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THE ROLE OF MILLETS IN DIABETES PREVENTION AND CONTROL: A COMPREHENSIVE REVIEW

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Abstract

Sorghum and other millets are highly nutritious, drought-tolerant crops with a low environmental impact. Their low Glycaemic Index (GI) makes them beneficial for diabetes management. A systematic review and meta-analysis of 65 studies found that millets have a significantly lower GI (52.7 ± 10.3) compared to milled rice (71.7 ± 14.4) and refined wheat (74.2 ± 14.9). Specific millets like teff, foxtail, Job's tears, and fonio had the lowest mean GI. Diabetic patients consuming millet long-term experienced significant reductions in fasting and post-prandial blood glucose levels by 12% and 15%, respectively, and a notable decrease in HbA1c levels in pre-diabetic individuals. Minimally processed millets also reduced the GI of meals by 30% compared to milled rice and refined wheat. Thus, millets are effective for diabetes management and prevention, suitable for individuals with diabetes, those at risk, and healthy individuals.

Keywords: Millets, Sorghum, Diabetes, Glycaemic Index, Meta-Analaysis

INTRODUCTION

Because of the increasing prevalence of diabetes mellitus (DM) and the difficulties that it causes, healthcare systems and individuals all over the world are under a significant amount of strain, which makes it a significant problem in the field of global health. A decrease in insulin synthesis or its action, or both, is the defining characteristic of this disorder. This condition causes an increase in blood glucose levels, which can lead to major complications that affect a variety of organ systems. One of the most important things that can be done to control and prevent diabetes is to make adjustments to one's lifestyle, particularly with regard to ones diet.

Millets are a type of small-seeded grains that include sorghum (*Sorghum bicolor*), pearl millet (*Pennisetum glaucum*), and finger millet (*Eleusine coracana*). There has been a lot of interest in millets because of the potential health benefits that they may offer. There is an abundance of dietary fiber, protein, vitamins, and minerals in millets, which have been consumed for a significant amount of time across a significant portion of Africa and Asia. Because of the delayed digestion of their complex carbohydrates, it may be feasible to achieve better control of glycemic levels.

Despite the fact that millets have a nutritional profile and have been consumed historically, there has been a growing interest in the specific impact that millets have on diabetes mellitus; nevertheless, these effects have not been completely researched. In light of the fact that the existing body of research only offers partial explanations, it is necessary to conduct a comprehensive evaluation using meta-analysis in order to acquire a more comprehensive understanding of the role that millets play in the prevention and control of diabetes.

A complete literature review and meta-analysis on millets and their capacity to treat diabetes mellitus and lower the chance of developing the condition is going to be carried out as part of this research project. The purpose of this study is to give light on the effects of millets on glycemic control, insulin sensitivity, and related biomarkers. The goal of this study is to synthesise current data in order to provide information that can be used to influence dietary recommendations and public health efforts that aim to lessen the impact of diabetes mellitus.

OBJECTIVE

1. To analyze fasting, post-prandial glucose level, insulin index and HbA1c outcomes in a meta-analysis

METHODS

The systematic review was carried out by the following steps: (1) collecting all of the pertinent studies on the glucogenic effect of millets in comparison to other staple foods; (2) reviewing the methods that were used to study this; (3) conducting a regression analysis to determine the effect of millets in managing diabetes; and (4) conducting a meta analysis to evaluate the scientific evidence on millets' capacity to reduce insulin concentration, HbA1c biomarker, and fasting and post-prandial blood glucose concentration, as well as their impact on the management of individuals with type 2 diabetes mellitus and prediabetic individuals in comparison to non-millet-based regular diets or other staples. Beginning in October 2017 and continuing through February 2021, the systematic review was carried out. The protocol for the study has been recorded in the Research Registry (Unique Identification Number; reviewregistry1094), and a PRISMA checklist consisting of 27 items was utilized in order to carry out the investigation of the systematic review and meta-analysis.

Search, Inclusion, and Exclusion Criteria

The search consisted of selecting all of the research studies that were conducted in English between the years 1950 and the last quarter of 2020. An initial scoping study was carried out by using PubMed and MEDLINE to check for studies that overlapped with the research question of the systematic review. This was done in accordance with the guidelines provided by Atkinson and Cipriani, 2018. Subsequently, a detailed search was carried out by using search engines such as Google scholar, Scopus, Web of Science, PubMed (MEDLINE), CAB Abstracts ClinicalTrials.gov, grey literature, and other Clinical Trial Registries. The search was carried out using the search strategy and keywords that were indicated in Table 1. Additional screening was performed to determine the relevance of the study, the completeness of the information, and the quality of the research based on the inclusion.

Inclusion Criteria

Human subjects have participated in experiments with a wide variety of millets, such as sorghum, pearl, little, kodo, barnyard, foxtail, proso, teff, fonio, and Job's tears. 2. In cases where human research on certain millets were severely lacking or nonexistent, such as with teff and fonio, in-vitro studies were nevertheless taken into account. 3. The next stage of screening included studies that included information on GI, fasting, post-prandial glucose level, insulin index, and HbA1c of any millets. 4. A study that was carried out in any part of the world was chosen. 5. Research designs that comprised both randomized cross-over and self-controlled case studies were considered. 6. Research including healthy individuals, those at risk for developing diabetes, and those with type 2 diabetes were all considered. 7. Articles that were peer-reviewed were the only ones that were chosen.

Exclusion Criteria

Review articles, animal studies, and papers with incomplete or questionable methodology were all part of this category. The meta-analysis did not include papers that only used figures to show glucose response levels and did not provide numerical values.

Data Collection Process

The study's methodology and inclusion/exclusion criteria are displayed in the PRISMA flow diagram. The publications that were downloaded were carefully selected to address the research topics. If just the abstract seemed right, we would go on to downloading open access publications and contacting the journal's editors, authors, and any relevant universities with library resources or subscriptions to get the full papers. We bought some whole papers. If any information on gastrointestinal (GI) and glycemic response was lacking after collecting the full manuscript, the authors were contacted to seek complete data for the meta-analysis. Each paper underwent a manual search to uncover additional research publications that were relevant. Additionally, full publications were obtained and incorporated into the study when applicable, and references within the chosen articles were also searched.

Following data extraction from the articles and documentation in an Excel sheet, regression analysis, forest plots, and publication bias plots were executed.

Data Items and Extraction

The analysis considered numerical factors such as mean Glycaemic Index (GI) with standard deviation (SD), mean fasting and postprandial blood glucose concentrations with SD, sample sizes for intervention and control groups, and mean insulin levels with SD. Control samples included roots, tubers, legumes, white and brown rice, refined wheat, and wheat. Data for glucose or white bread were used as controls if none were provided. Mean GI and SD were calculated or extracted, converting standard error (SE) to SD when necessary. The GI was calculated using the formula $F/R \times 100$, where F is the mean AUC for the test food and R is the mean AUC for the control food, or by contacting the study authors. Fasting and postprandial glucose concentrations were entered into an Excel spreadsheet in mg/dl, converting mmol/l to mg/dl for consistency. HbA1c was recorded as a percentage. Participants' health conditions (diabetic, prediabetic, and non-diabetic), types of cooked products (pancake, flatbread, porridge, cooked grain), types of samples used (grain, flour, batter), and cooking methods (baking/roasting, boiling, steam cooking) were recorded using categorical data. This comprehensive data collection allowed for a detailed comparison of the effects of consuming millet-based foods on GI and blood glucose metrics.

Meta-Analysis

For the meta-analysis, researchers drew from 65 human trials that employed different kinds of millets. The investigations included GI (112 observations) and glucose levels at 0 minutes (fasting blood glucose) and 120 minutes (post-prandial blood glucose) in healthy, pre-diabetic, and diabetic individuals. The study's control samples were compared with the millets. Forest plots were used to get the sample heterogeneity (I2) and overall test results. P-values were used to test for the significance of the effect. Each of the five outcomes' data were analyzed using one of two models: the random effect model or the fixed effect model. Whenever the level of heterogeneity was less than 50%, the results were interpreted using a fixed effect model. Furthermore, a fixed effect model was employed for interpretation in cases where there was only one source of information from the same population.

Subgroup Analysis

We conducted three subgroup analyses by looking for potential changes to the five outcomes. This was done according to the type of millet used in the studies, the health condition of the participants (non-diabetic, pre-diabetic, type 2 diabetic), and the type of control (glucose, refined wheat, rice, whole wheat, pulses and legumes, maize/corn, other cereals, and others). Take note that in a lot of studies, the participants' age was stated as the average age in years. Therefore, we did not perform an age-based subgroup analysis.

Glycemic index, fasting blood glucose, postprandial blood glucose, insulin level, and hemoglobin A1c were the five outcomes included in the meta-analysis, which drew from 65 human studies. Since several writers examined various millet varieties, it's possible that the same author was involved with multiple crops. As a result, 99 studies authored by 65 different researchers were located. Of these, 19 focused on finger millet, 20 on foxtail millet, 10 on sorghum millet, 7 on pearl millet, 4 on little millet, 3 on kodo millet, 1 on proso millet, and 15 on a combination of these millets. Additionally, 11 observations were made for GI, and two in vitro investigations were included for tiff and folio.

Descriptive Statistics

Table 1 shows the mean GI of each millet tested in vivo along with refined wheat and milled rice. The overall mean GI of millet, milled rice and refined wheat were 52.7 ± 10.3, 71.7 ± 14.4, and 74.2 ± 14.9, respectively. Except for proso millet, all other millets fell in the low to medium GI food category. Table 1 also shows the in vitro GI of two types of millets.

Meta-Analysis

A meta-analysis evaluated the impact of millet-based foods on Glycaemic Index (GI), fasting glucose, post-prandial glucose, HbA1c, and insulin levels, comparing them to control samples or pre-intervention values. Using fixed and random effect models, all millets, except small millet, demonstrated significantly lower GIs than control foods like white refined wheat, rice, maize, and glucose. Specific findings included:

- Fonio: Minimal heterogeneity (0%) and significantly lower GI ($p < 0.01$).

- Little Millet: High variability (97%) with no significant GI reduction ($p = 0.31$).
- Teff: Significant GI reduction ($p < 0.01$) despite considerable heterogeneity (75%).
- Barnyard Millet: Low GI ($p = 0.04$) with high heterogeneity (95%).
- Sorghum: Substantially low GI ($p = 0.03$) with moderate variability (75%).
- Pearl Millet: Minimal heterogeneity (38%) and significantly low GI ($p < 0.01$).
- Kodo Millet: Modest heterogeneity (50%) with significantly low GI ($p < 0.01$).
- Foxtail Millet: High variability (89%) with significantly low GI ($p < 0.01$).
- Finger Millet: High variability (88%) with significantly low GI ($p < 0.01$).
- Mixed Millets: Fairly low GI ($p < 0.01$) with high variability (93%).

TABLE 1 A comparison of millets' glycaemic index measured in vivo with control samples using different statistical analyses.

Type of millet	Mean glycaemic index	Regression coefficient (reduction in GI vs GI for maize) (%)	Meta-analysis (significant effect of millet-based diet on GI vs. control)		Glycaemic index food category
			Fixed effect model	Random effect mode	
Barnyard millet	42.3	−27.2	P < 0.01	P = 0.02	Low
Fonio	42.0	−28.9	P < 0.01	P = 0.07	Low
Foxtail millet	54.5	−29.9	P < 0.01	P < 0.01	Low
Job's tears	54.9	−35.6	P < 0.04	P = 0.4	Low
Mixed millet	42.7	−26.4	P < 0.01	P < 0.01	Low
Teff	35.6	−27.1	P < 0.01	P = 0.31	Low
Finger millet	61.1	−26.0	P < 0.01	P < 0.01	Intermediate
Kodo millet	65.4	−20.1	P < 0.01	P = 0.21	Intermediate
Little millet	64.2	−13.3	P = 0.98	P = 0.31	Intermediate
Pearl millet	56.6	−18.1	P < 0.01	P < 0.01	Intermediate
Sorghum	61.2	−22.7	P < 0.01	P < 0.01	Intermediate
Control					
Milled rice	71.7	−11.4	NA	NA	High
Refined wheat	74.2	−15.9	NA	NA	High
In vitro studies					

Teff	54.3	NA	P < 0.01	P < 0.01	Low
Fonio	56.3	NA	P < 0.01	P < 0.17	Low

Insulin Level

The insulin index, fasting insulin level, and Area Under the Curve of Insulin (AUC) were all measured in five studies that examined the effects of reducing GI. The results demonstrated a significant decrease in fasting insulin level ($p < 0.01$) and an insulin index in the fixed effect model, but no significant effect on AUC insulin ($p = 0.24$).

Fasting and Post-prandial Blood Glucose Level

A substantial decrease in blood glucose concentration was observed in all nine millets evaluated for post-prandial blood glucose in comparison to the control sample in short-term trials ($p < 0.01$). Abolition of overnight fasting did not significantly alter fasting blood glucose levels in short-term trials. Contrarily, Figures 5, 6 demonstrate that consuming millets for an extended period of time significantly reduced fasting (SMD −0.89 with 95% confidence interval of −1.11; −0.67) and postprandial (SMD −0.95 with 95% confidence interval of −1.46; −0.44) blood glucose levels ($p < 0.01$). No significant difference in post-prandial blood glucose levels was found between control samples and kodo millet, tiny millet, and barnyard millet when a random effect model was used. Since both fonio and proso millet were derived from the same reference, and since the samples were identical, the results were interpreted using a fixed effect model, which showed a substantial effect in lowering post-prandial blood glucose levels.

To find out how a millet diet affected HbA1c levels, six long-term studies were performed. When they consumed millet for an extended period of time, their HbA1c levels decreased. However, this decrease was much smaller when compared to when they had a control diet based on rice or their HbA1c levels before the intervention (baseline) ($p < 0.01$).

Table 2 Heterogeneity and p values from fixed and random effect models from forest plots on glycaemic index, fasting and post-prandial blood glucose levels.

Millet	Heterogeneity (I^2) (%)	Fixed effect model (p)	Random effect model (p)	95% confidence interval
Glycaemic index(GI)				
Fonio	0	<0.01	0.07	−6,655.5; −3,803.9
Little millet	97	0.98	0.31	−52.02; 27.43
Teff	75	<0.01	0.31	−1.98; −0.55
Job’s tears	97	0.04	0.40	0.08; 2.46
Barnyard millet	95	0.01	0.04	−29.18; −0.99
Sorghum	75	<0.01	<0.01	−2.59; −0.20
Kodo millet	50	<0.01	0.04	−2.91; −0.13

Mixed millet	93	<0.01	<0.01	−10.15; −3.73
Finger millet	88	<0.01	<0.01	−5.35; −2.85
Pearl millet	38	<0.01	<0.01	−2.11; −0.65
Foxtail millet	89	<0.01	<0.01	−5.77; −1.44
0 min/fasting blood glucose level				
Fonio	93	0.80	0.70	22.77; 21.01
Little millet	0	0.83	0.71	−1.53; 1.42
Teff	87	<0.01	0.77	10.20; 9.64
Job's tears	51	0.03	0.20	−1.19; 0.34
Barnyard millet	40	0.04	0.13	−1.19; 0.22
Sorghum	0	0.97	0.99	−0.30; 0.31
Kodo millet	0	0.49	0.25	−0.31; 0.09
Mixed millet	86	<0.01	0.21	−0.14; 0.32
Finger millet	86	<0.01	0.03	−2.48; −0.13
Pearl millet	55	<0.01	0.05	−0.52; 0.00
Foxtail millet	33	<0.01	0.09	−56; 0.04
120 min/post-prandial blood glucose level				
Fonio	28	<0.01	0.17	−9.09; 4.98
Little millet	99	<0.01	0.48	84.88; 88.11
Proso millet	87	<0.01	0.19	−2.54; 0.70
Barnyard millet	97	<0.01	0.33	−28.09; 120.33
Pearl millet	86	<0.01	0.07	−2.89; 0.14
Sorghum	0	<0.01	0.01	−0.82; −0.12
Mixed millet	90	<0.01	0.02	−1.97; −0.27
Finger millet	79	<0.01	<0.01	−3.51; −0.94
Foxtail millet	91	<0.01	0.02	−3.68; −0.29

Area under the curve glucose				
Finger and foxtail millet	11	<0.01	0.03	−3.24; −0.23
Proso millet	37	0.98	0.98	−0.65; 0.66

Subgroup Analysis

The subgroup analysis revealed that everyone's fasting blood glucose levels were significantly reduced when they consumed a millet-based diet for more than three months, regardless of whether they were non-diabetic, pre-diabetic, or diabetic, when compared to those who consumed a regular rice or wheat-based diet ($p < 0.01$). The groups did not differ significantly ($p < 0.13$). Subgroup analysis revealed a substantial decrease in blood glucose levels among type 2 diabetes patients compared to non-diabetic ones, with a post-prandial blood glucose level of less than 0.01. The small number of research on pre-diabetic participants made it impossible to discern this difference between diabetic and non-diabetic subjects. Although there was no statistically significant subgroup effect ($p = 0.69$) according to millet type in lowering fasting and postprandial blood glucose levels, this does suggest that long-term millet consumption may lower both types of blood glucose.

Conclusion

Based on the findings of this comprehensive review and meta-analysis, it is evident that the millets that were examined possess significant promise in the control of diet and the prevention of diabetes. Not only does it have significance for policy, but it also has ramifications for nutrition-sensitive agricultural interventions using millets and sorghum, as well as for the spread of the good effect that millets and sorghum have for glycemic management.

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