

THE IMPACT OF PEARL MILLET ON GLYCEMIC CONTROL AND ITS BIOMEDICAL APPLICATIONS IN CHRONIC DISEASE MANAGEMENT

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ABSTRACT

Diabetes mellitus is becoming a more common and problematic disorder. Treatment plans for preventing diabetes in both high-risk and afflicted patients are mostly credited to food and lifestyle modifications. As a result, it's critical to comprehend the nutritional aspects of dietary interventions. Eating millet-based meals on a regular basis is linked to a lower risk of diabetes. Though its consumption is limited to lower socioeconomic groups, pearl millet is a very nutritious grain that is even better than other major cereals in terms of calories, protein, vitamins, and minerals. Phenolic chemicals found in pearl millet have anti-diabetic properties. As a result, it may be used to make a range of dietary items for people with diabetes. Additionally, it reduces the risk of diabetes mellitus, cancer, cardiovascular diseases, tumor incidence, blood pressure, heart disease, cholesterol, and fat absorption rate, among many other health advantages. As a result, the topic of the present review is pearl millet's involvement in diabetes management.

Keywords: Diabetes mellitus; pearl millet; nutritional importance; health effects.

1. INTRODUCTION

Diabetes, commonly known as diabetes mellitus, is a series of metabolic illnesses characterized by persistently elevated blood sugar levels. It is predicted that the prevalence of diabetes would rise globally from 2.8% in 2000 to 4.4%. It is possible to anticipate that by 2030, there would be approximately 366 million cases of diabetes worldwide. It is often known that after a meal, a diabetic patient's blood glucose level increases dramatically above normal. It's also true that when the body finds it difficult to hold onto the additional glucose for later usage, the quantity of blood glucose in them rapidly drops. Diabetic conditions are divided into types 1 and 2. Since a patient's pancreas is unable to make insulin, type 1 diabetes is also known as juvenile diabetes or insulin-dependent diabetes. However, when the body becomes insulin resistant or is unable to produce enough insulin, type 2 diabetes often develops in adults first. Ninety percent of diabetics worldwide have T2D. Being overweight and engaging in little physical exercise may be the major causes. The additional challenge associated with type 2 diabetes is that it is often detected after adverse consequences have already materialized and has fewer symptoms than type 1 diabetes. The hardening and narrowing of blood arteries due to atherosclerosis involves serious problems brought on by hyperglycemia. Other health problems associated with diabetes include heart disease, stroke, retinopathy, and kidney failure. One percent of instances of blindness globally are caused by diabetic retinopathy, which weakens the small blood vessels in the eye over time. Similarly, renal failure brought on by persistently reduced blood flow is a relatively frequent consequence. Elevated blood glucose levels may potentially result in nerve damage, necessitating limb amputation. Patients with these diseases may have a worse quality of life and engage with others less often.

Other complications include an increased risk of bone fracture in individuals with Type 1 and Type 2 diabetes. It is interesting, therefore, that although the risk of fractures is high overall, people with Types 1 and Type 2 diabetes have correspondingly greater and lower mineral densities than those in stable health. The fracture risks connected to different bone mineral densities may become clearer in light of other diabetes-related factors. People with type 2 diabetes also tend to be less physically active and have greater body mass indices, which increases the risk of fractures with each fall. Despite the increased bone mineral density, the elevation in the body's glucose level physiologically disrupts with glycation, lowering collagen cross-linking and leading to more brittle bone. The parathyroid hormone T2D therefore leads to a greater fracture risk in several convergent ways. Additionally, reduced bone turnover rates in diabetes individuals induce poor fracture healing by interfering with alternate glycaemia with a critical bone remodelling regulator. As a result, fractures worsen diabetes by further limiting a patient's movement.

Another symptom that a patient with type 2 diabetes would have to deal with is muscle weariness brought on by inadequate glycaemic control. This ultimately results in exhaustion and low energy, which deters patients from engaging in physical activity. Patients also lose muscular mass as a result of the body using their broken down muscles as energy. Reduction of muscle mass is one of the primary issues that a diabetic patient must deal with because of this aberrant muscular anabolism. The ensuing loss of motor function causes further medical and psychological issues for the patient.

Millets for Diabetes Control

For those with type-2 diabetes, dietary therapies are an easy and affordable option to improve their quality of life and provide preventative advantages. Therefore, the current guidelines for managing type-2 diabetes advise following safe, nutrient-dense diets, especially those that include low-GI starchy carbs and increased dietary fiber, since they may help reduce body weight and regulate post-prandial hyperglycemia. It has been shown that a low-glycaemic, high-fiber diet effectively lowers plasma cholesterol and improves blood glucose balance in people with type 2 diabetes.

For people throughout Asia, Europe, and Africa, millet is a vital crop. It is better nutritionally than other major grains like wheat and rice. Because it contains so many important nutrients, it is also a desirable item to add to balanced meals. Millet grains have been effectively employed in African and Asian locations to make adult meals, beverages, and weaning foods including porridge, bread, and snacks, which are the main ingredients of traditional diets. Figure 1 displays the global millet production rates for different nations. Recent research has examined millet's beneficial effects on type 2 diabetes risk factors. Randomized experiments assessing the GR effects of millet had inconsistent results, however; some used short intervention periods or small sample sizes, which would have reduced the validity of the findings. Millets are basically higher in fat and lower in amino acid concentration. But 75% of this fat is healthy and does not pose a risk to the heart. It has polyunsaturated fatty acids, which are very beneficial to health. jowar, ragi, and bajra are among the millets that are utilized to form a significant portion of Indian cuisine. Because they are known to encourage diabetic control measures, diabetologists also suggest them. The high fiber content of millet causes the blood sugar level to decrease. In fact, it would be more appropriate to argue that a more uniform distribution of sugar is the outcome of digestive delays. By eating millets every day, a diabetic might perhaps avoid the hazardous spikes in blood sugar that lead to a number of issues. Millets are mostly advised for patients by diabetologists because to their potential to reduce the risk of type 2 diabetes and cardiovascular diseases.

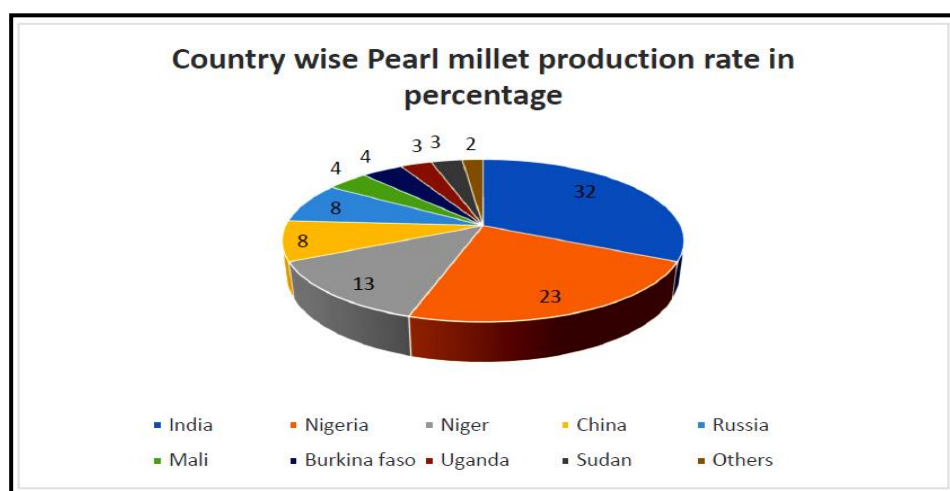


Figure 1. Pearl millet production rate (in percentages) of different countries.

Pearl Millet and Its Nutritional Significance

A cereal crop with many uses, pearl millet is a member of the Poaceae family. In several regional Indian languages, it's often called bajra, bajri, sajje, kambu, kamban, sajjalu, etc. It is often utilized as a food source and forage. In India, pearl millet ranks third in terms of key crops, after rice and wheat. In 2017–2018, it was developed on 7.4 million, or 9.13 million tons, of land. The states that cultivate the most pearl millet in the nation are Uttar Pradesh, Haryana, Gujarat, Rajasthan, and Maharashtra. The Ministry of Agriculture, Government of India, has classified pearl millet as one of the "Nutri-Cereals" due to its greater nutritional content. When it comes to fat digestibility, pearl millet is superior to other cereals. Additionally, it has a greater nutritional content of omega-3 fatty acids and is rich in unsaturated fatty acids. Compared to other millets, pearl millet has a maximum level of macronutrients and is much richer in resistant starch and soluble and insoluble dietary fiber. Basically, compared to other cereal crops like wheat, rice, maize, and sorghum, pearl millet has a larger root system that allows it to absorb minerals from the soil and is thus more important for nutrition. The mineral has significant levels of iron, zinc, magnesium, copper, manganese, potassium, and phosphorus. With a high fiber content and a calorific value of 361 Kcal/100 g, this is a potent energy source. It has a greater content and is a good source of calcium, magnesium, folic acid, vitamin B, and vitamin A. Compared to other cereals, pearl millet grain has more fat, which lowers the quality of the finished product. The nutritional values of pearl millet are shown in Table 1.

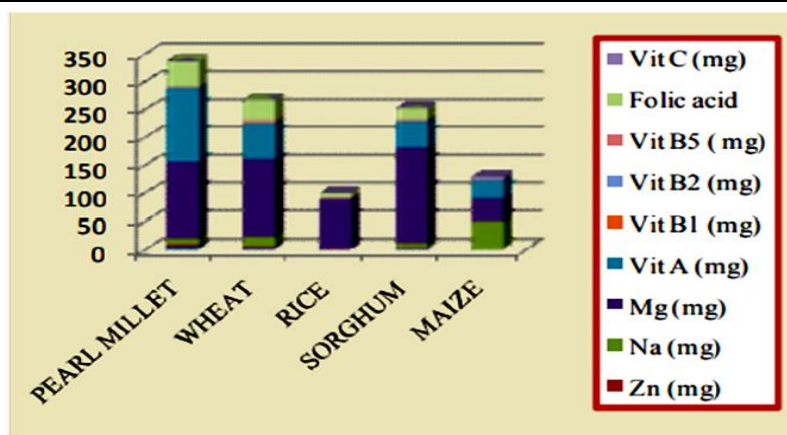


Figure 2. Comparison of nutritional values of pearl millet with other millets.

Table 1. Nutritional value of Pearl Millet.

Nutrients		Amount
Basic Components	Proteins	22 g
	Water	17.3 g
	Ash	6.5 g
Calories	Total Calories	756 cal
	Calories from Carbohydrates	600 cal
	Calories from Fates	71 cal
	Calories from Proteins	85.3 cal
Carbohydrates	Total Carbohydrates	146 g
	Dietary Fibre	17 g
Fatty acids	Total Fat	8.4 g
	Saturated Fat	1.4 g
	Monounsaturated Fatty Acid	1.5 g
	Polyunsaturated Fatty Acid	4.3 g
	Omega-3 Fatty Acids	236 mg
	Omega-6-Fatty Acids	4 g
Vitamins	Vitamin E	100 µg
	Vitamin K	1.8 µg
	Thiamine	842 µg
	Riboflavin	580 µg
	Niacin	9.4 mg
	Vitamin B6	768 µg
	Folate	170 µg
	Pantothenic Acid	170 µg

Different genotypes of pearl millet have varying amounts of starch (62.8–70.5%), soluble sugar (1.2–2.6%), and amylose (21.9–28.8%). Lower levels of amylose and starch were discovered in a few high-yielding Indian pearl millets. Raffinose was the second most important component of the total soluble sugar, behind sucrose. Measurable amounts of other sugars including fructose, glucose, and stachyose. Compared to sorghum, pearl millet had a lower total sucrose content. Similar to sorghum, pearl millet typically has 9% to 13% protein, however notable variations in protein levels, ranging from 6% to 21%, were noted. The first minimum amino acid found in pearl millet protein is lysine. Grain protein content and protein lysine content are strongly inversely correlated. In high-protein cultivars of pearl millet with a protein content ranging from 14.4% to 27.1%, significant inverse relationships were also identified between protein and tryptophan, methionine, and threonine. Pearl millet protein has higher levels of lysine, threonine, methionine, and cystine in its essential amino acid profile compared to millet proteins from sorghum and other sources. It also has a greater tryptophan concentration. Pearl millet fatty acid composition has varied due to genetic variability and changes in lipid extraction techniques. The main free and bound fatty acids were linoleic, oleic, and palmitic acids. Variations in the content of fatty acids were seen in the fractions of neutral lipids, phospholipids, and glycolipids. The most neutral lipids are linoleic and palmitic acid, whereas the lowest are phospholipids made of oleic acid. Compared to sorghum wheat and rice, pearl millet and finger millet had greater total dietary fiber contents. Pearl millet's total dietary fiber level was 17%.

Pearl Millet and Diabetes

Pearl millet aids diabetic individuals in maintaining stable blood sugar levels over an extended period of time. Because it has a relatively low glycaemic index compared to other meals, it helps individuals with diabetes digest and absorb glucose more gradually. Long-term blood sugar regulation will be aided by this.

About ten times more amylase is active in pearl millet than in wheat. The primary sugars in the flour are maltose and D-ribose, which are low in glucose and fructose. The cornerstone of treating diabetes mellitus is diet, particularly in non-insulin-dependent diabetes mellitus, where the major derangement is glucose metabolism with secondary lipid and protein deficits. Strong glycaemic control and a reduction in postprandial hyperglycemia are two aspects of diabetes dietary management. The definition of the Glycaemic Index was first presented by Jenkins et al. as a physiological foundation for the categorization of diets high in carbohydrates according to the blood glycosis response that they produce. Complete green grams, ragi, and pearl millet had the lowest GI when compared to varagu alone, according to Mani et al. Low-glycaemic diets can improve blood pressure and low-density lipoprotein cholesterol metabolism, which in turn results in less pronounced insulin reactivity. Pearl millet may be used to make a variety of novel foods, and traditional diabetic recipes need to be promoted.

Because of their high protein content, meals based on millet have also been linked to reduced GIs in people with type 2 diabetes as well as stable diabetes. According to Shukla et al., bajra chapati had a much lower GR than white bread in stable persons. Furthermore, mixing 30 g of fenugreek into millet chapati reduced GI even more, resulting in lower GR than when the fenugreek millet chapati was consumed. In this case, the quality and viscosity of the fenugreek fiber on the leaves may have contributed to the drop in GR by slowing GE. It has been shown that a significant decrease in the glucose impact occurs when individuals with type 2 diabetes consume proso millet. Colling et al. point out that the method and duration of meal preparation may have an impact on glycaemic and insulinemic responses. These results were specifically impacted by the amount of frying and the duration of fermentation.

Significant adiponectin rise was linked by Sukar et al. to a significant drop in blood glucose levels over the research periods. These results suggest that a diet that includes the entire pearl millet grain may be very helpful in bringing the plasma level of adiponectin back to a physiological level. It is commonly known that elevated adiponectin levels promote glucose utilization by activating AMP-activated protein kinase in the liver and skeletal muscle. As a result, a diet containing pearl millet may lower blood glucose levels by improving peripheral tissue glucose utilization and raising adiponectin levels. The hypoglycemic benefits of pearl millet are supported by a number of ideas. For example, it has been suggested that the high phytate and phenolic component content of pearl millet lowers rats' fasting hyperglycemia and attenuates their postprandial blood glucose response. Additionally, phenolic compounds have been shown to improve insulin activity. Pearl millet is also known to decrease hepatic gluconeogenesis, increase muscle glucose absorption, and modulate intestinal GLUT.

Cereal grains, such as pearl millet, are abundant in bioactive chemicals and antioxidants, along with other essential minerals. It has been suggested that pearl millet extracts provide protection against DNA damage. It is crucial to develop a technique that can enhance the natural substrate's nutritional profile. Numerous scientists are enhancing or improving the bioactive components of cereal grains via the use of biotechnological techniques. Fermentation technology, which has the potential to greatly increase the nutrients in cereal grains, is one of the effective techniques used by scientists and researchers. Due to their high nutritional content, existence of certain bioactive elements, and significance for health, pearl millet grains are becoming more and more popular. Because pearl millet has a high fiber content, it is often categorized as a low-glycaemic index food. The GI evaluates the degree to which the pace and magnitude of change in postprandial blood glucose levels are influenced by the amount of carbohydrates in diet. As a low-GI meal, pearl millet may help reduce blood glucose levels that are necessary for the formation of triacylglycerol. Moreover, millets further reduce plasma levels of triacylglycerol by condensing VLDL cholesterol, a transporter of triacylglycerol. Therefore, eating millet grains may be a significant factor in reducing blood lipid levels.

Type 2 diabetes and cardiovascular illnesses may be predisposed to in people with prediabetes, a condition of high plasma glucose that occurs before the threshold for diabetes is achieved. Prediabetes often has insulin resistance and compromised beta-cell activity already. In addition to increasing the formation of reactive oxygen species and upregulating indicators of chronic inflammation, hyperglycemia may lead to vascular dysfunction. On the other hand, insulin resistance and decreased insulin production may result from elevated oxidative stress and inflammation. Therefore, it is essential to suppress ROS overproduction in order to postpone the development of diabetes and avoid cardiovascular problems. Millet naturally contains a wide variety of bioactive chemicals, including phenolic acids, most flavonoids, and polyphenols. These compounds have been shown to have anti-inflammatory and antioxidant qualities, suggesting that they may have a number of health advantages.

It has already been shown that eating millet significantly reduces insulin response. When type 2 diabetics consumed

pearl millet, Shukla et al. saw no significant changes in insulin resistance; whereas, type 2 diabetics who had white bread showed slightly reduced insulin response one hour after treatment. Pearl millet showed low GIs and a high insulinemic index in stable individuals; however, the opposite was also true for those with type 2 diabetes who had high GIs and a low index. The scientists noted that while type 2 diabetics' insulin reserves would not have been sufficient to mobilize insulin after pearl millet consumption, pearl millet provoked insulin separation in healthy individuals, which reduced the gastrointestinal tract. Pearl millet is well recognized for its many health advantages, mostly because of the high concentration of antioxidant-rich polyphenols found in it.

According to epidemiological research, populations who consume millet have a decreased prevalence of diabetes. Pearl millet grains' high fiber content, fatty acid composition, and plant-based compounds provide them a variety of useful qualities. The comprehension of the nutritional impacts of pearl millet has great importance in nutritional initiatives. Obesity, high-glycemic food consumption, and genetic predispositions are the typical causes of diabetes. The effect of pearl millet consumption on the glucose metabolism of diabetic rats was evaluated by Nani et al. As an alternative to prevention, the authors proposed that consuming meals based on pearl millet might help treat type 2 diabetes with induced hyperglycemia, hence lessening the severity of the illness. According to Hegde et al., feeding animals that contain 55% kodo millet meal reduces hyperglycemia by 42%, cholesterol by 27%, and levels of enzymatic and non-enzymatic antioxidants by 27%. Because of the properties of starch, such as their amylase concentration, granular structures, fatty acid volumes, and kinds that may complicate starch molecules and lipid inter-acid starch protein, millet grains have a higher grade of slowly digesting starch than certain other cereals. Furthermore, the presence of phytochemicals may result in the inhibition of gastrointestinal α -amylase and α -glycosidase enzyme activity in monosaccharides, lowering the presence of hyperglycemia in the body. Nonetheless, the processing technique used on millets will have a significant impact on its hypoglycemic nature, hence it's critical to encourage the use of low starch hydrolysis procedures. Compared to other grain products, pearl millet has a higher leucine content, which stimulates insulin release via suppressing the development of the adrenergic alpha 2A receptor on the surface through the mammalian target of rapamycin pathways. The recommended pearl millet grains for type 2 diabetes therapy of insulin and cardiovascular issues include these characteristics.

Studies on the impact of pearl millet grains on diabetes were conducted in vivo. In a study, the effects of six common Sudanese meals high in carbohydrates on insulin and glucose responses in diabetics were evaluated. Pearl millet acid, followed by wheat gorasa, had a somewhat lower reaction to postprandial glucose and insulin, but maize acid elicited a stronger response. In comparison to people fed pearl millet, a different research revealed much lower levels of lipid peroxides, enzymatic antioxidants, and non-enzymatic antioxidants in normal proportions. As a result, pearl millet is also highly beneficial for managing diabetes. Because of its high fiber content, it digests more slowly than other meals and releases glucose into the bloodstream more quickly. For a considerable amount of time, this helps diabetes patients maintain a stable blood sugar level.

Pearl Millet in the Human Disease Management System

Because of its abundant protein and mineral content, pearl millet offers a wide range of nutritional advantages. It has a high protein content and important minerals including zinc, phosphorus, and magnesium. Moreover, it offers essential vitamins and amino acids that support a range of medical interventions.

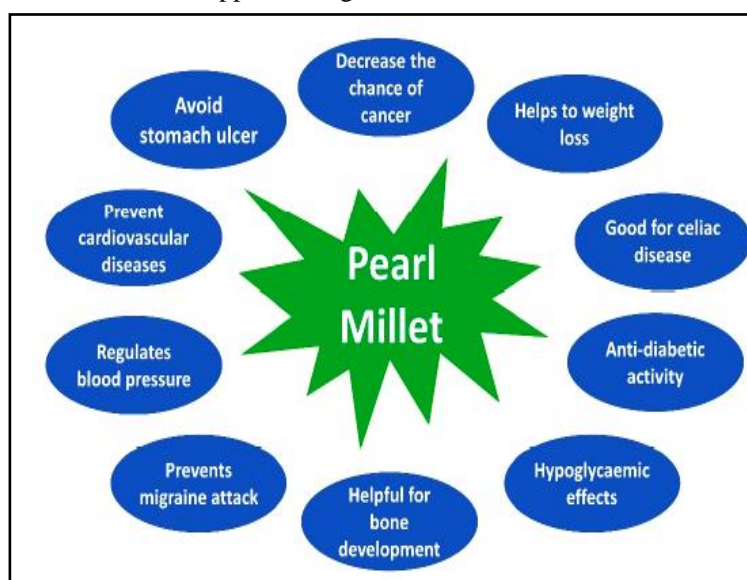


Figure 3. General Biomedical Application of Pearl Millet.

The most significant cause of stomach ulcers is an excess of acidity in the stomach after eating. Being one of the few grains that alkalizes the stomach and either prevents or lessens the effects of stomach ulcers, pearl millet is often recommended for treating stomach ulcers. Pearl millets include phytonutrients and lignin, which are potent antioxidants that help prevent cardiovascular illnesses. Additionally seen as beneficial for heart protection is pearl millet. Pearl millet has large amounts of magnesium, which lowers blood pressure and relieves cardiac tension. Rich in magnesium, it helps prevent migraines and reduces the frequency of respiratory symptoms in asthmatic patients. Because phosphorus is essential for bone growth and development as well as the synthesis of ATP, the body's energy currency, pearl millet has a high phosphorus concentration. Given that millets are known to lower the incidence of cancer, it is anticipated that pearl millet's high magnesium and phylate chemical concentration would have a similar impact.

Regulating one's calorie consumption is the biggest challenge for anybody trying to lose weight. Since pearl millet has a high fiber content, it will aid in weight reduction. Because of the fiber content, the grain takes longer to pass through the intestines from the stomach. This indicates that pearl millet helps control overall food consumption since it satisfies appetite for an extended period of time. A person with celiac disease is unable to withstand even trace amounts of gluten in their diet. Millet is excellent for those with celiac disease since it is devoid of gluten. It is often advised that those with high cholesterol consume pearl millet. It contains phytic acid, a phytochemical that is thought to affect cholesterol metabolism and regulate the levels of cholesterol in the body. The efficient operation of our bodies depends on amino acids. One of the rare foods that has all of the required amino acids is pearl millet. Unfortunately, due of their hypo-allergic nature, many of these amino acids are destroyed during cooking and cannot withstand high temperatures. To preserve as much of these amino acids as possible, it is better to consume them in a low-cooked form. It is also known that pearl millet's high fiber content reduces the chance of bile occurrence. Pearl millet's insoluble fiber content reduces the amount of excess bile produced by our system. Gallstones are also made worse by our intestines' excessive bile output. Pearl millet is suitable for infants, nursing mothers, the elderly, and those recovering from illness to include in their diets.

2. CONCLUSIONS

Growing awareness of nutrition puts pressure on the food sector to develop new products with unique features that may enhance people's health. New research has shown that diabetes and other chronic illnesses may be prevented and controlled via the creation of functional foods and substances that promote health. According to this review, pearl millet significantly affects people with diabetes. It is a great source of vitamins and minerals, and those with diabetes may benefit greatly from it. Pearl millet has a wide range of bioactive chemicals that have been shown to have a number of health advantages, including antibacterial, antioxidant, antidiabetic, and hypocholesterolemic properties. They also have hypoglycemic action and may protect against illnesses linked to diet. In rural places, it is still primarily limited to household-level groups. A crucial aspect of modifying one's diet for medical purposes and promoting the usage of pearl millet might include substituting processed carbs with traditional whole-grain and multigrain alternatives that are higher in nutrients. Diversification of food production and consumption, along with rising yields, must be encouraged at the national and family levels in order to boost pearl millet consumption and capitalize on its enormous nutritional potential.

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