) symptoms, such as bloating and stomach discomfort.

Buckwheat consumption has been linked to a decrease in the levels of inflammatory cytokines, indicating its possible ability to regulate inflammatory processes involved in gastrointestinal illnesses. Buckwheat has a high concentration of vitamins, fiber, minerals and polyphenolic antioxidants, which can promote gut health and offer health benefits other than avoiding gluten.

Regulation of the gut microbiome

Consumption of buckwheat has been associated with alterations in the makeup of gut microorganisms and metabolic pathways, resulting in the augmentation of beneficial bacteria and the generation of short-chain fatty acids. These effects promote intestinal health.

Gluten-free option

Buckwheat serves as a diverse and nutritious alternative to regular grains for individuals with gluten intolerance or celiac disease.

Constraints on the clinical effectiveness of buckwheat in patients with gastrointestinal sensitivity.

Limited sample size

Numerous studies examining the impact of buckwheat on gastrointestinal (GI) health outcomes have utilized limited sample sizes, which restricts the applicability of their results and necessitates further studies with larger groups of participants.

Absence of standardization

The inconsistency in buckwheat products and the many ways they are prepared can affect the results, making it difficult to create standardized procedures for evaluating their therapeutic effectiveness.

Nutritional deficiencies

Although buckwheat is abundant in nutrients, depending exclusively on buckwheat-based items in a gluten-free diet could result in nutritional deficiencies if it is not properly supplemented with other vital nutrients.

Additional research required

Despite encouraging results, the precise mechanisms by which buckwheat influences gastrointestinal health and regulates the microbiome need to be clarified through meticulously planned and controlled investigations.

Interindividual variability

The way individuals with gastrointestinal sensitivities respond to buckwheat consumption may differ, under scoring the significance of tailored dietary strategies and vigilant symptom monitoring.

Another clinical study (Nan *et al.,* 2024) assessed the safety and effectiveness of Tartary buckwheat seeds (TB) and Tartary buckwheat sprouts (TBS) as components of functional foods. The outcome showed that Tartary buckwheat sprouts (TBS) have been found to be a safer and more efficient option for functional food formulations. They provide improved nutritional advantages and have fewer negative effects than tartary buckwheat seeds (TB). The main findings are as follows.

Nutritional enhancement

The germination process of tartary buckwheat seeds resulted in an improvement in their nutritional composition.

Table 8: Overview of gluten consumption health problems and remediation role of buckwheat varieties.

Author(s)	Objective	Outcome
(Stanciu *et al.,* 2024)	Study gluten reaction forms.	Pointed the emergence of gluten-related health concerns.
(Mulder *et al.,* 2023)	Explore gluten-associated disorders in addition to celiac disease.	Emphasized the clinical importance of being able to identify a range of disorders associated with gluten.
(Lebwohl *et al.,* 2017)	Study gluten's effect on heart disease.	Inferred that gluten intake not linked to heart disease but should be kept under control.
(Theethira *et al.,* 2014)	Gluten-free diet implications for celiac disease.	Provided evidences of gluten control in certain cases of GI sensitivity.
(Foschia *et al.,* 2016)	Identifying gaps in gluten-free diets.	Found lack of diet routine and assessment of control strategies to reduce long-term ailments.
(Mousavi *et al.,* 2022)	Study impact of lentil-buckwheat mix on gut microbiome.	Confirmed sweet and tartary buckwheat's dietary effects.
(Sofi *et al.,* 2022)	Determine buckwheat's suitability for gluten-free diets.	Provided evidences of scope and better usages of the pseudocereal as GI treatment diet.
(Mattila *et al.,* 2018)	Enhancing buckwheat flour (sweet and tartary buckwheat) nutritional profile.	Showed nutrition sufficiency to be used for GI diet.
(Barbaro *et al.,* 2020; Stanciu *et al.,* 2024)	Reviewing gluten's role in GI disorders.	Assessed gluten's impact on GI disorders.
(Bhinder *et al.,* 2020; Lee *et al.,* 2016)	Explore buckwheat's nutritional and bioactive properties.	Highlighted buckwheat's potential for gluten-free products.

Table 9: Assessment outcomes of buckwheat's effects on gi health profile modifications and their role in gut microbiome control.

Author(s)	Objective	Outcome
(Stanciu *et al.,* 2024)	Identify the clinical and dietary processes of gluten-associated disorders.	Assisted in understanding the clinical ramifications and variety of gluten-related disorders.
(Yao *et al.,* 2022)	Assessing buckwheat's impact on gut microbiome.	Showed that buckwheat-wheat mixtures influenced gut microbiome and short-chain fatty acid production, indicating potential intestinal benefits.
(Dinu *et al.,* 2017)	Assessing buckwheat products in NCGS treatment.	Showed that buckwheat products alle*via*ted NCGS symptoms, improve nutrition.
(Zhou *et al.,* 2019)	Investigating buckwheat starch's regulatory effects.	Showed the role in regulating lipid profile and gut microbiota.
(Sofi *et al.,* 2023)	Evaluate the impact of microbiome on bioactive constituents and stability.	Stability and impact on bioactive components investigated.
(Zamaratskaia *et al.,* 2024)	Investigate buckwheat's effect on GI health.	Summarized buckwheat's potential GI benefits.
(Nan *et al.,* 2024)	Compare Tartary buckwheat seed and sprout effects.	Analyzed Tartary buckwheat seed and sprout effects and provided its better potency evidences.

This leads to an increase in bioactive chemicals and a decrease in anti-nutritional components.

Animal experiment

C57BL/6J mice were orally administered distilled water, TB, or TBS for 6 weeks. The consumption of TB has a negative impact on the gut microbiota and organs, such as a drop in serum Fe^{3+} levels and trypsin activity, as well as an increase in cytokine, IgE and histamine levels. In contrast, TBS did not have any discernible adverse effects on these indicators and was more effective in reducing cholesterol levels.

Tbs exhibited superior safety and efficacy outcomes compared to tb, indicating that it is a more desirable component for the production of functional meals targeting the prevention and treatment of illnesses, such as hyperlipidemia. the potential of buckwheat to mitigate symptoms of gluten-associated disorders, regulate lipid profiles and positively impact gut microbiome constitution is shown in Table 9. these findings underscore the prospective role of buckwheat in modifying gastrointestinal health.

RECOMMENDATION

To overcome the existing clinical limitations of buckwheat diet used in GI sensitivity treatment and gut-microbiome control (as mentioned in the buckwheat clinical assessment section), a few betterment recommendations are suggested:

Additional investigations using more extensive sample sizes and standardized methodologies are required to validate and clarify the mechanisms underlying the therapeutic capabilities of buckwheat.

Standardization in the manufacturing and evaluation of buckwheat products is essential to achieve a consistent and reliable assessment of its clinical effectiveness.

Healthcare practitioners might suggest buckwheat-based products as a component of dietary therapies for individuals with gastrointestinal sensitivity, in combination with customized dietary regimens and careful symptom monitoring.

Consumers should be urged to include buckwheat in their diets because of its advantageous impact on gastrointestinal (GI) health, given its varied nutritional composition and ability to regulate the gut microbiota.

Food makers may consider including buckwheat in functional food recipes to capitalize on its health advantages and cater to the increasing demand for healthy and gut-friendly goods.

CONCLUSION

Buckwheat efficacy, as discussed in this systematic review, has been shown to be effective in regulating gastrointestinal (GI) health and managing the gut microbiome, especially for individuals with GI sensitivity, such as non-celiac gluten sensitivity (NCGS) and celiac disease. Clinical research has demonstrated that buckwheat products can relieve gastrointestinal symptoms, including bloating and pain, while also potentially regulating inflammatory processes linked to gastrointestinal diseases.

The objectives proposed in this study are supported by the review's PICO analysis outcome, as done in terms of the comparison of scholarly works. Evidence, as shown in this article, regarding the nutritional benefits of buckwheat includes its potential to modulate lipid profiles and alleviate symptoms of gluten-associated disorders. The aforementioned results indicate that buckwheat has potential as an advantageous supplement to gastrointestinal-sensitive diets, which may have ramifications for enhancing general gastrointestinal well-being.

Due to its nutritional density and polyphenolic compounds, buckwheat can positively influence gut health and inflammatory pathways in gluten-related disorders.

Conflict of interest

All authors declared that there is no conflict of interest.

REFERENCES

Barbaro, M.R., Cremon, C., Morselli-Labate, A.M., Di Sabatino, A., Giuffrida, P., Corazza, G. R., Di Stefano, M., Caio, G., Latella, G., Ciacci, C., Fuschi, D., Mastroroberto, M., Bellacosa, L., Stanghellini, V., Volta, U. and Barbara, G. (2020). Serum zonulin and its diagnostic performance in non-coeliac gluten sensitivity. *Gut*. **69(11):** 1966-1974. https://doi.org/10.1136/GUTJNL-2019-319281.

Bhinder, S., Kaur, A., Singh, B., Yadav, M.P. and Singh, N. (2020). Proximate composition, amino acid profile, pasting and process characteristics of flour from different Tartary buckwheat varieties. *Food Research International.* **130:** 108946. https://doi.org/10.1016/J.FOODRES.2019.108946.

Dinu, M., Macchia, D., Pagliai Msc, G., Gori, A.M., Cesari, F., Marcucci, R., Sofi, F. and Casini, A. (2017). Symptomatic efficacy of buckwheat products in non-celiac gluten sensitivity (NCGS). *Asia. Pac. J. Clin. Nutr.* **26(4):** 630-636. https://doi.org/10.6133/apjcn.072016.07.

Foschia, M., Horstmann, S., Arendt, E.K. and Zannini, E. (2016). Nutritional therapy-facing the gap between coeliac disease and gluten-free food. *International Journal of Food Microbiology*. **239:** 113-124. https://doi.org/10.1016/J.IJFOODMICRO.2016.06.014.

Giménez-Bastida, J.A. and Zieliński, H. (2015). Buckwheat as a functional food and its effects on health. *Journal of Agricultural and Food Chemistry*. **63(36):** 7896-7913. https://doi.org/10.1021/ACS.JAFC.5B02498/ASSET/IMAGES/MEDIUM/JF-2015-02498K_0004.

King, J.A., Jeong, J., Underwood, F.E., Quan, J., Panaccione, N., Windsor, J.W., Coward, S., Debruyn, J., Ronksley, P.E., Shaheen, A.A., Quan, H., Godley, J., Veldhuyzen Van Zanten, S., Lebwohl, B., Ng, S.C., Ludvigsson, J.F. and Kaplan, G.G. (2020). Incidence of celiac disease is increasing over time: A systematic review and meta-analysis. *American Journal of Gastroenterology*. **115(4):** 507-525. https://doi.org/10.14309/AJG.0000000000000523.

Koh, A., De Vadder, F., Kovatcheva-Datchary, P. and 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/ASSET/95008553-7832-494E-9FD9-91A065597DE1/MAIN.ASSETS/GR4.

Kumar, P., Singh, R.K. and Kumar, V. (2021). Nutritional interventions in celiac disease: A review. *Indian Journal of Agricultural Biochemistry*. **34(1):** 45-50.

Lebwohl, B., Cao, Y., Zong, G., Hu, F.B., Green, P.H.R., Neugut, A.I., Rimm, E.B., Sampson, L., Dougherty, L.W., Giovannucci, E., Willett, W.C., Sun, Q. and Chan, A.T. (2017). Long Term Gluten Consumption in Adults Without Celiac Disease and Risk of Coronary Heart Disease: Prospective Cohort Study. BMJ (Clinical Research Ed.). **357:** j1892. https://doi.org/10.1136/BMJ.J1892.

Lee, L.S., Choi, E.J., Kim, C.H., Sung, J.M., Kim, Y.B., Seo, D.H., Choi, H.W., Choi, Y. S., Kum, J.S. and Park, J.D. (2016). Contribution of flavonoids to the antioxidant properties of common and tartary buckwheat. *Journal of Cereal Science*. **68:** 181-186. https://doi.org/10.1016/J.JCS.2015.07.005.

Ludvigsson, J.F., Leffler, D.A., Bai, J.C., Biagi, F., Fasano, A., Green, P.H.R., Hadjivassiliou, M., Kaukinen, K., Kelly, C.P., Leonard, J.N., Lundin, K.E.A., Murray, J. A., Sanders, D.S., Walker, M.M., Zingone, F. and Ciacci, C. (2013). The Oslo definitions for coeliac disease and related terms. *Gut*. **62(1):** 43-52. https://doi.org/10.1136/GUTJNL-2011-301346.

Mattila, P.H., Pihlava, J.M., Hellström, J., Nurmi, M., Eurola, M., Mäkinen, S., Jalava, T. and Pihlanto, A. (2018). Contents of phytochemicals and antinutritional factors in commercial protein-rich plant products. *Food Quality and Safety*. **2(4):** 213-219. https://doi.org/10.1093/FQSAFE/FYY021.

Melini, V. and Melini, F. (2019). Gluten-free diet: Gaps and needs for a healthier diet. *Nutrients*. **11(1):** 170. https://doi.org/10.3390/NU11010170.

Morales, D., Miguel, M. and Garcés-Rimón, M. (2021). Pseudocereals: A novel source of biologically active peptides. *Critical Reviews in Food Science and Nutrition*. **61(9):** 1537-1544. https://doi.org/10.1080/10408398.2020.1761774.

Morrison, D.J. and Preston, T. (2016). Formation of short chain fatty acids by the gut microbiota and their impact on human metabolism. *Gut Microbes*. **7(3):** 189-200. https://doi.org/10.1080/19490976.2015.1134082.

Mousavi, M.H., Gharekhani, M., Alirezalu, K., Roufegarinejad, L. and Azadmard-Damirchi, S. (2022). Production and characterization of nondairy gluten free fermented beverage based on buckwheat and lentil. *Food Science and Nutrition*. **11(5):** 2197. https://doi.org/10.1002/FSN3.3095.

Mulder, C.J.J., Elli, L., Lebwohl, B., Makharia, G.K., Rostami, K., Rubio-Tapia, A., Schumann, M., Tye-Din, J., Zeitz, J. and Al-Toma, A. (2023). Follow-up of celiac disease in adults: "When, what, who and where." *Nutrients*. **15(9).** https://doi.org/10.3390/NU15092048.

Nan, G., Zhao, H., Wu, Q., Liu, L., Guan, Z., Li, C., Wu, H., Xiang, D. and Wu, Q. (2024). Comparative study of the effects of Tartary buckwheat seed and sprout consumption on the physiological indices and gut microbiota of C57BL/6J mice. *Food Science and Human Wellness*. **13(2):** 791-800. https://doi.org/10.26599/FSHW.2022.9250067.

Patel, R. and Meena, D. (2020). Exploring pseudocereals for dietary applications. *Indian Journal of Agricultural Research*. **54(3):** 212-218.

Pietzak, M. (2012). Celiac disease, wheat allergy and gluten sensitivity: When gluten free is not a fad. *JPEN. Journal of Parenteral and Enteral Nutrition*. **36(1):** 68S-75S. https://doi.org/10.1177/0148607111426276.

Pirzadah, T.B. and Malik, B. (2020). Pseudocereals as super foods of 21st century: Recent technological interventions. *Journal of Agriculture and Food Research*. **2:** 100052. https://doi.org/10.1016/J.JAFR.2020.100052.

Prakash, P. and Yadav, K. (2016). Buckwheat (*Fagopyrum esculentum*) as a functional food: A nutraceutical pseudocereal. *Agricultural and Food Sciences*. **1(3):** 1-15.

Sapone, A., Bai, J.C., Ciacci, C., Dolinsek, J., Green, P.H.R., Hadjivassiliou, M., Kaukinen, K., Rostami, K., Sanders, D.S., Schumann, M., Ullrich, R., Villalta, D., Volta, U., Catassi, C. and Fasano, A. (2012). Spectrum of gluten-related disorders: Consensus on new nomenclature and classification. *BMC Medicine*. **10(1):** 1-12. https://doi.org/10.1186/1741-7015-10-13/FIGURES/4.

Sharma, R. and Singh, A. (2022). Role of dietary fiber in modulation of gut microbiota. *Agricultural Reviews*. **43(2):** 134-140.

Shewry, P.R. (2009). Wheat. *Journal of Experimental Botany*. **60(6):** 1537-1553. https://doi.org/10.1093/JXB/ERP058.

Singh, P., Arora, A., Strand, T.A., Leffler, D.A., Catassi, C., Green, P.H., Kelly, C.P., Ahuja, V. and Makharia, G.K. (2018). Global prevalence of celiac disease: Systematic review and meta-analysis. *Clinical Gastroenterology and Hepatology*. **16(6):** 823-836.e2. https://doi.org/10.1016/J.CGH.2017.06.037/ASSET/B793E993-D291-4F8A-B09C-394D7DACE910/MAIN.ASSETS/FX1_LRG.JPG.

Sofi, S.A., Ahmed, N., Farooq, A., Rafiq, S., Zargar, S.M., Kamran, F., Dar, T.A., Mir, S.A., Dar, B.N.and Mousavi Khaneghah, A. (2022). Nutritional and bioactive characteristics of buckwheat and its potential for developing gluten free products: An updated overview. *Food Science and Nutrition*. **11(5):** 2256. https://doi.org/10.1002/FSN3.3166.

Sofi, S.A., Ahmed, N., Farooq, A., Rafiq, S., Zargar, S.M., Kamran, F., Dar, T.A., Mir, S.A., Dar, B.N. and Mousavi Khaneghah, A. (2023). Nutritional and bioactive characteristics of buckwheat and its potential for developing gluten free products: An updated overview. *Food Science and Nutrition*. **11(5):** 2256-2276. https://doi.org/10.1002/FSN3.3166'.

Stanciu, D., Staykov, H., Dragomanova, S., Tancheva, L., Pop, R.S., Ielciu, I. and Cri'an, G. (2024). Gluten unraveled: Latest insights on terminology, diagnosis, pathophysiology, dietary strategies and intestinal microbiota modulations-A decade in review. *Nutrients*. **16(21).** https://doi.org/10.3390/NU16213636.

Theethira, T.G., Dennis, M. and Leffler, D.A. (2014). Nutritional consequences of celiac disease and the gluten-free diet. *Expert Review of Gastroenterology and Hepatology*. **8(2):** 123-129. https://doi.org/10.1586/17474124.2014.876360.

Valido, E., Stoyanov, J., Gorreja, F., Stojic, S., Niehot, C., Kiefte-de Jong, J., Llanaj, E., Muka, T. and Glisic, M. (2023). Systematic review of human and animal evidence on the role of buckwheat consumption on gastrointestinal health. *Nutrients*. **15(1):** 1. https://doi.org/10.3390/NU15010001/S1.

Venegas, D.P., De La Fuente, M.K., Landskron, G., González, M.J., Quera, R., Dijkstra, G., Harmsen, H.J.M., Faber, K.N. and Hermoso, M.A. (2019). Short chain fatty acids (SCFAs) mediated gut epithelial and immune regulation and its relevance for inflammatory bowel diseases. *Frontiers in Immunology*. **10(MAR):** 424615. https://doi.org/10.3389/FIMMU.2019.00277/XML/NLM.

Wieser, H. (2007). Chemistry of gluten proteins. *Food Microbiology*. **24(2):** 115-119. https://doi.org/10.1016/J.FM.2006.07.004.

Yao, D., Yu, Q., Xu, L., Su, T., Ma, L., Wang, X., Wu, M., Li, Z., Zhang, D. and Wang, C. (2022). Wheat supplement with buckwheat affect gut microbiome composition and circulate short-chain fatty acids. *Frontiers in Nutrition*. **9:** 952738. https://doi.org/10.3389/FNUT.2022.952738/FULL.

Yilmaz, H.Ö., Ayhan, N.Y. and Meriç, Ç.S. (2018). Buckwheat: A useful food and its effects on human health. *Current Nutrition and Food Science*. **16(1):** 29-34. https://doi.org/10.2174/1573401314666180910140021.

Zamaratskaia, G., Gerhardt, K., Knicky, M. and Wendin, K. (2024). Buckwheat: An underutilized crop with attractive sensory qualities and health benefits. *Critical Reviews in Food Science and Nutrition*. **64(33):** 12303-12318. https://doi.org/10.1080/10408398.2023.2249112.

Zhou, Y., Zhao, S., Jiang, Y., Wei, Y. and Zhou, X. (2019). Regulatory function of buckwheat-resistant starch supplementation on lipid profile and gut microbiota in mice fed with a high-fat diet. *Journal of Food Science*. **84(9):** 2674-2681. https://doi.org/10.1111/1750-3841.14747.

Zhu, F. (2016). Buckwheat starch: Structures, properties and applications. *Trends in Food Science and Technology*. **49:** 121-135. https://doi.org/10.1016/J.TIFS.2015.12.002.