Potential of Indonesian Community Food Sources which are Rich in Fiber as an Alternative Staple Food for Type 2 Diabetics: A Scoping Review

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Abstract

BACKGROUND: Staple foods as a source of carbohydrates contribute most of human energy needs. Based on Perkeni’s recommendation, diabetic patients can consume at least 45–60% of carbohydrate sources. In addition, several previous studies have shown that increasing the adequacy of dietary fiber above 20–25 g/day can improve glycemic control.

AIM: Our scoping review investigated the potential of Indonesian food sources, namely, sorghum and corn as a source of carbohydrates and also fiber as a substitute rice for diabetic patients.

METHODS: We systematically used electronic databases searched such as PubMed, Science Direct, Web of Science, Portal Garuda, Sinta Ristekbrin, and Google Scholar. We choose the relevant documents used experimental animals and humans’ studies then published between 2011 and 2021.

RESULTS: In total, 17 relevant articles discuss the relationship between giving corn or sorghum with blood glucose levels of animal studies and human. Some studies showed that the effect of eating sorghum or its derivatives can reduce blood glucose. As well as, the other articles indicated eating corn or its derivatives also decrease glycemic levels of animal studies and human. Some studies showed that the effect of eating sorghum or its derivatives can reduce blood glucose.

CONCLUSIONS: Sorghum and corn have the potential as an alternative staple food to achieve a better glycemic response in diabetic patients.

Introduction

Indonesia and several countries in the world are still struggling to deal with the COVID-19 pandemic. Comorbid disease is one of the important factors in the treatment of COVID-19 patients. Diabetes mellitus is one of the major comorbid diseases that are often found in COVID-19 patients [1]. Poor glycemic control in diabetic patients is related to immune system dysfunction [2]. Hyperglycemic conditions experienced by patients with diabetes mellitus can cause disturbances in cytokine production, phagocytosis, and the ability of immune cells to kill microbes [3]. Hyperglycemia in patients with diabetes mellitus is caused by a carbohydrate metabolism disorder due to reduced/absence of insulin produced by pancreatic beta cells. In field practice, good glycemic control can be achieved by applying the general pillars of diabetes mellitus management that are diet, exercise, medication, and education.

Eating disorder, especially in food choices of source of carbohydrate and fiber, becomes the major problem in diabetes patient. Primanda et al. (2011) and Puri (2019) mention that several problems related to the diet of diabetics include the ability to determine the amount of energy needs, selection of carbohydrate sources, fiber consumption, salt use, and consumption of sodium sources and intake of fat sources [4], [5]. Perkeni (Perkumpulan Endokrinologi Indonesia) recommends carbohydrate consumption between 45% and 65% of total energy needs diabetes patient. Rice (Oryza sativa L.) is the staple food for a greater number people in Asia [6], [7]. Rice is one of the sources of carbohydrate. White rice is predominantly consumed by many people without exception diabetes patients. Some studies showed that white rice has a high glycemic index (GI) and glycemic load, low in fiber, polyphenols, and micronutrients such as magnesium that may benefit in glucose metabolism [8], [9], [10]. Consumption of white rice is often associated with increased blood glucose levels in diabetic patients. Diversification of staple foods is very important as an effort to control blood glucose levels in diabetics.

Corn is one of the commodities that have the potential to develop as an alternative source of carbohydrates that high in fiber [11]. In the context of...
Sorghum is an ancient cereal grain that belongs to the grass family (Poaceae). Some farmers in India, Thailand, and Indonesia, especially Java and Nusa Tenggara, cultivate sorghum in the traditional way. However, several developed countries, such as the United States, Australia, and several European countries, have managed modern sorghum plants using advanced technology such as quality hybrid seeds and fertilization tailored to soil fertility and plant needs [17], [18]. Sorghum contains bioactive compounds including phenolics, sorghum is a food source of antioxidants due to the presence of phenolic components such as phenolic acids, flavonoids, and condensed tannins as well as pegan fibers such as resistant starch and beta-glucan [19], [20].

The objective of our scoping review is to provide several evidence that related potential of corn and sorghum as a substitute for the main staple food (rice). The basic question that may arise is the effect of consumption of corn or sorghum on increasing blood glucose levels. Furthermore, other substances contained in corn or sorghum also have benefits for diabetes patients in controlling blood glucose levels.

Methods

This scoping review will be carried out some stages: (1) Identifying the research question, (2) identifying relevant studies through electronic databases (i.e., PubMed, Science Direct, Web of Science, Portal Garuda, Google Scholar, and Sinta Ristekdikti), (3) selection of studies to be included based on inclusion criteria such as we using the following search strategy: (“corn” OR zea mays OR corn flour; “sorghum” OR sorghum flour; “alternative staple food for diabetic patient” OR fiber contain in staple food; staple food AND GI OR GI of corn processing OR GI of sorghum processing). Then, the studies must have (a) treatment/intervention; (b) been published from January 1, 2011, to December 31, 2020; (c) provided an information about blood glucose response the respondent; and (d) reported the processed form used (4) charting and categorizing extracted data in a pretested data extraction form; and (5) collating, summarizing, and reporting the results. Detail process identifying of studies is presented in Figure 1.

Results

Totally, we got 17 articles that suitable with our topic. The main characteristic of the article is presented in Table 1. Nine articles presented about the effect of giving corn and its processed products to blood glucose levels healthy people, diabetes patient, and experimental animals. Then, there were eight articles that met the inclusion criteria regarding the topic of sorghum. Most of the articles contain research study designs using experimental with some samples using Wistar rats or humans. Overall, each study discusses the main effect of corn or sorghum in blood glucose levels.

All articles are taken using experimental methods. Most of the samples in the research articles obtained were experimental animals (Wistar rats), healthy humans, and diabetes patients, respectively, there were nine articles, four articles, and three articles. The intervention that gives to subjects in articles in the form of extracts, flour, or food/meal. Whole article using glucose levels as an indicator of the effect of giving corn/ sorghum. However, there were some additional results such as composition and nutritional value of extract/ flour/or food, body weight, fat profile, liver function, and insulin levels. In general, giving corn or sorghum to
Table 1: Original article included in review

| No. | Authors and years                     | Study design, sample, variable, Instrument, analysis                                                                 | Outcome of analysis factors                                                                 | Summary of results                                                                 |
|-----|---------------------------------------|-----------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------|
| 1   | Dada et al., 2015 [16]                | Design: Quasi-experimental intervention study design Sample: 32 participants (11 males and 21 females) Variable: Corn flour with tempeh flour supplementation and blood glucose levels Analysis: One-way ANOVA with a Tukey test analysis | Baseline characteristic patients, glycemic response indices of corn meals and Duncan’s multiple range test (DMRT) | Methods of preparing a meal from corn affect glycemic response                      |
| 2   | Song et al., 2015 [24]                | Design: Quasi-experimental intervention study design Sample: 12 healthy adults, 21–50 years old Variable: Muffin made with wheat, rice, corn, oat, and barley, glycemic responses (AUC). Amylose contain Analysis: Repeated ANOVA, one-way ANOVA with Tukey’s test | Baseline characteristic subject, random blood glucose                                       | GI of muffins baked with wheat, rice, corn, oat, and barley flour is 74, 79, 73, 55, and 55. Corn, oat, and barley muffins have amylose higher than other. Amylose in blood related with GI potency |
| 3   | Djunaidi et al., 2014 [25]            | Design: Laboratory experimental design Sample: 30 rats Variable: The composite flour (50% sweet potato, 30% corn, and 20% cowpea) and hypoglycemic effect Analysis: One-way analysis of variance (ANOVA) and Duncan’s multiple range test (DMRT) | Blood glucose level, body weight, and feed intake weight                                       | The composite flour could reduce plasma glucose level on diabetic rats and did not give negative effects on body weight and food consumption |
| 4   | Lushovyy et al., 2014 [26]            | Design: Experimental study Sample: 30 respondents (Male) Variable: The effects of whole grain high-amylose maize flour as a source of resistant starch, blood glucose, satiety, and food intake Analysis: ANOVA, and the Tukey–Kramer post hoc test | Blood Glucose levels, Satiety, and Food Intake                                               | HAM flour as a source of RS and incorporated into a cookie was associated with better glycemic control in young men |
| 5   | Forester et al., 2012 [27]            | Design: Experimental study Sample: 10 rats Variable: Epigallocatechin-3-gallate, blood glucose levels Analysis: Two-tailed Student’s t-test | Blood glucose levels                                                                         | EGCG acutely reduces postprandial blood glucose levels in mice when coadministered with CCS and this may be due in part to inhibition of e-amylase. The relatively low effective dose of EGCG makes a compelling case for studies in human subjects |
| 6   | Brits et al., 2011 [28]               | Design: Experimental study Sample: 36 Wistar rats Variable: The effect of resistant starch enriched breads, postprandial glycemic responses Analysis: One-way analysis of variance using the Proc GLM in the SAS software (SAS Institute, Cary, NC) and Duncan’s Test | Feed intake, body weight gain, liver weight, fecal pH, postprandial blood glucose response, blood triglycerides, and total cholesterol | Maize bread has a lower glycemic index than wheat bread, and the magnitude of the effect of RS on glycemic response depends on type of bread |
| 7   | Gallo et al., 2021 [29]               | Design: Double-blind, crossover, randomized clinical trial Sample: 13 healthy male Variable: Gluten-free sorghum bread genotypes on glycemic and antioxidant responses Analysis: One-way ANOVA with Tukey post hoc test (food composition. Antioxidant status-ORAC and FRAP; glucose and insulin AUC between glucose and test meal. Two ways repeated ANOVA for examining the effect of test meal on postprandial glycemic and insulimetic response with post hoc Bonferroni) | Subject characteristics, bread composition chemical, postprandial glucose, insulin response antioxidant capacity | All sorghum bread showed significantly more fiber than rice bread (control). Brown sorghum bread was classified as low GI, bronze and white as medium GI, and control as high GI. Brown sorghum bread presented a low carbohydrate content, a significant amount of fiber, and a significantly lower 3 h AUC glucose response than those of the control, aside from the highest antioxidant activity value (p ≤ 0.001) Supplementation of 65 g of RS rich rava (broken sorghum) for 90 days, significantly reduced body mass index (BMI), fasting glucose (FG), TC (total cholesterol) and LDL-C (low-density lipoprotein) (p = 0.05) in diabetic subjects (n = 15), while a non-significant reduction was found in HbA1c, eAG (estimated average glucose), TG, HDL-C and VLDL-C |

(Contd...)
Table 1: (Continued)

| No. | Authors and years | Study design, sample, variable, Instrument, analysis | Outcome of analysis factors | Summary of results |
|-----|-------------------|-----------------------------------------------------|----------------------------|-------------------|
| 12  | Salazar-Lopez et al, 2020 [31] | Design: True experimental Sample: 24 male Wistar rats Variable: Extracted sorghum bran (ESB) or raw sorghum bran (RSB) (Sorghum bran supplementation), the plasma glucose, triglycerides (Tg), total cholesterol (TC), high-density lipoprotein-cholesterol (HDL-C), and low-density lipoprotein-cholesterol (LDL-C) concentrations Analysis: To compare the dietary groups, a one-way analysis of variance (ANOVA) followed by a Tukey comparison test was used. The level of significance was p < 0.05. Tests of the correlations between the response variables were calculated using standard Pearson correlation | Phenolic profile, adipocyte’s size in abdominal tissue of rats, plasma glucose, lipid profile, antioxidant activity | The intake of HFD supplemented with ESB or RSB hindered the fat storage in adipocytes of abdominal tissue, dyslipidemia, and the loss of glucose homeostasis. A positive correlation between inflammation biomarkers (interleukin-1β and interleukin-6), and glucose homeostasis was observed, while a negative correlation between antioxidant capacity (TEAC) and interleukin-1β and interleukin-6 was observed. |
| 13  | Skieluma et al., 2019 [32] | Design: True experimental Sample: Diabetic rats Variable: Sorghum-tigernut a fasting blood glucose level. Analysis: Analysis of variance (ANOVA) | Proximate composition sorghum-tigernut flour blend, body weight of the rats, fasting blood glucose levels of diabetic rats | The sensory of blend flour can acceptable. Giving flour mix shows a decrease fasting blood glucose level in 48 and 72 h after test diet. The sorghum-treated groups also showed statistically significant (p < 0.05) decrease in liver dysfunction indices and markers of oxidative damage compared with the control. In addition, statistically, the diets significantly decreased (p < 0.05) the relative expression of superoxide dismutase, glutathione peroxidase, glutathione, phosphohydroxycinases, and hexokinase genes in the experimental animals compared with the control. |
| 14  | Olaowe et al., 2018 [33] | Design: True experimental Sample: 36 healthy female Wistar albino rats with diabetes mellitus Variable: Formulation of sorghum diet, blood glucose, and liver Analysis: One-way ANOVA with post hoc Dunnett’s | Effect of fermented sorghum diet on blood glucose before and after induction of alloxan, alloxan transaminase activity in the erythrocyte, ALT activities in the liver and AST activities in the liver of alloxan-induced diabetic rats | The average blood glucose level was reduced after consuming sorghum grains, particularly at 45–120 min intervals. The average glucose was significantly reduced by about 26%. Serum levels of glucose were significantly lower in mice that got 0.5% sorghum extract and 1% sorghum extract. |
| 15  | Poquette et al., 2014 | Design: Randomized crossover Sample: 10 boys Variable: Sorghum seeds to decrease insulin and glucose levels | Flour composition and starch analysis, mufin composition and starch analysis, glucose and insulin yield | The average blood glucose level was reduced after consuming sorghum grains, particularly at 45–120 min intervals. The average glucose was significantly reduced by about 26%. Serum levels of glucose were significantly lower in mice that got 0.5% sorghum extract and 1% sorghum extract. |
| 16  | Park et al., 2012 [34] | Design: True experimental Sample: 21 rats with high fat diet Variable: Sorghum extract on insulin sensitivity through PPAR in diabetic rats Analysis: One-way analysis of variance, followed by Dunnett’s multiple-range test | Dietary intake, body weight and various organ weight. Lipid profile, glucose, insulin, AUC of glucose, GOT and GPT | Administration of SE and G reduced the concentration of triglycerides, total and LDL-cholesterol and glucose, and the area under the curve of glucose in non-diabetic rats. |
| 17  | Kim and Park, 2012 [35] | Design: Experimental Sample: 25 male Wistar rats Variable: Sorghum extract, hepatic glucoseonogenesis Analysis: (ANOVA) followed by Duncan’s multiple range test | Dietary intake, body weight, organ weight. Lipid profile, insulin, glucose, glutamic oxaloacetate transaminase, glutamic pyruvic transaminase, AUC of glucose | Administration of SE and G reduced the concentration of triglycerides, total and LDL-cholesterol and glucose, and the area under the curve of glucose in non-diabetic rats. |

Dietary fiber is defined as a component in plants that is not enzymatically degraded into subunits that can be absorbed in the stomach and small intestine [40]. Fiber that is still intact in the large intestine is then fermented by bacteria in the large intestine to form short chain fatty acid which can induce the secretion of the hormones glucagon-like peptide-1, gastric inhibitory polypeptide, and peptide YY which will increase insulin sensitivity and ultimately cause a decrease in blood glucose levels [41].

In general, food that has been eaten will be digested in the gastrointestinal tract and then will be converted into a form of sugar called glucose. Intake of adequate amounts of fiber can help control blood glucose levels by increasing gastric distention which is associated with increased blood glucose levels. Fiber provides a feeling of fullness because it cannot be digested in the stomach so that the digestive process becomes slow which results in a low blood glucose response [42].

Corn fiber is readily digestible after it is cooked or thermally processed become some products. Consumption corn in human and animal laboratory related with improving sensitivity of insulin, increase satiety, and decrease of lipoid profile. The other ingredients in corn that can be used for human research subjects in selected articles showed a positive response where giving corn/sorghum could reduce blood glucose levels.

Discussion

Corn and sorghum are source of carbohydrate besides rice. The present study shows role of corn and sorghum in health benefit as functional foods [36]. Foods can be categorized as functional foods if it is natural food or contain two or more components that can be beneficial to human health [36], [37]. Corn is not only contained carbohydrate, vitamin, and mineral but also specific phytochemical such as phenolic acids. Corn contains carbohydrates by 70–75% and some vitamin (carotenoids, thiamine, riboflavin, niacin, pyridoxine, folate, ascorbic acid, Vitamin E, and Vitamin K), minerals (calcium, magnesium, phosphorus, potassium, sodium, and zinc), and resistant starch [14], [38]. Fiber in corn about 2.2 g/100 g if compared with white rice 0.2 g/100 g [39]. In the other studies, fiber content in corn product like boiled corn was 2.03 mg [15].
products, sorghum has great potential to be processed
the increasing demand for healthier and gluten-free
alternative for gluten-free applications [29], [46]. With
seeds have nutritional potential. Sorghum is an excellent
for 90 days showed good glycemic control based on the
giving sorghum as a substitute for rice in diabetes patients
[45]. Meanwhile, Salazar-Lopert et al (2020) reported that
average glucose was significantly reduced by about 26%
were observed 15 min before and after treatment. The
muffin in a 1-week period, then glucose and insulin levels
studies that have used direct subjects to humans who
digesting foods; however, limited research has explored
GI value in the given composite flour diet where corn is also an ingredient of
the composite flour diet. The benefits of foods with low GI values and high fiber can cause postprandial blood
levels and lower insulin responses so that they
can improve lipid profiles and reduce the incidence of
insulin resistance [37]. From several research reports
conducted on humans and experimental animals, it can
be concluded that giving corn or its processed products
has an effect on reducing blood glucose levels. This
result may associate with high-fiber content and a low GI value in corn that causing the absorption of glucose
into the blood to be slow and can give a taste. Satiety is
longer due to the slow rate of gastric emptying.

Sorghum is a plant that is rich in phytochemicals
and has a low GI. Sorghum seeds contain 10.4% higher
protein than rice [13]. The protein in sorghum divided into
prolamin proteins (such as kafirins) and non-prolamin
proteins (such as globulins, glutelins, and albumins). In
addition, sorghum also contains antioxidants, mineral
elements, especially Fe, fiber, oligosaccharides, and
β-glucan, are a non-starch polysaccharide carbohydrate
component contained in sorghum seeds, making it a
potential source of functional food [29].

Several studies have identified grain sorghum
as a potential functional ingredient in food applications,
and studies using sorghum have shown strong evidence
of decreased plasma glucose levels after consumption
in animal models. Sorghum has been known as slow-
digesting foods; however, limited research has explored
its health effects in humans. There are only two in eight
studies that have used direct subjects to humans who
were given the intervention of consuming sorghum in form
muffin in a 1-week period, then glucose and insulin levels
were observed 15 min before and after treatment. The
average glucose was significantly reduced by about 26%
[45]. Meanwhile, Salazar-Lopert et al (2020) reported that
giving sorghum as a substitute for rice in diabetes patients
for 90 days showed good glycemic control based on the
results of the patient’s glucose and lipid profile [31].

The dietary fiber and tannin content in sorghum
seeds have nutritional potential. Sorghum is an excellent
alternative for gluten-free applications [29], [46]. With
the increasing demand for healthier and gluten-free
products, sorghum has great potential to be processed
in a variety of food applications as a healthy food,
carbohydrate diet and also has the potential to assist in
controlling glucose and insulin levels in humans.

The phenolic components in sorghum have
the function of lowering blood sugar levels. There is
also research on sorghum extract which shows that
administration of sorghum extract can reduce blood
glucose levels in diabetic rats and improve insulin
sensitivity in mice fed a high-fat diet. Phenolic extract
of sorghum can also decrease serum glucose and increase serum insulin in diabetic rats as evidenced by
two studies [34], [35]. The other study giving sorghum
to experimental animals in the form of flour, bread, and
fermentation also showed similar response in lowering
blood glucose, improving hepatic enzyme, and profile
lipid [31], [32], [33]. Decrease in blood glucose occurs
due to phytochemicals compounds contained in
sorghum. The phenols contained can stimulate glucose
and fat metabolism, so as to prevent the accumulation
of glucose and fat in the blood. In its mechanism,
phenolic compounds will inhibit glucose synthesis
by inhibiting the enzymes glucose 6-phosphatase and
fructose 1,6-bisphosphatase which play a role in
reducing the formation of glucose from substrates other
than carbohydrates so that blood glucose levels will
decrease [35], [47].

The dietary fiber content of sorghum is thought
to cause a decrease in blood glucose levels. Dietary
fiber has the ability to lower blood glucose through the
mechanism of inhibiting the absorption of glucose into
the blood [13], [20]. Sorghum is one of the food sources
of antioxidants because of the presence of phenolic
components such as phenolic acids, condensed
tannins, and flavonoids that can provide hypoglycemic
effects and reduce oxidative stress in the treatment of
diabetes mellitus patients.

Conclusions

Sorghum and corn have the potential as an
alternative staple food to achieve a better glycemic
response in diabetic patients. Corn and sorghum
processed products that can be an alternative food for
diabetes mellitus patients can be in the form of bread
and muffins. In addition, corn and sorghum can also be
given as a substitute for flour and rice.

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