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Evaluating the efficacy of Millet-Based foods and beverages in glycemic control: A prisma-2020 Systematic Review

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Abstract

Type 2 diabetes mellitus (T2DM) represents a growing global health challenge that necessitates effective dietary interventions. Millets, recognized as functional foods, have attracted increasing attention for their potential in glycemic control due to their high fiber content and favorable nutritional profile. This systematic review aimed to evaluate the efficacy of millet-based foods and beverages in regulating glycemic levels among individuals with T2DM. An extensive review of literature was carried out through PubMed, Google Scholar, and COPE databases in accordance with the PRISMA 2020 guidelines. Studies published between 2000 and 2024 that focused on millet-based dietary interventions for T2DM management were included. Out of 1,296 articles screened, 26 were selected for detailed review, and 10 met the final inclusion criteria. The findings indicated that millet-based foods consistently exhibited low glycemic indices (GI ranging from 37 to 53) and moderate glycemic loads. Regular consumption of millets led to significant reductions in fasting blood sugar (11.8%) and post-prandial blood sugar (15.1%) levels when compared to other staple foods. Processing techniques, particularly parboiling, further improved the nutritional benefits by enhancing resistant starch content and antioxidant capacity. The results point toward the usefulness of millet-based foods as supportive options in T2DM management due to their slow carbohydrate release, high

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dietary fiber, and antioxidant properties. The evidence supports the inclusion of millets in dietary recommendations aimed at diabetes control.

Key words : Glycaemic Control, Millet-based Foods, Type 2 Diabetes Mellitus (T2DM), PRISMA-2020, Insulin Sensitivity.

Type 2 diabetes mellitus(T2DM) is becoming an increasingly important global health concern for which diet plays an important role in its management. Millets being functional foods are gaining special attention in glycaemic control because of their high contents of fibre and nutrients. This study evaluates the effectiveness of millet-based foods and beverages in the regulation of blood glucose levels. Recent studies show that millets may cause improvement in insulin sensitivity and lower post-meal glucose spikes. However, the entire body of evidence regarding their relative efficacy in T2DM is still incomplete. The present study is therefore aimed at addressing this lacuna by reviewing available evidence on millet-based therapies. The study investigates how millets affect glycaemic response and their possible role in nutritional therapy for diabetes management. By analysing clinical trials and observational studies, this work gives evidence on the benefits of millet consumption. The results can help in establishing a plan for practical dietary recommendations for T2DM patients. Millets are a viable option for low-cost, sustainable and widely available staple food sources for many populations. This research adds to existing knowledge around how traditional grains can be engaged to overcome contemporary health challenges. It further proclaims a case for millets to be utilized in functional foods and beverages to help ameliorate glycaemic control. The findings may also feed into health provider and policymaker support of millet-based diets. In conclusion, this study underscores the importance of millets in ameliorating diabetic outcomes and overall health.

Significance of the study :

Millets are gaining global attention due to their rich nutritional profile, low glycaemic index, and potential benefits in the management of metabolic disorders like Type 2 Diabetes Mellitus (T2DM). Even though several studies have demonstrated the benefits of millet-based foods and beverages for glycaemic control, a systematic and comprehensive review of this evidence has not yet been conducted. This study, adhering to PRISMA-2020 guidelines, aims to critically evaluate and consolidate existing research on the efficacy of millet-based dietary interventions in glycaemic regulation. The findings will provide valuable insights for nutritionists, healthcare practitioners, policymakers, and researchers in developing evidence-based dietary recommendations for diabetes management.

Objectives :

This systematic review aims to assess how foods and drinks prepared with millet influence glycaemic control in adults with Type 2 Diabetes Mellitus.

More specifically, this review is aimed at the following:

1. Evaluate the effectiveness of millet

consumption in regulating blood glucose levels, HbA1c, and insulin response.
2. Compare the glycaemic outcomes of different types of millet-based foods and beverages.
3. Propose future research directions on dietary interventions in diabetes management based on gaps in the current literature.

Review question :

As a guide for conducting this systematic review, the following research question has been formulated: "What is the efficacy of millet-based foods and beverages in regulating glycaemic levels among individuals with Type 2 Diabetes Mellitus?"

Aim of the review :

This review aims to evaluate the impact of millet-based foods and beverages on glycaemic control in individuals with Type 2 Diabetes Mellitus. It focuses on assessing the influence of millet intake on fasting blood glucose, postprandial glucose, insulin levels, and HbA1c — a key marker used to gauge long-term diabetes management — using data from existing literature. That is, the studies sought to study these variables in relation to some recommended use of millet for the purposes of diabetic prevention and control, with further identification of the issues that may need other investigation.

The PRISMA 2020 standards were followed for conducting this review

Literature search and Inclusion/Exclusion Criteria :

Data were gathered through a structured internet search using Pub Med, Google Scholar, and COPE (UK). The search strategy included key terms like "Cereal Based Foods" "Millet based foods and beverages" "Glycaemic Control," and "T2DM" based on existing knowledge. Only human studies in English, published between 2000 and 2024, were considered. Editorials, commentaries, case studies, qualitative studies, book chapters, and reviews were excluded. Duplicate articles were removed after merging results from all databases. Studies were then screened for quality by reviewing titles, abstracts, and full texts. Any study that didn't meet the criteria was discarded. The inclusion criteria required peer-reviewed journals published since 2000. Non-peer-reviewed sources and non-English articles were excluded.

After conducting a thorough search using PubMed, Google Scholar, and COPE (UK), a total of 1296 research articles were identified. Duplicate entries were removed using Mendeley, reducing the count by 579. Automated tools flagged 272 records as ineligible. An additional 168 articles were excluded due to complicated or irrelevant titles. This left 139 records for screening based on titles and abstracts. However, 87 records were inaccessible due to journal restrictions. Further exclusions were made for high risk of bias (6 articles), lack of clarity (8 articles), and studies focusing only on male subjects (12 articles). In the end, 26 articles were selected for review. Total 10 articles were reviewed from the selected documents for systematic literature review process.

Description of all studies and Results :

Tan *et al*.,[13] investigated the glycaemic

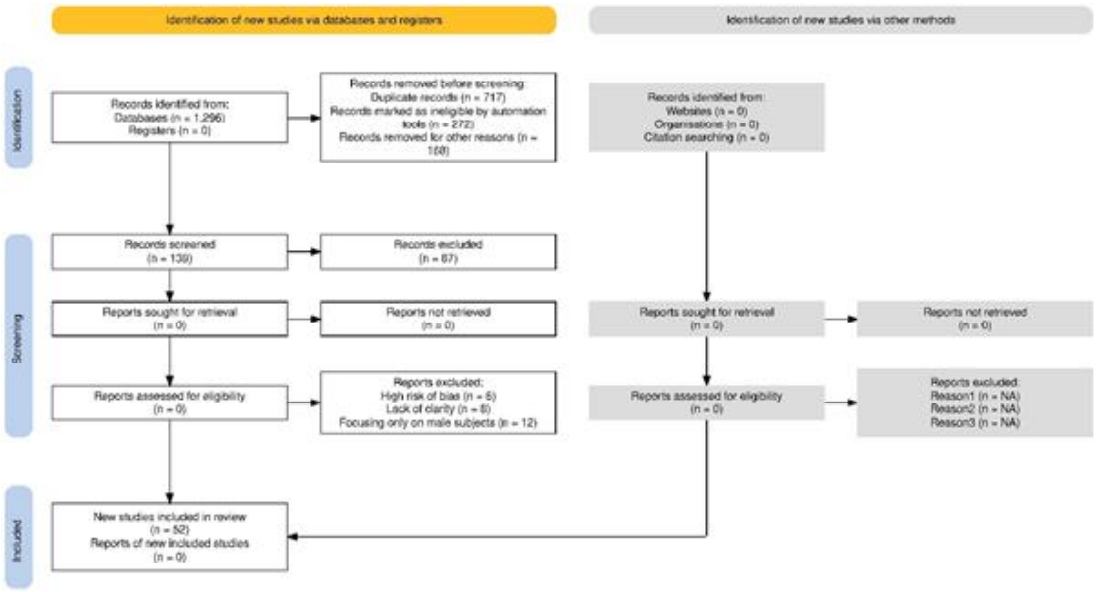

Figure 1. PRISMA 2020 Flow Chart.[5]

index (GI) of millet-based foods, specifically roti, dosa, and dumpling, and their impact on individuals with prediabetes. The results revealed low GI values (37 for dosa, 48 for dumpling, 53 for roti) and moderate glycaemic loads. After a 120-day intervention involving these foods, participants showed notable reductions in fasting blood glucose levels (from 120.50 to 97.81 mg/dL) and HbA1c values (from 6.14% to 5.67%). The millet-based food mixture is noted for its rich protein and dietary fiber content, demonstrated good sensory acceptance, highlighting its promise as a beneficial dietary choice for managing diabetes.[13]

Anitha *et al*.[3] examined the impact of millet intake on blood glucose regulation, with particular emphasis on fasting blood sugar (FBS) and postprandial blood sugar (PPBS). Results indicate significant reductions in both FBS (11.8%) and PPBS (15.1%) among those consuming millets compared to other staple diets. However, the impact on glycated haemoglobin (HbA1c) was not statistically significant, suggesting the need for further investigation. The findings advocate for millet-based dietary interventions to mitigate the risk of type 2 diabetes, highlighting the importance of dietary diversity for improved health outcomes.[3]

Kumari *et al.*,[9] evaluated the effects of various processing methods on finger millet porridges, focusing on their glycaemic index (GI), antioxidant properties, and health benefits for adults. Twelve different porridges were analyzed, revealing that most had low GI values, indicating potential usefulness for managing blood sugar levels. Additionally, consuming these porridges notably enhanced plasma antioxidant capacity, though long-term effects on blood glucose and cholesterol levels were minimal. The findings suggest that

specific processing techniques can optimize the nutritional profile of finger millet, making it a beneficial dietary option for health-conscious individuals.[9]

Journal,[8] explored the nutritional and functional potential of millet milk and flour in food applications. The findings reveal that both products are rich in essential nutrients, including vitamins and minerals, making them excellent alternatives to dairy. Millet milk, being hypoallergenic and gluten-free, suits those with dietary restrictions. Results also indicate that millet flour enhances dietary fiber intake and provides health benefits, such as improved digestive health. The study concludes that integrating millet-based ingredients into food products can meet the rising demand for nutritious and sustainable food options, fostering better health and supporting environmentally friendly agricultural practices.[8]

Sarkar *et al.*,[12] reviewed the anti-diabetic properties of phenolic bioactive in plant-based foods, emphasizing their role in glycaemic control. It highlights how these compounds possess antioxidant characteristics, improve insulin sensitivity, and inhibit key carbohydrate-digesting enzymes, thereby aiding in managing blood sugar levels. The study underscores the variability of phenolic content influenced by different cultivation and processing methods. It concludes that integrating diverse, phenolic-rich foods into diets can provide effective strategies for preventing and managing type 2 diabetes, particularly for underprivileged communities facing health disparities. Further research is encouraged to optimize food sources for better health outcomes.[12]

Jaybhaye *et al.*,[7] reviewed the advancements in millet processing and their potential for creating value-added food products. Despite millets being nutritionally superior to traditional cereals, their utilization remains limited to specific consumer groups. The research highlights the necessity for advanced processing technologies to improve their digestibility and nutrient bioavailability. Promising results suggest that innovative methods can enhance the nutritional profile of millets, making them more appealing to urban and rural consumers alike. Greater focus on developing health-oriented products from millets could lead to increased consumption and contribute to food security while addressing malnutrition challenges[7].

Meena *et al.*,[10] explored the impact of ultrasound treatment on the fermentation dynamics and quality attributes of probiotic beverages made from white finger millet (variety KMR-340). Results demonstrate that ultrasound treatment, particularly when applied after inoculation, significantly shortens fermentation time while enhancing properties such as viscosity and water holding capacity. The study identifies optimal treatment parameters, highlighting ultrasound's effectiveness in improving fermentation efficiency and product quality. These findings suggest that ultrasound technology could be a valuable tool in developing high-quality millet-based probiotic products, contributing to the growing market for non-dairy probiotic beverages.[10]

As a food security and health issue, millets were emphasized as having nutritional benefits by Anita *et al.*,[2]. It highlights millets' rich micronutrient profiles, protein content, and potential to aid in managing diabetes,

cardiovascular diseases, and digestive disorders. Findings indicate that millets, particularly sorghum and finger millet, possess advantageous glycaemic index properties, supporting better metabolic control. The authors conclude that promoting millet consumption could enhance dietary diversity, improve nutritional status, and provide sustainable agricultural solutions in resource-limited settings. The overarching message advocates for increased integration of millets into daily diets for better health outcomes.[2]

Amwoma *et al*.,[1] investigated the glycaemic index (GI) of stiff porridge (ugali) made from maize, millet, and sorghum, as well as the effects of fermented milk on GI values. Results indicated that plain sorghum ugali had the highest GI (72), followed by maize (67), and millet showed the lowest GI (46). When served with fermented milk, the GI increased for maize (79) and millet (67) but decreased for sorghum (57). The findings suggest that incorporating millet based ugali could be advantageous for diabetes management, while the effects of fermented milk on GI vary by grain type.[1]

Huang *et al*.[6] explored the association between cereal intake, cooking techniques, and the risk of hypertension in a Chinese population. The study revealed that greater consumption of total, fried, and baked cereals was linked to an elevated risk of hypertension, whereas intake of whole grains was associated with a reduced risk. Notably, switching from frying or baking to boiling cereals could significantly reduce hypertension risk by up to 28%. The study highlights the significance of cereal processing and cooking techniques in formulating dietary guidelines for the prevention and management of hypertension. This highlights the potential for strategic dietary shifts in public health initiatives.[6]

Table-1. Summary of selected articles for review and its outcome

Author, Article and Study design	Aim of the study	Outcome or key findings
(Geetha *et al.*,[4]) "Glycemic index of millet-based food mix and its effect on pre diabetic subjects," using an experimental study design.	"To assess the glycaemic index of traditional recipes prepared from a developed millet-based food mix and evaluate their effect on pre-diabetic subjects"	"The millet-based food mix recipes (roti, dosa, dumpling) had low glycaemic index values (53, 37, and 48), moderate glycaemic load, high acceptability, and significantly reduced fasting blood sugar and HbA1c in pre-diabetics, suggesting they may help manage diabetes."
(Anitha *et al.*,[3]) "Impact of regular consumption of millets on fasting and post-prandial blood glucose level:	"To evaluate the effects of regular millet consumption on fasting blood	"Millet consumption significantly reduced FBS (-11.8%) and PPBS (-15.1%) levels, without affecting HbA1c, indicating its potential to

a systematic review and meta-analysis," conducted as a systematic review and meta-analysis of randomized controlled trials	sugar (FBS), post-prandial blood sugar (PPBS), and glycated haemo-globin (HbA1c) compared to major staple diets"	manage blood glucose and lower type 2 diabetes risk."
(Kumari *et al.*,[9]) "Finger millet porridges subjected to different processing condi-tions showed low glycemic index and variable efficacy on plasma antioxidant capacity of healthy adults," using a randomized cross-over study.	"To explore how finger millet grain processing impacts healthy people's porridge glycaemic response, phenolic content, antioxidant activity, blood glucose, and cholesterol."	"Most finger millet porridges had a low glycaemic index, parboiling (15 min) increased phenolic content and antioxidant activity, and both short- and long-term consumption significantly increased plasma antioxidant capacity without changing fasting blood glucose or cholesterol in healthy adults."
(Journal,[8]) "Millet Milk and Flour in Food Industry Applications: Harnessing Nutritional and Functional Potential," which is a narrative review of current literature and innovations in the field	"To explore and highlight the nutri-tional advantages, functional properties, and food industry applications of millet milk and flour"	"Millet milk and flour are hypoallergenic, gluten-free, and rich in essential nutrients, making them suitable for health-conscious consumers and those with dietary restrictions. Incorporating them into food products improves nutrition, sustainability, and product development in the food industry."
(Sarkar *et al.*,[12]) "Phenolic Bioactives from Plant-Based Foods for Glycemic Control," which is a comprehensive narrative review of preclinical, in vitro, and intervention studies.	"Identify the antioxi-dant, anti-hyperglyc-aemic, and associated therapeutic mechani-sms of phenolic bioactive from various plant-based meals in glycaemic manage-ment for type 2 diabetes."	"Plant-derived phenolic bioactive support glycaemic control with antioxidant, enzyme inhibitory, and insulin-sensitizing effects. Their efficacy varies by plant source, processing, and bioavailability, and pre- and post-harvest strategies can improve their health benefits for type 2 diabetes management."
(Jaybhaye *et al.*,[7]) "Processing and Technology for Millet Based Food Products: A Review," is a review article summarizing	"To review the com-position, processing technologies, traditio-nal and convenience foods, and product	"The review shows that millets are nutritionally superior to major cereals, have health benefits, and can be processed to add value, however processing problems and lack of

existing research and technological advances related to millet processing and product development	characteristics of millet-based food products"	large-scale industrial acceptance limit their use."
(Meena *et al.*,[10]) "Ultrasound as a pre-treatment in millet-based probiotic beverage: Its effect on fermentation kinetics and beverage quality," is an experimental research article.	"To investigate the effect of ultrasound pre-treatment on fermentation kinetics and quality parameters of white finger millet-based probiotic beverages."	"Ultrasound treatment, especially after probiotic inoculation, reduced fermentation time (by up to 2.6-fold), increased lactic acid production, and improved beverage quality attributes like water holding capacity and viscosity, suggesting ultrasound as a promising alternative to pasteurization in millet-based probiotic beverage production."
(Anita *et al.*,[2]) "Nutritional and Health Benefits of Millets," is a comprehensive review book summarizing empirical studies and research on the nutritional composition and health benefits of millets	"To review and synthesize scientific evidence on the nutritional value, functional properties, health benefits, and processing technologies of millets, with a focus on their role in promoting nutritional security and preventing lifestyle diseases"	"Millets are rich in protein, dietary fiber, essential minerals, and phytochemicals, lowering the risk of diabetes, cardiovascular disease, obesity, and certain cancers. However, lack of awareness, processing issues, and policy disincentives have reduced their consumption, highlighting the need for promotion and value addition."
(Amwoma *et al.*,[1]) "Glycemic Index Values of Stiff Porridge (Ugali) Prepared from Maize, Millet, and Sorghum Flours: Which One for Diabetes Management?", is an experimental research article.	"To determine the glycaemic index (GI) of ugali made from maize, millet, and sorghum flours, and assess the impact of fermented milk on their GI."	"Millet-based ugali has a low GI and may be recommended for diabetes management; fermented milk lowers the GI of sorghum ugali but increases the GI of maize and millet ugali."
(Huang *et al.*,[6]) "Assessing the Hypertension Risk: A Deep Dive into Cereal Consumption and Cooking Methods—Insights from China," is a prospective cohort study.	"To examine the associations between the consumption of cereals prepared using different cooking methods and the risk of hypertension in Chinese adults."	"Total, fried, and baked cereals increased hypertension risk, but whole grain consumption decreased risk by 8%. Boiling cereals lowered risk by 28% and 14%, respectively."

Millet-based foods, such as dosa, mudde, roti, and finger millet porridges, consistently exhibit low to moderate glycaemic indices (GI below 55) and moderate glycaemic loads (GL under 20), making them effective for managing blood sugar levels.[4] Studies demonstrate that regular millet consumption significantly reduces fasting blood sugar (FBS) by about 11.8% and post-prandial blood sugar (PPBS) by 15.1% compared to other staples, with effect sizes of –0.71 for FBS and –0.42 for PPBS.[3] Dietary interventions with millets in prediabetic subjects led to notable reductions in FBS and HbA1c, indicating their suitability for diabetes management. Processing methods, particularly parboiling, further enhance the health benefits of finger millet by lowering GI, increasing resistant starch (23–25 g/100 g), and boosting antioxidant capacity.[9] Overall, millet-based foods are promising dietary options for preventing and managing diabetes due to their slow carbohydrate release, high dietary fiber, and antioxidant properties.

Whereas Millet milk and flour are nutritious, gluten-free options packed with protein, fiber, and antioxidants, benefiting digestive health and reducing chronic disease risks while catering to lactose-intolerant individuals. Through processing techniques like soaking, germination, and fermentation, they enhance nutritional value and versatility in products like yogurt, baked goods, and noodles, promoting sustainable agriculture and meeting the demands of health-conscious consumers.[8]

By improving glucose metabolism and reducing oxidative stress, plant-based foods like berries and whole grains may be useful for managing type 2 diabetes. Additionally, it underscores millets' nutritional superiority over traditional cereals, with processing methods enhancing their digestibility and health benefits, though further research is needed to expand their industrial use for diabetes and obesity management.[7,12]

The study demonstrated that ultrasound (US) pre-treatment notably enhanced both the fermentation efficiency and overall quality of a millet-based probiotic beverage (MPB). Applying high-intensity US (0.53–1.59 W/mm² for 5–15 minutes) prior to inoculation shortened the fermentation duration by 2.6 times, while low-intensity US (0.21–0.35 W/mm² for 1–5 minutes) post-inoculation promoted improved probiotic growth.[11]

It is found that higher intake of total cereals, especially fried and baked varieties, increased hypertension risk by 15–20%, while whole grains reduced risk by 8%, and replacing fried or baked cereals with boiled options lowered risk by 28% and 14%, respectively, due to harmful compounds from high-temperature cooking and the benefits of fiber-rich whole grains, with stronger associations in women, non-smokers, and abstainers, suggesting public health strategies should prioritize whole grains and boiling methods to combat hypertension.[1,6]

This systematic review presents strong evidence supporting the effectiveness of millet-based foods and drinks in regulating glycaemic levels in individuals with Type 2 Diabetes Mellitus. The reviewed studies consistently show that millets possess beneficial glycaemic characteristics, including low to moderate glycaemic indices and marked reductions in both fasting and postprandial blood glucose levels.

The key findings indicate that millet consumption can reduce fasting blood sugar by approximately 11.8% and post-prandial blood sugar by 15.1% compared to conventional staples. Processing techniques, particularly parboiling and fermentation, further enhance the health benefits by increasing resistant starch content and antioxidant capacity.

However, this review identifies several limitations, including limited long-term studies and insufficient research on HbA1c outcomes. Future research should focus on conducting randomized controlled trials with larger sample sizes and longer intervention periods to establish definitive dietary guidelines. The findings support the integration of millet-based foods into nutritional therapy for diabetes management, offering a sustainable, cost-effective, and culturally acceptable dietary intervention for healthcare practitioners and policymakers.

Conflicts of Interest: None

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