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Resistant starch's effect on blood glucose levels in individuals with prediabetes and diabetes mellitus: A systematic review

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ABSTRACT

Background: *Diabetes ranks among the ten leading causes of mortality. Patients with diabetes who do not effectively manage their condition run the risk of developing severe complications. An appropriate dietary regimen is considered a fundamental aspect of effectively managing diabetes. One potential treatment option for diabetics is resistant starch (RS), which is supposed to control blood glucose levels.*
Objectives: *The objective of this study is to investigate the impact of resistant starch on food items characterized by a high glycemic index.*
Methods: *The methodology employed in this scholarly article is a systematic review. A comprehensive search was conducted across five prominent academic databases, namely EBSCO, PubMed, ProQuest, Scopus, and Google Scholar. The search strategy involved utilizing specific keywords, The presentation of the findings in this article adheres to the established guidelines and principles outlined in the Preferred Reporting Items for Systematic Review (PRISMA).*
Results: *A total of eight statistically significant findings were observed, indicating that the consumption of starches effectively reduced blood sugar levels*. The papers utilized genuine experimentation and quasi-experiment approaches within the past five years. *Numerous interventions involving resistant starch have demonstrated efficacy in the reduction of blood glucose levels. These interventions include the retrogradation of rice, the consumption of natural starch found in bananas and whole grains, as well as the addition of oil during the cooking process of rice.*
Conclusions: *The inclusion of different forms of resistant starch in the dietary regimen of individuals with diabetes may be a viable option. However, it is important to acknowledge the significance of incorporating complementary food items in addition to the primary staple foods that are consumed. The utilization of resistant starch has been found to be an effective strategy for reducing blood glucose levels among individuals with diabetes.*

KEYWORD*:* *resistant starch; diabetes mellitus; blood glucose; diet*

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INTRODUCTION

The dietary regimen for individuals with diabetes is a pivotal component in the effective management of diabetes since it plays a significant role in maintaining stable blood glucose levels. For certain individuals with diabetes, dietary modifications often involve the reduction of foods high in sweetness. The prevailing perception in Indonesian society is misguided and continues to gain traction. Foods that lack sweetness, such as rice, possess a relatively elevated glycemic index value. According to Atkinson et al. (2021), rice demonstrates an average glycemic index score of 67. This score demonstrates that rice has the potential to substantially elevate blood glucose levels (1). Despite the fact that several individuals from the middle and upper socioeconomic classes have transitioned to other food sources, white rice continues to serve as a fundamental dietary staple in Indonesia (2). A significant number of individuals consume white rice in substantial quantities and with notable frequency. This phenomenon has the potential to induce fluctuations in blood glucose levels. The presence of persistent fluctuations in blood glucose levels can heighten the susceptibility to diabetes among individuals with prediabetes or non-diabetes. Moreover, for those already diagnosed with diabetes, such fluctuations can potentially lead to the onset of complications and mortality.

According to the International Diabetes Federation (IDF), the worldwide incidence of individuals affected by diabetes is projected to reach 536 million in 2021, accompanied by a mortality rate of 6.7 million individuals. the projected prevalence of diabetes in Southeast Asia for the year 2021 is estimated to affect around 90 million individuals. Additionally, the mortality rate associated with this condition is expected to exceed 747 thousand individuals. According to the International Diabetes Federation (IDF), in 2021, the estimated number of individuals affected by diabetes in Indonesia is projected to reach 19 million, while the mortality rate is expected to reach 236 thousand individuals (3). The International Diabetes Federation (IDF) reports that a significant proportion of people diagnosed with diabetes reside in lower-middle-income nations, mostly due to the rapid transformation of their dietary patterns. A comprehensive investigation including 195 countries worldwide revealed a prevalent issue of improper dietary choices among individuals. The consumption of inappropriate food items emerged as a significant contributor to mortality rates on a global scale(4).

Diabetes is a persistent medical condition characterized by insufficient insulin production by the pancreas or ineffective utilization of insulin by the body's cells , Diabetes is characterized by elevated levels of blood glucose, necessitating the maintenance of glucose levels within the established acceptable range of 70–100 mg/dL for fasting blood glucose(5,6). Over the course of time, elevated levels of glucose in the bloodstream have the potential to inflict harm upon many organs, ultimately resulting in the development of problems associated with diabetes (7). Efforts aimed at mitigating difficulties encompass the maintenance of stable blood glucose levels through self-management, with dietary interventions being one such approach. The Indonesian population is familiar with a dietary regimen for managing diabetes referred to as the 3J approach, which involves considering the numerical value, kind, and timing of food intake (4). The selection of foods is mostly based on considerations of calorie content and glycemic index. Even if the quantity and timing of meal consumption are appropriately managed, the consumption of high-glycemic index (GI) foods can still pose the potential danger of elevating blood glucose levels. According to a study conducted by Harvard in 2023, there is an inverse relationship between the glycemic index (GI) of food and the rate at which blood glucose levels increase following their consumption.

Rice is a significant provider of dietary carbohydrates, with a predominant composition of starch accounting for the majority of its nutritional content. Starch is composed of homopolysaccharides, specifically amylose and amylopectin. According to Egharevba (2020), amylose is characterized by a linear arrangement of approximately 500–2000 glucose units, whereas amylopectin consists of approximately 1,000,000 glucose units. During the metabolic process, starch undergoes conversion into glucose and is subsequently absorbed in the small intestine. Consequently, the consumption of food that is rapidly ingested leads to an elevation in blood glucose levels. Failure to consider the glycemic index factor when consuming rice may result in diabetes patients experiencing sustained elevations in blood glucose levels, ultimately leading to problems associated with diabetes. Hence, it is imperative to explore alternate approaches aimed at modifying staple meals to enhance their glycemic response(8).

The 2015 national conference of the American Chemical Society, which was attended by numerous researchers, presented findings indicating that augmenting levels of resistant starch (RS) can serve as a viable approach to decreasing the calorie content of rice. Resistant starch (RS) refers to the portion or proportion of starch that remains undigested, specifically not converted into glucose, within the small intestine. Consequently, this undigested starch proceeds to the large intestine, where it can undergo fermentation (8). Resistant starch (RS) exerts a suppressive influence on the absorption process occurring in the small intestine. Consequently, the consequences of RS intake are linked to the moderation of postprandial blood glucose levels, characterized by the absence of excessive elevation following a meal. the relationship between resilience (RS) and glycemic control was examined. The present meta-analysis encompassed a total of 16 clinical studies in which the RS intervention was employed as the sole intervention. The findings of this study demonstrated a noteworthy decrease in fasting plasma glucose levels(9).

As of present, a comprehensive analysis specifically examining the impact of chest treatments on blood glucose levels in individuals with diabetes has not been conducted. Based on the aforementioned reasoning, researchers aim to conduct a comprehensive study pertaining to the efficacy of resistant starch in modulating blood glucose levels among individuals diagnosed with prediabetes and diabetes mellitus.

MATERIALS AND METHODS

From August 30 to September 10, 2023, a literature search was undertaken. The results of the article were compiled in accordance with the Preferred Reporting Items for Systematic Reviews (PRISMA) guidelines and protocols. The process of conducting an article search was executed with the PICOT framework.

Table 1. PICOS Framework

PICOS framework	Inclusion Criteria	Exclusion Criteria
Population	Diabetes Mellitus Type 1, Type 2, gestational diabetes and prediabetes	Non-human experiment
Intervention	Resistant starch intervention	Rapidly Digestible Starch (RDS), Slowly Digestible Starch (SDS)
Comparator	No comparator Compare with other diet intervention	
Outcomes	Blood glucose level	It does not discuss the effectiveness or effect of resistant starch interventions on blood glucose levels in diabetics.
Study Design and publication type	True Experiment dan Quasi experimental	Review and analysis: literature review, systematic review, meta-analysis

Search Strategy

A literature search was conducted using four databases (Scopus, ProQuest, Pubmed, and EBSCO) to gather information from the last five years, 2018–2023. The process of retrieving articles or journals involves the utilization of keywords and boolean operators (AND, OR, NOT). These operators serve to broaden or refine the search, facilitating the identification of desired publications or specific numbers for reference. The process of aligning the keywords in the systematic review with the Medical Subject Heading (MeSH) of the article involved selecting the following: ("DM" OR "Diabetes" OR "Diabetic" OR "T1D" OR "T2D") AND ("Resistant Starch"). The selection criteria for this study were articles published within the past five years that employed both true experimental and quasi-experimental designs. The primary objective of this study was to thoroughly investigate the efficacy of resistant starch in regulating blood glucose levels in individuals diagnosed with diabetes mellitus.

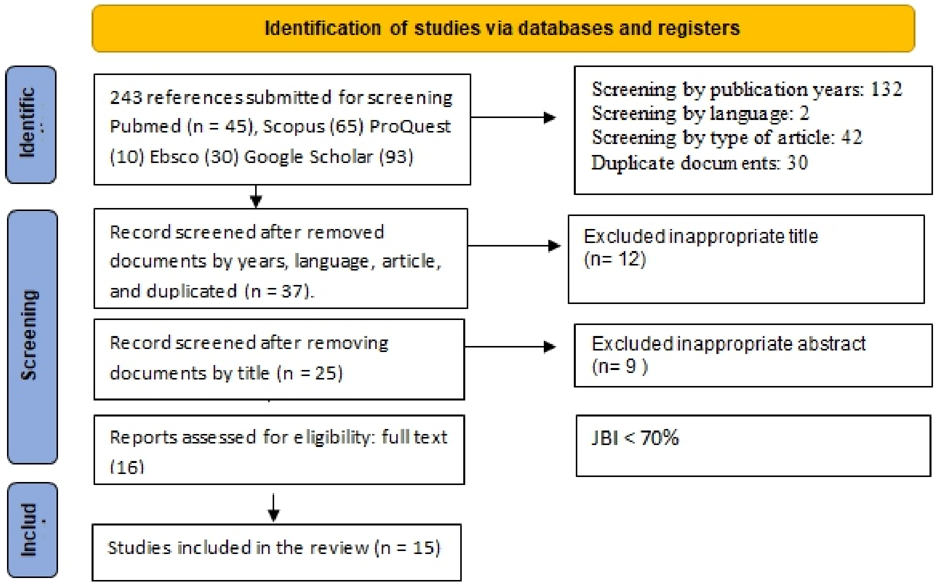

Figure 1. Flowchart Prisma

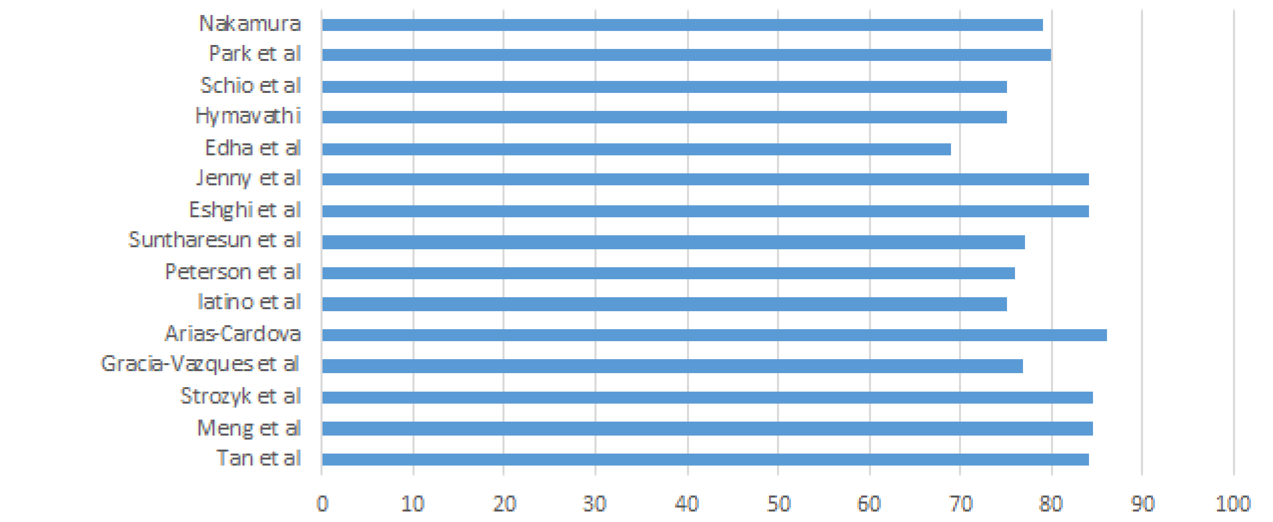

Figure 2. Bias Risk

Data Extraction

A total of 243 articles were retrieved based on keywords, as determined by MeSH, for the purpose of conducting a thorough assessment to assess article eligibility. The articles were further subjected to screening criteria, including year of publication, language, document type, and the exclusion of duplicate papers, resulting in a total of 206 articles. A total of 37 articles underwent a subsequent screening process to evaluate their eligibility based on their titles, resulting in the exclusion of 12 articles.

A total of 25 articles underwent a secondary screening process, wherein the abstracts were evaluated, resulting in the exclusion of 9 articles. There are currently 16 articles that have not been analyzed. Upon completion of reading the entire text, it has been determined that 15 of these articles meet the criteria for analysis.

Eligibility

The bias of a study was assessed using the Joanna Briggs Institute (JBI) for various types of studies, including randomized controlled trials (RCTs) and quasi-experimental studies. The quality of each study's methodology (n = 15) was analyzed to evaluate its adherence to specific criteria. The criteria were evaluated using scores of “yes”, “no”, or “not applicable”, and these scores were then aggregated to determine if the studies met the 70% threshold for meeting the critical appraisal criteria.

The standards, measurements, and recommendations known as appraisal criteria are employed in performance appraisals and expense appraisals, generally, to appraise and evaluate an object's performance, efficacy, or value. The articles that met the criteria established by the researchers conducting the study were included in the sample.

RESULTS AND DISCUSSION

RESULTS

Characteristic of Articles

The publications included in this study comprised a total of 15 articles that satisfied the inclusion and exclusion criteria established by the researchers. The papers utilized genuine experimentation and quasi-experiment approaches within the past five years. The objective of this study was to investigate the efficacy of resistant starch in regulating blood glucose levels in individuals diagnosed with diabetes mellitus. There are a total of six studies that employ the randomized crossover research design. Among these, five articles utilize the randomized control trial methodology, two articles employ the randomized comparative approach, one article adopts the pre-post test study design, and one article utilizes the non-randomized crossover method. The articles included in this study were sourced from various databases, including Ebsco (9 articles), Proquest (4 articles), Scopus (4 articles), Pubmed (8 articles), and Google Scholar (3 articles). The present study was carried out in multiple nations, with two articles completed in Mexico, two articles in Japan, and two articles in Indonesia. Additionally, the research encompassed a diverse range of countries and genders, as outlined in the table provided.

Characteristics of Interventions

Feeding regulation interventions, also known as resistant starch interventions, are implemented in order to observe alterations in the individual's blood glucose levels. Multiple strategies for implementing resistant starch treatments exist. The further interventions that can be implemented.

Resistant Starch Type 2

Type 2 resistant starch refers to a specific kind of starch that possesses resistance to digestion in the human body. This type of starch occurs naturally in various food sources. The study conducted observed notable distinctions in blood glucose levels on the fourth day of the intervention. Specifically, the group receiving the NBS (Green Banana Starch) intervention exhibited a greater reduction in blood glucose values compared to those who received the HMS (corn flour) intervention, which is characterized by its high amylose content, and the DMS (corn starch) intervention. The consumption of foods rich in starch has been demonstrated to positively impact the gut microbiome associated with gestational diabetes mellitus (GDM), leading to enhanced regulation of blood sugar levels. Long-grain white rice and brown rice are sources of natural starch or resistant starch type 2. Similarly, natural grain-type sorghum can also be utilized to obtain this form of starch (10).

Resistant starch Supplements

In individuals diagnosed with metabolic syndrome who are prescribed statin medications, adherence to a certain dietary regimen for a duration of four weeks results in a notable elevation in fasting levels of low-density lipoprotein (LDL) and overall cholesterol, in contrast to those who do not concurrently utilize statins. The statistical study conducted indicates that there is no statistically significant relationship between the duration of a diet and glucose levels. There was no statistically significant disparity observed in the findings of the oral glucose tolerance test (OGTT) between the two groups of participants, even after two weeks of intervention. Although glucose tolerance was assessed after this period, no significant distinction was found between the two groups ($p = 0.221$).

Resistant Starch Type 3

This study also conducted a comparison between freshly cooked rice and rice that had been cooled in the refrigerator. The findings revealed a significant reduction in the maximum glycemia value for the cooled rice group compared to the freshly cooked rice group [9.9(9.4–10.9) vs. 11(10.3–11.7) mmol/L, $p = 0.0056$]. Additionally, the maximum glycemic increase was found to be higher in the cooled rice group compared to the freshly cooked rice group [2.7 (1.5-3.6) vs 3.9 (2.5-4.7) mmol/L, $p < 0.0001$]. According to Strozyk et al. (2022) The regulation of resistant starch intake has an impact on the blood glucose mechanism, particularly postprandial blood glucose levels. In the case of resistant starch rice, the postprandial blood glucose levels are lower compared to regular rice, with values of 2.80 ± 1.38 mmol/L and

3.04 ± 1.50 mmol/L, respectively (P=0.043). The regulation of food intake has the potential to impact the hormonal responses of leptin and insulin in individuals with obesity. Individuals who ingested rice with a high resistant starch (RS) content exhibited notable reductions in postprandial blood glucose fluctuations compared to those who drank conventional rice, as evidenced by statistically significant differences observed at both the 30- and 60-minute time points (P < 0.05)(11).

Duration of intervention

The duration of the intervention refers to the length of time during which the intervention is implemented or administered. The duration of the intervention ranges from a minimum of two weeks to a maximum of six months. The findings indicate that implementing a 12-week intervention involving high-resistant starch and low-protein has a discernible impact on the glycemic status of patients, leading to observable variations in blood glucose readings. In a study conducted by Meng et al. (2019), it was observed that individuals who consumed light foods for a duration of four weeks exhibited a statistically significant difference compared to the control group (p=0.04). Notably, this difference was observed without any concurrent changes in body mass index (BMI). The study found a significant drop in leptin levels in the RS group (p=0.00). The control group had a statistically significant reduction in blood glucose levels (p=0.01) and a minor elevation in leptin. (12) The findings of a systematic review of 15 scholarly articles with rigorous inclusion criteria indicate the necessity of implementing interventions aimed at managing resistant starch. These interventions have been shown to yield significant improvements in patients' glucose levels.

Furthermore, it is recommended that patients engage in collaborative efforts with nurses and nutritionists to modify their dietary habits, as this approach has been found to yield optimal outcomes.

Table 2. Literature review

Journal name	Author, year publication	Title	Method (DSVIA)	Result
Journal of Renal Nutrition	Yan Meng , Hao Bai, Qingtao Yu , Jin Yan, Lili Zhao, Shijun Wang, Zhaoping Li , Qian Wang, Liyong Chen (12)	High-Resistant Starch, Low-Protein Flour Intervention on Patients With Early Type 2 Diabetic Nephropathy: A Randomized Trial	Design: Randomized, single-center, comparative, open-label trial design Sample: 75 patients aged 18-80 years with diabetic nephropathy; group intervention (n=34) and group control (n=36). Variable Dependentt: Blood glucose level, blood lipid level, Nutritional parameters. Variable InDependentt: High–Resistant Starch, Low-Protein Flour	Following the 12-week intervention, a notable alteration was observed in the intervention group, wherein the average Fasting Blood Glucose exhibited a drop of 0.9.

			Instrument: Ethylenediamine tetraacetic acid (EDTA) and plain tubes Analysis: InDependentt sample t-test Paired sample t test Analysis of covariance	Previously: 9.0 +- 2.9 Following: 8.1 +- 2.8 P-values less than 0.05
Nutrition and Diabetes	Sylwia Strozyk, Anita Rogowicz-Frontczak, Stanislaw Pilacinski, Joanna LeThanh-Blicharz, Anna Koperska and Dorota Zozulinska-Ziolkiewicz(11)	Influence of resistant starch resulting from the cooling of rice on postprandial glycemia in type 1 diabetes	Design: Randomized, single-blind crossover study Sample: 32 patiet with type 1 diabetes, > 18 y.o Variable Dependentt: Post prandial glycemia Variable InDependentt: Resistant starch (cooled rice), fresh rice Instrument:Body Composition Analyzer Bc-418 Ma's Tanita Analysis: Shapiro–Wilk test, paired t-test Wilcoxon signed-rank t	The ingestion of test meals including chilled rice resulted in a significant reduction in the maximum glycemia value compared to fresh rice [9.9(9.4–10.9) vs. 11(10.3–11.7) mmol/L, p = 0.0056]. Additionally, there was a greater increase in maximum glycemic levels observed with fresh rice compared to chilled rice [2.7 (1.5–3.6) versus 3.9 (2.5–4.7) mmol/L, p < 0.0001].
European Journal of Nutrition	Carlos García Vázquez, Jorge L. Ble Castillo, Yolanda Arias Córdova, Meztli Ramos García, Viridiana Olvera Hernández, Crystell G. Guzmán Priego, Mirian C. Martínez López, Guadalupe Jiménez Domínguez, Josafat A. Hernández Becerra (13)	Efects of resistant starch on glycemic response, postprandial lipemia and appetite in subjects with type 2 diabetes	Design: Single-blind crossover study Sample: 17 respondent with type 2 diabetes Variable Dependentt: Glycemic response, postprandial lipemia and appetite Variable InDependentt: Resistant starch Instrument:The measuring of appetite is often conducted with the Visual Analog Scale (VAS), while blood collection is performed through the insertion of an intravenous (IV) catheter into the arecubital vein. Analysis : Anova dan T-test	Fasting glucose concentrations were significantly lower with NBS consumption for four days than with DMS (P<0.005). Following the administration of NBS, it was observed that the peak levels of GR were comparatively lower at the 60-minute mark compared to

				the levels observed after DMS administration. Furthermore, when comparing the NBS group to the HMS group, it was found that the levels of GR were significantly lower at both the 90-minute and 120-minute time points (P<0.05).
Nutrients	Yolanda Arias-Córdova, Jorge Luis Ble-Castillo, Carlos García-Vázquez, Viridiana Olvera-Hernández, Meztli Ramos-García, Adrián Navarrete-Cortes, Guadalupe Jiménez-Domínguez, Isela Esther Juárez-Rojop, Carlos Alfonso Tovilla-Zárate, Mirian Carolina Martínez-López and José D. Méndez(10)	Resistant Starch Consumption Effects on Glycemic Control and Glycemic Variability in Patients with Type 2 Diabetes: A Randomized Crossover Study	Design : Randomized, crossover, single- blind controlled Sample : The study included a sample of 17 individuals diagnosed with type 2 diabetes, ranging in age from 28 to 65 years, and with a body mass index (BMI) over 25 kg/m2. Variable Dependentt: Glycemic control, glycemic variability Variable InDependentt: Resistant starch, banana Instrument : CGM system (Medtronic, Inc., Northridge, CA, USA) Analysis : ANOVA	On the fourth day of the experiment, the values obtained for NBS were found to be significantly greater than those for DMS and HMS (P=0.005, P=0.0016, respectively). The administration of NBS supplementation over a period of four days resulted in a notable decrease in fasting glucose levels compared to the control group receiving DMS (P<0.005).
Frontiers in Nutrition	Ling-li Tan, Wei-qian Duan, Meng-xue Chen, Ying Mei, Xiao-ya Qi and Yong Zhang (14)	Naturally cultured high resistant starch rice improved postprandial glucose levels in patients with type 2 diabetes: a randomized, double-blind, controlled trial	Sample : 73 individuals, aged 40–70 years, with type 2 diabetes who did not have any immediate problems. The participants were divided into two groups, with Group A consisting of 37 individuals and Group B consisting of 36 individuals. Variable Dependentt: Postprandial glucose level	At 30 and 60 minutes, subjects who consumed high RS rice exhibited substantially lower postprandial blood glucose changes compared to those who consumed regular rice (P <0.05).

			Variable InDependentt: Resistant starch, rice Instrument : Nutritional parameters, and venous blood glucose retrieval device. Analysis : ANOVA Paired t-test t-tests, chi-square tests	
Eur J Nutr	Anne Grethe Schioldan, Søren Gregersen, Stine Hald, Ann Bjørnshave, Mette Bohl, Bolette Hartmann, Jens Juul Holst • Hans Stødkilde Jørgensen, Kjeld Hermansen(15)	Effects of a diet rich in arabinoxylan and resistant starch compared with a diet rich in refined carbohydrates on postprandial metabolism and features of the metabolic syndrome	Design : Rondomozed crossover study Sample : A total of 22 patients were identified as having Metabolic Syndrome (MetS) type 2 diabetes; among these, 7 women and 15 men were diagnosed with Dignosa Metabolic Syndrome. Variable Dependentt:Postprandial metabolism and features of the metabolic syndrome Variable InDependentt: Diet rich in arabinoxylan and resistant starch compared with a diet rich in refined carbohydrates Instrument: Oral glucose tolerance test (OGTT), ELISA, Radioimmunoassay Analysis : ANOVA, Regresi Linier	The glucose levels in both the WSD and HCD groups exhibited a decrease, with a reduction of -0.47mmol/L and 0.87mmol/L, respectively. However, it is important to note that this decrease did not reach statistical significance. In summary, our findings do not support the validation of our hypothesis that a 4-week intervention targeting Metabolic Syndrome (MetS) through a diet enriched with Arabinoxylan (AX) from cereals and Resistant Starch (RS) leads to improvements in postprandial lipemia or other characteristics associated with MetS.
Journal of the Medical Sciences	Jenny Hidayat, Sunarti, Mustofa, Ahmad Hamim Sadewa (16)	Effects of resistant starch of mixed tubers snacks on glucose metabolism,	Design : Cross over study desain Sample : A cohort of sixteen individuals, ranging in age from 40 to 60 years, were diagnosed with type 2 diabetes; their blood glucose levels were at least 126 mg/Dl.	Following a period of 4 weeks of intervention, the cluster of the intervention group experienced

		leptin, visceral fat and body mass index in type 2 diabetes mellitus (T2DM)	The criteria for exclusion include individuals who engage in smoking, are pregnant, are breastfeeding, or have severe Type 2 Diabetes Mellitus (T2DM). Variable Dependent : Glucose metabolism, leptin, visceral fat variable InDependent:Resistant starch, mixed tube snack Instrument : Pengukuran antropometri, Lemak visceral diukur dengan Bioelectrical Impedance Analysis (BIA). Analysis : Paired t-test, Wilcoxon test, Person correlation	a reduction from 151.6 to 147.91. However, it is important to note that this decline did not reach statistical significance (p = 0.30).
British Journal of Nutrition	Edna S. Costa, Carolina N. França, Francisco A. H. Fonseca, Juliana T. Kato, Henrique T. Bianco, Thiago T. Freitas, Henrique A. R. Fonseca, Antonio Martins Figueiredo Neto and Maria Cristina Izar (17)	Beneficial effects of green banana biomass consumption in patients with pre-diabetes and type 2 diabetes: a randomised controlled trial	Design : Prospective, randomised, open-label trial, with parallel arms and blinded endpoints Sample : 11 of the 142 respondents who underwent screening were excluded from the study on the grounds of HbA1c levels (≤5.7%) or the requirement to administer antihyperglycemic medications during the course of the research (n 7). Group of biomass G1 = 62, G2 (control group) = 51 Variable Dependent : Blood glucose Variable InDependent :Starch, green banana biomassa Instrument : Anthropometric parameters and bioelectrical impedance analysis. Analysis : Pearson's χ2 test, Kolmogorov-Smirnov test, Mann-Whitney U tests, paired t or Wilcoxon tests	Both the intervention and control groups exhibited a reduction in blood glucose levels following a six-month intervention period. The average value of the intervention group exhibited a drop from 107 mg/dL to 102 mg/dL. The average value of the control group exhibited a drop from an initial measurement of 106 mg/dL to a final measurement of 100 mg/dL. There was no statistically significant difference observed between the control group and the intervention group

Journal of Pharmaceutical Research International	T. V. Hymavathi, E. Jyothsna, T. Pradeepa Robert and V. Teja Sri (18)	Effect of Resistant Starch (RS) Rich Sorghum Food Consumption on Lipids and Glucose Levels of Diabetic Subjects	Design : A pre and post-study Sample : Type 2 diabetes affects 15 individuals. The inclusion criteria for this study encompass the utilization of exclusively diabetes medications, individuals aged between 25 and 60 years, a body mass index (BMI) ranging from 18 to 30, and a lack of smoking history Variable Dependent: Lipids and Glucose Levels Variable InDependent: Resistant starch, rich sorghum Instrument : Vital sign assessment and anthropometric measurement Analysis : ANOVA	Thirty days into the study, fasting blood glucose (FBG) decreased substantially from an initial value of 205 mg/dL to 153.0 mg/dL. A further reduction in levels was noted at the 30-day and 60-day time points, with values decreasing from 153.0 to 133.2 mg/dl. However, at the 90-day mark, there was an increase to 146 g/dl, although this change did not reach statistical significance ($p > 0.05$).
				The administration of a 65g dose of rawa, which is high in resistant starch (RS), over a period of 90 days resulted in a decrease in Body Mass Index (BMI), Fasting Glucose (FG), Total Cholesterol (TC), and Low Density Lipoprotein Cholesterol (LDL-C).
The American Journal of Clinical Nutrition	Courtney M Peterson, Robbie A Beyl, Kara L Marlatt, Corby K Martin,	Effect of 12 wk of resistant starch supplementation on cardiometabolic risk factors in adults with	Desain: A randomized, double-blind, placebo controlled, parallel-arm trial con Sampel: (N=30 in the control group and N=29 in the intervention group) of 59 participants	In comparison to the control group, the administration of RS2 resulted in a reduction of

	Kayanush J Aryana, Maria L Marco, Roy J Martin, Michael J Keenan, and Eric Ravussin. (19)	prediabetes: a randomized controlled trial	completed the research. Variable Dependentt: cardiometabolic risk factors Variable inDependentt: Resistant starch tipe 2 (RS2) DXC600 instrument : Dual-energy X-ray absorptiometry (Lunar iDXA; General Electric, Milwaukee, WI), Magnetic resonance spectroscopy (1H-MRS), MinMod software (MINMOD-PC, R. Bergman) Analysis: Linear mixed models, Nonparametric tests.	HbA1c values by approximately -0.1±0.2% (-1±2 mmol/mol; P=0.05). Furthermore, it has been observed that RS2 exhibits a considerable reduction in body fat (p = 0.02), in addition to its impact on HbA1c levels. Nevertheless, the intervention of RS2 did not have a significant impact on fasting glucose levels (mean difference of 0±8mg/dL; P= 0.99).
Asia Pac J Clin Nutr	Yuta Nakamura, Ayaka Takemoto, Takeshi Oyanagi, Shingo Tsunemi, Yui Kubo, Tomoko Nakagawa, Yoshio Nagai, Yasushi Tanaka, Masakatsu Sone (20)	Effects of cooked rice containing high resistant starch on postprandial plasma glucose, insulin, and incretin in patients with type 2 diabetes	Design : This single-center, open, randomized, crossover comparative study Sample : Twenty patients with type 2 diabetes who were admitted to the Diabetes Center at St. Marianna Medical University Hospital in Kawasaki, Japan, between April 2020 and March 2021 participated in the study. Variable inDependent: cooked rice containing high resistant starch, Variable Dependentt: postprandial plasma glucose, insulin, and incretin in patients with type 2 diabetes Instrument: ELISA kits (YK 161, Yanaihara Institute Inc., Shizuoka, Japan). Food palatability questionnaire Analysis : Chi-Square	Following the intervention, a reduction in the area under the curve (AUC) for plasma glucose was observed in both the RS group (38329 min.mg/dL) and the WR group (45147 min.mg/dL). There is a disparity of 8223 min.mg/dL between the two. The obtained p-value of less than 0.001 indicates statistical significance.

J Med Sci	Synta Haqqul Fadlilah, Sunarti, Arta Farmawati (21)	Effect of rich resistant starch snack on MCP 1 promoter methylation and triglycerides levels in type 2 diabetes mellitus patients	Design : This study was a cross-over trial. Sample : Nineteen T2DM patients, aged between 40 and 60, who met the fasting blood glucose (FBG) inclusion criteria of >126 mg/dL and had had DM for at least a year, participated in this study from RSUP Dr. Sardjito Yogyakarta. Variable inDependentt: Rich resistant starch snack Variable Dependentt: MCP 1 promoter methylation, triglycerides levels in type 2 diabetes mellitus patients Instrument: Anthropometric measurements, blood samples are used to analyze biochemical parameters Analysis : Fisher exact test, paired t-test, unpaired t test, Spearman correlation test, Mann Whitney test	The participants ingested snacks with a daily intake of up to 32 g, containing a total of 4.25 g of resistant starch, throughout a period of four weeks. A reduction in fasting blood sugar levels was seen, with a decline from 169.01 mg/dL to 159.77 mg/dL. Nevertheless, the decrease seen did not reach statistical significance ($p = 0.184$).
Clinical Nutrition on Research	Fereshteh Eshghi, Farnush Bakhshimoghaddm ,Yousef Rasmi , Mohammad Alizadeh (22)	Effects of Resistant Starch Supplementation on Glucose Metabolism, Lipid Profile, Lipid Peroxidation Marker, and Oxidative Stress in Overweight and Obese Adults: Randomized, Double-Blind, Crossover Trial	Design : Randomized, double-blin Sample : A total of 126 individuals who were classified as overweight or obese were evaluated for their suitability to participate in the study. A total of 27 patients were included in the study based on their adherence to the inclusion criteria, specifically their body mass index (BMI) measured in kilograms per square meter (kg/m2). The age range of individuals under consideration is between 27 and 40 years old, as well as between 20 and 50 years old. Variable Dependent : Glucose Metabolism, lipid profile, lipid perpxidation marker, Oxidative Stress in Overweight and Obese Adults	The duration of the intervention spans a period of 12 weeks. The intervention did not result in a reduction in fasting blood glucose levels. There were no statistically significant variations observed in systolic blood pressure (SBP) and diastolic blood pressure (DBP), body weight, body mass index (BMI), or waist circumference across the initial three stages, following the implementation of

			variable InDependent: Resistant Starch, supplementation, Instrument : Homeostatic model assessment of insulin resistance (HOMA-IR) and quantitative insulin sensitivity check index (QUICKI). Anthropometric and blood pressure measurements. Dietary records were analyzed using a nutrition analysis program (Nutritionist IV, version 3.5.2; First Data Bank Division, San Bruno, CA, USA) Analysis : general linear model, paired t-test.	of resistant starch intervention, and subsequent administration of placebo.
BMJ Journal	Jananie Suntharesan, Navoda Atapattu, Eresha Jasinghe, Sagarika Ekanayake, Delpachitra Acharige Gajabahu Harendra de Silva, Gareth Dunseath ,Steohan Luzio,Lakdasa Premawardhana (23)	Acute postprandial gut hormone, leptin, glucose and insulin responses to resistant starch in obese children: a single blind crossover study	Design : Single blind, non-randomised, crossover study. Sample : A total of 20 children who met the inclusion criteria and were classified as obese were consecutively enrolled in the study following the acquisition of written consent from their parents or guardians. The study sample consisted of children between the ages of 10 and 14, encompassing both males and females. These children exhibited a body mass index (BMI) that fell within the 95th percentile range for their respective age and sex, specifically ranging between +2 and +3 standard deviations (SD) according to the World Health Organization's normative data. Variable Dependent : postprandial, leptin, glucose and insulin Variable InDependent : Resistant Starch	Among the three types of food utilized for intervention, M2 has the largest concentration of resistant starch, achieved through the incorporation of oil during the rice cooking process. Significant reductions in postprandial maximum concentrations (∆C) and areas under the glucose curve (∆AUC) were seen following M2 in comparison to M1 ($p<0.05$ and <0.01, respectively). The postprandial curve area (OC) and the change in area under the curve (∆AUC) for plasma insulin following M2 exhibited a statistically significant decrease

			Instrument : Insulin was measured using a chemiluminescent immunoassay (Invitron IV2-001, Invitron, Monmouth, UK). Height and weight measurements Analysis : ANOVA, Friedman's test with Wilcoxon's signed-rank test, t-tests, Mann-Whitney tests	when compared to M1 (both p<0.05).
nutrients	Jiyoung Park, Sea-Kwan Oh, Miae Doo, Hyun-Jung Chung , Hyun-Jin Park and Hyejin Chun (24)	Effects of Consuming Heat-Treated Dodamssal Brown Rice Containing Resistant Starch on Glucose Metabolism in Humans	Design : Double-blind, placebo-controlled clinical trial Sample : 36 individuals were classified as obesity. Every participant in the study provided their signature on a written consent form before to their involvement. Subsequently, they were assigned to either the test group or the control group in a random manner, following the sequence of their participation. Variable Dependent : Glucose Metabolism Variable InDependent: Consuming Heat-Treated Dodamssal Brown Rice Containing Resistant Starch Analysis : one-way analysis of variance and Duncan's multiple comparisons.	The participants in the HBD group, which included resistant starch (RS) in their diet, and the HBI group, which did not include RS, were provided with additional food items and powdered test materials for a duration of two weeks. Despite the absence of notable disparities in dietary outcomes pertaining to body weight, body composition, cholesterol levels, and OGTT measurements, the consumption of greater amounts of resistant starch (RS) exhibited statistically significant beneficial impacts on glucose

DISCUSSION

Based on PICOS framework on **Table 1**, a literature search was undertaken. The results of the article were compiled in accordance with the Preferred Reporting Items for Systematic Reviews (PRISMA) guidelines and protocols. The process of conducting an article search was executed with the PICOT framework. it is known that we included resistant starch intervention and it may include 5 type of resistant starch diet, so not specific to 1 type of resistant stach.

Figure 1 A total of 243 articles were retrieved based on keywords, as determined by MeSH, for the purpose of conducting a thorough assessment to assess article eligibility. Eligtability results **Figure 2** show if the article has good quality so that it is able to describe blood glucose and resistant starch. eligibility test results show a value of more than 75% of the entire article. The articles that met the criteria established by the researchers conducting the study were included in the sample. all 15 articles are included to the **Table 2** for analysis. Fifteen studies examining diverse RS interventions for individuals with diabetes mellitus were included in this systematic review. Eight of the fifteen articles examined demonstrated a reduction in blood glucose levels following the RS intervention that was statistically significant.

However, the decrease in blood glucose levels observed in seven additional articles failed to reach statistical significance. Thus, it may be said that hospital intervention lowers diabetic patients' blood glucose levels. The findings align with a meta-analysis conducted by Xiong et al. (2021) on the relationship between glycemic control and RS. The study found that supplementing with RS significantly decreased fasting plasma glucose levels but had no effect on HbA1c levels.The results of the subgroup meta-analysis indicated that the impact was more pronounced in cases where the duration of the intervention exceeded 8 weeks or when the daily dose of resistant starch exceeded 28 g. Xiong et al.'s meta-analysis from 2021 differs from this systematic review in that it did not include diabetic patients as respondet in the article screening (9).

The study mentioned above produced encouraging findings. These findings are consistent with the earlier meta-analysis. Wang et al.'s 2020 study revealed that while the placebo group did not experience a significant drop in fasting insulin or HbA1c, the intervention group did. While both HOMA-IR and fasting plasma glucose improved, there was no discernible change. By decreasing blood glucose in patients with type 2 diabetes, the innovative high-RS rice as a staple diet may offer prospective health benefits when substituting for widely consumed ordinary rice. (1). Similarly, resistant starch types 1 and 2 appear to alter glycemia differentially, suggesting that they may regulate glucose homeostasis via distinct pathways, according to a systematic review and prior meta-analysis that examined 36 RCT studies. To fully understand the impact of resistant starch types 3, 4, and 5 on glucose metabolism, more investigation is needed. For patients with T2D or prediabetes, adding resistant starch to their diet as a dietary intervention may stop their glycemic control from getting worse (2).

In addition to the meta-analysis, there are intervention studies in which blood glucose levels are lowered by RS outcomes. When compared to white rice, resistant starch (OR) rice can dramatically lower postprandial plasma glucose levels in patients with type 2 diabetes (20). Similarly, compared to the food in the control group, Sanders et al.'s research from 2021 demonstrates a significant decrease in fasting blood sugar, an increase in hydrogen respiration, and a decrease in FFA (free fatty acid) concentrations following the last postprandial period when potatoes containing RS were given. Previous studies have also clarified why increasing the heating procedure and then cooling it for an hour at 4°C did not raise RS levels or lower the estimated glycemic index (25). One systematic review of RS types 1 and 2 provided an explanation for how this form of RS may impact glucose homeostasis. since it seems to have varying effects on glycemia (26).

In addition to focusing on individuals with diabetes, a number of studies have looked at how hospital interventions affect respondents who do not have the disease. In 2015, Sonia et al. conducted a study to investigate the impact of starch retrogradation on healthy individuals. Their findings indicated that reheating cooked white rice after it had been chilled for 24 hours at 4°C would lower its glycemic response in comparison to cooking it fresh. Additionally, according to in vitro research, rice cooked with coconut milk and the cooling-reheating method has a higher resistant starch content than freshly cooked rice (27).

A homopolysaccharide made up of glucose units is starch. There are two types of homopolysaccharides: amylose, which has 500–2000 glucose units, and amylopectin, which has more than one million glucose units. Approximately 98–99% of the dry weight of starch is composed of homopolysaccharides (8). The enzymes α-amylase, glucoamylase, and sucrase-isomaltase hydrolyze starch in the small intestine to create monosaccharides that are subsequently absorbed (28). Three types of starch are distinguished by their digestibility: resistant starch (RS), slowly digestible starch (SDS), and rapidly digestible starch (RDS) (29). Digestive enzymes break down RDS in less than 20 minutes, whereas SDS takes longer -less than 120 minutes- to break down.

Resistant starch (RS) is a percentage of starch that travels to the large intestine, where it can ferment since it is not fully broken down by digestive enzymes in the small intestine (i.e., it is not hydrolyzed into glucose) (30). There are five categories for RS, numbered RS1 through RS5. The protein matrix and intact cell wall of RS1, a starch granule (amyloplast), operate as a physical barrier to prevent enzymatic hydrolysis (31). The majority of raw starch (RS 2), also known as uncooked granular starch, travels through the small intestine without being transformed into glucose (30). Amylose that has undergone retrogradation is known as RS3 (30) The level of resistant starch decreases in RS3 due to the gelatinization of cooked starch, whereas the level of RS increases due to the retrogradation of the starch during cooling. RS4 is a starch that has undergone chemical modification to make it resistant to the α-amylase enzyme's hydrolysis (30) In order to create an amylose-lipid complex that is resistant to digestive enzymes, RS5 is made up of amylose molecules that have first complexed with lipid molecules and then formed a single-helix complex with starch molecules. In addition to the hospital types that have been split out, hospital supplements have also been turned into interventions in a number of research projects.

Even though RS is still being broken down into little bits as it enters the digestive tract, the amylase enzyme in the small intestine is responsible for turning it into monosaccharides like glucose. Digestion enzymes are unable to hydrolyze resistant starch due to the nature of the lengthy chains and strong bonds that make up starch. Resistant starch does not absorb in the small intestine; rather, it just flows through it. A portion of the carbs that are taken are not fully absorbed because of resistant starch absorption. Remember, too, that the carbohydrates you eat still contain RDS and SDS. Blood glucose will undoubtedly still rise in the presence of RDS and SDS, but it will not rise sharply-especially after eating.

Even if glucose serves as the body's primary energy source, RDS and SDS must still be present. Simply put, it's to ensure that blood glucose levels do not rise sharply after meals. Keep in mind that diabetics typically have issues with the body's cells absorbing glucose, so controlling their food intake can help to maintain stable blood glucose levels. For those with diabetes, increasing RS levels in carbohydrates may be the best option for managing their condition on their own, particularly with regard to food.

CONCLUSION AND RECOMMENDATION

A comprehensive examination of 15 articles revealed that the implementation of resistant starch (RS) interventions utilizing different varieties of RS were efficacious in reducing blood glucose levels among individuals with diabetes. To support the findings of more important research, more investigation is necessary. The limitation of this study is that the analysis of resistant starch in general is not specific to 1 type of resistant starch. So, it is hoped that the next study will analyze by focusing on one type of starch resistance only.

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