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Effects of Dietary Fiber Interventions on Gut Health and Glycemic Control in Type 2 Diabetes Mellitus: A Systematic Review of Human Intervention Studies

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type 2 diabetes mellitus; dietary fiber; gut microbiota; glycemic control; HbA1c.

ABSTRACT
Type 2 diabetes mellitus (T2DM) is a rapidly increasing global health burden, with dietary fiber proposed as a modifiable nutritional strategy to improve glycemic control and gut health. However, clinical evidence regarding different fiber types and underlying mechanisms remains heterogeneous. This systematic review aimed to evaluate the effects of dietary fiber interventions on gut microbiota composition and glycemic outcomes in adults with T2DM. A systematic literature search was conducted in PubMed, ScienceDirect, the Cochrane Library, and Europe PMC in accordance with Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. Human intervention studies, including randomized controlled trials, crossover trials, and controlled clinical trials involving adults with T2DM receiving dietary fiber supplementation or high-fiber dietary interventions, were eligible for inclusion. Risk of bias was assessed using the Joanna Briggs Institute (JBI) Critical Appraisal Checklist.Twenty-six studies involving 1,601 participants were included. Dietary fiber interventions consistently improved glycemic outcomes, with the most consistent effects observed in reductions in fasting glucose and glycated hemoglobin (HbA1c), particularly with psyllium and inulin supplementation. Improvements in postprandial glucose responses were demonstrated across multiple fiber types in acute and short-term interventions. Dietary fiber supplementation may improve glycemic control in individuals with T2DM, with preliminary evidence suggesting that modulation of gut microbiota may contribute to these effects. Standardized, long-term clinical trials integrating metabolic and microbiota-related outcomes are required to further clarify these mechanisms.

INTRODUCTION

Type 2 diabetes mellitus (T2DM) has emerged as one of the most pressing global health challenges of the modern era, accounting for approximately 90% of all diabetes cases among adults (Ojo et al., 2020a). The World Health Organization has documented a dramatic increase in prevalence, from an estimated 108 million cases in 1980 to more than 422 million cases by 2014, with projections indicating that this number could exceed 642 million by 2040 (Saeedi et al., 2019). This growing burden is particularly pronounced in low- and middle-income countries, where access to conventional pharmacological interventions remains limited,

highlighting the urgent need for accessible and cost-effective adjunctive strategies, including dietary modification (Saeedi et al., 2019). Multiple interacting risk factors contribute to its pathogenesis, including overweight and obesity, sedentary lifestyles, genetic susceptibility, and dysbiosis of the gut microbial community (Ojo et al., 2020a, 2021a). Of particular relevance, dietary patterns characteristic of Western lifestyles, particularly low fiber intake combined with high consumption of fat and sugar, have been associated with reductions in specific bacterial taxa and decreased overall gut microbiome diversity, potentially creating conditions that promote metabolic dysfunction (Makki et al., 2018).

Dietary fiber encompasses a broad category of carbohydrates that resist digestion and absorption in the small intestine, including non-starch polysaccharides (NSP), resistant starch, oligosaccharides such as fructo-oligosaccharides, galacto-oligosaccharides, and inulin, as well as soluble fibers such as pectin and guar gum (Abutair et al., 2016a; Kim et al., 2016a; Moreira et al., 2024a). These components can be classified as soluble or insoluble fibers, each with distinct physiological functions. Higher dietary fiber intake has consistently been associated with a reduced risk of noncommunicable metabolic diseases, certain cancers, and all-cause mortality (Pugh & Chambers, 2025a). However, translating these epidemiological associations into clinical recommendations for T2DM management requires evidence from intervention studies capable of establishing causality and quantifying treatment effects. Beyond its direct gastrointestinal effects, dietary fiber, particularly fermentable soluble fibers such as inulin and resistant starch, is metabolized by gut bacteria, resulting in changes in microbial community composition and stimulating the production of short-chain fatty acids (SCFAs), including acetate, propionate, and butyrate. These SCFAs support intestinal barrier integrity by promoting tight junction protein expression and mucus secretion. After entering circulation, they also influence host metabolism by enhancing insulin secretion from pancreatic β-cells, reducing adipose tissue lipolysis, and increasing glucose uptake in skeletal muscle.

Despite these well-established mechanistic pathways, evidence linking dietary fiber intake with improved glycemic control in individuals with T2DM remains heterogeneous across clinical studies. Some trials have reported significant improvements in fasting glucose, HbA1c, and insulin resistance, whereas others have demonstrated no significant differences compared with placebo interventions. Regarding gut microbiota, although some studies have reported increases in beneficial bacterial genera, particularly Bifidobacterium (H. Li et al., 2024) , broader effects on microbial composition and diversity have varied considerably across randomized controlled trials (Birkeland et al., 2021a; Dehghan et al., 2014a; Pugh & Chambers, 2025a). These discrepancies may be attributed to differences in fiber type, dosage, intervention duration, and baseline participant characteristics. However, no systematic review has simultaneously evaluated glycemic and microbiota outcomes to determine which fiber interventions are most likely to provide clinically meaningful benefits.

Given these research gaps, a comprehensive and updated evaluation of the relationship between dietary fiber, gut microbiota, and glycemic regulation in individuals with T2DM is warranted. The importance of this review is further supported by the rapidly expanding evidence regarding the role of the gut microbiome in metabolic diseases, which may contribute

to personalized dietary recommendations but has not yet been comprehensively synthesized with a focus on clinically relevant outcomes. Therefore, this systematic review aimed to evaluate recent human intervention studies examining the effects of increased dietary fiber intake in individuals with T2DM.

Specifically, this review sought to identify the types of fiber interventions used; evaluate their effects on gut microbiota composition and related biomarkers, including SCFAs and indicators of gut barrier integrity; summarize their effects on glycemic outcomes; and compare the relative effectiveness of different dietary fiber strategies in improving metabolic health. By integrating evidence from both metabolic and microbiological perspectives, this review contributes to the development of evidence-based dietary recommendations for T2DM management and highlights critical knowledge gaps to guide future research.

METHOD

This systematic review was conducted in accordance with the PRISMA guidelines. Although the review protocol was not registered, the methodology followed established standards for systematic reviews of intervention studies. Relevant human intervention studies evaluating dietary fiber interventions in adults with type 2 diabetes mellitus (T2DM) were identified through a structured literature search using predefined eligibility criteria. Studies were included if they were randomized controlled trials, crossover trials, or controlled clinical trials involving adults (≥18 years) with confirmed T2DM and evaluated oral dietary fiber supplementation or high-fiber dietary interventions with a comparator group (placebo, usual care, or low-fiber control). Studies were excluded if they were observational studies, animal studies, protocol papers, or lacked sufficient outcome data.

A comprehensive literature search was conducted in PubMed, ScienceDirect, Europe PMC, and the Cochrane Library from inception to December 2024. The search strategy combined Medical Subject Headings (MeSH) terms and free-text keywords related to dietary fiber, T2DM, gut microbiota, glycemic control, and randomized controlled trials. Two reviewers independently screened titles and abstracts, followed by full-text assessments based on the eligibility criteria. Disagreements were resolved through discussion or consultation with a third reviewer. Data were extracted using a standardized form covering study characteristics (author, year, design, sample size, and population), intervention details (fiber type, dose, and duration), comparator, and outcomes, including glycemic parameters, microbiota composition, SCFAs, and gut barrier markers.

The methodological quality of the included studies was assessed using the JBI Critical Appraisal Checklist for randomized controlled trials and quasi-experimental studies. Each study was classified as having a low, moderate, or high risk of bias based on relevant domains, including randomization, allocation concealment, blinding, follow-up completeness, and other methodological criteria. Due to substantial heterogeneity in fiber types, doses, intervention durations, and outcome measures, meta-analysis was not performed. Instead, a narrative synthesis was conducted by grouping studies according to fiber type (psyllium, inulin, β-glucan, high-fiber diets, and other fibers) and outcome domains (glycemic control and gut

health). Findings were summarized in tables and figures, with effect estimates reported as mean differences or percentage changes when available.

RESULT AND DISCUSSION

Study selection and identification

A literature search across PubMed, ScienceDirect, Europe PMC, and Cochrane Library identified a total of 4,570 records (PubMed, n=1,304; ScienceDirect, n=2,838; Europe PMC, n=360; Cochrane Library, n=68). After removal of duplicates, 3,901 records remained for screening. During title and abstract screening, 3,699 records were excluded because they were not relevant to the topic of interest, leaving 202 records for further assessment. A total of 202 full-text articles were assessed for eligibility. Studies were excluded based on PICOS criteria due to intervention not aligned with the review objective (n=92), ineligible study design (n=29), protocol studies (n=4), insufficient data (n=13), and irrelevant outcomes (n=38). Ultimately, 26 studies met the eligibility criteria and were included in the systematic review. The study selection process is summarized in Figure 1.

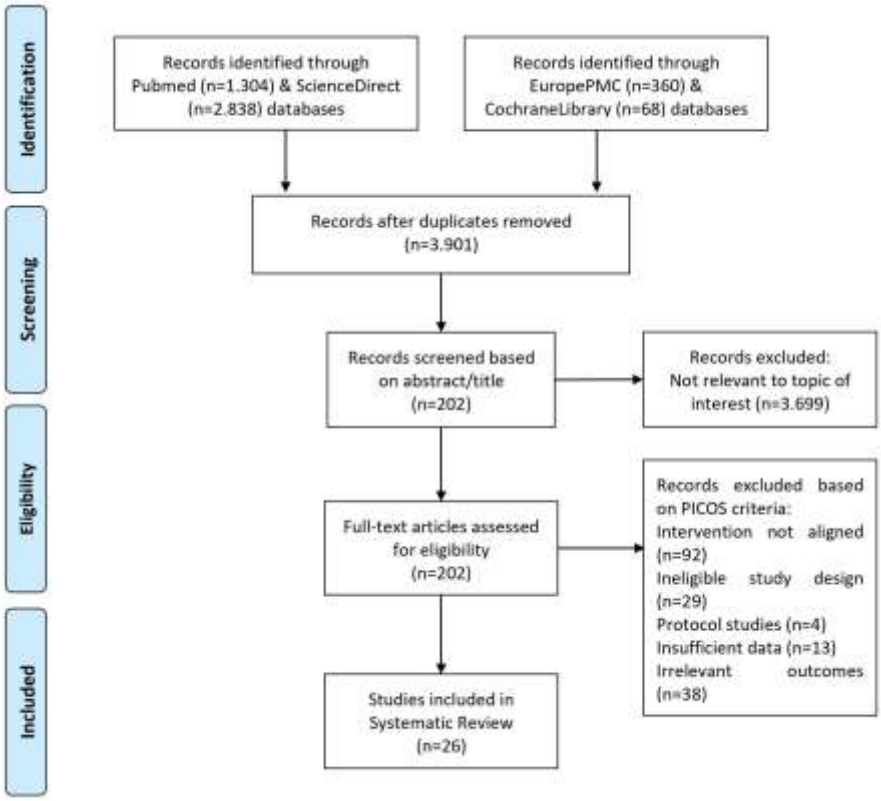

Figure 1. Studies Selection and Identification Flowchart

Risk of bias assessment

The risk of bias assessment of the 26 included intervention studies. Overall, the methodological quality of the included studies was generally acceptable, with most studies demonstrating appropriate randomization procedures and comparable baseline characteristics

between intervention groups. Thirteen studies were classified as having a low risk of bias due to robust study designs, including adequate randomization procedures, placebo-controlled designs, and appropriate blinding methods. Thirteen studies were classified as having a moderate risk of bias, mainly due to methodological limitations such as open-label designs, insufficient reporting of allocation concealment, lack of blinding procedures, small sample sizes, and incomplete follow-up reporting. No studies were classified as having a high risk of bias. Overall, the included evidence demonstrated moderate-to-good methodological quality, although several methodological limitations may influence the interpretation and reliability of the reported findings.

Characteristics of studies

A total of 26 studies published between 1988 and 2024 met the eligibility criteria, comprising 1,601 participants with Type 2 Diabetes Mellitus (T2DM). Most studies were randomized controlled trials (RCTs). Several studies used crossover designs, while five employed acute single-meal interventions to assess postprandial glycemic responses . Sample sizes ranged from 7 to 298 participants (X. Li et al., 2016), with most studies including adults with confirmed T2DM, although some focused on specific populations such as patients with nephropathy or chronic constipation(Noureddin et al., 2018a) .

A broad range of dietary fiber interventions was evaluated, with psyllium husk being the most frequently studied (6.8–15 g/day). Other interventions included inulin-type fructans (10,11,16), β-glucan from oats, wheat-derived fibers, high-fiber dietary patterns, galacto-oligosaccharides, PolyGlycopleX, and other fibers such as glucomannan, sodium alginate, resistant starch, okara products, oat bran concentrate bread, and fiber-enriched cereals. Intervention durations ranged from a single meal to 52 weeks, with most studies lasting 2–12 weeks. Glycemic outcomes, including fasting plasma glucose, HbA1c, postprandial glucose, insulin, and HOMA-IR, were assessed across all studies, while gut health outcomes such as microbiota composition, microbial diversity, and short-chain fatty acid production were reported in seven studies (Table 1).

Table 1. Characteristics and outcomes of included studies examining the effects of dietary fiber interventions on glycemic and gut health outcomes in adults with type 2 diabetes mellitus

Author, Year	Design	na	Fiber type	Dose	Comparator	Duration (wks)	Gut health outcomes	Key glycemic outcomes
PSYLLIUM								
(Anderson et al., 1999b)	DB-PC parallel RCT	29	Psyllium husk	10.2 g/day (5.1 g × 2)	Cellulose + std. diabetic diet	8	*NR*	FG ↓6.1%; HbA1c ↓6.3%; all-day PPG ↓11.0%; post-lunch glucose ↓19.2%
Abutair et al., 2016	RCT	36	Soluble psyllium	10.5 g/day	Regular diet	8	*NR*	FBS 163→120 mg/dL; HbA1c 8.5→7.5%; HOMA-IR ↓ 11.3→5.8; insulin 27.9→19.7 μIU/mL

Pastors et al., 1991	PC crossover	18	Psyllium hydrophilic mucilloid	6.8 g × 2/day	Placebo	Acute	*NR*	Breakfast glucose peak ↓14%; dinner glucose peak ↓20%; 2nd-meal glucose ↓31%; breakfast insulin AUC ↓17%
Rodríguez-Morán et al., 1998	DB-PC trial	123	Plantago psyllium	15 g/day (5 g × 3)	Placebo + low-fat diet	6	*NR*	FPG significantly reduced (p<0.01)
Soltanian & Jalali, 2018	SB-PC RCT	51	Psyllium (in cookies)	10 g/day	Placebo cookies	12	*NR*	FPG ↓13.6 mg/dL (p=0.04); HbA1c ↓1.7% (p=0.002)
Sartore et al., 2009	Controlled intervention	40	Psyllium	10.5 g/day (3.5 g × 3)	Controlled diet alone	8	*NR*	HbA1c 6.78→6.58% (p<0.05); FPG 140.4→135.6 mg/dL (p<0.05)
Ziai et al., 2005	DB-PC parallel	36	Psyllium husk	10.2 g/day (5.1 g × 2)	MCC placebo + std. therapy	8	Better gastric tolerance to metformin reported	FBS 208.2→155.6 mg/dL (↓52.8 mg/dL, p<0.05); HbA1c 10.5→8.9% (p<0.001)
INULIN / INULIN-TYPE FRUCTANS (ITF)								
Dehghan et al., 2014	Triple-blind RCT	49	High-performance inulin	10 g/day	Maltodextrin placebo	8	Plasma LPS ↓27.9% (p<0.05)	FBS ↓8.5%; HbA1c ↓10.4%; fasting insulin ↓34.3%; HOMA-IR ↓39.5%
Birkeland et al., 2020	DB-PC crossover RCT	25	ITF (oligofructose + inulin)	16 g/day	Maltodextrin	6	Total SCFA ↑ (p=0.04); acetic acid ↑; propionic acid ↑; Bifidobacterium adolescentis ↑; butyrate: NS; α-diversity: NS	Fasting & PPG: NS; insulin: NS
Birkeland et al., 2021	DB-PC crossover RCT	29	ITF (oligofructose + inulin)	16 g/day	Maltodextrin	6	Fecal bifidobacteria ↑; SCFA ↑ (previously reported)	GLP-1 AUC: NS; fasting glucose: NS; insulin: NS
OAT / β-GLUCAN								
Pick et al., 1996	Crossover pilot RCT	8	Oat bran concentrate	~18 g/day add'l fiber (~9 g soluble)	White bread products	24	*NR*	Total glucose AUC ↓46%; breakfast glucose excursion ↓42%; lunch glucose excursion ↓52%; insulin AUC ↓25%
Li et al., 2016	Parallel RCT	298b	Wholegrain oats	50 or 100 g/day (β-glucan 2.65–5.3 g)	Healthy diet or usual care	4 + 52	*NR*	PPG ↓ (50 & 100 g groups); HOMA-IR ↓ (100 g group, MD −1.77); 1-yr HbA1c ↓0.64% (100 g group)
Tessari et al., 2017	Controlled parallel	22	β-glucan functional bread	7 g fiber/100 g bread	White bread	~24	*NR*	HbA1c 7.97→7.45% (p=0.026); PPG 9.2→8.4 mmol/L (p=0.011)
HIGH-FIBER DIET / MIXED DIETARY FIBER								
Chandalia et al., 2000	Crossover RCT	13	High-fiber diet	50 g/day (25 g soluble + 25 g insoluble)	ADA diet (24 g/day)	6	*NR*	Mean plasma glucose ↓13 mg/dL (p=0.04); 24-h glucose AUC ↓10%;

								insulin AUC ↓12%; HbA1c: NS
Hagander et al., 1988	Crossover dietary	14	High-fiber diet	~43.7 g/day	Low-fiber diet (~15.7 g/day)	8	*NR*	FBG ↓ (6.3 vs 6.7 mmol/L, p<0.01); HbA1c: NS; insulin: NS
Zhao et al., 2018	Parallel RCT	43	High-fiber diet (whole grains + prebiotics)	High-fiber dietary pattern	Usual care + acarbose	12	Butyrate-producing bacteria ↑; fecal butyrate ↑; SCFA ↑; GLP-1 ↑; gut pH ↓	HbA1c <7% in 89% vs 50%; FG reduced earlier in intervention group
de Carvalho et al., 2017	Open-label crossover	19	HFD or HFS meal	9.7 g fiber/meal (5.4 g soluble)	Usual-fiber meal (2.4 g)	Acute	*NR*	Glucose AUC: HFD=7861; HFS=7847 vs UF=9527 mg/dL·min (both p<0.05 vs UF); insulin iAUC: NS
OTHER FIBER TYPES								
Birkeland et al., 2020 / Torsdottir et al., 1991	Crossover meal RCT	7	Sodium alginate	5 g/meal (~3.75 g soluble)	Fiber-free meal	Acute	Gastric emptying half-time ↑ 60.6→77.6 min (p<0.05)	Peak glucose rise ↓31% (2.83→1.96 mmol/L, p=0.02)
Chearskul et al., 2007	SB-PC crossover	20	Glucomannan	3 g/day (1 g before each meal)	White rice flour placebo	4	*NR*	Acute glucose rise: 3.3±3.2% vs 12.9±5.0% placebo (p=0.032); 120-min glucose AUC ↓; HOMA-IR improved in women only
Kim et al., 2016	Open-label crossover	13	Fiber-enriched cereal	14.7 g fiber/serving	Conventional cereal (2.9 g)	Acute	*NR*	Post-breakfast glucose ↓ (198.5 vs 245.9 mg/dL, p<0.05); glucose iAUC ↓33% (p<0.001); insulin: NS
Lu et al., 2004	Crossover RCT	15	(Lu et al., 2004)	14–17 g/day dietary fiber	Control bread/muffins	5	Fecal output ↑61.5 g/day (p=0.05); microbiota/SCFA: NR	FPG ↓ (p=0.002); 2-h glucose ↓ (p<0.001); 2-h insulin ↓ (p=0.015)
Meng et al., 2019	Randomized open-label	70	Resistant starch (RS)	17.41 g/day RS	Common staple + protein-restricted diet	12	RS noted as prebiotic (SCFA potential); no direct microbiota data	FBG ↓0.9±2.3 mmol/L (p=0.027); HbA1c ↓0.6±0.7% (p=0.001)
Moreira et al., 2024	Crossover RCT	19	Raw wheat bran (RWB)	15 g before breakfast (5.8 g insoluble)	Std. breakfast without RWB	Acute	*NR*	Glucose peak rise ↓15.8% (p=0.001); glucose AUC ↓23.1% (p<0.001)
Nguyen et al., 2019	Parallel RCT	49	Okara fiber	~6 g fiber/day	Usual diet	2	*NR*	FBG 6.3→5.4 mmol/L (p<0.05); fructosamine 319→301 mmol/L (p<0.05)
Pedersen et al., 2016	DB-PC parallel RCT	29	GOS	5.5 g/day	Maltodextrin	12	Bacterial diversity ↑ within intervention group; composition: NS; Veillonellaceae inversely	Glucose tolerance: NS; insulin: NS; HbA1c: NS

							correlated with glucose response	
Reimer et al., 2020	DB-PC RCT	290	PGX® (PolyGlycopleX)	15–20 g/day	Rice flour placebo	52	*Collinsella, Parabacteroides, Roseburia relative abundance* ↑	HbA1c ↓0.23% at 52 wks (p=0.022); FG: NS

Abbreviations & footnotes: ADA = American Diabetes Association; AUC = area under the curve; AX = arabinoxylan; DB-PC = double-blind placebo-controlled; FBG / FBS / FG / FPG = fasting blood/plasma glucose; GIP = glucose-dependent insulinotropic polypeptide; GLP-1/-2 = glucagon-like peptide-1/-2; GOS = galacto-oligosaccharide; HbA1c = glycated haemoglobin; HFD = high-fiber diet meal; HFS = high-fiber supplement meal; HOMA-IR = homeostatic model assessment of insulin resistance; HOMA-β = homeostatic model assessment of β-cell function; iAUC = incremental area under the curve; ITF = inulin-type fructans; LPS = lipopolysaccharide (endotoxin); MCC = microcrystalline cellulose; MD = mean difference; NIDDM = non-insulin-dependent diabetes mellitus (= T2DM); NR = not reported; NS = not statistically significant; OGTT = oral glucose tolerance test; PC = placebo-controlled; PGX = PolyGlycopleX; PPG = postprandial glucose; RCT = randomised controlled trial; RS = resistant starch; RWB = raw wheat bran; SB = single-blind; SCFA = short-chain fatty acids; std. = standard; T2DM = type 2 diabetes mellitus; UF = usual-fiber meal; wks = weeks. an = number of participants who completed the study. | b Overweight T2DM subgroup of larger trial (n = 298 across 4 arms). | ↑ = significant increase; ↓ = significant decrease; arrows without colour = directional trend or reported as significant in original study.

Efficacy of Dietary Fiber on Gut Health

Of the 26 included studies, only seven assessed gut health outcomes, and findings were largely limited to prebiotic and fermentable fiber types. (Birkeland et al., 2020b) demonstrated that inulin-type fructan supplementation (16 g/day) produced modest but statistically significant shifts in microbiota composition, with increased abundance of *Bifidobacterium adolescentis* and elevated total SCFA, acetic acid, and propionic acid ($p<0.05$), though alpha-diversity remained unchanged. Similarly, Dehghan et al. (2014) reported a 27.9% reduction in plasma lipopolysaccharide (LPS) following inulin supplementation, indicating reduced metabolic endotoxemia. (Reimer et al., 2021) observed increased relative abundance of *Collinsella*, *Parabacteroides*, and *Roseburia* after 52 weeks of PGX supplementation. The most comprehensive gut health evidence came from Zhao et al. (2018), the only study simultaneously reporting increases in butyrate-producing bacterial strains, elevated fecal butyrate, augmented GLP-1 secretion, and reduced gut pH alongside significant glycemic improvement — providing the strongest indication of a fiber-mediated gut-glycemic axis among included studies.

In contrast, gut health evidence from non-prebiotic fiber studies was limited or absent. (Pedersen et al., 2016b) found no significant changes in microbiota composition following GOS supplementation, despite within-group increases in bacterial diversity. Lu et al. (2004) reported only increased fecal output (61.5 g/day), and Torsdottir et al. (1991) documented delayed gastric emptying (60.6 to 77.6 minutes) as a mechanistic gut finding, neither of which constitutes direct microbiota evidence. Notably, 19 of the 26 included studies did not assess any gut health outcomes whatsoever, and among those that did, heterogeneity in methodology precluded meaningful cross-study comparison. This represents a substantial evidence gap,

particularly given that gut microbiota modulation is frequently proposed as a primary mechanism through which dietary fiber exerts metabolic benefits in T2DM.

Efficacy of Dietary Fiber on Improving Glycemic Outcomes

Across all 26 included studies, dietary fiber interventions consistently improved at least one glycemic parameter, with the strongest evidence observed for reductions in fasting glucose and HbA1c **(Figure 2)**. Psyllium supplementation demonstrated particularly robust and reproducible effects: (Ziai et al., 2005b) reported the largest fasting glucose reduction (208.2 to 155.6 mg/dL; reduction of 52.8 mg/dL) and HbA1c decrease (10.5% to 8.9%) over 8 weeks, while Abutair et al. (2016) documented concurrent improvements in FBS (163 to 120 mg/dL), HbA1c (8.5% to 7.5%), and HOMA-IR (11.3 to 5.8) (5,14). Similarly, Soltanian et al. (2018) reported a 1.7% reduction in HbA1c over 12 weeks (20). Beyond psyllium, inulin supplementation produced some of the largest metabolic improvements, with Dehghan et al. (2014) reporting reductions of 8.5% in FBS, 10.4% in HbA1c, 34.3% in fasting insulin, and 39.5% in HOMA-IR, representing the greatest improvement in insulin resistance observed across the review. High-fiber dietary patterns also demonstrated meaningful long-term benefits; Li et al. (2016) observed a 0.64% reduction in HbA1c at one-year follow-up in the 100 g oat group, while Zhao et al. (2018) reported HbA1c levels below 7% in 89% of participants compared with 50% in the usual care group after 12 weeks.

Postprandial glucose attenuation was consistently demonstrated across acute and short-term studies, regardless of fiber type. (Ding et al., 2024) reported the largest reduction in postprandial glucose AUC (46%), followed by (Moreira et al., 2024a) , which demonstrated a 23.1% reduction after a single dose of raw wheat bran, and Kim et al. (2016), which showed a 33% reduction in glucose AUC following fiber-enriched cereal consumption (6,7,31). Viscous soluble fibers appeared particularly effective in acute settings: Torsdottir et al. (1991) found that sodium alginate reduced peak glucose rise by 31% through delayed gastric emptying (60.6 to 77.6 minutes, rs = 0.92), suggesting a plausible mechanistic pathway (23). However, two studies reported null glycemic findings. Birkeland et al. (2021) found no improvement in fasting or postprandial glucose following inulin-type fructan supplementation, while Pedersen et al. (2016) observed no significant effect on glucose tolerance or HbA1c after galacto-oligosaccharide supplementation (10,13). Both studies involved prebiotic fibers in well-controlled or mildly affected T2DM populations, suggesting that baseline glycemic status and fiber fermentability may influence glycemic response.

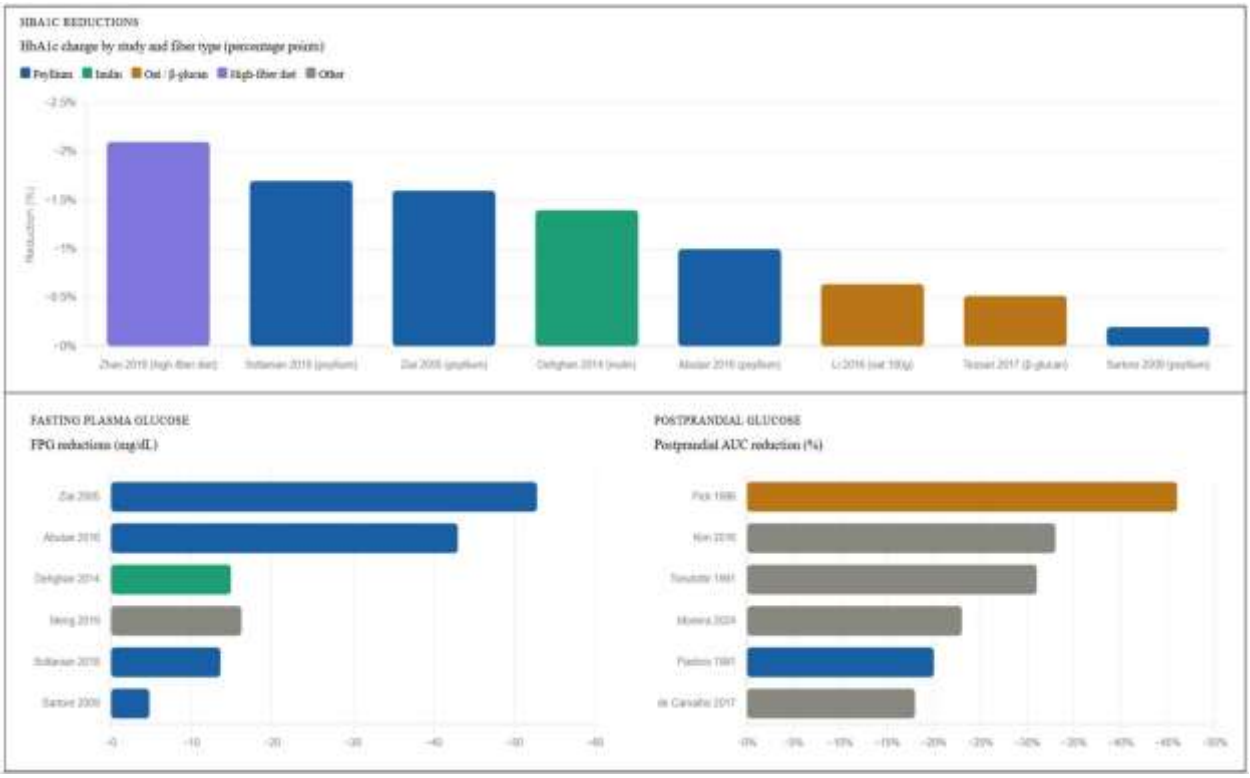

Figure 2. Effects of dietary fiber interventions on glycemic outcomes in type 2 diabetes mellitus across included studies.

Type 2 diabetes mellitus is among the fastest-growing chronic conditions globally, and dietary strategies, particularly increased fiber intake, have emerged as a central component of its management. Epidemiological evidence consistently links higher dietary fiber consumption with a reduced risk of T(Ojo et al., 2020b, 2021b; Pugh & Chambers, 2025b), 2021b; Pugh & Chambers, 2025b). The present systematic review synthesized findings from 26 human intervention studies and demonstrated that dietary fiber supplementation broadly improves glycemic outcomes in individuals with T2DM. Fasting blood glucose reductions were reported across studies using psyllium (5,14,15), inulin, resistant starch, and high-fiber dietary patterns, while HbA1c improvements were consistently observed in longer-duration trials. These findings support dietary fiber as a meaningful adjunct to standard diabetes care.

Soluble, viscous fibers appear to exert glycemic benefits primarily through physicochemical mechanisms in the gastrointestinal tract. By forming viscous gels within the intestinal lumen, soluble fibers such as psyllium, glucomannan, β-glucan, and sodium alginate slow gastric emptying, delay carbohydrate absorption, and attenuate postprandial glucose excursions. This was illustrated acutely by Torsdottir et al. (1991), where a 5 g dose of sodium alginate reduced peak postprandial glucose by 31% and significantly delayed gastric emptying time. Similarly, Pastors et al. (1991) showed that psyllium taken before meals reduced breakfast and dinner glucose peaks by 14–20%, with a 31% reduction in the second-meal glucose response. Glucomannan also reduced the acute postprandial glucose rise from 12.88%

to 3.3% in the intervention group compared to placebo. Collectively, these findings highlight that even modest doses of soluble fiber can meaningfully blunt postprandial hyperglycemia, a key therapeutic target in T2DM management.

Insoluble fiber, while historically considered metabolically inert, also demonstrated glycemic benefits in several included studies. Raw wheat bran reduced postprandial glucose peak by 15.8% and area under the curve (AUC) by 23.1%, likely through inhibition of alpha-glucosidase and alpha-amylase enzymes, the same pathway targeted by the antidiabetic drug acarbose. The mechanism by which insoluble fiber reduces diabetes risk remains less clearly defined than that of soluble fiber, though enzyme inhibition and altered gastrointestinal transit time are plausible contributors. High-fiber dietary patterns combining both soluble and insoluble sources, as tested by Chandalia et al. (2000) and Zhao et al. (2018), produced some of the most substantial glycemic improvements, with mean plasma glucose reductions of up to 8.9% and over 89% of participants in the fiber group achieving HbA1c below 7%, compared to 50% in the control group. Therefore using multiple fiber types through the whole diet, rather than supplementing one type alone, may yield stronger metabolic results.

A distinct mechanistic pathway through which dietary fiber may confer metabolic benefits involves modulation of the gut microbiota **(Figure 3)**. Patients with T2DM consistently exhibit reduced microbial diversity, lower abundance of butyrate-producing bacteria, and decreased fecal short-chain fatty acid (SCFA) concentrations compared to healthy individuals. Prebiotic fibers, including inulin-type fructans (ITF) and galacto-oligosaccharides, resist small intestinal digestion and are fermented in the colon, stimulating the growth of beneficial bacteria and increasing SCFA production. Birkeland et al. (2020) demonstrated that 16 g/day of a 50:50 inulin/oligofructose blend increased fecal bifidobacteria, total SCFA, acetic acid, and propionic acid compared to maltodextrin placebo. Dehghan et al. (2014) reported a 27.9% reduction in plasma lipopolysaccharide (LPS), a marker of metabolic endotoxemia, following inulin supplementation—suggesting improved gut barrier integrity. In the most comprehensive gut-microbiota study included, Zhao et al. (2018) linked increased fecal butyrate and enrichment of butyrate-producing bacterial genes to greater HbA1c reductions in participants following a high-fiber dietary intervention. Reimer et al. (2020) similarly observed increased Roseburia, a butyrate-producing genus with anti-inflammatory properties, in the PGX fiber group, alongside a modest but significant 0.23% HbA1c reduction over 52 weeks. Across these studies, the gut microbiota emerges as a central player in how dietary fiber translates into meaningful metabolic gains in people with T2DM.

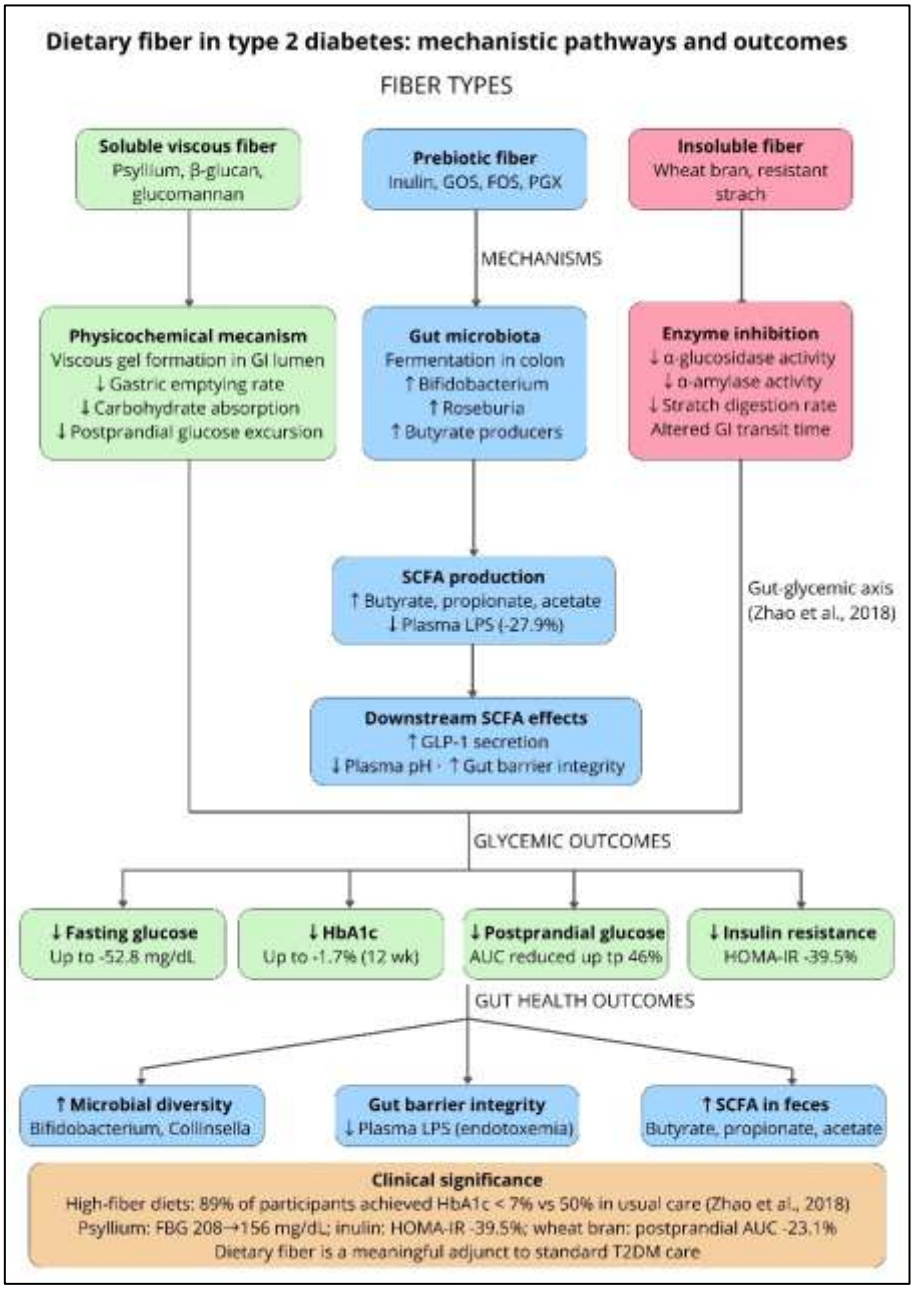

Figure 3. Proposed mechanisms by which dietary fiber improves glycemic control in type 2 diabetes mellitus

This review has several strengths and limitations. To our knowledge, it is among the first systematic reviews to simultaneously evaluate the effects of dietary fiber interventions on both glycemic control and gut microbiota health in adults with T2DM, drawing exclusively from human clinical trial evidence. However, considerable heterogeneity was present across included studies in terms of fiber type, dose, duration, and outcome measures, limiting direct comparison. Many studies were of short duration and small sample size, reducing their statistical power and generalizability. Notably, only a minority of included trials assessed gut

microbiota composition or SCFA production, and when measured, effect sizes were often modest and explained only a small proportion of microbiota variation. Furthermore, several trials enrolled specific subpopulations — such as men only, patients with diabetic nephropathy, or those with concurrent chronic constipation — which may limit the applicability of findings to the broader T2DM population. Future large-scale, long-duration trials that integrate both glycemic and microbiota endpoints are needed to better characterize the mechanistic links between fiber intake, gut health, and metabolic outcomes in T2DM.

CONCLUSION

Dietary fiber interventions improve glycemic control in individuals with type 2 diabetes mellitus (T2DM), with the most consistent benefits observed in reductions in HbA1c, fasting glucose, postprandial glucose, and insulin resistance, particularly following psyllium and inulin supplementation. Although some evidence suggests that modulation of the gut microbiota may contribute to these effects, limited and heterogeneous gut health data prevent definitive conclusions regarding the underlying mechanisms. Further standardized and long-term intervention studies are required to clarify the gut-mediated effects of dietary fiber in T2DM.

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