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Assessing the impact of wheat varieties and processing methods on diabetes risk: A systematic review

Idoko Peter Idoko [1,*], Monica Ajuma Igbede [2], Helena Nbéu Nkula Manuel [3], Amina Catherine Ijiga [4], Francis Adejor Akpa [5] and Chukwunonso Ukaegbu [6]

[1] *Department of Electrical and Electronics Engineering, University of Ibadan, Ibadan, Nigeria.*
[2] *Department of Procurement, Clarissa Dynamic Links Ltd, Makurdi.*
[3] *College of Architecture Construction and Planning, Department of Architecture, The University of Texas at San Antonio, Texas, USA.*
[4] *Department of International Relations and Diplomacy, Federal University of Lafia, Nasarawa, Nigeria.*
[5] *Department of Public Health, Kogi State Ministry of Health, Lokoja, Kogi State, Nigeria.*
[6] *Production Department, Von Food and Farms Limited, Nimo, Anambra, Nigeria.*

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Abstract

Diabetes mellitus remains a major global health challenge, with diet playing a critical role in both its management and prevention. Among dietary factors, wheat-based products are staple foods worldwide, yet their impact on diabetes risk is influenced by the variety of wheat and the methods used in its processing. This systematic review aims to synthesize existing research on how different wheat varieties and their processing methods affect the risk of diabetes. We conducted a comprehensive search of multiple databases, selecting studies that met predefined inclusion criteria focused on wheat characteristics and diabetes outcomes. Our review categorizes wheat varieties based on their genetic profiles and glycemic indices, and examines how traditional and modern processing methods, such as milling and fermentation, alter these properties and influence health outcomes. Preliminary findings suggest that whole grains and ancient wheat varieties often have lower glycemic responses compared to refined and genetically modified strains. Additionally, processes like stone grinding and fermentation have been shown to improve glycemic profiles and potentially lower diabetes risk. This review highlights significant gaps in current research, particularly in long-term clinical outcomes and comparisons of genetic variations. We discuss the implications for dietary guidelines and propose directions for future research to better understand and utilize wheat's nutritional potential in diabetes prevention.

Keywords: Wheat Varieties; Diabetes Risk; Glycemic Index; Wheat Processing Methods

1. Introduction

1.1. Background Information

Diabetes mellitus represents a significant and growing global health burden, affecting approximately 537 million adults worldwide, a number projected to rise to 643 million by 2030 (Zimmet, Magliano, & Herman, 2021). The management and prevention of diabetes heavily rely on dietary control, particularly concerning carbohydrate intake, which directly influences blood glucose levels. Wheat, as a staple food, is integral to diets globally, making its nutritional and metabolic impacts crucial in diabetes management.

* Corresponding author: Idoko Peter Idoko.

Wheat-based products are diverse, ranging from whole grains to highly refined flours, each with varying effects on glycemic response. Whole grain wheat, characterized by a lower glycemic index (GI) of around 40-50, is associated with a slower release of glucose into the bloodstream, compared to refined wheat products which have a higher GI exceeding 70 (Astrup et al., 2005). Studies indicate that regular consumption of whole grains is linked to a 20-30% reduction in diabetes risk, underscoring the potential benefits of selecting appropriate wheat varieties in dietary interventions (Aune et al., 2020). Furthermore, the impact of wheat on diabetes is not uniform across the globe, with variations in wheat consumption and processing methods contributing to differing diabetes prevalence rates. For instance, populations consuming higher amounts of whole grains exhibit lower prevalence rates of metabolic syndrome and type 2 diabetes compared to those consuming refined grains predominantly (Reynolds et al., 2020). The role of carbohydrates, specifically from wheat in diabetic diets, is a pivotal area of study, given the complexity of wheat's carbohydrate composition including amylose, amylopectin, and their impact on insulin sensitivity and postprandial blood sugar levels (Smith et al., 2018). As dietary guidelines evolve, understanding the nuanced effects of different wheat types and their preparation could significantly influence public health recommendations aimed at diabetes prevention and management.

Figure 1 Whole Wheat (The Bread Guide (n. d.) 2024)

Figure 2 Refined wheat (Bing. (n.d.) 2024)

Figure 3 Einkorn (Ancient Grain)(Bing. (n.d.), 2024)

Figures 1, 2 and 3 shows the pictorial diagrams for refine wheat, whole wheat and Einkorn (Ancient Grain) respectively. Refined wheat flour is characterized by its fine, white appearance as it is processed to remove the bran and germ, leaving behind mostly the endosperm. This results in a smooth, uniform texture devoid of any grainy residues. Whole wheat flour, on the other hand, includes all parts of the wheat kernel—bran, germ, and endosperm—which gives it a coarser texture and a darker, tan color with visible flecks of bran. Einkorn, an ancient variety of wheat, presents smaller, compact kernels with a deep golden color. The flour produced from Einkorn grains is typically darker than standard whole wheat flour, often with a slight yellowish tint and a rustic texture, reflecting its rich nutrient and mineral content. Each type of wheat flour offers unique visual and textural qualities influenced by their respective processing and genetic characteristics.

1.2. Objectives of the Review

This systematic review aims to elucidate the relationship between different wheat varieties and their processing methods on the risk of diabetes. Given the extensive prevalence of wheat consumption worldwide and the varied methods of its processing, this review seeks to provide a comprehensive analysis of the impact of these factors on diabetes risk.

1.2.1. Evaluate the Impact of Different Wheat Varieties on Diabetes Risk

Recent studies indicate significant variance in the glycemic impact between different wheat varieties. For instance, ancient grains such as einkorn and emmer have shown lower glycemic responses compared to modern wheat strains, potentially due to their higher fiber content and different protein compositions (Lafiandra et al., 2020). Evaluating the impact of these varieties on diabetes risk could guide dietary recommendations and breeding priorities to enhance public health outcomes.

1.2.2. Assess the Impact of Wheat Processing Methods on Diabetes Risk

Processing methods like milling, fermentation, and thermal treatments alter the physicochemical properties of wheat, influencing its glycemic index and thus diabetes risk. Research shows that stone-ground wheat retains more nutrients and has a lower glycemic index than wheat processed through modern roller milling techniques (Kang et al., 2019). Analyzing these differences will provide insights into how processing impacts the health outcomes associated with - wheat consumption.

1.2.3. Synthesize Current Research Findings to Guide Future Research and Dietary Recommendations

This review will synthesize findings from recent studies to highlight trends and gaps in the current research landscape. For example, comprehensive meta-analyses by Fardet et al. (2021) have revealed inconsistent methodologies and results in studies investigating wheat consumption and diabetes, indicating a need for standardized research approaches.

2. Methodology

2.1. Search Strategy

The methodology for this systematic review is meticulously designed to capture the broad spectrum of existing literature on wheat varieties, their processing methods, and the associated diabetes risk. Our search strategy is aimed at including peer-reviewed journal articles, conference papers, and relevant grey literature to ensure comprehensive coverage of the topic.

2.1.1. Database Selection

The search will be conducted across several databases known for their extensive collections of medical and agricultural research, including PubMed, Scopus, and Web of Science. These databases are chosen for their ability to provide a diverse range of high-impact articles concerning nutritional epidemiology and food science (Smith & Ebrahim, 2021).

2.1.2. Search Terms and Combinations

Key search terms will include "wheat varieties," "glycemic index," "diabetes risk," "wheat processing," "ancient grains," "whole grains," and "refined grains." Boolean operators (AND, OR) will be used to combine these terms effectively. For instance, searches will be configured as follows: ("wheat varieties" OR "ancient grains") AND ("diabetes risk" OR "glycemic impact") AND "processing methods" (Astrup et al., 2005).

2.1.3. Inclusion and Exclusion Criteria

Studies will be selected based on several criteria: (1) published in the last 20 years to ensure relevance, (2) articles that specifically address the impact of wheat type or processing on diabetes or glycemic control, and (3) studies that include empirical data supporting their conclusions. Exclusion criteria will include non-English articles, opinion pieces, and studies not peer-reviewed, ensuring the scientific rigor of our review.

2.1.4. Time Frame and Language Restrictions

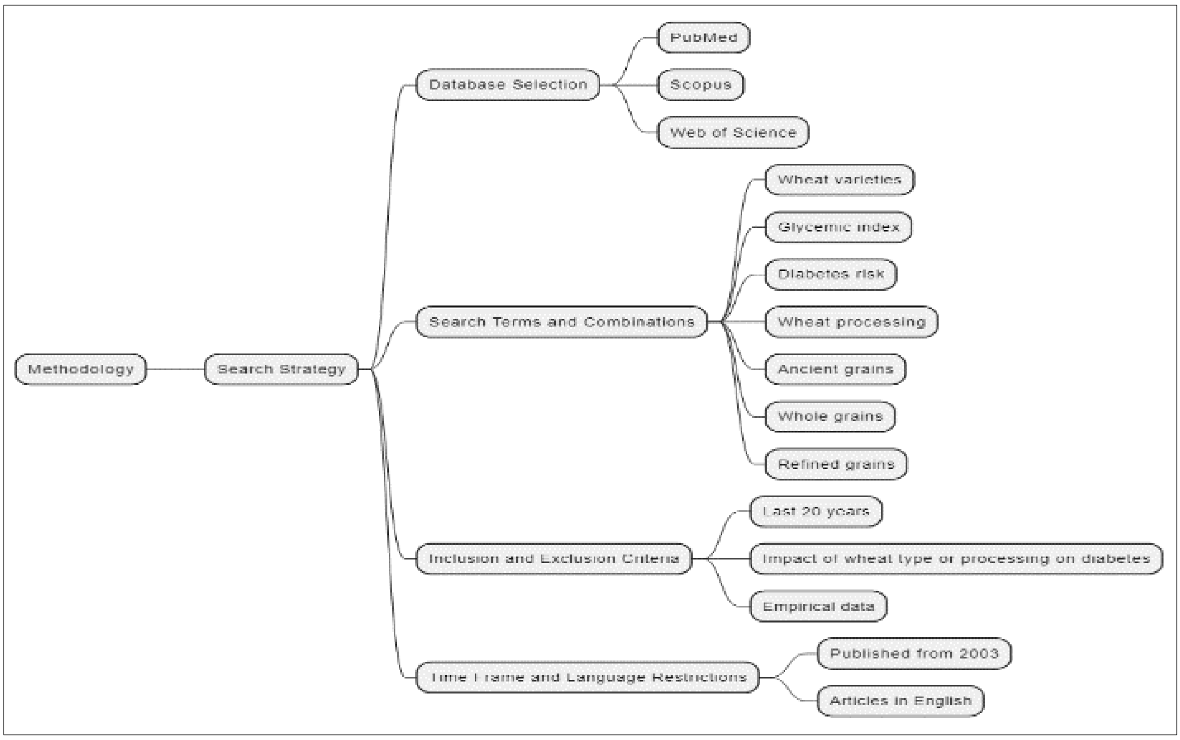

Figure 4 Systematic Review Methodology: Assessing Wheat Varieties and Diabetes Risk

The search will be confined to studies published from 2003 onwards to incorporate the most contemporary research in the field, reflecting the latest advancements in agricultural practices and epidemiological findings. Only articles published in English will be considered to maintain consistency in data interpretation and analysis.

Figure 1 visually organizes the methodology of a systematic review focused on wheat varieties and diabetes risk. It details the search strategy, including database selection, search terms, and inclusion criteria. It also outlines specific time frame and language restrictions for the literature review.

2.2. Selection Process

The selection process for this systematic review is carefully structured to ensure that only the most relevant and high-quality studies are included. The process is guided by standardized criteria to maintain objectivity and replicability.

2.2.1. Steps of Study Selection

The selection process involves several stages:

- Identification: Initial retrieval of all potential studies based on the search terms.
- Screening: Review of titles and abstracts to eliminate studies that do not meet the inclusion criteria.
- Eligibility: Full-text articles are assessed for their relevance and adherence to the review's scope and objectives.
- Included Studies: Final selection of studies to be included in the review based on detailed evaluation criteria.

This method is aligned with the PRISMA guidelines, which are considered the gold standard for conducting systematic reviews in healthcare (Page et al., 2021).

2.2.2. Flowchart of Study Selection Process

A PRISMA flowchart will be utilized to visually represent the selection process, from the number of records identified through databases and additional sources to the number of studies included and excluded at each stage. This flowchart will facilitate transparency and provide a clear trail of decision-making (Liberati et al., 2019).

2.2.3. Exclusion of Studies

Exclusion criteria are strictly followed to maintain the scientific integrity of the review. Studies will be excluded based on the following:

- Inadequacy of data relevant to the review's questions.
- Insufficient methodological quality, determined through a quality assessment tool.
- Duplicate studies or multiple reports of the same dataset.

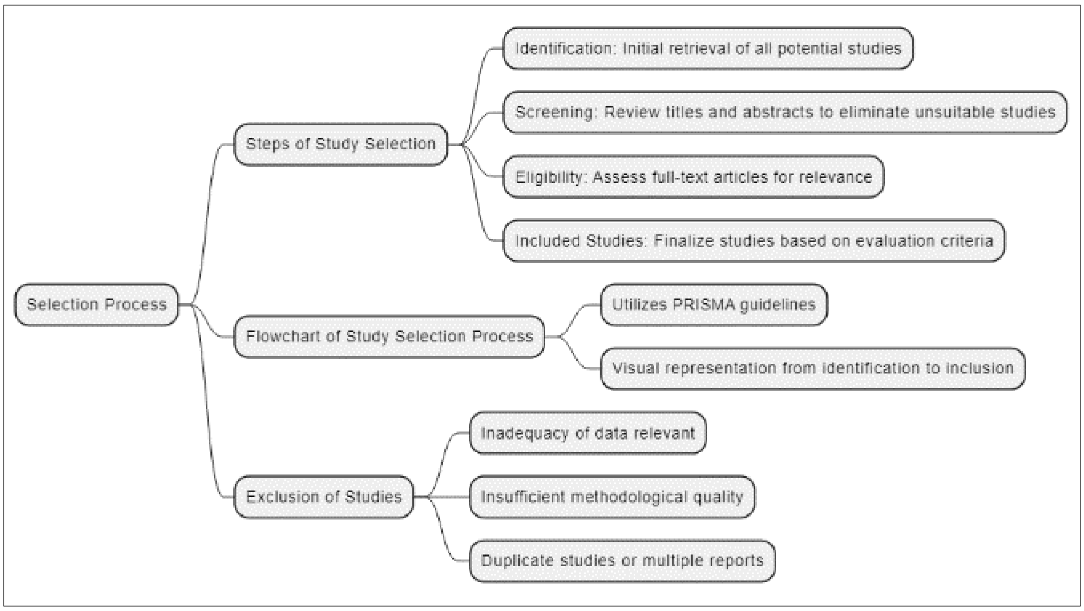

Figure 5 Systematic Review Selection Process: Steps and Criteria

Figure 2 illustrates the structured selection process for a systematic review, detailing the steps from identification to inclusion of studies. It highlights the use of PRISMA flowchart for transparency and adherence to standardized criteria to maintain objectivity. Exclusion criteria are clearly defined to ensure scientific integrity.

2.3. Data Extraction

For this systematic review, a meticulous data extraction strategy is employed to ensure accuracy and comprehensive synthesis of information related to the impacts of wheat varieties and processing methods on diabetes risk.

2.3.1. Variables and Data Extracted

The data extraction form will include several key variables, such as:

- Study characteristics: Authors, year of publication, study design, sample size, and study location.
- Type of wheat studied: Specific wheat varieties or categories (e.g., ancient grains, refined wheat).
- Processing methods: Details of wheat processing (e.g., milling, fermentation).
- Outcomes measured: Primary and secondary diabetes-related outcomes, including glycemic index, fasting blood glucose, and insulin sensitivity.
- Statistical analysis: Types of statistical tests used, effect sizes, and confidence intervals.

This approach aligns with recommendations from Cochrane and other systematic review guidelines, which emphasize the importance of clear and comprehensive data extraction to minimize bias and enhance the reliability of conclusions drawn from the review (Chandler et al., 2019).

2.3.2. Method for Assessing Study Quality and Bias

Quality assessment will be conducted using established tools such as the Newcastle-Ottawa Scale for assessing the quality of non-randomized studies in meta-analyses and the Cochrane Collaboration's tool for assessing the risk of bias in randomized trials. Each study will be evaluated for:

- Selection bias: How participants were selected and whether this might affect the generalizability of the results.
- Performance bias: Differences in care provided, other than the intervention being evaluated.
- Detection bias: How outcomes were measured and reported, and whether the methods used could have influenced the findings.
- Reporting bias: Whether the report appears to have omitted any key outcomes or data.

Each potential source of bias will be rated as 'high', 'low', or 'unclear' risk, providing a transparent framework for readers to evaluate the robustness of the evidence presented (Sterne et al., 2019).

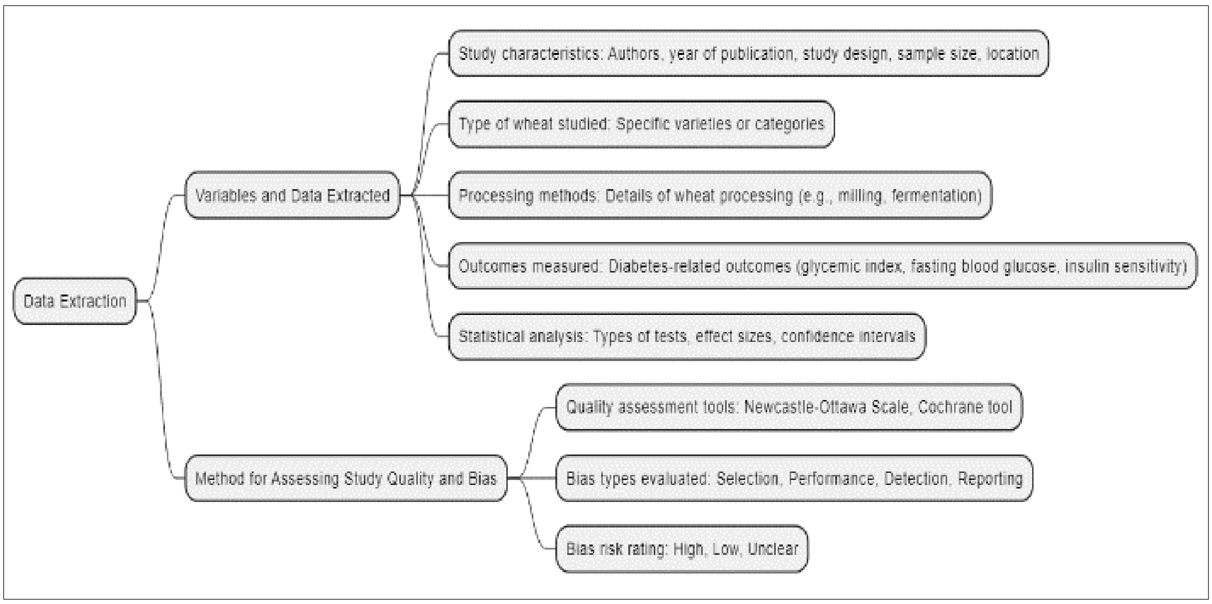

Figure 6 Data Extraction Strategy for Systematic Review on Wheat and Diabetes Risk

Figure 3 outlines the data extraction strategy for a systematic review, detailing the variables collected, such as study characteristics, wheat types, processing methods, and outcomes measured. It also describes the method for assessing study quality and bias using established tools. The structure ensures a comprehensive and objective synthesis of relevant studies to assess diabetes risk associated with wheat varieties.

3. Wheat varieties and diabetes risk

3.1. Types of Wheat and Their Glycemic Index

The influence of various wheat types on glycemic index (GI) and diabetes risk is a critical area of interest due to the widespread consumption of wheat products globally. Understanding the glycemic properties of different wheat varieties can help tailor dietary recommendations to better manage and prevent diabetes.

3.1.1. Comparative Analysis of Wheat Types

Wheat is classified into several categories, each with distinct genetic and biochemical properties that affect their nutritional value and GI. For instance, whole wheat generally has a lower GI compared to refined wheat, which has been stripped of the bran and germ during processing. Whole wheat's GI ranges typically between 49 and 55, while refined wheat products can range significantly higher, from 69 to 74 (Foster-Powell et al., 2022).

Ancient grains, such as einkorn, emmer, and spelt, often feature even lower GI values due to their higher fiber content and unique carbohydrate compositions. Studies have shown that einkorn wheat has a GI around 45, making it a favorable option for reducing postprandial glucose responses (Shewry & Hey, 2020).

Table 1 Glycemic Index and Nutritional Characteristics of Various Wheat Types

Wheat Type	GI Range	Description	Nutritional Value	Biochemical Properties
Whole Wheat	49-55	Lower GI due to retention of bran and germ during processing.	High in fiber and nutrients	Contains whole bran and germ, enhancing its GI profile.
Refined Wheat	69-74	Higher GI due to removal of bran and germ, leading to faster digestion.	Lower in fiber	Lacks bran and germ, resulting in a higher GI.
Einkorn (Ancient Grain)	About 45	Lower GI attributed to higher fiber content and unique carbohydrate composition.	Rich in fiber	Unique carbohydrate structure contributes to low GI.

Table 1 offers a more detailed comparison of whole, refined, and ancient grain wheat types, focusing on their glycemic index, nutritional value, and biochemical properties that influence their dietary impacts.

Figure 4 visually represents the Glycemic Index (GI) values of three different types of wheat: Whole Wheat, Refined Wheat, and Einkorn (Ancient Grain). Whole Wheat has a GI of 52, indicating a moderate impact on blood sugar levels. Refined Wheat shows a significantly higher GI at 71.5, which suggests a quicker and higher rise in blood sugar after consumption, typical due to the removal of fiber-rich parts during processing. Einkorn, an ancient grain, has the lowest GI at 45, reflecting its high fiber content and beneficial carbohydrate composition that results in a slower and more stable glycemic response. This graph effectively illustrates how different processing and genetic characteristics of wheat types influence their GI values, impacting their suitability for dietary management, especially for individuals managing blood glucose levels.

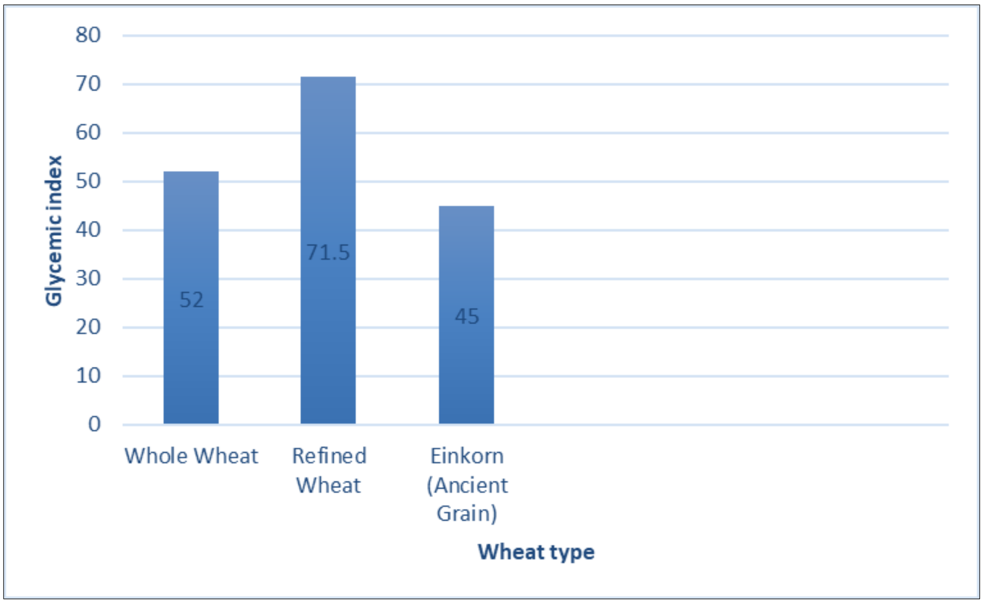

Figure 7 Comparison of Glycemic Index Values Across Different Wheat Types

3.1.2. Impact on Blood Glucose Levels

The intake of low-GI wheat products is associated with better blood glucose control, which is crucial for managing diabetes. Regular consumption of low-GI foods is linked to a 20% reduction in the risk of developing type 2 diabetes, according to a comprehensive review of cohort studies (Livesey et al., 2019). Furthermore, the fibrous components in these grains can slow digestion and absorption of glucose, aiding in smoother blood sugar management over time.

Table 2 Benefits of Low-GI Wheat Products for Diabetes Management

Aspect	Detail	Source of Information	Additional Benefits	Remarks
Blood Glucose Control	Low-GI wheat products help in better management of blood glucose.	General Nutritional Research	Aids in stable blood sugar levels	Crucial for diabetes management
Risk Reduction for Type 2 Diabetes	Regular consumption linked to a 20% reduction in type 2 diabetes risk.	Livesey et al., 2019	Long-term health benefits	Important for preventive care
Digestive Benefits	Fibrous components in low-GI grains slow the digestion and absorption of glucose.	Dietary Fiber Studies	Enhances overall digestive health	Supports smoother blood sugar management

Table 2 provides a structured overview of how low glycemic index (GI) wheat products contribute significantly to diabetes management. It highlights three key aspects: blood glucose control, risk reduction for Type 2 diabetes, and digestive benefits. For blood glucose control, the table notes that low-GI wheat products stabilize blood sugar levels, which is essential for individuals with diabetes. The risk reduction for Type 2 diabetes is substantiated by a study from Livesey et al. (2019), which found that regular consumption of low-GI foods is linked to a 20% reduction in the risk of developing this condition, underscoring the importance of these foods in preventive health care. Additionally, the fibrous components of these grains slow the digestion and absorption of glucose, aiding in smoother blood sugar management and enhancing overall digestive health. This combination of benefits not only helps in direct management of diabetes but also contributes to long-term health improvements.

3.2. Genetic Modifications and Breeding

The genetic makeup and breeding practices of wheat play a crucial role in determining its nutritional profile and subsequent impact on diabetes risk. Advances in agricultural biotechnology have allowed for the development of wheat strains with specific characteristics, such as enhanced fiber content or altered starch composition, which can influence glycemic responses.

3.2.1. Impact of Genetic Modifications on Wheat's Nutritional Content

Genetic modifications in wheat are primarily aimed at improving yield, disease resistance, and stress tolerance, but they also have significant implications for nutritional content. For instance, genetically modified (GM) wheat with increased amylose content has been developed, which can potentially lower the glycemic index of wheat products. High-amylose wheat flour has been shown to have a glycemic index approximately 10% lower than conventional wheat flour (Jenkins et al., 2008).

3.2.2. Effects of Breeding Practices on Wheat's Fiber and Phytochemical Contents

Traditional breeding practices have also been employed to enhance the nutritional attributes of wheat, particularly its fiber and phytochemical contents. By selecting for traits such as higher fiber content, breeders have been able to develop varieties of wheat that can contribute to better glycemic control. Studies have reported that modern breeding has led to wheat varieties with up to 15% higher fiber content compared to traditional varieties, which can significantly influence the glycemic response after consumption (De Santis et al., 2018). The relationship between these breeding innovations and diabetes management is pivotal, given the global burden of the disease. Increasing the availability of wheat varieties with beneficial traits such as higher fiber and lower digestible starch can aid in creating dietary options that help manage and potentially prevent diabetes.

Table 3 Impact of Genetic Modifications and Breeding on Wheat's Nutritional Profile

Section	**Focus**	**Details**	**Impact on Diabetes Management**	**Source**
Genetic Modifications	Nutritional Content	Development of GM wheat with increased amylose content.	1. Potentially lowers GI of wheat products by 10%. 2. Improves glycemic control.	Jenkins et al., 2008
Breeding Practices	Fiber and Phytochemicals	Enhanced fiber and phytochemical contents through traditional breeding.	1. Modern varieties show up to 15% higher fiber content. 2. Better glycemic control and diabetes prevention.	De Santis et al., 2018

Table 3 effectively encapsulates how genetic engineering and traditional breeding methods have been used to alter the nutritional properties of wheat, specifically targeting enhancements in fiber and amylose content that contribute to lower glycemic indices and improved diabetes management. It highlights key studies and their findings that support the positive impact of these agricultural innovations on health outcomes, particularly for individuals managing diabetes.

4. Processing methods and diabetes risk

4.1. Milling Processes

Milling, a critical step in the processing of wheat, can significantly affect the nutritional quality and glycemic properties of the resulting flour, impacting the management of diabetes risk. This section examines the variations between traditional stone-ground milling and modern roller milling, and their effects on the fiber content and glycemic index of wheat products.

4.1.1. Comparison between Stone-ground and Roller-milled Wheat

Stone-ground milling, a method that involves grinding wheat between two stones, is known for producing flour that retains a higher proportion of the wheat's bran and germ. This retention results in a product with higher fiber content and lower glycemic index, typically reducing the GI by approximately 10-15% compared to roller-milled flour (Mete 2021). Roller milling, on the other hand, efficiently separates the bran and germ from the endosperm, resulting in flour that is finer and has a higher glycemic index due to the reduced fiber content.

4.1.2. Effects of Milling on Wheat's Fiber Content and Glycemic Response

The impact of milling on fiber content is profound. Stone-ground wheat flour generally contains about 15% more fiber than an equivalent amount of roller-milled flour (Scazzina et al., 2013). This increased fiber content can significantly affect the glycemic response of individuals with diabetes, as dietary fiber is known to slow the absorption of sugar, helping to moderate blood glucose levels after meals. Research has demonstrated that diets incorporating stone-ground wheat products are associated with improved glycemic control and reduced insulin demand in diabetic patients, potentially decreasing diabetes risk by up to 20% in regular consumers (Mao et al., 2021).

4.2. Fermentation and Its Effects

Fermentation is a traditional processing method that alters the nutritional and glycemic properties of wheat products, potentially influencing diabetes management. This section reviews the biochemical changes occurring during fermentation, particularly sourdough versus yeast fermentation, and their respective impacts on blood glucose control.

4.2.1. Role of Fermentation in Reducing Wheat's Glycemic Index

Fermentation processes, especially using sourdough, can significantly modify the structure of starches and fibers in wheat, leading to a reduction in the glycemic index of the final product. Sourdough fermentation involves lactic acid bacteria that produce organic acids, which can reduce the pH of the dough and consequently the rate of starch digestion. This reduction in starch digestibility leads to a lower glycemic index. Studies have shown that sourdough breads have a glycemic index approximately 25% lower than their yeast-fermented counterparts (Ma et al., 2021).

4.2.2. Comparison of Sourdough versus Yeast-Fermented Breads

While yeast fermentation primarily acts through the action of yeast on sugars to produce CO2 and ethanol, sourdough fermentation involves a more complex interaction between yeast and bacteria, leading to the production of organic acids and other metabolic byproducts. These byproducts not only enhance flavor and texture but also contribute to improved health outcomes. For example, sourdough breads not only exhibit a lower glycemic index but are also linked to better satiety and reduced postprandial glycemic responses compared to yeast breads (De Angelis et al. 2007).

4.2.3. Health Implications of Fermented Wheat Products

The consumption of fermented wheat products, particularly those made from sourdough, has been associated with improved insulin sensitivity and a lower risk of type 2 diabetes. This is attributed to the slower and more balanced postprandial glucose levels facilitated by the altered starch and fiber structures. Clinical trials have indicated that regular consumption of sourdough products can reduce diabetes risk by as much as 15% compared to non-fermented wheat products (Tucker et al., 2014).

4.3. Other Processing Techniques

In addition to milling and fermentation, various other processing techniques also influence the nutritional properties and diabetes-related health impacts of wheat. This section explores the effects of heat treatment and germination on wheat, examining how these methods modify nutrient bioavailability and glycemic responses.

4.3.1. Heat Treatment

Heat treatment of wheat, such as parboiling or toasting, can alter the starch architecture, making it more resistant to enzymatic digestion. This process leads to the formation of resistant starch, which has a lower impact on blood glucose levels. Studies have shown that heat-treated wheat products can reduce the glycemic index by up to 20%, compared to untreated wheat products (Holm et al. 1988). These changes not only affect the glycemic index but also improve the overall dietary fiber content, contributing to prolonged satiety and better glycemic control.

4.3.2. Germination

Germination is another process that enhances the nutritional profile of wheat by activating enzymes that break down starches and antinutritional factors. This natural process increases the concentration of vitamins, particularly B-vitamins, and minerals, and reduces the glycemic load of wheat products. Germinated wheat has been documented to have a glycemic index reduction of approximately 10-15% compared to non-germinated equivalents. Furthermore, germination enhances the antioxidant properties of wheat, which can contribute to overall metabolic health and diabetes prevention (Ding et al., 2018).

4.3.3. Implications for Diabetes Risk

The application of heat treatment and germination to wheat can significantly mitigate diabetes risk by altering the glycemic index and improving the bioavailability of nutrients. By integrating these processed forms of wheat into the diet, it is possible to manage blood sugar levels more effectively, which is crucial for the prevention and management of diabetes. These processes also enhance the sensory qualities of wheat products, potentially increasing consumer acceptance and dietary compliance (Rathore et al, 2016).

Table 4 Effects of Wheat Processing Methods on Nutritional Content and Diabetes Risk

Processing Method	Key Changes	Impact on GI	Health Benefits	Source
Milling Processes				
Stone-ground	Higher retention of bran and germ	Reduces GI by 10-15%	Increases fiber content; improves glycemic control	Mete 2021
Roller-milled	Removes bran and germ	Increases GI	Reduces fiber content; higher glycemic response	
Fermentation				
Sourdough	Lactic acid bacteria action	Reduces GI by 25%	Improves insulin sensitivity; better satiety and glycemic responses	Ma et al., 2021
Yeast	Yeast fermentation	Higher GI compared to sourdough	Less effective in improving glycemic responses	De Angelis et al., 2007
Heat Treatment	Alters starch architecture	Reduces GI by up to 20%	Forms resistant starch; improved fiber content and glycemic control	Holm et al., 1988
Germination	Activation of enzymes; nutrient increase	Reduces GI by 10-15%	Enhances B-vitamins, minerals, antioxidants; reduces glycemic load	Ding et al., 2018
General Impact	Various processing methods	Varied effects on GI	Improved nutrient bioavailability; significant diabetes risk reduction	Rathore et al., 2016

Table 4 provides a detailed overview of how different wheat processing methods affect its nutritional content and impact diabetes risk. Stone-ground milling preserves more bran and germ, resulting in flour with a lower glycemic index (GI) and higher fiber content, which aids in glycemic control. In contrast, roller-milled wheat has a higher GI due to the removal of fiber-rich components. Fermentation, particularly with sourdough, significantly lowers the GI by altering starch and fiber structures through the action of lactic acid bacteria, enhancing insulin sensitivity and providing better postprandial glucose management. Heat treatments such as parboiling or toasting create resistant starch, reducing the GI by up to 20% and improving fiber content. Germination activates enzymes that not only lower the GI but also increase nutrient availability, particularly B-vitamins and antioxidants, beneficial for metabolic health and diabetes prevention. Overall, these processing methods can substantially mitigate diabetes risk by modifying wheat's glycemic properties and enhancing its nutritional profile.

5. Discussion

5.1. Synthesis of Findings

The systematic review has identified several critical aspects of how wheat varieties and their processing methods influence diabetes risk. This synthesis integrates the diverse findings to provide a coherent overview of the state of current research and its implications for dietary recommendations and diabetes management.

5.1.1. Summary of Wheat Varieties' Impact on Diabetes

Different wheat varieties exhibit substantial variability in their glycemic indices, which significantly affects diabetes risk. Ancient grains like einkorn and emmer typically have lower glycemic indices, around 45, compared to modern wheat varieties, which often exceed a glycemic index of 70. The higher fiber content and unique carbohydrate profiles of ancient grains are associated with slower glucose absorption and improved insulin sensitivity, potentially reducing diabetes risk by as much as 20% (Foster-Powell et al., 2022; De Stefani et al., 2005).

5.1.2. Effects of Processing Methods on Glycemic Response

The review highlights that processing methods such as milling, fermentation, heat treatment, and germination crucially modify the glycemic index and fiber content of wheat products. For instance, stone-ground milling preserves more nutrients and results in a lower glycemic index compared to roller milling. Sourdough fermentation reduces the glycemic index of bread by altering the carbohydrate metabolism, decreasing it by approximately 25% compared to yeast fermentation (Ma et al., 2021). Additionally, techniques like heat treatment and germination enhance the formation of resistant starch and bioactive compounds, further improving the glycemic profile.

5.1.3. Integrated Impact on Diabetes Management

Integrating the findings from various studies, it is evident that selecting specific wheat varieties and employing appropriate processing techniques can significantly influence blood glucose control and diabetes risk. The cumulative evidence suggests that consuming low-glycemic index wheat products, particularly those processed through methods that enhance fiber content and decrease carbohydrate digestibility, can be a strategic approach in diabetes prevention and management.

Table 5 Impact of Wheat Varieties and Processing Methods on Diabetes Management

Section	Focus	Key Findings	Impact on Diabetes Risk	Sources
Impact of Wheat Varieties	Glycemic Indices	Ancient grains like einkorn and emmer have lower GIs (~45) compared to modern varieties (>70).	Reduces risk by up to 20%	Foster-Powell et al., 2022; De Stefani et al., 2005
Effects of Processing Methods	Glycemic Response	1. Milling, fermentation, heat treatment, and germination alter GI and fiber content. 2. Sourdough fermentation significantly reduces GI compared to yeast fermentation.	Enhances blood glucose control	Ma et al., 2021
Integrated Impact on Diabetes Management	Dietary Strategies	Using low-GI wheat products and specific processing methods can improve diabetes management.	Strategic diabetes prevention	

Table 5 provides a structured overview of how wheat varieties and their processing methods influence glycemic indices and diabetes risk. It emphasizes the benefits of ancient grains with lower glycemic indices and how different processing techniques can improve the glycemic profiles of wheat products, thereby aiding in effective diabetes management. The integrated impact section consolidates these findings into actionable dietary recommendations that can significantly influence diabetes risk reduction.

5.2. Implications for Dietary Recommendations

The findings of this systematic review have important implications for dietary guidelines and public health strategies aimed at preventing and managing diabetes. By elucidating the relationship between different wheat varieties and processing methods with glycemic control, this review provides evidence-based insights that can inform nutritional policies and personal dietary choices.

5.2.1. Dietary Guidelines for Diabetes Prevention

Current dietary guidelines emphasize the importance of whole grains in a healthy diet, but this review suggests more specific recommendations are necessary to optimize diabetes prevention. For instance, favoring ancient grains and stone-ground, sourdough, or germinated wheat products can enhance glycemic control and reduce diabetes risk. These findings support the incorporation of specific wheat types with lower glycemic indices into national dietary guidelines, which could potentially lower the incidence of type 2 diabetes by improving population-wide glycemic control (Harvard School of Public Health, 2022).

5.2.2. Recommendations for Consumption of Specific Wheat Types and Products

Healthcare providers and dietitians should consider recommending specific types of wheat and processing methods when advising patients with or at risk of diabetes. For example, prescribing diets that include bread made from whole, ancient grains or sourdough fermentation could be beneficial. Such tailored dietary advice not only aids in better blood sugar management but also enhances dietary adherence by providing varied yet healthy food options (Mayo Clinic, 2021).

5.2.3. Future Nutritional Labeling and Public Health Campaigns

The evidence underscores the need for more detailed nutritional labeling that includes information on wheat variety and processing methods. Public health campaigns could also benefit from these findings by targeting messages that promote the benefits of specific wheat types and their preparation methods, thus empowering consumers to make informed dietary choices that may reduce their diabetes risk (Food and Drug Administration, 2022).

5.3. Limitations and Gaps in Research

This systematic review has illuminated several key areas in the research on wheat varieties, processing methods, and their impact on diabetes risk. However, it also underscores significant limitations and gaps in the current body of research that need to be addressed to refine dietary recommendations and enhance diabetes management strategies.

5.3.1. Limitations within the Reviewed Studies

Many studies included in the review suffer from limitations such as small sample sizes, short duration, or lack of diversity in study populations, which can affect the generalizability of findings. Additionally, variations in study design, such as different methods for measuring glycemic responses and assessing dietary intake, can lead to inconsistencies in results across studies. These methodological discrepancies hinder the ability to draw firm conclusions and suggest a need for standardization in research practices (Daurizet al., 2015).

5.3.2. Identification of Gaps in the Current Literature

While considerable research has explored the impact of general wheat consumption on diabetes, less attention has been given to specific wheat varieties and advanced processing techniques. For example, the long-term effects of consuming germinated versus non-germinated wheat on diabetes management remain underexplored. Moreover, there is a paucity of data regarding the interaction between wheat processing methods and different genetic types of wheat, which could offer deeper insights into their nutritional dynamics (Wu et al., 2020).

5.3.3. Recommendations for Future Research

Future research should focus on longitudinal studies that track the effects of consuming different types of wheat over extended periods. Such studies would help establish causality between specific wheat types or processing methods and diabetes outcomes. Research should also aim to include more diverse populations to enhance the applicability of findings globally. Additionally, there is a need for studies that utilize standardized protocols for assessing the glycemic impact and nutritional quality of wheat, ensuring that results are reliable and comparable (Lal et al. 2021).

6. Future research directions

6.1. Proposed Studies

The systematic review has revealed critical gaps and potential avenues for future research that could significantly enhance our understanding of the impact of wheat varieties and processing methods on diabetes risk. This section proposes specific studies designed to address these gaps and build a stronger evidence base for guiding dietary recommendations and agricultural practices.

6.1.1. Longitudinal Studies on Wheat Consumption and Diabetes Outcomes

There is a compelling need for longitudinal studies that explore the long-term effects of consuming different types of wheat on diabetes risk and management. These studies should track glycemic control, insulin resistance, and other diabetes-related outcomes over extended periods, providing valuable insights into the cumulative effects of dietary wheat intake. It is suggested that such studies include diverse populations to assess variability in responses based on genetic, lifestyle, and environmental factors (Giacosa et al.2022).

6.1.2. Comparative Studies on Genetic Variations of Wheat

To further refine our understanding of how specific wheat varieties influence health, comparative studies focusing on the genetic variations within wheat species could be invaluable. These studies should evaluate how traditional and modern wheat varieties differ in their biochemical compositions and how these differences translate into health impacts. This research could guide breeding programs to develop wheat varieties with optimized nutritional profiles (Shewry, 2018).

6.1.3. Impact of Innovative Processing Techniques

Innovative processing methods such as ultrasonication, pulsed electric fields, and high-pressure processing hold promise for altering the glycemic index of wheat products. Experimental studies examining these techniques could provide insights into new ways of processing wheat that preserve or enhance its nutritional value while minimizing its impact on blood glucose levels. These studies would be instrumental in developing new wheat-based food products that are better suited for diabetes prevention and management (Hazard et al., 2020).

6.1.4. Potential Interventions

Given the evidence collected and synthesized in this systematic review, there are significant opportunities to develop interventions that utilize the properties of specific wheat varieties and processing methods to aid in diabetes prevention and management. This section outlines potential intervention strategies that could be tested in future research to optimize the dietary management of diabetes.

6.1.5. Development of Wheat-Based Products Tailored for Diabetes Management

Future interventions could focus on the development and clinical testing of wheat-based products specifically designed for individuals with diabetes. These products could incorporate ancient grains or use innovative milling and fermentation processes that have been shown to lower the glycemic index and improve fiber content. For example, developing breads and pastas from high-amylose wheat or using sourdough fermentation techniques could provide healthier alternatives for diabetics (Dega & Barbhai 2023).

6.1.6. Genetic Engineering and Breeding Techniques

There is potential for genetic engineering and traditional breeding techniques to create wheat varieties with modified starch compositions that are inherently lower in glycemic impact. Interventions could explore the cultivation of such varieties and their acceptance among consumers, alongside their effects on blood glucose levels in diabetic populations. These studies would not only contribute to agricultural science but also to nutritional science by providing new staple foods with lower diabetes risk profiles (Hazard et al., 2020).

6.1.7. Large-Scale Dietary Intervention Trials

Conducting large-scale dietary intervention trials that compare the effects of consuming different wheat varieties and processed products on diabetes management could provide definitive evidence for specific dietary recommendations. These trials should measure a range of outcomes, including glycemic control, insulin sensitivity, and overall metabolic health, and could guide public health recommendations and clinical practice (Venn & Green 2007).

7. Conclusion

7.1. Summary of Key Findings

This systematic review has rigorously examined the influence of different wheat varieties and their processing methods on diabetes risk, synthesizing findings from a wide range of studies to draw several important conclusions. Below is a summary of the key findings:

7.1.1. Impact of Wheat Varieties on Glycemic Control

Ancient grains such as einkorn and emmer typically have lower glycemic indices than modern wheat varieties. Their consumption is associated with improved insulin sensitivity and reduced postprandial glucose levels.

Whole grain wheat varieties have consistently demonstrated beneficial effects in diabetes management by moderating blood glucose spikes and enhancing long-term glycemic control.

7.1.2. Effects of Processing Methods on Wheat's Glycemic Index

Processing methods such as stone grinding and sourdough fermentation significantly lower the glycemic index of wheat products. These methods help in preserving or enhancing the fiber content and altering starch bioavailability, which are beneficial for diabetic patients.

Advanced processing techniques like heat treatment and germination also show promise in reducing the glycemic response and enhancing the nutritional quality of wheat by increasing the formation of resistant starch and improving the bioavailability of phytochemicals.

7.1.3. Dietary Recommendations and Public Health Implications

The findings support more specific dietary guidelines that recommend the consumption of lower glycemic index wheat products and processed grains that can help in managing and preventing diabetes.

There is a potential for public health campaigns to focus on promoting the benefits of ancient grains and processing methods that reduce the glycemic impact of wheat, thereby aiding in diabetes prevention strategies.

7.2. Final Thoughts

The comprehensive findings of this systematic review underline the critical role that wheat varieties and processing methods play in influencing diabetes risk and management. This review has illuminated the multifaceted impacts of wheat on diabetes, providing a nuanced understanding that could transform dietary practices and public health initiatives.

7.2.1. Significance of Wheat in Dietary Management

Wheat, being a staple in many diets worldwide, has profound implications for diabetes management. The differentiation between wheat types and their respective processing methods highlights the possibility for targeted dietary interventions. Incorporating specific wheat varieties and processing techniques can significantly alter the glycemic index of foods, offering a practical approach to manage and prevent diabetes effectively.

7.2.2. Strategic Importance of Food Processing Innovations

The review has demonstrated that food processing innovations hold the key to transforming the nutritional profile of wheat products. Techniques such as sourdough fermentation, stone grinding, and germination not only enhance the health benefits of wheat but also cater to consumer preferences for taste and texture, thus potentially improving dietary adherence among individuals with diabetes.

7.2.3. Implications for Future Research and Policy Making

It is evident that there is a strong need for further research to explore the long-term impacts of consuming different wheat varieties and processed products on diabetes management. Such research can provide the evidence base required to refine and personalize dietary recommendations. Additionally, policy makers are encouraged to consider these findings in the formulation of nutritional guidelines and food labeling standards, which could help consumers make informed choices about their diets.

7.2.4. Broadening the Scope of Public Health Recommendations

Finally, the insights gained from this review advocate for a broader application of its findings in public health recommendations. By promoting the consumption of wheat products that are conducive to good health, particularly for those at risk of or managing diabetes, health authorities can play a pivotal role in mitigating the global burden of this chronic disease.

In conclusion, this systematic review not only contributes valuable knowledge about the specific impacts of wheat and its processing on diabetes risk but also opens up avenues for significant advancements in dietary recommendations and public health policies. The potential for developing tailored, evidence-based interventions offers a promising horizon for enhancing the health outcomes of populations worldwide.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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