# PEARL MILLET THE REAL PEARL FOR DIABETES

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## ABSTRACT

*Pennisetum glaucum, often known as bajra or pearl millet. High energy, minimal starch, high fibre (1.2g/100g, most of which is insoluble), extremely high -amylase activity, and a low glycemic index (55) are all characteristics of pearl millet. While fructose and glucose levels are low, maltose and D-ribose predominate in the flour. Pearl millet germplasm has genetic variants for features including slowly digested starch (SDS) and resistant starch (RS), which are known to help pearl millet have a low glycemic index (GI). With a higher fat digestibility (5 mg/100g), pearl millet has a high fat content. It has a high level of nutritionally significant n-3 fatty acids and is rich in unsaturated fatty acids (75%). The high magnesium levels in pearl millet aid in the prevention of diabetes by improving the effectiveness of insulin and glucose receptors in the body. This study aims to demonstrate pearl millet's potential for treating diabetes mellitus, especially in nations where it is widely consumed, like India.*

**Keywords:-** *Pearl Millet, Diabetes, Glycemic Index*

**Main Name:** Pearl Millet

**Biological Name**: Pennisetumglaucum

**Names in Other Languages:** Bajra (Bengali, Oriya, Punjabi & Urdu), Type de graine (French), Bajra (Hindi), Kamboo (Tamil & Malayalam), Bajri (Marathi, Gujarati), Grano (Spanish), Sajjalu (Telugu)

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## INTRODUCTION

Although Pearl Millet, also known as Bajra (Pennisetum glaucum), is not as pricey as pearl, it does has pearl-like qualities that are advantageous to the body. In so many areas of Rajasthan, it serves as a common supper. Due to their resilience in challenging agro-climatic circumstances, millets are regarded as a crop of food security (Ushakumari et al., 2004). The reason they are referred to as "nutri-cereals" is that they are abundant in protein, fibre, minerals, and fatty acids, as well as having antioxidant characteristics. (Saleh, Zhang, Chen, & Shen, 2013; Annor, Marcone, Corredig, Bertoft, & Seetharaman, 2015). In addition, millet grains' chemical makeup can support a number of health advantages, including a decrease in oxidative stress (Islam, Manna, & Reddy, 2015; Nani et al., 2015). Millets are nutritious, but they also provide health advantages that may be incorporated into a regular diet to help manage conditions including diabetes, obesity, hyperlipidemia, and others (Veena, 2003).

About 90% of diabetics have Type 2 diabetes. The American Diabetes Association (ADA) presently recognises four different types of diabetes. Type 1 diabetes (T1D), also referred to as insulin-dependent or juvenile diabetes, type 2 diabetes (T2D), also referred to as none insulin-dependent or adult-onset diabetes, gestational diabetes (GDM), which is defined as hyperglycemia discovered for the first time during pregnancy, as well as diabetes brought on by genetic defects (monogenic diabetes), diabetes brought on by other diseases, or diabetes brought on by drugs or chemicals.One in eleven individuals (463 million people globally) have diabetes, with T2D making up 90% of all cases. However, 232 million adults—roughly one in two—do not have a diagnosis for the disease. By 2030, it is predicted that 578 million people worldwide would have diabetes based on current trends. However, there are significant regional differences in the frequency of insulin resistance and related diseases. Strong lifestyle factors affect it, and financial position, culture, and education all have an impact on these factors. Younger age groups and emerging countries are experiencing an increase in its prevalence (ADA, 2022).

## Pearl millet composition

Table 1: Pearl Millet Nutrition Facts Weight: 100 g

| **Nutrients** | **Amount (gram)** | **Nutrients** | **Amount (gram)** | **Nutrients** | **Amount (gram)** |
|---|---|---|---|---|---|
| **Energy** | **1456KJ** | **Fatty acid** | | **Vitamin** | |
| **Protein** | **10.96g** | Total fat | 5.43g | Thiamine | 0.25mg |
| **Water** | **8.97g** | Palmitic(C16:0) acid | 729mg | Riboflavin | 0.20mg |
| **Ash** | **1.37g** | Stearic(C18:0) acid | 128mg | Niacin | 0.86mg |
| **Carbohydrate** | | Arachidic(C20:0) acid | 18.21mg | Pantothenic acid | 0.50mg |
| Carbohydrate | 61.78g | Palmitoleic(C16:1) acid | 6.97mg | Biotin (B7) | 0.64µg |
| Total starch | 55.21g | Oleic (C18:1n9) acid | 1040mg | Total Folates (B9) | 36.11µg |
| Fructose | 0.21g | **Minerals** | | Ergocalcife (D2) | 5.65µg |
| Glucose | 0.60g | Calcium (Ca) | 27.35mg | Vitamine E | 0.24mg |
| Total free sugars | 0.81g | Iron | 6.42mg | Vitamine K | 2.85µg |
| Dietary fiber | 11.49g | Copper | 0.54mg | | |
| Insoluble fiber | 9.14g | zinc | 3.1mg | | |
| Soluble fiber | 2.34g | | | | |

Indian food composition tables, National institute of nutrition, 2017

## Nutritional quality of pearl millet grains

In recent years, there has been an increase of products based on pearl millet because they contain a higher content of dietary fiber, micronutrients and bioactive compounds (Gong et al., 2018).

### Carbohydrates

Carbohydrate components of pearl millet grains comprise of starch, dietary fiber and soluble sugars. Pearl millet starches have amylose content ranging 20-21.5% and have a higher swelling power and solubility than other starches (Lestieme et al., 2007). In different pearl millet varieties the starch content of the grain varies from 62.8 to 70.5 %, soluble sugar from 1.2 to 2.6 %. Free sugars like glucose, fructose, sucrose and raffinose are present in a range of 1.2 to 2.5% (Gupta and Nagar, 2010).

Starch is generally divided into three different digestibility types: rapidly digestible starch (RDS), slowly digestible starch (SDS), and resistant starch (RS) (Englyst et al., 1992). RS is characterized by the fact that it is unable to be broken down in the small intestine and is therefore passed onto the large intestine. RS is further divided into three different types: physically inaccessible starch (RS1), resistant starch granules (RS2), and retrograded amylose (RS3) (Sajilata et al., 2006). RDS is referred to the starch fraction that is transformed into glucose soon upon ingestion (20 min). RDS is digested and absorbed in the duodenum and proximal regions of the small intestine (Englyst et al., 1992). The rapidly digestible nature of the RDS causes a rapid rise of blood glucose followed by a subsequent hypoglycaemia. On the other hand, SDS is referred to starch that breaks down into glucose over a longer duration (Zhang and Hamaker, 2009). The slow release of SDS improves overall blood glucose control as well as providing stable energy to patients with T2D. While RS is not digested and absorbed by human as energy, it has a positive role against diabetes. Johnston et al. (2010) has discovered that consumption of resistant starch improves insulin sensitivity. It does not affect body weight, fat storage in muscle, liver or visceral depots significantly. Also, it helps managing meal-associated hyperglycaemia (Lehmann and Robin, 2007). This is particularly important for people who are at risk of, or suffering from, T2D.

**Energy**

Pearl millet is a rich source of energy (361 Kcal/100g) which is comparable with commonly consumed cereals such as wheat (346 Kcal/100g), rice (345Kcal/100g) maize (125 Kcal/100g) and sorghum (349Kcal/100g) as per the Nutritive value of Indian foods (NIN, 2003).

**Proteins**

Pearl millet contains generally 9 to 13% protein. The essential amino acid profile shows more lysine, threonine, methionine and cystine in pearl millet protein (Adeola et al., 2005). Its tryptophan content is also higher (Ejeta et al., 1987; Hoseney et al., 1994; Rooney et al., 1987). The lysine content of the protein reported in pearl millet grain ranges from 1.9 to 3.9 g per 100 g protein (SernaSaldivar, McDonough and Rooney, 1994). This favorable amino acid balance with a high level of essential amino acids, coupled with the superior in vitro pepsin digestibility values, suggests that pearl millet is a nutritious and well-digested source of calories and protein for humans (Ejeta et al., 1987). Among the essential amino acids, ariginine, threonine, valine, isoleucine and lysine had higher digestibility in pearl millet. Pearl millet exhibits higher apparent small intestine digestibility of essential amino acids than other grains (Kalinova and Moudry, 2006). Nevertheless, the lysine content of pearl millet (3.1 g/100 g protein) is relatively higher than maize, rye, wheat and sorghum. This is possibly a consequence of the large germ of pearl millet with a relatively high proportion of albumin and lysine-rich globulins (Taylor, 2016).

Protein has been repeatedly identified as an important component for dietary strategies for diabetics (Singh et al., 2010; Ajala et al., 2013). There are many findings of proteins or specific amino acids such as leucine that have some positive influence on the condition of diabetic patients. These include improved glycaemic control and muscle loss prevention (Melnik, 2012; Norton et al., 2012). Since muscle is made up of protein, intake of amino acid is vital. In particular, the amino acid leucine has been known to induce muscle growth thus benefiting diabetic patients in terms of retaining muscle mass (Katsanos et al., 2006). Examining the role of dietary protein and establishing intake guidelines among individuals with diabetes is complex. The 2013 American Diabetes Association (ADA) standards of care recommend an individualized approach to decision making with regard to protein intake and dietary macronutrient composition. Needs may vary based on cardiometabolic risk factors and renal function. Among individuals with impaired renal function, the ADA recommends reducing protein intake to 0.8–1.0 g/kg per day in earlier stages of chronic kidney disease (CKD) and to 0.8 g/kg per day in the later stages of CKD. Epidemiological studies suggest animal protein may increase risk of diabetes; however, few data are available to suggest how protein sources influence diabetes complications.

**Lipids**

Pearl millet is richer in fat content (5 mg/100g, NIN 2017) as compared to most grains, 75% of the fatty acids are unsaturated. According to Taylor (2016) and Annor et al. (2015) the major fatty acids of pearl millet grain are linoleic acid (C18:2), typically 39–45%; oleic acid (C18:1), 21–27%; and palmitic acid (C16:0), 20–21%. On the other hand, the presence of unsaturated fatty acids may be beneficial. According to Annor et al. (2015), the composition of fatty acids present in each species of millet is directly related to the hypoglycemic properties of this cereal.

**Minerals**

Regarding mineral composition, phosphorus (~3.338 mg/kg dry basis), potassium (~3.932 mg/kg dry basis) and magnesium (~1.333 mg/kg dry basis) are found in considerable quantities, while minerals such as calcium (~300 mg/kg dry basis), iron (~ 18 mg/kg dry basis) and zinc (~43 mg/kg dry basis) are in much lower quantities (Serna, 1994,Ragaee, Abdel-Aal, & Noaman, 2006; Saldivar, 2003; Taylor, 2016). Due to the low content of zinc and iron, some research programs have concentrated efforts on promoting biofortification of pearl millet (Ullah et al., 2016).

**Bioactive compounds**

Studies have demonstrated that whole grain millet and its bran are rich sources of phenolic compounds (phenolic acids and flavonoids) and a source of natural antioxidants (Chandrasekara et al., 2012; Chandrasekara & Shahidi, 2011a, 2011b, 2011c). According to the above mentioned works, these compounds, which are secondary products of plant metabolism, have antioxidant capacities and are associated to reduced risk of chronic diseases related to oxidative stress. Pearl millet grains have low concentrations of benzoic acid derivatives (hydroxybenzoic acid, gallic acid, p-hydroxybenzoic, vanillic, syringic and protocatechuic), but high levels of cinnamic acid derivatives (hydroxycinnamic, coumaric, ferulic, sinapic) (Chandrasekara & Shahidi, 2011a; Taylor & Duodu, 2015). Nani et al. (2015) reported that pearl millet contained gallic acid (15.3 μg/g), syringic acid (7.4 μg/g), pcoumaric (1350 μg/g) and ferulic acid (199 μg/g). When comparing the quantities of phenolic acids with other cereals, N'Dri et al. (2013) found that pearl millet presented higher amounts (64.8 mg/kg) of phenolic acids than sorghum (27.3 mg/kg). Among the phenolic acids, ferulic and p-coumaric acids are predominant in pearl millet grains, according to Chandrasekara and Shahidi (2011b) and N'dri et al. (2013). In general, phenolics are not distributed evenly in the grain, these compounds are mainly found in the pericarp so the most beneficial form to consume pearl millet is as whole grain or bran (Chandrasekara & Shahidi, 2011b). Prajapati, Patel, Parekh, and Subhash (2013) found that pearl millet grains had the most phenolic compounds and the highest antioxidant activity

## Micronutrients

### Vitamins and minerals

Overall mineral content of pearl millet is 2.3 mg/100g which is high as compared to commonly consumed cereals. It is rich in B-vitamins, potassium, phosphorous, magnesium, iron, zinc, copper and manganese (NIN, 2017). Dried, matured kernels do not contain vitamin C and the B vitamins are concentrated in the aleurone layer and germ. Removing the hull by decortication reduces the levels of thiamine, riboflavin and niacin by about 50% in the flour. The niacin content of the hulled millet seed is still significant. This is why the PP vitamin insufficiency disease, pellagra, is not found in areas where millet is consumed in great quantities. Pearl millet, along with other grains, contains oxalic acid, which forms an insoluble complex with calcium, thereby reducing biological availability of this mineral. Calcium concentration in pearl millet is quite low, and the presence of oxalate can exacerbate the deficiency (Irén Léder, 2004). Among the millets, pearl millet (Bajra) has the highest content of macronutrients, and micronutrients such as iron, zinc, Mg, P, folic acid and riboflavin, significantly rich in resistant starch, soluble and insoluble dietary fibres (Antony et al. 1996; Ragaee et al., 2006). The niacin content in pearl millet is higher than all other cereals.

### Pearl millet for Diabetics

Diabetes is less common in millet-eating cultures, according to epidemiological studies (Taylor, 2017) Diabetes can be effectively managed with pearl millet. Due to its high fibre content, it digests more slowly than other foods and releases glucose into the blood at a slower rate. This significantly aids in keeping diabetic patients blood sugar levels consistent for an extended length of time (ICMR, 2017). Pearl millets may help to reduce the signs and symptoms of diabetes (Choi et al., 2005; Park et al., 2008; Shobana et al., 2010; Jali et al., 2012), which is an additional benefit. They are known to include higher levels of leucine (Ejeta et al., 1987; FAO, 1995), SDS (Liu et al., 2006), minerals (FAO, 1995), and other nutrients that are positively associated with a healthy diet for diabetes.

About ten times as much amylase is present in pearl millet as there is in wheat. While fructose and glucose levels are low, maltose and D-ribose predominate in the flour (Oshodi et al 1999). With regard to noninsulin-dependent diabetes mellitus (NIDDM), where glucose metabolism is the major abnormality and lipid and protein metabolism are the secondary abnormalities, diet is regarded as the cornerstone of care of diabetes mellitus. Millets do really have a number of qualities that make them a suitable dietary choice for diabetics. This is supported by studies. For instance, a study that tested several diets on diabetic mice came to the conclusion that adding millet protein can raise insulin sensitivity, lower blood sugar levels and lower triglyceride levels (Nishizawa et al., 2009). In their three-week trial, additional advantages including increased plasma levels of adiponectin and high-density lipoprotein cholesterol were also discovered.

Pearl millet (Pennisetum glaucum (L.)) consumption was examined by Nani et al. in 2012. The authors came to the conclusion that eating pearl millet meal would be a good way to treat type 2 diabetes-related hyperglycemia and lessen the severity of the condition as a substitute for prevention. Compared to other cereals, pearl millet grains have more slowly digestible starch, which Annor, Tyl, Marcone, Ragaee, and Marti (2017) attribute to the starch's amylose content, granular structure (polygonal format with porous surfaces), amount and type of fatty acids (oleic acid content) capable of forming complexes with starch molecules, the starch-protein-lipid interactions, and the grain's high fibre content.

## ANTIOXIDANT QUALITY OF PEARL MILLET

Over 50 phenolic compounds belonging to several classes, namely, phenolic acids and their derivatives, dehydrodiferulates and dehydrotriferulates, flavan-3-ol monomers and dimers, flavonols, flavones, and flavanonols in 4 phenolics fractions of several whole millet grains (kodo, finger, foxtail, proso, little, and pearl millets) were positively or tentatively identified using HPLC and HPLC-tandem mass spectrometry (MS) (Chandrasekara and Shahidi, 2011a). As a result, millet grains can be employed as sources of natural antioxidants and as functional dietary additives.

Additionally, the presence of phytochemicals (phenolic acids, flavonoids and phytates) may help to reduce body hyperglycemia by inhibiting the activity of gastrointestinal -amylase (pancreatic) and glycosidase (intestinal) enzymes that hydrolyze starch, oligosaccharides and disaccharides to monosaccharides [Petroski, 2020]. The use of methods that preserve minimal starch hydrolysis should be promoted since millets hypoglycemic nature can be considerably impacted by the type of processing used on them (Annor et al., 2017).

## Glycemic index and Pearl Millet

The blood glucose response following ingestion of a test item containing carbohydrates is described by the glycemic index (GI), which is commonly glucose or white bread. The glycemic index calculates how quickly a specific item will boost your blood sugar. In this study, pearl millet flour-based Cheela and Uthapam's IAUC was considerably lower compared to their control product, according to kumari nidhi. In compared to control Uthapam and Cheela, which had GI values of 39.91 and 44.07 respectively, pearl millet flour-based Uthapam and Cheela (20% and 25%) had reduced GI values of 38.72 and 36.83 in 2012. In comparison to sorghum, finger millet and mungbean, pearl millet has the lowest glycemic index (55) (Mani et al., 1993).

Diabetes may be managed with diet by reducing postprandial hyperglycemia and maintaining stable blood sugar levels. Jenkins et al. (1981) established the idea of glycaemic index (GI) as a physiological foundation for classifying carbohydrate meals according to the blood glucose response they cause when consumed. According to Mani et al. (1993), compared to Varagu (Plaspalum scorbiculatum) alone and in combination with whole and dehusked greengram (Phaseolus aureus Roxb), Jowar (Sorghum vulgare) and Ragi (Eleusine coracana), pearl millet (Penniseteum typhoideum) had the lowest GI (55) of the four. Due to a less prominent insulin response, foods with a low glycemic index are helpful in managing maturity-onset diabetes by improving metabolic regulation of blood pressure and plasma low density lipoprotein cholesterol levels (Asp, 1996). Numerous unique food products based on pearl millet may be created, and diabetes patients need to be encouraged to use traditional recipes. Because of their high protein content, millet-based foods (pearl, foxtail and finger) have also been linked to reduced GIs in people with type 2 diabetes and stable diabetes (Geeta et. al.,2020). According to Shukla et al. (2014), white bread had a considerably higher GR than bajra chapati in stable people. Because of its high fibre content, pearl millet is typically categorised as a low-glycaemic index (GI) food. The GI determines how much the amount of carbohydrates in food affects the pace and magnitude of change in post-prandial blood glucose levels. As a low-GI meal, pearl millet may help reduce the amount of blood glucose available for the formation of triacylglycerol. Additionally, millets reduce plasma levels of triacylglycerol by condensing VLDL cholesterol, which is a transporter of the fatty acid. Because of this, eating millet grains may be beneficial for decreasing blood lipid levels [Kam et al, 2016]. Obesity, genetic predispositions, and excessive consumption of foods with a high glycemic index are the main risk factors for developing diabetes. As a result of their low glycemic index, millet grains have been used to create novel products that, according to Nani, Brixi-Gormat, Bendimred-Hmimed, Benammar, and Belarbi (2012) and Ugare, Chimmad, Naik, Bharati, and Itagi (2014), can help reduce the risk of diabetes.

## Diabetes and adiponectin

According to Sukar et al. (2020), there was a significant increase in adiponectin over the study periods, which was accompanied by a significant drop in blood glucose levels. These results suggest that a diet rich in pearl millet whole grains might contribute significantly to bringing back plasma levels of adiponectin to their normal levels. It is well known that an increase in adiponectin levels stimulates glucose utilisation by activating AMP-activated protein kinase in the liver and skeletal muscle [Annor *et al*, 2017 ], and a diet containing pearl millet may lower blood sugar levels as a result of improved peripheral tissue glucose uptake and increased adiponectin levels. Numerous hypotheses explain how pearl millet lowers blood sugar levels, including the idea that pearl millet's high phytate and phenol content lowers fasting hyperglycemia and attenuates the postprandial blood glucose response in rats. Pearl millet controls intestinal GLUT, boosts muscle glucose uptake, and decreases hepatic gluconeogenesis, and phenolic substances are also known to improve insulin activity [Cao, H. and Chen, X. 2012].

## Bioactive compounds of Pearl Millet

Cereal grains, particularly pearl millet, are abundant in bioactive chemicals and antioxidants in addition to other significant minerals. It has been claimed that pearl millet extracts can guard against DNA deterioration. The creation of a technique that can enhance the nutritional composition of the natural substrate is crucial. Numerous researchers are enhancing or improving the bioactive components of cereal grains utilising biotechnological approaches. Researchers and scientists have found success with fermentation technology, which may significantly increase the nutritional value of cereal grains. Because of their relevance for health, existence of unique bioactive components, and high nutritional value, pearl millet grains are gaining popularity. Millet naturally contains a variety of bioactive substances, including polyphenols, the majority of flavonoids, and phenolic acids. These substances may have a number of health advantages due to their antioxidant and anti-inflammatory activities [Adéoti *et al* 2017, Shahidi *et al* 2015].

## Pearl millet and insulin response

It has previously been shown that eating millet causes a reduction in insulin response. Pearl millet did not significantly alter the insulin response in type 2 diabetes or stable persons, according to Shukla et al. (2014), while white bread did cause a slightly diminished insulin response in type 2 diabetics one hour after treatment. Pearl millet had low GIs and high insulinemic indices in healthy individuals, whereas it had high GIs and low insulinemic indices in those with type 2 diabetes. The insulin reserve in type 2 diabetics may not have been sufficient to mobilise insulin following consumption of pearl millet, according to the scientists observations that pearl millet provoked insulin separation in healthy individuals, which reduced the gastrointestinal tract.

However, the way millets are processed has a significant impact on how hypoglycemic they are, thus it's critical to encourage the adoption of low starch hydrolysis technologies [Benton and Young, 2017]. Compared to other grain products, pearl millet generates large levels of the amino acid leucine, which stimulates the release of insulin by inhibiting the expression of the adrenergic alpha 2A receptor on the surface of cells by means of the mTOR (mammalian target of rapamycin) pathways (leucine secretion route). The pearl millet grains with these characteristics are chosen for treating insulin and cardiovascular issues in type 2 diabetes [Taylor and Emmambux, 2008]. Studies on the impact of pearl millet grains on diabetes were conducted in vivo. In one study, the effects of six typical Sudanese meals high in carbohydrates on diabetic subjects' glucose and insulin responses were evaluated. Pearl millet acid and wheat gorasa (pancakes) caused a somewhat reduced reaction to postprandial glucose and insulin, but maize acid resulted in a larger postprandial glucose and insulin response [Hassan *et al*, 2021]. Another study found that diabetic populations fed on pearl millet had significantly lower levels of non-enzymatic antioxidants (glutathione, vitamin E, and vitamin C), enzymatic antioxidants (superoxide dismutase, catalase, glutathione peroxidase, and glutathione reductase), and lipid peroxides [Kajla *et. al.*, 2020]. As a result, pearl millet is also particularly efficient in managing diabetes. Due to its high fibre content, it slowly digests and releases glucose into the blood at a greater rate than other meals. This aids diabetic patients in long-term blood sugar stability maintenance.

## Conclusion

This research intends to highlight the significant nutritional potential of pearl millet grains for human consumption by educating consumers and food industry professionals about its advantages, particularly for diabetics due to its low glycemic index.

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