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HARNESSING THE POTENTIAL OF YAVANALA (SORGHUM BICOLOR L.)- 'THE KING OF MILLETS' IN REGULATING THE PATHOGENESIS OF DIABETIC INDIVIDUALS: A PATHWAY TO SUSTAINABLE HEALTH DEVELOPMENT

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ABSTRACT

Ayurveda offers vital counsel for diabetes care, emphasising the strategic insertion of millets as foods into the daily routine to stabilise blood sugar levels and promote overall wellness. Diabetes, often associated with an imbalance of *kapha dosha* (A bodily element) that results in *kleda* (Dampness) presents significant health challenges globally. A meticulous search strategy was applied to synthesize data from PubMed, Scopus, and Google scholar resulting in the inclusion of 45 articles for this review. Specific keywords like "*Yavanala*", "Sorghum", "*Prameha*", "Diabetes", "*Kleda*", "Ayurveda", and "Sustainable Health Development" were used in different combinations to maximize the precision and comprehensiveness of the search. The concept of Kleda is being rigorously reviewed, with a comparison of its effects on *prameha* and advanced glycation end products (AGEs). *Yavanala*, a robust cereal crop, known in Ayurvedic classics for its *Madhura* (Sweet), *Ruksha* (dry), and *Kashaya* (Astringent) qualities, aid in achieving the equilibrium of *doshas*, notably *Kapha*. The current exploration also delves into *Yavanala's kledaghna* (Mitigating the dampness) property, which may hold promise in dropping the pathologic progression of diabetes and contributing positively to maintaining balanced blood glucose levels, as well as its possible significance for advancing sustainable health development. Furthermore, the adoption of *Yavanala*-based food products can be an essential

phase towards long-term health development by offering a low-cost and easily accessible alternative to conventional grains for diabetes-affected communities. By embracing *yavanala's* potential, we can take a significant step towards ensuring equitable and inclusive health development for diabetes-affected communities globally through certification.

KEYWORDS: Ayurveda, diabetes, *kleda*, sorghum, sustainable health development, *yavanala.*

INTRODUCTION

Modernization has resulted in modified eating patterns, which has contributed to a spike in the incidence of lifestyle-related illnesses. A balanced diet is vital for optimal health and disease prevention.[1] According to the World Health Organization (WHO), diet plays a crucial role in predicting non-communicable diseases (NCDs), and various strategies have been explored to address unhealthy eating habits. The global prevalence of diabetes is projected to rise by 51% by 2045, reaching 700 million individuals, with type 2 diabetes accounting for nearly 90% of cases, notably, that 87% of diabetes-related deaths occur in low- and middle-income countries, where staple diets are often limited in diversity.[2]

In Ayurveda, Diabetes Mellitus is recognized as *prameha*, a clinical condition with distinct characteristics and treatments.[3] Acharya emphasized the crucial significance of *kleda* (dampness) in the pathologic progression of *prameha.*[4] *Prameha* is also characterized by the presence of *kleda* in two forms: *prakrutha* (Natural) and *vikrutha* (Vitiated) state.[5,6] This *prakrutha kleda* plays an essential role in the body's normal physiological activity. The functions of dosha (physiological constituents), *dhathu* (Physiological elements), *agni* (Digestive fire), and *mala kriya* (Excretory functions) are hampered when the *vikrutha kleda* emerges and surpasses a certain level which leads to the manifestation of *prameha* and its complications. Currently, the concept of *kleda* is not being widely considered in therapeutic strategies for diabetes mellitus. However, by addressing the presence of *kleda*, it is possible to potentially modify the disease prognosis. While medications play a significant role in managing *prameha*, their effectiveness in regulating its pathologic progression is limited. In Ayurvedic healing, *pathya* (Wholesome dietary regimen) hold a paramount significance in promoting overall well-being and balance. They serve a dual purpose by promoting overall wellness and enhancing the healing process in the treatment of illness.[7] Drugs, exercise, education in monitoring glucose levels, and food are the four defined pillars of diabetes management. Diabetes prevention, as well as treatment, can benefit from a healthy diet.[8]

Millets can be effectively integrated into the diets of individuals with diabetes. Millets contain antioxidative, anti-inflammatory, and insulin-reducing bioactive components that consist of non-starch polysaccharides, flavonoids, polyphenols, protein, certain vitamins, and minerals. Millet's nutraceutical potency helps to reduce the glycaemic index (GI) of foods containing millets.[9] Among the millets stated by Acharya, *yavanala* (Sorghum) has the *kledaghna* (Property of mitigating dampness) property, which will aid in the *kledanirharana* (Elimination of dampness).[10] The elimination of *vikrutha kleda* is considered as a crucial stage in achieving the successful *upakrama* (treatment). This exploratory review examines the potential of *yavanala* in reducing *kleda* among individuals with diabetes, with an emphasis on the enhancement of diabetic management.

MATERIALS AND METHODS

In the process of synthesizing data, a rigorous search strategy was employed. Initially, the bibliographic databases like PubMed, Scopus, Google scholar, and Ayurveda-related databases were screened using a combination of keywords and Boolean operators. Keywords such as "*yavanala*", "sorghum", "*prameha*", "diabetes", "*kleda*", "Ayurveda", and "Sustainable Health Development" were used individually or combined using Boolean operators (AND, OR, NOT) to enhance the precision and exhaustiveness of the search. Using the phrase "Sorghum AND Diabetes" yielded 58 articles that explored the relationship between sorghum and diabetes management. After the retrieval of the relevant literature, a selection process was executed, excluding 13 studies that were not directly related to the topic. The final set of 45 articles were then in-depth analysed, data was collated, and insights were gleaned to provide a holistic perspective on *yavanala's* potential in diminishing *kleda* and thereby enhancing the healing process among diabetic population.

AIMS

- To conduct a comprehensive review and provide a summary of the current scientific literature regarding the impact of *kleda* in managing diabetes.
- To elucidate and investigate the potential mechanisms of *yavanala* (Sorghum) may offer advantages in addressing *kleda* among individuals with diabetes.
- To examine the potential implications of incorporating *yavanala* (Sorghum) into the diet for promoting sustainable health development, especially within communities affected by diabetes.

OBJECTIVES

- Compile and review relevant studies and trials investigating the relationship between *kleda* and diabetes
- Synthesize data on potential mechanisms of action, considering both in-vivo and clinical studies to provide a broad overview of how *Yavanala* (Sorghum) might aid in anti-diabetic activity.
- Assess the potential role of *Yavanala* (Sorghum) as a part of sustainable health development strategies, focusing on its nutritional content, availability, and overall impact on health outcomes.

Unravelling the pathogenic influence: The pivotal role of *kleda* in disease generation

Kleda, often overlooked, is a crucial component of the human body. It can be understood as hydration, moisture, or dampness. In the *bhava padartha* (True entities of Ayurveda), *kleda* is described as the embodiment of *jala mahabhootha*, representing the water element in the body.[11] Its *drava* (Liquid portion*), snigdha* (Unctuous), and *mrdu* (Soft) qualities facilitate the loosening of solid materials. When there is accumulation of excess fluids in the tissues due to metabolism or pathological conditions, it is necessary to eliminate them through *mootra* (Urine) and *sweda* (Sweat). Failure to do so leads to the development of *vikrutha kleda* in the body. While *sweda* also plays a role in elimination, it is primarily through *mootra* that *kleda* is expelled, hence its association with *kledavahana* (Vehicle to transport dampness).[12]

Decoding the link: The role of *kleda* in the pathogenesis of diabetes mellitus

Prameha is recognised as an *anushangi vyadhi* (Chronic in nature).[13] According to Acharya Charaka, the excessive generation of *meda* (Bodily fat), and *mutra* are the cardinal signs of *prameha*.[14] These factors primarily generate an undue stress on cellular metabolism, resulting in intermediate metabolites. The altered metabolism triggers an increase in the synthesis of *kleda*, *mutra*, and *sveda*. In Ayurvedic medicine, *'kleda'* is a critical notion profoundly connected with *'prameha'* reflecting current perceptions of diabetes and other metabolic disorders.[4] *Kleda* refers to the accumulation of excessive fluids or unhealthy substances in the body, leading to an imbalance in the three doshas - *vata*, *pitta*, *kapha* (Bodily elements*). Acharya Charaka* recognized *kleda* as a primary causative factor in the development of *prameha*.[15] Excessive production of *kleda* can hinder *agni*, causing blockages in the channels (*Srotoavarodha*) and contributing to the progression of *prameha*.

Therefore, effective management of *kleda* is considered crucial in the prevention and treatment of *prameha* in Ayurveda. According to *ashray- ashrayi bhava* (Inter-dependency of elements), *vikrutha kleda* affects the *mamsa* (Muscle bulk) and *meda*, it enters the *basti* (Urinary bladder) and impairs the function of *mootra*.[16] This condition exhibits similar to *prabhoota aavila mootrata* (Excessive turbid urine).[17] Thus, *kleda* represents a hidden risk factor that can aggravate the pathogenesis of diabetes, pushing the disease into a more complex stage in the affected population.

Restoring balance: The role of *kledanirharana* (Expulsion of *kleda*) in mitigating *prameha*

Kledanirharana (The expulsion of *kleda)* is considered as a crucial step in ensuring the accurate completion of *upakrama* (Treatment). The extent of this practice can range from a minor *dushtavrana* (Localized wound) where a small amount of *kleda* is present, to a complex *prameha* where *vikrutha kleda* is widespread. A deep understanding of *kleda* can assist a doctor in comprehending even the smallest factors involved in the development of an illness. *Mutrapraiksha* (Examination of urine) can be a valuable tool in this regard. In the context of *prameha*, significant emphasis is placed on *mutra* and *mutra pariksha* for the diagnosis, treatment, and resolution of the condition. Therefore, *mutra pariksha*, particularly in relation to *aavilatha* (turbidity), holds utmost importance.[18,19,20]

Aavilatha is considered one of the cardinal signs of *pramehi mutra* (Urine in diabetes) mentioned in all Ayurvedic classical texts.[16] The knowledge of *aavilatha* is summarized under terms like *"samala"* (Cloudy), "*isat pichila"* (Slightly slimy), and "*dhusara*" (Turbid) after an extensive review of various sources. Collectively these terms describe *kleda* as a nearly opaque and appears translucent that has sedimentation power. *Aavilatha* is thus associated with light absorption and diffusion, which relates to the object's transparency and optical density (OD).[21,22,23] Therefore, the colorimeter instrument, based on OD principles, has been chosen for *mutra pariksha*.[24] With the use of optical density methods, it is now possible to analyse *kleda* and potentially mitigate the pathogenesis of diabetes in the future, offering valuable insights for improved treatment.

The Ayurvedic notion of *kleda* bears similarities with the accumulation of detrimental by-products resulting from metabolic process, such as formation of advanced glycation end products (AGE's). Increased *kleda* can be seen as a metaphorical representation of imbalance in the body, such as metabolic waste build-up, including AGEs, as a result of poor dietary

habits and imbalanced lifestyle. In this metaphorical sense, AGEs might be associated with the concept of dampness or moisture. The accumulation of AGEs can also contribute to insulin resistance. Insulin resistance is a hallmark of type 2 diabetes which in turn can lead to pancreatic exhaustion and a further escalation in blood glucose levels. This creates a vicious cycle, as increased blood glucose levels lead to more AGEs, which further contribute to insulin resistance and diabetes progression. Therefore, the relationship between AGEs and diabetes is multifaceted and contributes to both the progression of the disease and its associated complications.[25] The treatment approach for *vikrutha kleda* in the human body should be multifaceted. In addition to internal and external therapeutic strategies addressing the disturbed state of *kleda*, it is crucial to incorporate *kleda*-reducing foods into the dietary plan for treating *prameha*. These foods play a significant role in regulating the condition and improving the patient's overall health.

Tracing ancient wisdom: A literary review of the role of *yavanala* in managing *prameha*

The essential characteristics of *trina dhanya* (Millets) as mentioned in the text include *ushna veerya* (Hot in potency), *kashaya* and *madhura rasa* (Astringent and sweet taste), *katu vipaka* (Pungent post-digestive effect), *laghu* (Light), *ruksha* (Dry), *kledashoshaka* (Absorbs dampness), *lekhaniya* (Scraping), *vatahara* (Balancing Vata), *baddha mala* (binding stools), and *pitta-raktha* and *kapha shamaka* (Balancing pitta-raktha and kapha).[26,27]

Among the millets, *Sorghum bicolor L*, commonly known as king of millets or *yavanala*, is highly valued in Ayurveda for its unique properties that help balance these doshas. The *kasaya-madhura rasa* (Astringent-sweet taste), *sheetha virya* (Cold in potency) of *yavanala* can aid in balancing *Vata* and *Pitta doshas*, while its *kashaya* (Astringent) and *ruksha* (Dry) attributes can support in regulating the *kapha dosha*. These balancing properties may be the key to how *yavanala* aids in managing *kleda* among individuals with diabetes. Also, the *madhura kashaya rasa* and *katu vipaka* of *yavanala* effectively mitigate carbohydrate absorption in the human body, aiding in the regulation of glycated end products, thereby arresting the progression of diabetic pathological processes. The *kledaghna* (Reducing dampness) property of *yavanala*, as stated in '*kaiyyadeva nighandu's' dhanya varga*, is a defining aspect of this article.[28]

Harvesting health: Exploring the potential benefits of sorghum on human well-being

Sorghum possesses a wide range of potential due to its agronomic qualities; and the increasing knowledge about the biological properties of the phytochemicals present in the

grain, which significantly impact human health. However, in vitro and animal studies have shown that various phytochemicals such as tannins, phenolic acids, anthocyanins, phytosterols, and policosanols benefit the gut microbiota and parameters related to noncommunicable diseases such as obesity, type 2 diabetes, dyslipidemia, cardiovascular disease, cancer, and hypertension. Sorghum includes a varied spectrum of significant bioactive phenolic chemicals in addition to its agronomic benefits.[29]

Sorghum's resurgence: A comprehensive review of its role in mitigating diabetes

Studies related to the effect of sorghum in glucose metabolism in animals	**Scientific evidence**
Chung IM et. Al,[30] Kim J[31]	The presence of phenolic chemicals. This makes sorghum a viable food option for individuals with obesity and diabetes. In rat experiments, extracts of sorghum phenolic compounds significantly reduced plasma glucose and glycaemic levels. Because of its substantial influence on plasma glucose and insulin, in-vivo investigations revealed that phenolic extracts of sorghum had a hypoglycaemic effect similar to glibenclamide, an anti-diabetic medicine used in the control group. Hence suggests that sorghum phenolics may regulate insulin and serve as an adjunct in diabetes treatment. Also suggest that phenolic substances of sorghum may also impact insulin-dependent processes, including insulin concentrations and sensitivity in humans. Diabetic rats that received extracts of phenolic components showed increased insulin concentration, indicating improved cell activity. Furthermore, it has been proposed that phenolic substances lower blood glucose concentrations by blocking hepatic gluconeogenesis via downregulation of the PEPCK (Phosphoenolpyruvate carboxykinase) and p38 (Mitogen-activated protein kinases) genes and overexpression of the AMPK (Activated protein kinase) gene.
Chung IM et. al[32]	The phenolic extract was found to increase serum insulin levels in these rats
Poquette NM et. al[33]	Eating muffins containing sorghum has been proven to alter blood glucose and insulin levels, improve glycemic response in healthy adults.
Hargrove JL et. al[34]	The presence of condensed tannins in sorghum may contribute to its anti-diabetic activity. At low concentrations, a tannin-rich extract from brown sorghum bran possesses inhibitory effects against porcine pancreatic -amylase
Links MR et. al[35]	The crude extract from type III tannin sorghum also had substantial inhibitory actions against yeast -glucosidase that was approximately 20,000 times stronger than acarbose, a known inhibitor of pig pancreatic α-amylase and these findings suggest

	that sorghum phenolic compounds may act on metabolic pathways involved in carbohydrate absorption, thus helping to prevent and treat glycaemic issues in humans. This inhibiting digestive enzymes to limit glucose digestion may be the initial activity in anti-diabetic mechanism of sorghum phenolic compounds in humans
Park JH et. al[36]	Oral administration of sorghum phenolic extracts can prevent and operate as an adjuvant factor in treating diabetes by insulin sufficiency. This hypothesis is supported by evidence that sorghum phenolic compounds exerted anti-diabetic effects in rats fed a hyper lipidemic diet by increasing adiponectin and decreasing TNF-α (Tumour necrosis factor alpha) through overexpression of PPAR-γ (Peroxisome proliferators- activated receptor γ), leading to improved insulin sensitivity.

The impact of sorghum-based food products in the Management and Mitigation of *prameha*: a comprehensive study

According to a study by Madhrapakkam Pagadala Rajendra Prasad et al., sorghum-based products such as sorghum semolina upma, flakes poha, cookies, and pasta have lower glycaemic index (GI) and glycaemic load (GL) compared to wheat/rice-based foods. This can be attributed to the higher dietary fibre content in sorghum-based goods, which may affect carbohydrate digestion and result in a reduced glycaemic response.[37] Scientifically another noteworthy effect of sorghum is its utilisation in producing high quality gluten free products, attributed to its phytochemicals and low glycaemic index. This characteristic renders sorghum extremely beneficial for diabetes management.[38]

The recipes are provided in this table

Recipe name	Preparation method
Roti	This was made by kneading flour (Sorghum-rich multigrain) and water (50 mL) into a soft, homogenous dough. The dough was made into little balls and flattened on a hard wooden or metal surface before being baked on both sides in a hot pan.
Upma	To make coarse semolina upma and fine semolina upma, coarse semolina (Particle size 1.18 mm) and fine semolina (Particle size 0.6 mm) were combined. One cup of semolina was roasted till brown. One teaspoon of oil was heated in a pan and seasoned with mustard seeds, Bengal gram dhal, chopped onion, green chilies, and curry leaves. The mixture was cooked in three cups of water and a pinch of salt were added. The roasted semolina was then slowly added and cooked at a low temperature until soft.
Poha	After washing sorghum flakes in a sieve under running water for 2 minutes and allowing them to drain, one tablespoon of oil was heated in a pan over medium heat. Mustard seeds, curry leaves, turmeric, chopped onions, and green chilies were added to the

	heated oil and cooked for 1 minute before adding the drained flakes.
Pasta	In a deep pan, the required amount of water was boiled, then pasta (Sorghum) with a pinch of salt was added and cooked until soft (But firm). The cooking water was preserved after it was drained. The prepared pasta was also set aside. In a separate pan, one teaspoon of oil was heated and sauteed with chopped onions, green chilies, and ginger garlic paste. Tomatoes were cooked in the mixture until tender. Chilli powder, salt, garam masala (A spice blend), and cooked pasta were all mixed together and tossed together. Because carbohydrates were lost in the cooking water, the volunteers were also given the drained water when the pasta was provided.
Biscuits	Coconut palm sugar (11.1%) and fat (22.2%) were creamed in a mixer with a flat beater for 30 minutes to make biscuits. Sorghum or wheat flour (55.5%) was sieved with baking powder (0.8%) and salt (1.1%). The cream, milk solids (7.4%), flour mixture, and essence (1.9%) were combined into a dough. The dough was sheeted using a rolling pin and flat rolling board and baked for 30 minutes at 150 °C.

This table displays the levels of dietary fibre (gkg^{-1}) such as insoluble dietary fibre (IDF), soluble dietary fibre (SDF) and total dietary fibre (TDF) of afore mentioned recipes.[37]

Recipe name	IDF (gkg^{-1})	SDF (gkg^{-1})	TDFR (gkg^{-1})
Roti	98.0	29.4	127.4
Upma	79.1	13.1	92.2
Poha	54.3	5.4	59.7
Pasta	48.4	7.6	55.9
Biscuits	35.4	17.0	52.4

The average glycaemic index and glycaemic load values with respect to the available carbohydrate content (CHO) for the recipes discussed earlier.[37]

Recipe	GI	Serving size (g)	Available CHO (g per serving)	GL
Roti	68±8.63	119	52	35±6.2
Upma	53±2.84	232	44	23±1.24
Poha	45±5.27	277	111	50±5.85
Pasta	46±6.47	330	133	60±2.8
Biscuits	54±6.30	75	44	23±8.4

Advancing sustainable health development with *yavanala*: Potential implications for diabetes-affected communities

Diabetes, a chronic metabolic illness that impacts many individuals worldwide, presents significant challenges to public health systems. Embracing the concept of sustainable health

development, which integrates health, societal, and environmental factors, can offer a more comprehensive approach to managing diabetes. The utilization of natural resources, such as *Yavanala*, a versatile grain that has demonstrated promising effects in managing chronic diseases like diabetes, plays a crucial role in this endeavour.

Attributes of sustainable development

Attributes of sustainable development	**Explanation**
Food security [39]	Sorghum is adaptable to a variety of agronomic and environmental conditions and offers nutritional value to humans, animals, and industrial usage.
Biodiversity and Resilience [40]	The genetic diversity of sorghum allows it to adapt to varying ecological conditions, enhancing the resilience of agricultural systems to climate change and pests
Soil health [41]	Sorghum, being a resilient crop improves soil fertility in a variety of cropping systems by increasing soil organic matter, improving microbial activity, and inhibiting soil-borne diseases.
Economic development [42]	Sorghum is listed as the fifth key cereal crop globally as a source of food, feed, alcoholic beverages, fodder and industrial applications such as biofuels and bioplastics, contributing to economic development and job creation.
Climate change mitigation [43]	Sorghum is a C4 plant, implying it transforms CO_2 into biomass efficiently through photosynthesis. As a result, its cultivation aids in the sequestration of carbon dioxide, a key greenhouse gas, potentially moderating climate change.
Resource efficacy [44]	In comparison to other grains such as maize or wheat, sorghum requires less water and may thrive in low-nutrient soils. Because of this, it is a resource-efficient crop that is excellent for sustainable agriculture.

The prospects for *yavanala* (Sorghum) in urging long-term health progress, particularly in diabetes-affected communities, are highly promising. Sorghum has a variety of direct health benefits, such as improved blood glucose regulation and antioxidant properties, and indirect benefits through its role in sustainable farming and economic growth. These characteristics make sorghum a versatile resource for long-term health improvement. Nonetheless, further research is needed to completely comprehend and optimise these benefits, paving the way for a new era of comprehensive, long-term health improvement.

Future Possibilities and Research scope

Potential theme	Avenue for research
Validating and standardizing the concept of *kleda*	Identify biomarkers that could represent *kleda* in a biological context.
Mechanistic studies	Investigations into the mechanisms by which *yavanala* influences diabetes pathologic process which can contribute to the field of molecular biology.
Clinical trials	By comparing the effects of *yavanala* as a dietary supplement with other diabetes management regimens, researchers could conclusively determine its efficacy through clinical trials.
Standardisation and quality control	For *yavanala* to be adopted as a mainstream dietary supplement, it would need to be standardized and subject to strict quality controls.
Environmental impact	Research on the sustainable production and use of *Yavanala*, could contribute to environmentally friendly practices in health and agriculture.
Nutritional science	Research on *Yavanala* would contribute to the broader field of nutritional science, particularly regarding the role of dietary supplements in disease prevention and management.

CONCLUSION

In conclusion, data gathered on *Yavanala* suggests that it may play a promising role in reducing *Kleda* in the diabetes pathologic process and, opening up new avenues for furthering sustainable health development. The hypothesized *kledaghna* property of *yavanala*, as described in *Kaiyyadeva Nighandu*, may have significant therapeutic implications in managing the cardinal element of *Kleda* associated with diabetes. The apparent potential of *yavanala* in fostering improved glycaemic control and treating the debilitating effects of *kleda* in the diabetes population emphasises the significance of additional research and development of this cereal crop for dietary therapies. By acknowledging *yavanala* as an appealing alternative to conventional grains, healthcare practitioners, policymakers, and agricultural experts can collaborate to open up the way for long-term health development, addressing diabetes challenges while ensuring food security and environmental sustainability. However, more structured clinical trials and longitudinal studies are needed to determine *yavanala's* long-term efficacy, safety, and appropriate use in the management of diabetes-related *Kleda*, thus fully realizing its potential for improved global public health outcomes.

Author contribution

Dr. Varshanath. B: Writing- original draft and developed the review concept of *kleda* and *yavanala* in *prameha* and provided the structure for the article, Dr. Harikrishnan. G- Analysed

and evaluated the existing experiments from multiple research articles, resulting in an in-depth knowledge of how Sorghum bicolor L. can assist in diabetic control.

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