**Advances in Bioresearch**
Adv. Biores., Special Issue (1) 2024: 60-67
©2024 Society of Education, India
Print ISSN 0976-4585; Online ISSN 2277-1573
Journal's URL:http://www.soeagra.com/abr.html
CODEN: ABRDC3
DOI: 10.15515/abr.0976-4585. SPL1.6067

Advances in Bioresearch

# The Potential Impacts of Millet: Diabetes Mellitus and Other Health Applications

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**ABSTRACT**
*Diabetes and other age-related degenerative diseases, such as cancer, blood pressure, and cardiovascular diseases (CVD), have become serious and common conditions. Improvements in dietary and lifestyle management are primarily responsible for treatment techniques for diabetes prevention in both high-risk and afflicted persons. Understanding the nutritional parameters to be exploited in dietary intervention is crucial. Regularly eating millet-based meals has been associated with a lower risk of diabetes. Regarding Calories, protein, vitamins, and minerals, millet is a very nutrient-dense grain that even performs better than other major cereals.Millet is an excellent source of complex dietary fibres, health-improving phytochemicals, vitamins, and minerals. Millets include bioactive chemicals that have antibacterial, antioxidant, immune-modulating, detoxifying, antidiabetic, hypocholesterolemic, and hypoglycaemic properties among other health benefits. As a result, it may be used to make a range of food items for people having diabetes. Additionally, it improves digestion, lowers blood pressure, lowers the risk of heart disease, lowers cholesterol, and lowers the rate at which fat is absorbed. It also fights cancer, cardiovascular problems, and tumour occurrence. As a result, the present review discusses how millet can help people with diabetes and other health issues.*
***Keywords:*** *Millets, Antidiabetic, Nutritional value, Phytochemicals, Anticancerous*

Received 04.08.2024 Revised 21.10.2024 Accepted 19.11.2024

**How to cite this article:**
Neha D, Yuvraj Y, Parmjeet K and Sonal. The Potential Impacts of Millet: Diabetes Mellitus and Other Health Applications. Adv. Biores. Special Issue [1] 2024. 60-67

## INTRODUCTION

Millet is one of the cereals along with wheat, rice and maize. Millions of people around the world, especially those living in hot and dry climates, rely heavily on millets as a food source. They are mostly cultivated in marginal lands where agricultural circumstances prevent major crops from yielding considerable amounts of output [1]. Several developing nations now grow millet as a staple crop due to its resilience to harsh climate, including high temperatures (42–46 °C) and low to moderate rainfall (200–600 mm). Additionally, millet exhibits a high degree of adaptability to marginal regions and lower soil fertility. Millets, which are a member of the Poaceae grass family and were among the first crops, are still grown today. Millets come in a wide range of varieties. There are three main varieties: Pearl millet or Bajra (*Pennisetum glaucum*), Sorghum (Jowar) and Finger Millet or Ragi/Mandua (*Eleusine coracana*) [2]. The most commonly used millet cultivars for food and feed are finger millet and pearl millet. The minor millets are Foxtail millet (*Setaria italica*), Proso millet (*Panicum miliaceum*), Little millet (*Panicumsu matrense*), Barnyard millet (*Echinochloa colona*), and Kodo millet (*Paspalum scrobiculatum*). Two pseudo-millets are Buck-wheat (Kuttu) and Ameranthus (Chaulai). While millets have primarily been used for animal feed in developed countries, they are consumed by humans in most underdeveloped nations. Millets are comparable to other cereal varieties in terms of nutrition and are a rich source of protein, minerals, and phytochemicals. The amount and activity of antioxidants are influenced by processing techniques as soaking, malting, decortications, and cooking [3]. The millets' amino acid profile is superior and also has a greater level of protein digestibility due to the reduced content of cross-linked prolamins, which may also be another contributing factor.

According to Obilana and Manyasa, and Yang *et al.*, millet serves a variety of nutritional and therapeutic purposes [4,2]. Millets differ from other cereals in that they are abundant in dietary fibre, polyphenols,

protein and calcium [5]. Millet is more than just an intriguing alternative for grains that are more often used. The grain is also abundant in phytochemicals, such as phytic acid, which may decrease cholesterol, and phytate, which has been linked to a lower risk of developing cancer [6]. The wide varieties of phytochemicals, have been discovered to possess chemopreventive properties and have been implicated in some of these health benefits. These phytochemicals include antioxidants, which are abundant in foods like millets [7]. Since millet is gluten-free, it is a perfect substitute for people with celiac disease patients who are frequently aggravated by the gluten content of wheat and other more widely consumed cereal grains. It is also advantageous for people with diabetic heart disease and atherosclerosis [8]. Studies by Choi et al. and Park et al. [9, 10] showed that proso millet and foxtail millet protein concentrate significantly raised plasma levels of HDL cholesterol and adiponectin which produced significant drops in insulin levels in type 2 diabetic mice when compared to a casein diet. Additionally, proso millet improved glycemic responses and plasma levels [10]. Furthermore, protein concentrate of parso millet shields the liver of rats from the harm caused by D-galactosamin [11]. It is possible to treat type 2 diabetes with Proso millet protein [9,10]. Finger millet also contains polyphenols and dietary fibre, which are both important for the millet's health advantages [5]. According to research by Chandrasekara and Shahidi on the free-radical quenching activity of finger millet (*Eleusine coracana*), unprocessed brown finger millet had a higher radical quenching activity than processed finger millet [12]. Numerous investigations postulated that the activity was caused by phytic acid and tannins [5,13,14]. When compared to whole wheat extract, millets extract from the seed coat has allegedly shown stronger antibacterial and antifungal activity because of the high polyphenol content in the seed coat [15,16]. It was shown that a number of millets, including Finger millet, Kodo millet, Foxtail millet, Little millet, Barnyard millet (kudiraivali), and Sorghum (jowar), and their white variants, exhibit substantial antioxidant activity using the 1, 1, Diphenyl -2-picrylhydrazyl (DPPH) technique. Furthermore, fractionated foxtail millet protein hydrolysate was found to have a variety of radical scavenging properties [14].

**NUTRITIONAL VALUE OF MILLETS**

Nutritional value of food has a significant role in the wellbeing and healthy functioning of the metabolism of the human body. To grow and maximise the genetic potential of humans, the dietary content is essential. Millets nutritionally equivalent to that of the three main staple grains (rice, wheat, and maize), Because millet is an excellent source of carbohydrates, protein, dietary fibre, minerals, vitamins, and phytochemicals, Millets have an energy content per 100 g that ranges from 320 to 370 kcal. Compared to other cereals, millets contain between 65 and 75 percent carbohydrates but also include higher amounts of dietary fibre and non-starchy polysaccharides. Table 1 and Table 2 highlight an extensive overview of the nutritional composition and soluble vitamin profile of a millets and staple cereals.

Compared to other major staple grains, proso millet may contain higher concentrations of dietary fiber and micronutrients (Table 1). Proso millet is rich in iron (Fe), potassium (K), zinc (Zn), calcium (Ca), phosphorous (P), magnesium (Mg), niacin, vitamin B-complex, and folic acid, to name a few vitamins and minerals. Proso millet provides essential amino acids in significantly greater amounts than wheat, with the exception of lysine, which is the limiting amino acid, and has an essential amino acid index that is almost 51% higher than wheat [17]. Additionally, products made from proso millet exhibit a lower glycemic response when compared to cereal-based products. Pearl millet has the same amount of energy as the main grains. Compared to other grains, pearl millet has fewer carbohydrates. Its high amylose starch content (20–22%) and significant amount of insoluble dietary fiber allow it to have a lower glycemic response. Pearl millet protein is beneficial for people who are sensitive to gluten because it contains a higher prolamin proportion and is free of gluten. Although pearl millet has an excellent amino acid profile, it is not a good source of tryptophan, lysine, threonine, or other sulfur-containing amino acids [18, 19]. Pearl millet is a rich source of omega-3 fatty acids, docosahexaenoic acid, eicosapentaenoic acid, and other essential nutritional fatty acids. It is also a rich source of micronutrients, including manganese (Mn), B-vitamins, Fe, Zn, copper (Cu), K, Mg, and P [18]. Kodo millet, with the exception of finger millet, has less protein than other millets but does contain gluten-free protein (Table 1). Kodo millets contain noteworthy concentrations of various minerals and vitamins, as well as the B-complex vitamins B6, folic acid, niacin, Fe, Ca, Mg, K, and Zn (Table 2). Because kodo millet is so easy to digest, it can be used to make products for older people and babies.

Compared to other grains, foxtail millet contains more dietary fiber, resistant starch, vitamins, minerals, and essential amino acids, with the exception of lysine and methionine. The highest protein content of all the millets is found in foxtail millet (Table 1). Moreover, foxtail millet contains significant amounts of stearic and linoleic acids, which help to maintain a balanced lipid profile. Of all the millets, finger millet has the highest carbohydrate content and the lowest protein content (Table 1). But because they are mostly made up of resistant starch, dietary fiber, and slowly digesting starch, carbohydrates have a lower

glycemic index than other common cereals [20]. Compared to other millets, finger millet has higher amounts of lysine, threonine, and valine and has a superior amino acid score. This makes micronutrients like calcium, magnesium, potassium, iron, and zinc broadly available, as well as B vitamins like folic acid, niacin, and B6 (Table 2). Little millet has a similar nutritional profile to millets and cereal. It has a balanced amino acid profile, 8.7% protein content, and is a good source of lysine and the sulfur-containing amino acids like cysteine and methionine, which are absent in various cereals [21]. Due to the abundance of dietary fibre, resistant starch, and slowly digesting starch, it is usually thought to provide a reduced glycemic response [22]. Additionally, it is an excellent source of micronutrients including niacin, iron, and phosphorus. To capitalise on the health advantages of little millet, a lot of value-added products have recently been created.

**Table 1. Overview of the nutritional composition of a millets and staple cereals.**

| Grains | Energy (kcal) | Protein (g) | Carbohydrate (g) | Starch (g) | Fat (g) | Dietary Fiber (g) | | | Minerals (g) | Ca (mg) | P (mg) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Total | Soluble | Insoluble | | | |
| Sorghum | 347 | 9.97 | 67.68 | 59.70 | 1.73 | 10.22 | 8.49 | 1.73 | 1.6 | 27.60 | 222 |
| Pearl millet | 366 | 10.96 | 61.78 | 55.21 | 5.43 | 11.49 | 9.14 | 2.34 | 2.3 | 27.35 | 296 |
| Finger millet | 330 | 7.16 | 66.82 | 62.13 | 1.92 | 11.19 | 9.51 | 1.67 | 2.7 | 364.0 | 283 |
| Proso millet | 341 | 12.50 | 70.04 | - | 1.10 | - | | | 1.9 | 14.0 | 206 |
| Foxtail millet | 331 | 12.30 | 60.09 | - | 4.30 | - | | | 3.3 | 31.0 | 290 |
| Kodo millet | 353 | 8.92 | 66.19 | 64.96 | 2.55 | 6.39 | 4.29 | 2.11 | 2.6 | 15.27 | 188 |
| Little millet | 346 | 8.92 | 65.55 | 56.07 | 2.55 | 6.39 | 5.45 | 2.27 | 1.7 | 16.06 | 220 |
| Barnyard millet | 307 | 6.20 | 65.55 | - | 2.20 | - | | | 4.7 | 14.0 | 121 |
| Maize | 334 | 8.80 | 64.77 | 59.35 | 3.77 | 12.24 | 11.29 | 0.94 | 1.5 | 8.94 | 348 |
| Wheat | 321 | 10.59 | 64.72 | 56.82 | 1.47 | 11.23 | 9.63 | 1.60 | 1.5 | 39.36 | 306 |
| Rice | 353 | 9.36 | 74.80 | 71.31 | 1.24 | 4.43 | 3.60 | 0.82 | 0.6 | 10.93 | 160 |

Source: Indian Food Composition Tables and nutritive value of Indian foods.

**MILLETS FOR DIABETES MANAGEMENT**

Diabetes is the most prevalent metabolic illnesses lead to hyperglycemic situations because of inadequate insulin production and decreased insulin sensitivity. There are two types of diabetes: Type 1 and Type 2. Type 1 diabetes results due to the auto immune complete or partial destruction of pancreatic β-cells which produce insulin, so type 1 diabetes is characterized by insufficient or no insulin production [23]. Type 2 diabetes, on the other hand, is more complicated, since it can result in high glycemic circumstances by either developing insulin resistance or having decreased sensitivity to insulin levels [24].Diabetes is a long-term metabolic condition that can cause a number of side effects, such as obesity, abnormal lipid metabolism that raises triglyceride levels, cardiovascular illnesses, and neuropathy due to elevated glucose levels [25,26]. The WHO estimates that about 422 millions of people are suffered from diabetes all over the world, which causes 1.5 million fatalities every year [27].

**Table 2. Overview of soluble vitamin profile of a millets and staple cereals.**

| Grains | Thiamine B1 (mg) | Riboflavin B2 (mg) | Niacin B3 (mg) | Pantothenic Acid B5 (mg) | Total B6 (mg) | Biotin B7 (µg) | Total Folates B9 ( µg) |
|---|---|---|---|---|---|---|---|
| **Sorghum** | 0.35 | 0.14 | 2.10 | 0.2 | 0.28 | 0.70 | 39.42 |
| **Pearl millet** | 0.25 | 0.20 | 0.86 | 0.50 | 0.27 | 0.64 | 36.11 |
| **Finger millet** | 0.3 | 0.17 | 1.34 | 0.29 | 0.05 | 0.88 | 34.66 |
| **Proso millet** | 0.41 | 0.28 | 4.50 | 1.20 | - | - | - |
| **Foxtail millet** | 0.59 | 0.11 | 3.20 | 0.82 | - | - | - |
| **Kodo millet** | 0.29 | 0.20 | 1.49 | 0.63 | 0.07 | 1.49 | 39.49 |
| **Little millet** | 0.26 | 0.05 | 1.29 | 0.60 | 0.04 | 6.03 | 36.20 |
| **Barnyard millet** | 0.33 | 010 | 4.20 | - | - | - | - |
| **Maize** | 0.33 | 0.09 | 2.69 | 0.34 | 0.34 | 0.49 | 25.81 |
| **Wheat** | 0.46 | 0.15 | 2.68 | 1.08 | 0.26 | 1.03 | 30.09 |
| **Rice** | 0.27 | 0.06 | 3.40 | 0.16 | 0.37 | 1.38 | 11.51 |

Obesity, reduced systemic inflammation, higher glycemic indexalong with a rise in oxidative stress are all variables that contribute to the development of diabetes and enhance its severity. Probiotic, Prebiotic, and Synbiotic dietary approaches, as well as foods having high content of polyphenols, effectively mitigated some of the negative effects of diabetes [28]. A grain with significant nutritional value, millet is also having highfibre content, vitamins and minerals content. It has complicated sugars that breakdown gradually and deliver glucose into circulatory systems gradually. This helps the body's blood sugar levels to be controlled. Pearl millet helps diabetic people to maintain stable blood sugar level over a long period of time. It is advantageous for diabetics because it has a relatively low glycaemic index, aids in consistent digestion, and contains glucose at a slower rate than other meals [29].

Pearl millet has an exceptionally elevated degree of amylase action — about ten times more than wheat. The main sugars in the flour are maltose, D-ribose and contain little fructose and glucose [30]. Diet is regarded as the cornerstone of diabetes mellitus therapy, and it is crucial in the case of non-insulin-dependent diabetes mellitus (NIDDM), which includes metabolism of glucose and secondary lipid and protein deficiency as the major derangement [31]. Similarly, the high fibre, flavonoid, and polyphenol content of finger millet's bioactive components make them anti-diabetic. They also regulate hyperglycemia and lessen oxidative stress by serving as antioxidants. The phytic acid (0.48%) and trypsin inhibitory substances in finger millet grains negatively influence the absorption of proteins and sugars in the gut and reduce glycemic index [5]. Finger millet's high content of polyphenols and prebiotic dietary fibers makes it easy for gut bacteria to produce the short-chain fatty acids (SCFAs) mainly butyrate, which regulates insulin sensitivity, mild systemic inflammation, and glucose-lipid metabolism [32.33].

Dietary management of diabetes involves lowering postprandial hyperglycemia and maintaining strict glycemic control. Jenkins *et al.,* (1981) introduced the Glycaemic Index (GI) concept, which has its roots in the physiological categorization of carbohydrate diets according to the blood glycosis reaction they cause [34]. Mani *et al.* (1993) stated that Kudo millet has the lowest Glycaemic index alone as well as in combination with other minor millets like greengram (*Phaseolus aureus* Roxb), Bajra (*Penniseteum typhoideum*), Jowar (Sorghum vulgare) compared to other meal which helps to control glucose in non-insulin-dependent diabetes mellitus (NIDDM) patients [35].Low-glycemic diets help to assist in LDL cholesterol metabolic regulation and control blood pressure, which results in less pronounced insulin reactivity [36]. Millets can be used to make a variety of novel foods, and traditional diabetic recipes must be promoted.

Millet-based food stuffs have also been associated to lowering GIs in pre diabetic individuals and individuals with type 2 diabetes due to their high dietary fibre and protein content [37]. It has been demonstrated that type 2 diabetes subjects who consumed proso millet had a significantly reduced glucose impact [38]. The technique and duration of cooking a meal may affect the glycemic and insulinemic reactions [39]. These results were particularly affected by the temperature of frying and the time of the fermentation. According to Sukar *et al.*, adiponectin levels significantly increased the study, which was accompanied by a significant drop in blood sugar levels [40]. These results suggest that a diet rich in pearl millet whole grains might contribute significantly to bringing back adiponectin levels in the blood to their normal levels. It is well documented that high adiponectin levels stimulates activation of AMP-activated protein kinase in the liver and skeletal muscle to utilize glucose [41], and pearl millet based diets 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 the reaction of postprandial blood glucose in rats. Pearl millet controls intestinal GLUT, boosts muscle glucose absorption, and decreases hepatic gluconeogenesis, and phenolic substances found in millets are also known to enhance insulin action [42].

A condition known as prediabetes, which can promote the onset of diabetes (type 2) and cardiovascular illnesses, is characterised by high plasma glucose levels but no yet-attained diabetes-related threshold. In prediabetes, insulin resistance and decreased beta-cell activity are frequently present. Due to increased reactive oxygen species (ROS) production and upregulated indicators of chronic inflammation, hyperglycemia can lead to vascular dysfunction. In contrast, high levels of oxidative stress and inflammation can cause insulin resistance and reduced insulin production. Therefore, preventing ROS overproduction is essential for postponing the development of diabetes and avoiding cardiovascular problems. Millet naturally contains various types of bioactive substances, including polyphenols, the majority of flavonoids, and phenolic acids which may lead to a number of health advantages due to their antioxidant and anti-inflammatory effects [43].

Diabetes is less common in millet-eating cultures, according to epidemiological studies [44]. Due to the high levels of fibre content, plant-based compounds and fatty acid composition, pearl millet grains

provide a wide range of beneficial characteristics [45]. In nutritional programming, the knowledge gathered about pearl millet's nutritional impact is extremely important. Obesity, inherited predispositions, and a high consumption of high-glycaemic foods are the usual contributors to diabetes. The effects of pearl millet consumption on the glucose metabolism of diabetic rats were evaluated by Nani*et al.* [46].

As an option in contrast to prevention, the authors proposed that consuming meals made from pearl millet might be beneficial in treating type 2 diabetes with induced hyperglycemia and so lowering the the seriousness of the disease. It was discovered by Hegde*et al.* that animal food containing 55% kodo millet shows 42% reduction in hyperglycemia, 27% in cholesterol level and 27% reduction in the levels of both non-enzymatic antioxidants (glutathione, vitamin E and vitamin C) and enzymes (glutathione reductase) [47].Due to the characteristics of starch, such as amylase content, polygonal size with porous surfaces and oleic acid content, which can cause problems with lipid inter-acid starch protein and starch molecules, compared to several other cereals, millet grains provide a higher quality of slowly digested starch [48].Additionally, the presence of phytochemicals like phenolic acids, flavonoids, and phytats might result in an inhibition of gastrointestinal -amylase (pancreatics) and -glycosidase (intestinal) activity in monosaccharides, lowering the presence of hyperglycemia in the body [49]. However, the way millets are processed has significantly affect hypoglycemic condition, thus it's critical to encourage the adoption of low starch hydrolysis technologies [50].

**MILLET FOR OTHER HEALTH BENEFITS**

Millets high mineral and protein content offers a number of nutritional benefits. Along with vital minerals like magnesium, phosphorus, zinc, and others, it is high in protein. Additionally, it gives essential nutrients such as amino acids and vitamins that support a number of human therapies, such as those to prevent stomach ulcers, decrease the chance of cancer, help with weight loss, prevent cardiovascular diseases, manage blood pressure, halt migraines, and encourage bone formation [48]. Excessive stomach acid after eating is the primary cause of stomach ulcers [51]. Among the selected cereals that alkalizes the stomach, inhibits stomach ulcers, or reduces the symptoms of ulcers, pearl millet is commonly recommended for healing of stomach ulcers [52]. Millets are beneficial for heart patients due to their high amount of dietary fibre and cholesterol-lowering qualities. Pearl millet's phytic acid accelerates the body's metabolism of cholesterol and stabilises its levels. Niacin is another vitamin that lowers cholesterol. Furthermore, pearl millet has been found to be heart-healthy. Magnesium lowers cardiovascular stress and controls blood pressure, has been discovered in pearl millet in substantial proportions [53]. Millets offer a greater supply of healthy omega-3 fatty acids than other grains. Omega-3 fatty acids are known to have cardiac protective properties and are linked with normal heart rhythm, lower blood pressure, and triglycerides. It helps to reduce migraine episodes and has a high magnesium content, which helps asthma sufferers have less respiratory problems [54].Pearl millet's high phosphorus content is essential for bone formation and growth along with the production of ATP, the body's primary source of energy [55]. Pearl millet is anticipated to have the same impact as millets, which are known to lower the incidence of cancer, possibly due to high magnesium content and phylate chemical concentration [56].

Regulating calorie intake is the biggest challenge for those who want to lose weight. Due to its abundance of fibre content, it will aid in weight loss. Pearl millet helps to reduce overall calorie consumption since it satiates appetite for a very long time [57]. Small amount of gluten is intolerable for someone with celiac disease. Due to its lack of gluten, millet is great for those with celiac disease [58]. Amino acids are necessary for the organism to function properly [59]. Pearl millet serves as one among the rare foods that has all essential amino acids. Unfortunately, a large number of these amino acids are lost during cooking since they can't resist high temperatures owing to their hypo-allergic nature. To preserve the maximum amount of amino acids possible, it is preferable to consume them in a low-cooked form[60].It is also well known that pearl millet's high fibre content reduces the risk of bile formation. Pearl millet contains insoluble fibre that reduces the body's generation of extra bile. Excessive bile production from the intestines aggravates gallstones [61]. It's safe to provide pearl millet to young children, nursing mothers, the elderly, and people who are recovering from sickness [19]. Potassium, which is essential for those with high blood pressure, is also abundant in pearl millet. Increasing your consumption of foods high in potassium lowers blood pressure by aiding the body's process of excreting salt.

**CONCLUSION**

The food business is under pressure to develop novel foods with special properties that can enhance people's health as a result of growing nutritional understanding. The health advantages of millet and foods made from it are increasingly notable, and they are especially beneficial for diabetics. It is an

excellent source of complex dietary fibres, health-improving phytochemicals, vitamins, and minerals and is especially advantageous for diabetes people. Different bioactive substances found in millet have a wide range of health advantages, including antimicrobial, antioxidant, immune modulator, detoxifying agents, antidiabetic, and hypocholesterolemic effects, as well as hypoglycaemic activity and protection against age-related degenerative diseases like cardiovascular diseases (CVD), diabetes, cancer, etc. The inclusion of more nutrient-dense and traditional whole-grain and multigrain alternatives to processed carbohydrates as part of a therapeutic dietary adjustment and also to promote the usage of millets. In rural places, it is still mostly limited to household-level communities. Diversification of food production and consumption, along with increased yield, must be encouraged at both the household and national levels in order to enhance the dietary intake of millets and millet-based food products and make effective use of its enormous nutritional potential.

**Conflict of Interest**
**The authors declare that there is no conflict of interest.**

**Authors Contribution**
**Neha Dahiya:** Investigation, Conceptualization, Writing - Original Draft preparation, **Yuvraj Yadav:** Validation, Supervision**, Parameet Kaur:** Writing - Review & Editing, **Sonal:** Proofreading and formatting.

**Funding**
The research carried out received no grant or funding from any public or private sectors

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