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REVIEW ARTICLE OPEN ACCESS

APPRAISAL OF ANTI HYPERGLYCEMIC EFFECT OF *KODO* MILLET (*PASPALUM SCROBICULATUM*) - A REVIEW

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ABSTRACT

Background: India is the second country in the world having 77 million people with Diabetes after China. An estimated 88 million adults are prediabetes, 34.5% of the U.S. adult population. According to National Urban Diabetes Survey, the estimated prevalence of prediabetes is 14 per cent in India. Prediabetes is a serious health condition where blood sugar levels are higher than normal (hyperglycaemia), but not high enough yet to be diagnosed as diabetes. In Ayurveda Prediabetes and Diabetes Mellitus has been described in the context of Prameha/Madhumeha in which a person passes honey like (sweet) urine. *Kodo* millet (Paspalum scrobiculatum) is a nutritious grain popularly known as poor man's food. Acharya Sushruta has mentioned *Koradusha* in the management of *Prameha* as *a Pathya Ahara*. **Aim and objective**: 1. To explore the role of Kodo millet in the management of Prediabetic and Diabetes mellitus. 2. To explore different properties of *kodo* millet in Ayurvedic and Modern point of view. **Materials and methods:** Ayurvedic treaties Bhrittrayi and Laghuttrayi, text books, magazines, News, previous dissertations. Electronic search was done by using PUBMED, SCOPUS, Google scholar, research gate etc. **Results:** *Kodo* millet is rich in Phenolic compounds, Tannins, Saponins, Proteins and amino acid, fibre, magnesium, Phytic acid, polyphenols, tannin and antioxidants. According to Ayurveda *Kodo* contain *Madhura Kashaya rasa, Katu vipaka, Sheeta virya, Lekhana, Shoshana* properties which further leads to *Kleda shoshana* i.e. absorption of *kleda* and controls *Madhumeha* or Diabetes. **Conclusion**: Hyperglycemia can be effectively controlled if *kodo* millet is incorporated as a daily diet in Prediabetes and Diabetes Mellitus.

Keywords: Hyperglycemia, Prediabetes, Diabetes Mellitus, *Prameha/Madhumeha*, Millets, *Kodo* millet/ *Koradusha*, *Paspalum scrobiculatum*

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INTRODUCTION

India is the second country in the world having 77 million people with Diabetes after China. According to diabetics statistics 2021, 34.2 million U.S. adults are with diabetes, approximately 7.3 million of those are undiagnosed. An estimated 88 million adults have prediabetes, 34.5% of the U.S. adult population. About 7% of pregnant women develop gestational diabetes.[1] Prediabetes is a serious health condition where blood sugar levels are higher than normal (hyperglycemia), but not high enough yet to be diagnosed as diabetes. In this modern era, due to varying factors of faulty dietary habits, work pressure, competitive lifestyles, longevity, all contribute to hypreglycemia.[2] In this SARS CoV 2 pandemic, Diabetes is one of the most relevant co-morbidity in worsening the prognosis of COVID-19. Hyperglycemia at the admission in hospital seems worsening the prognosis of COVID-19 more in people without diabetes than in people with diabetes. Inappropriate and abusive use of corticosteroids has given rise the condition of hyperglycemia in this pandemic.[3]

Hence glucose control and management is a main key in the management of hyperglycemia. Patients with hyperglycemia, with or without diabetes can manage or prevent the high glucose levels in blood by managing stress, Exercise, Maintaining a healthy weight and proper Diet control.

In Ayurveda Prediabetes and Diabetes Mellitus has been described in the context of *Prameha/Madhumeha* in which a person passes honey like (sweet) urine.[4] The main causative factor for this condition is said to be sedentary lifestyle, excessive in-take of sweet, non-vegetarian, dairy product, Jaggery (Canesugar preparations) and heavy & excess meals.[5]

Ahara is one of the three supporting factors of life which plays a key role in the promotion of health & prevention of diseases.[6] Millets have been widely used in therapeutics in Ayurveda classics. One of the most important and nutritional millet is Kodo Millet or Kordusha. Acharya Sushruta has mentioned Koradusha in the management of Prameha as a Pathya Aahara [7] *Kodo* is classified under *Truna dhanya* (grassy grain) or *Kudhanyahas*.[8] It has the properties like; *Laghu* (light to digest) *Rukha Guna, Kashaya* (astringent) *Madhura* (sweet) *rasa* (taste), *Katu* (pungent) *Vipaka* (post digestion effect), *Sheeta Virya* (cold potency). It's mode of action is *Kapha Pitta shamaka, Grahi, Shoshana* and *Lekhana*.[9] All these will lead to *Kleda Shoshana* which ultimately controls *Madhumeha* or Diabetes.

Kodo millet also provides essential Macro and micronutrients. It is a rich source of Phenolic compounds, Tannins, Saponins, Proteins and amino acid, fibre, magnesium, phytic acid and antioxidants. It contains 7.7g of Protein, 4.48g of fat, 6.12g crude fiber and 71.8g of carbohydrates per 100g. Apart from this it contain; calcium, magnesium, iron, zinc, maganese ect., important nutrients. All of these components provide nutrition and helps in the management of hyperglycemia.[10]

In present review article an efforts has been made to explore the anti hyperglycemic properties of Kodo millet so that it can be incorporated as daily diet in Prediabetic or diabetic Mellitus patients for prevention of progression of diseases.

AIM AND OBJECTIVES

- To explore the role of *Kodo* millet in the management of Prediabetes and Diabetes mellitus
- To explore different properties of *kodo* millet in Ayurvedic and Modern point of view

MATERIALS AND METHODS

Materials has been searched from the Ayurvedic treaties Bhrittrayi and Laghuttrayi, text books, magazines, News, previous dissertations. Electronic search has been done through PUBMED, SCOPUS, Google scholar, research gate etc.

Diabetes mellitus

Diabetes Mellitus is defined as the state of chronic hyperglycemia due to impairment of insulin secretion or its action.

CLASSIFICATION

Broadly it can be classified as:

1. Type I Diabetes Mellitus – Insulin Dependent Diabetes Mellitus (IDDM) or juvenile diabetes or childhood-onset diabetes.
2. Type II – Non Insulin Dependent Diabetes Mellitus (NIDDM) or Maturity onset / adult-onset diabetes, obesity related diabetes.
3. Gestational diabetes

Type I Diabetes

Type 1 Diabetes Mellitus develops as a result of the synergistic effects of genetic, environmental and immunologic factors that ultimately destroy the pancreatic beta cells. Individuals with a genetic susceptibility have normal beta cell mass at birth but begin to lose beta cells secondary to autoimmune destruction that occurs over months to years. This autoimmune process is thought to be triggered by an infectious or environmental stimulus and to be sustained by a beta cell-specific molecule in the pancreas.

Prediabetes and Diabetes Mellitus or Type II Diabetes mellitus pathogenesis

When a person eats carbohydrates, the body breaks them down into simple sugars that enter the bloodstream. After this the pancreas releases Insulin. Insulin is a hormone that allows the body's cells to absorb and use

sugars from the blood for producing energy. When the body does not make any or enough insulin, or when the cells are unable to use the insulin correctly, blood sugar levels increase. This condition is termed as Hyperglycemia. If hyperglycemia is untreated for long periods of time, it can damage nerves, blood vessels, tissues and organs. It will first develop diabetes and further leads to cardiovascular diseases, kidney damage and much more. Prediabetes is a serious health condition where blood sugar levels are higher than normal, but not high enough yet to be diagnosed as type II diabetes.

The causative factors for Prediabetes and Diabetes Mellitus are, ageing, genetic risk background, lifestyle changes like lack or decrease in physical activities, obesity, comorbidities, inflammation, faulty food habits. The beta cells of the islets of Langerhans in pancreatic gland are responsible for the secretion of the hormone insulin. Insulin allows the body's cells to absorb and use sugars from the blood for producing energy. Insulin is extremely essential for the proper utilization of the carbohydrates in our body. If its function gets dysfunctional or altered, then these carbohydrates get accumulated in the blood stream in the form of glucose leading to hyperglycemia. This is called as insulin resistance which further leads to b-cells dysfunctions. The glucose then collects in the urine, which is one of the primary characteristics diabetes mellitus. Also this Excess glucose gets stored in the liver as glycogen or, with the help of insulin, converted into fatty acids, circulated to other parts of the body and stored as fat in adipose tissue. And after chronic hyperglycemia it can lead to central obesity. This is a risk factor of many non-communicable diseases like, hypertension, atherosclerosis, dyslipidemia, cardiovascular diseases.[11]

Prediabetes and Diabetes according to Ayurveda

In Ayurvedic texts there are two major categories of *Prameha* 1. *Sahaja Prameha* and 2. *Apathyanimittaja Prameha*.[12] Sahaja prameha occur mainly due to *Mathru Pithru Bija* Dosha i.e., defects in *Bija* or *Bijaavayava* implies defects in genetic material which can be taken forDiabetes due to Hereditary origin in modern parlance. It can be correlated with Type I Diabetes Mellitus. The second variety of Prameha i.e. *Apathyanimittaja Prameha*, occurs due to unhealthy habits or lifestyle. *Apathyanimittaja Prameha* has close resemblance with the contemporary concepts of Prediabetes and Type-2 Diabetes mellitus.

Ayurveda has also described *Sthula Pramehi* and *krish pramehi*,[13] out of which *Sthula Pramehi* clearly corresponds to the current concepts of overweight & obesity and its role in the genesis of Diabetes mellitus.

Aetiology of *Prameha/* Prediabetes/Diabetes Mellitus

An excessive intake of *kapha*-vitiating food articles or lifestyle activities contributes to *Kapha Prakopa* [14]

Frequent and excessive intake of:

- Newly harvested grains like *hayanaka, yavaka* (barley) (a variety of Hordeum vulgare Linn) etc
- Newly harvested pulses like *harenu* (pea) (Pisum sativum Linn.) and *masha* (udad daal) (Phaseolus radiates Linn.), consumed with ghee,
- The meat of domesticated, marshy and aquatic animals,
- cakes of *tila,* pastries, *payasa* (milk-based pudding), *krisara* or *khichadi* (gruel prepared of tila, rice, and black gram), *vilepi* (a type of thick gruel), and sugarcane-based food preparations,
- Milk, new wine, immature curd (curd which is mostly liquid and sweet),
- Various dietary regimen that produces excess *kapha*, fat, and urine,
- Lifestyle related activities, including, avoidance of physical exercise, Excessive sleep, bed rest and sedentary habits;

Samprapti (patho-phyiology) [15]

All of these above mentioned aetiological factors *(dosha, duhya* and *nidana*) help in vitiating the *Tridoshas. Kaphadosha* is predominantly vitiated because of its close resemblance with etiological factors. This vitiated *Kapha* will leads to *Agnimandya* (decrease digestive fire) and further leads to *Dhatvagnimandya*. This vitiated *Kapha* dosha also vitiate the similar entities in the body like; *Rasa, Rakta, Lasika, Mamsa, Meda, Kleda, Majja, Oja, Shukra, Jala* (Specially *Meda*) All this will increase the amount of jala part in the body which interferes with the normal functioning of *Kleda*. This will leads to the *Kleda vikriti*. To eliminate this increased *Kleda*, more amount of urine is produced. Due to *dhatvagni mandya;* the normal functions of *dhatus* get deteriorated. Hence the functioning of *rasa, rakta, mamsa*, *meda dhatu* get altered. Involvement of different *Dhatus* results in the manifestations of various types of diseases like, *Medorog* (obesity, cardiovascular diseases), *Prameha* (diabetes), *Prameha pitika* (diabetic carbuncles), *vandhatva* (infertility), *stree rog* (gynaecological problems), etc.

In present article an efforts has been made to manage *Prameha* or *Madhumeha* or Diabetes with the help of *Koradusha ahara* or *Kodo* millet diet.

Kodo millet (Kordusha) [16]

Other Names

Taxonomic name: *Paspalum scrobiculatum L.*

Sanskrit Name: Kodrava, Kordusha, Kodo, Harika, Varagu

Hindi Name: Kodo dhana, Kodava, Kodo, Kodon, Kodaka, Koddo

Marathi Name: Kodra, Harika, Kodru

English: Kodo millet, Cow grass, Rice grass, Ditch millet, Indian crown grass

Bengali: Kodo aadhana

Gujarati: Kodra, Kodro,Meya

Panjabi Name: Kodra

Kannada Name: Harka, Gowdru Kanaja, Kodon, Arikelu, Varagu, Arka, Haraka

Tamil Name: Varagu, Koduain Odia, Karuvaragu, Varau

Telugu Name: Arika, Allu, Alu, Arikalu, Aruga

Urdu Name: Kodon

Taxonomic Classification [17]

Kingdom: Plantae

Subkingdom: Viridiplantae

Super division: embryophyta

Division: tracheophyta – vascular plants

Class: Magnoliopsida

Superorder: lilianae - monocots, monocotyledons

Order : Poales

Family: Poaceae – grasses, graminees

Genus: *Paspalum,* crowngrass

Species*: Paspalum scrobiculatum L*. ricegrass paspalum, kodomillet, ricegrass, Kodo-millet

Characteristics [18]

Kodo millet is an annual grass grain that is grown primarily in Nepal and also in India, Philippines, Indonesia, Vietnam, Thailand, and in West Africa. It is grown as a major crop in Deccan plateau in India where it is grown as a major food source. It is a very hardy crop that is drought tolerant and can survive on marginal soils where other crops may not survive, and can supply 450–900 kg of grain per hectare. This millet crop is grown in arid and semi-arid grainsof African and Asian countries. Africa and elsewhere.

Fig.1. Kodo millet Seeds

The seeds it produces are very small and ellipsoidal, being approximately 1.5 mm in width and 2 mm in length; they vary in colour from being light brown to a dark grey.

Plant morphology

Macroscopic Medicinal qualities

According to Ayurveda the properties of Koradusha are, *Kashaya madhura* in taste, *laghu, Ruksha, vatala, kaphapittaraktaghna, sheeta virya, grahi, sangrahi* and *shoshana*.[9]

Fig. 2 Kodo millet plant

Sushruta has mentioned *Katu Vipaka* of *Koradusha*.[19] Vaghbhat has mentioned *Lekhana* and *vishanashaka* property of kodo.[20] In Kaideva Nighntu *Koradusha* is classified in *Trunadhanya* and *Kledanashaka* property has been mentioned.[21]

Taste – bitter (kashaya), Madhura (sweet),

Laghu – light to digest

Ruksha – dry in nature

Virya (potency) – cold

Grahi and shoshana– absorbent in intestine

Vishajit – anti poisonous

Lekhana – scrapes excess fat

Baddhamala – constipating in nature

Kapha pitta Rakta nashaka – balances pitta and kapha dosha and used in bleeding disorders

Vayukaraka – increase vata dosha

Macroscopic Medicinal qualities (modern view)

Kodo millet (*Paspalum scrobiculatum*) is a nutritious grain. Physico functional properties revealed that kodo millet was dark grey in colour before dehulling and light yellow in colour after dehulling. According to this study nutritional composition of kodo contains per 100g.;

- 7.7g of Protein
- 4.48g of fat
- 6.12g crude fibres
- 71.8g of carbohydrates

Apart from this it contain calcium, magnesium, iron, zinc, maganese ect. important nutrients. Antioxidants property of Kodo millet has also been mentioned [6]

This study Qualitative phytochemical studies of grains were performed by another study revealed the presence of Tannins and Phenolic compounds, Carbohydrate, Saponins, Protein & Amino acid, by using suitable chemicals and reagents.[22]

DISCUSSION

Mode of action of Kodo Millet diet in Hyperglycemia (Ayurvedic view)

Koradusha has *Kashaya rasa* which helps in pacifying increased *Kapha dosha. Madhura rasa* and *katu vipaka* will help in pacifying *Pitta Dosha*. *Vikrit pitta* helps in formation of excess *drava* (liquid part) so it can be controlled. *Laghu guna* aids easy digestion. *Ruksha, sangrahi guna* absorb excess liquidity of doshas, dhatus, malas. Hence increased Jala or liquid part in the Dhatus and Malas due to vikrita Kapha and pitta dosha can be controlled.

Lekhana property – Ruksha Laghu and Shoshana properties of kodo will help in scraping excess fat i.e. Meda dhatu. Hence excess weight gain can be controlled.

Kapha pitta shamaka properties - Kodo has Kapha pitta shamaka properties, i.e. it will help in pacifying the increases Kapha dosha and altered function of Pitta doha.

Kleda shoshana- Ruksha guna is Agni and Vayu mahabhuta pradhan. Hence it will perform Kapha kshaya. So increases Kapha dosha due to Nidaan sevan can be controlled.

Katu vipaka will help in Kapha Kshaya.

Sangrahi and shoshana property of Kodo helps in absorbing excess Drava or liquid part in the different dhatus.

All the above properties will help in balancing Tridosha. Excess Kapha and Vikrita pitta will stop the formation of excess Drava dhatu. Hence excess Kleda can be controlled. This will help in samprapti vighatana. And the risk of different diseases like Prameha, Prameha pidika, Hrud rog, Medorog etc. due to Kleda vikriti can be prevented. Thus Kodo can be a very useful food article in decreasing excess Kleda and excess Meda from the body.

Mode of action of kodo millet in hyperglycemia (Modern view)

Role of phenolic compounds on hyperglycemia

According to American diabetes association (2004), diabetes is a metabolic disease and is caused by chronic hyperglycemia, leading to long term damage, dysfunction and failure of various organs. Pancreatic alpha- amylase and alpha-glycosidase play an important role in hydrolysing dietary carbohydrates such as starch to glucose and its absorption in the intestine respectively. Therefore inhibiting these enzymes play an important role in managing post prandial hyperglycemia by regulating starch breakdown and intestinal glucose absorption. Phenolic compounds derived from Kodo millet can inhibit these enzymes and helps in managing hyperglycemia. Peroxisome proliferator-activated receptor gamma (PPAR-γ) has a vital role in glucose and fat metabolism. Thus, PPAR-γ agonists, are widely used in the treatment of hyperglycemia, dyslipidaemia and their complications. Phenolic compound and PPAR-gamma ligand binding activity can help in managing hyperglycemia.[23]

Obesity is one of the major burning problems in the world today. In this SARS CoV 2 Pandemic due to almost one year lockdown; many people are doing work from home and limited or no outdoors activities. Due to this long time sitting work leads to lockdown induced obesity, over nutrition and many more lifestyle disorders.

Inhibition of dietary triglyceride absorption via inhibition of pancreatic lipase using natural products is one of the most recent approaches implemented in the treatment of obesity. According to one study in high fat diet-induced obese mice, Phenolics can inhibit the activities of α-amylase and lipase causing inhibition of digestion, impairment of lipid and carbohydrate absorption, acceleration of lipid metabolism and up regulation of energy expenditure [24]

Free radicals play an important role in the development of cancer, diabetes, neurodegenerative, ageing related and cardiovascular diseases. Phenolics have scientifically proven to prevent various oxidative stress-related as well as chronic diseases, such as cancer, cardiovascular and neurodegenerative diseases due to potent antioxidant properties.

Role of Tannins on Hyperglycemia

Tannins are one of the major groups of antioxidant polyphenols found in food and beverages. They have been considered to be cardio-protective, anti-inflammatory, anti-carcinogenic and anti-mutagenic, among others. These protective effects are related to their capacity to: (i) act as free radical scavengers; (ii) activate antioxidant enzymes. They have been observed to enhance the glucose uptake through mediators of the insulin-signaling pathways, such as PI3K (Phosphoinositide 3-Kinase) and p38 MAPK (Mitogen-Activated Protein Kinase) activation and GLUT-4 translocation.[25]Tannins have also been described as anti-hyperglycemic agents in diabetic rats.[26]

Role of Saponins in Hyperglycemia

Saponin regulates blood glucose level and prevents diabetic complications due to their antioxidant activity. Dyslipidemic activity of saponin will help to decrease the risk of atherosclerosis and cardiovascular disease in diabetic patients.[27]

Role of Fibers in Hyperglycemia

Kodo millet is rich in dietary fiber. According to a study, those consuming the highest amounts of dietary fiber, especially cereal fibre, may benefit from a reduction in the incidence of developing type 2 diabetes. There also appears to be a small reduction in fasting blood glucose concentration, as well as a small reduction in glycosylated haemoglobin percentage for individuals with type 2 diabetes who add β-glucan or psyllium to their daily dietary intake.[28]

Role of Proteins in Hyperglycemia

Due to slow conversion of protein to glucose, less protein is being converted to glucose and released into blood. Glucose get incorporated into hepatic glycogen stores but does not increase the rate of hepatic glucose release. The process of gluconeogenesis from protein occurs over a period of hours and glucose can be disposed of if presented for utilization slowly and evenly over a long time period. In this way protein prevents hyperglycemia.

Recipes of Kodo millet

Kodo flour can be used in making Idli, Dosa, Upma, Dahi wada, Chappathi, Pongal, Puttu, Idiyappam, Kozhukattai, Boli, Biscuit, Soup, Adai, Payasam, Cutlet, bread, cookies and Laddoo.

CONCLUSION

Kodo millet is a nutritional grain. It provides essential Macro and micronutrients. It is gaining importance as a gluten free food and is a component in multigrain gluten free food products. According to a recent study by Professor M Daniel former Head of M S University Botany has revealed that *Kodrava* which yield white husked grain has a number of medicinal properties that can help diabetics and obese. "Recent experiments proved aqueous and ethanolic extracts of this grain produced a dose dependent fall in fasting blood glucose (FBS) and significant increase in serum insulin level. Hyperglycemia can be effectively controlled if kodo millet is incorporated as a daily diet in diabetics. Kodo millet can be a good substitute to rice or wheat in hyperglycemic or prediabetic or Diabetic Patients. Still the availability of Kodo millet in local market is not as frequent as other millets and cereals. According to some literature Kodo grain is referred to be poisonous to human and cattles due to the fungus found in these grains. But by taking consideration of its nutritional and medicinal properties, cultivation and marketing should be done on large scale. Farmers should be educated against kodo-poisoning so that suitable precautionary measures can be taken up for production in large area. Further research study is required for assessment of benefits of Kodo millet.

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