

Review Article

Dietary Fibre Enrichment of Wheat Bread and Postprandial Glucose Response in Healthy Adults: A Randomized Crossover Trial

Balazova S^{1*}, Leitner L² and Wagner J³

¹Department of Food Science and Technology, Comenius University, Bratislava, Slovakia

²Department of Clinical Nutrition, University of Innsbruck, Innsbruck, Austria

³Department of Public Health Nutrition, University of Heidelberg, Heidelberg, Germany

*Address for Correspondence: Stefan Balazova, Department of Food Science and Technology, Comenius University, Bratislava, Slovakia; E-mail: stefan.balazova@comeniusuniversity.edu

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Abstract

Background: Wheat bread is a major dietary source of rapidly digestible starch, and fibre enrichment is widely studied for blunting postprandial glycaemia.

Objective: To synthesise trial evidence on fibre-enriched wheat bread and postprandial glucose response in healthy adults.

Methods: Narrative review of published randomised trials, meta-analyses, and mechanistic studies.

Findings: Beta-glucan gives the most consistent, dose-dependent reductions in glucose area-under-the-curve (up to 55%; ~8% per gram per meta-analysis); resistant starch reduces area-under-the-curve ~39%; arabinoxylan effects are smaller and inconsistent; inulin gives modest, dose-correlated reductions (14-16%).

Conclusions: Fibre type, molecular weight, dose, and food matrix jointly determine glycaemic benefit, with beta-glucan and resistant starch offering the strongest evidence for reformulation.

Keywords: Dietary fibre; Postprandial glucose; Beta-glucan; Resistant starch; Wheat bread

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Introduction

Bread remains one of the most widely consumed staple foods worldwide, and refined wheat bread typically elicits a rapid, high-amplitude postprandial glucose excursion because its starch is readily gelatinised and digested. The glycaemic index (GI) concept, introduced to rank carbohydrate foods by their blood glucose-raising potential relative to a reference food, provided the first standardised framework for comparing such responses [1], later refined into a harmonised measurement methodology [2]. Because repeated large postprandial glucose and insulin excursions are implicated in cardiometabolic risk, reformulating bread with non-digestible or slowly digestible carbohydrate fractions has become a major focus of clinical nutrition and food science research. Dietary fibres differ substantially in their

physicochemical behaviour: viscous, gel-forming fibres such as beta-glucan and, to a lesser extent, arabinoxylan act primarily in the upper gastrointestinal tract, whereas resistant starch and inulin act mainly by evading small-intestinal digestion and undergoing colonic fermentation. This review synthesises the published randomised trial and meta-analytic literature on fibre-enriched wheat bread and related cereal foods, comparing beta-glucan, arabinoxylan, resistant starch, and inulin with respect to their effect on postprandial glucose response, the doses and molecular characteristics required for benefit, and the practical constraints of incorporating each fibre into a bread matrix.

Methods

This is a narrative review of the published literature identified through PubMed, Europe PMC, and Google Scholar searches combining terms for wheat bread, cereal foods, dietary fibre subtypes (beta-glucan, arabinoxylan, resistant starch, inulin), and postprandial glycaemic outcomes (glycaemic index, glycaemic load, incremental area-under-the-curve). Randomised crossover and parallel-arm human trials, systematic reviews and meta-analyses, and mechanistic studies addressing viscosity, gastric emptying, and short-chain fatty acid production were prioritised. It is not a report of a single unpublished trial, nor a systematic review with a registered protocol, but a synthesis intended to orient readers to the comparative evidence base.

Mechanisms Linking Dietary Fibre to Postprandial Glycaemia

Two broad mechanisms link fibre enrichment to attenuated postprandial glycaemia. First, viscous, gel-forming fibres increase digesta viscosity in the stomach and small intestine, delaying gastric emptying and slowing the diffusion of glucose to the mucosal brush border; a randomised crossover trial confirmed that beta-glucan-enriched oat bread significantly prolonged

gastric emptying half-time relative to control bread, in parallel with a markedly lower glucose incremental area-under-the-curve [3]. Second, non-viscous but fermentable fibres such as resistant starch and inulin largely escape small-intestinal digestion and are fermented by colonic microbiota to short-chain fatty acids (SCFAs), chiefly acetate, propionate, and butyrate, which stimulate glucagon-like peptide-1 (GLP-1) secretion via the free fatty acid receptor FFAR2 [4] and more broadly influence host glucose and lipid metabolism [5]. A narrative synthesis of gut microbiota, SCFA, and dietary fibre interactions concluded that higher habitual fibre intake favours SCFA-producing taxa and correlates with improved glycaemic control [6]. These two mechanisms are not mutually exclusive: several fibres, including arabinoxylan, exhibit intermediate viscosity and are also colonically fermented, so acute glycaemic effects and downstream fermentation benefits can co-occur within a single fibre-enriched product [7].

Beta-Glucan Enrichment: Dose, Molecular Weight, and Glycaemic Response

Beta-glucan is the fibre with the strongest and most reproducible acute glycaemic evidence. A systematic review and meta-analysis of oat beta-glucan trials found significant, dose-dependent reductions in postprandial glucose and insulin incremental area-under-the-curve, estimating roughly an 8% reduction in glucose and 10% reduction in insulin response per gram of beta-glucan per 30 g available carbohydrate [8]. A subsequent meta-regression showed that the minimum effective dose depends critically on molecular weight: high-molecular-weight beta-glucan (>1000 kg/mol) achieved significant glycaemic reduction at only 0.2 g per 30 g available carbohydrate, whereas medium- and low-molecular-weight fractions required roughly 2.2 g and 3.2 g respectively (Figure 1) [9]. In a randomised crossover trial in healthy adults, beta-glucan-enriched oat bread

lowered glucose incremental area-under-the-curve from 87.1 to 38.9 mmol-min/L (a 55% reduction) and insulin area-under-the-curve from 1440 to 938 mLU-min/L relative to control bread, with prolonged gastric emptying but no change in GLP-1 response [3]. Whole-grain barley and oat breads reduced postprandial glycaemia by approximately 24–30% relative to white bread in another randomised crossover trial [10], and a dose-ranging barley trial confirmed lower glucose incremental area-under-the-curve with higher beta-glucan content [11]. These findings underpin the European Food Safety Authority's approved health claim that oat and barley beta-glucan, incorporated at sufficient dose, reduces post-meal blood glucose rise [12].

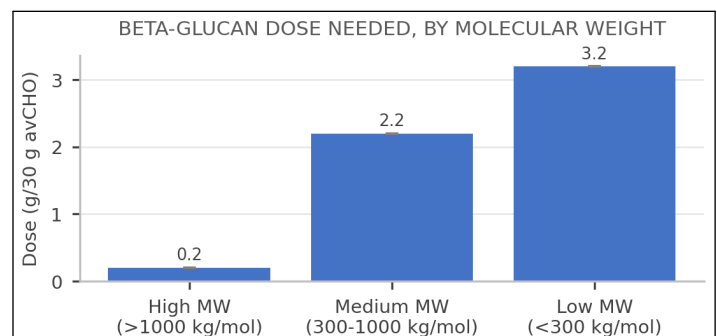


Figure 1: Minimum effective dose of oat beta-glucan required for a significant reduction in glucose incremental area-under-the-curve, by molecular weight (MW) category, from a systematic review and meta-regression analysis [9].

Arabinoxylan Enrichment

Arabinoxylan, the principal non-starch polysaccharide of wheat bran and endosperm cell walls, has a more variable evidence base. Early work established that arabinoxylan-rich fibre from wheat flour processing significantly lowered peak postprandial glucose concentration in normoglycemic subjects [13], and arabinoxylan supplementation reduced postprandial glucose, insulin, and ghrelin responses in subjects with impaired glucose tolerance [14]. However, a randomised comparison found that concentrated arabinoxylan bread improved only the postprandial glucose peak, not the

overall glycaemic profile, whereas beta-glucan and whole-kernel rye breads improved the full response curve [15], and combined arabinoxylan-and-resistant-starch feeding favourably shifted gut microbiota and SCFA production without necessarily producing a large acute glycaemic effect [16]. A recent systematic review and meta-analysis of arabinoxylan and glycaemic control reported small-to-moderate pooled effects (standardised mean difference approximately -0.4 for glucose incremental area-under-the-curve and -0.5 for peak glucose), with larger benefits in metabolically impaired than healthy populations [17]. Mechanistically, water-extractable arabinoxylan has also been shown to inhibit intestinal alpha-glucosidase in vitro, suggesting a supplementary enzymatic mechanism alongside viscosity [18]. The European Food Safety Authority similarly evaluated arabinoxylan from wheat endosperm for a postprandial glycaemic health claim [19].

Resistant Starch Enrichment

Resistant starch escapes small-intestinal digestion, lowering the immediately available glucose load and undergoing colonic fermentation. A systematic review and meta-analysis of 19 randomised controlled trials found that resistant starch significantly reduced fasting plasma glucose, with larger effects at higher doses (>28 g/day) [20], while a comparative meta-analysis found that resistant starch types 1 and 2 lowered acute postprandial glucose, with type 2 additionally improving fasting glucose and insulin on chronic consumption [21]. In a randomised controlled crossover trial directly comparing bread made from high-amylose (resistant-starch-enriched) wheat with conventional wheat bread in healthy adults, the high-amylose bread produced a 39% lower glycaemic area-under-the-curve and 24–30% lower insulinaemic and incretin responses (Table 1) [22].

Inulin and Other Fermentable Fibres

Table 1: Selected randomized controlled trials of fibre-enriched bread/cereal products and postprandial glucose response in healthy or metabolically at-risk adults.				
Study	Fibre type	Product/dose	Design	Key glycaemic outcome
Revheim 2024	Beta-glucan	Oat bread, enriched	RCT crossover	Glucose iAUC reduced 87.1 to 38.9 mmol.min/L (-55%)
Caferoglu 2022	Beta-glucan	Whole-grain barley/oat bread	RCT crossover	Glucose response reduced ~24-30% vs white bread
Kellogg 2025	Beta-glucan	Barley preload, ~4-6 g	RCT crossover	Higher beta-glucan dose associated with lower glucose iAUC
Lu 2000	Arabinoxylan	Bread, 6-12 g AX-rich fibre	RCT crossover	Peak glucose significantly lower with 6 g AX fibre
Hartvigsen 2014	Arabinoxylan/beta-glucan	Bread, concentrated fibre	Randomized study	AX improved glucose peak only; beta-glucan improved full curve
Belobrajdic 2019	Resistant starch	High-amylose wheat bread	RCT crossover	Glucose AUC reduced 39% vs conventional wheat bread
Lightowler 2018	Inulin-type fructans	Fruit jelly/yogurt, sugar replacement	RCT (2 trials)	Glucose iAUC reduced 14-16%, dose-correlated
Hlebowitcz 2009	Whole-grain (bran)	Rye whole-meal bread	RCT crossover	No significant difference vs white wheat bread

Inulin-type fructans are fermentable but essentially non-viscous, so their acute glycaemic effect is generally attributed to carbohydrate displacement and downstream fermentation rather than delayed gastric emptying. Two double-blind randomised controlled trials replacing sugars with inulin-type fructans in a yogurt and a fruit jelly produced postprandial glucose incremental area-under-the-curve reductions of approximately 14% and 16% respectively, correlated with the proportion of sugar replaced [23]. A repeated single-arm trial similarly found that pre-meal high-performance inulin supplementation suppressed the postprandial glycaemic response in healthy subjects [24]. Because inulin's benefit in these studies derived substantially from carbohydrate substitution rather than fibre viscosity per se, its

translation into a bread matrix, where it typically supplements rather than replaces available starch, may yield a smaller net effect than in sugar-replacement applications.

Comparative Evidence Across Fibre Types

Table 2 summarises comparative trial characteristics across fibre types and doses. Considered together, the acute percentage reduction in postprandial glucose area-under-the-curve achieved by realistic bread-compatible doses is largest for beta-glucan, intermediate for high-amylose resistant starch, and smallest for inulin-type fructans in the trials reviewed here (Figure 2). Arabinoxylan effects are the least consistent, likely reflecting variation in extraction method, molecular weight, and whether outcomes were measured as peak concentration or full area-under-the-curve [15,17]. Not all whole-grain or bran-containing products confer a glycaemic advantage: a randomised trial found no significant difference in postprandial glucose or gastric emptying between commercial rye whole-meal bread and white wheat bread [25], and another crossover trial found only modest, non-uniform differences between wholegrain and refined wheat bread and pasta on postprandial glycaemia and appetite [26]. These findings indicate that whole-grain labelling alone is a poor proxy for glycaemic benefit; the concentration, molecular weight, and physical state of the fibre fraction actually incorporated determine the physiological effect. A soluble dietary fibre systematic review and meta-analysis restricted to viscous fibres in people with type 2 diabetes reinforces that a minimum effective viscous fibre dose is generally in the range of 8–10 g/day for meaningful glycaemic benefit [27].

Table 2: Comparative characteristics of the four principal fibre types reviewed, drawn from mechanistic and meta-analytic literature [8,9,17,20,21,23,27].

Characteristic	Beta-glucan	Arabinoxylan	Resistant starch	Inulin
Primary mechanism	Viscosity/gastric emptying delay	Viscosity + enzyme inhibition	Carbohydrate-load reduction + fermentation	Fermentation/carbohydrate displacement
Typical effective dose	0.2-4 g/30 g avCHO (MW-dependent)	6-15 g	>28 g/day for fasting glucose benefit	Correlates with % sugar replaced
Acute glucose iAUC effect	Large, dose/MW-dependent	Small-mode rate, inconsistent	Large in high-amylose bread	Small-mode rate
Bread matrix compatibility	Good, established	Good, but variable extraction quality	Good via high-amylose flour	Limited above modest inclusion levels

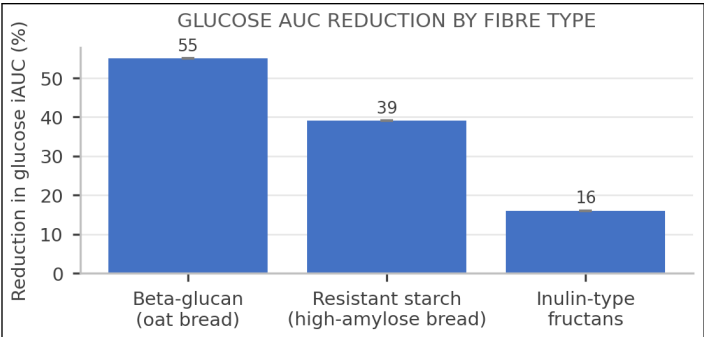


Figure 2: Percentage reduction in postprandial glucose incremental area-under-the-curve by fibre type, from representative randomized crossover trials of beta-glucan-enriched oat bread [3], high-amylose (resistant-starch-enriched) wheat bread [22], and inulin-type fructan substitution [23].

Food Matrix and Practical Considerations

Incorporating a functional fibre dose into bread without compromising loaf volume, crumb structure, or palatability is a persistent technological constraint. A study fortifying wheat bread with oat, flax, and apple fibre sources confirmed that all three additions lowered in vitro glycaemic index relative to control bread, though the magnitude varied by fibre source and inclusion level [28]. Because fibre fortification can alter dough rheology and starch gelatinisation, the fibre dose shown to be efficacious in isolated meal-challenge studies does not always transfer directly to a marketable bread product,

underscoring the need for trials that test the final formulated food rather than the isolated fibre alone.

Conclusion

Across randomised trials and meta-analyses, dietary fibre enrichment of wheat bread and related cereal foods can meaningfully blunt postprandial glucose response, but the magnitude of benefit depends strongly on fibre type, dose, molecular weight, and the underlying mechanism of action. Beta-glucan has the most robust, dose- and molecular-weight-dependent evidence base, largely through delayed gastric emptying and increased digesta viscosity; high-amylose resistant starch offers a comparably strong effect through carbohydrate-load reduction and fermentation; arabinoxylan and inulin produce smaller and more variable acute effects. Future trials that standardise fibre characterisation and test genuinely marketable bread formulations will help translate this mechanistic and comparative evidence into practical reformulation guidance for reducing population-level postprandial glycaemic burden.

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