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## Exploring the Role of Millets or Kudhanya in Metabolic Syndrome: A Review Article

	
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### ABSTRACT

Metabolic syndrome (MetS) is a health condition characterized by a cluster of risk factors, including central obesity, insulin resistance, dyslipidemia, and hypertension, which collectively increase the risk of cardiovascular diseases and type 2 diabetes. In recent years, there has been growing interest in the potential of millets, commonly referred to as "Kudhanya" in some regions, as dietary interventions for managing and preventing MetS. This review article aims to comprehensively analyze and synthesize the existing scientific literature and Ayurveda literature on the role of millets in addressing MetS. Millets, a group of ancient, gluten-free grains, have gained prominence due to their exceptional nutritional composition. They are rich in dietary fiber, vitamins, minerals, and bioactive compounds, all of which contribute to their potential health benefits. Millets have been shown to improve glycaemic control by reducing postprandial blood glucose levels, enhancing insulin sensitivity, and promoting weight management through increased satiety. Furthermore, their low glycaemic index and abundant antioxidants may help mitigate oxidative stress and inflammation, two critical components of MetS. This review explores various studies that highlight the positive effects of millet consumption on individual MetS components, such as reductions in BMI, improved lipid profiles, and lowered blood pressure. Additionally, the Ayurvedic point of view about the benefits of millets in *Sthoulya* (obesity), *Prameha* (diabetes) etc. is discussed in detail. In conclusion, millets exhibit great promise as a dietary strategy to prevent and manage MetS. Future research should focus on elucidating the mechanisms underlying millets' effects on MetS and optimizing their integration into dietary guidelines.

## INTRODUCTION:

Millets have been an integral part of the diet of over half a billion people across Asia and Africa for centuries. Millets are grown in around 130 countries. India is the world's largest producer of millets. On the proposal moved by India and supported by 72 countries United Nations declared the year 2023 as the International Year of Millets on 5<sup>th</sup> March 2021. UN proposed 17 sustainable development goals in 2015 which include End hunger, achieve food security and improved nutrition and promote sustainable agriculture<sup>1</sup>. Millets are such superfoods which have benefits under all these 3 heads.

Metabolic syndrome (MetS) is a modern-day disease caused by of sedentary lifestyle and unhealthy eating habits. MetS (syndrome X or insulin resistance syndrome) is a cluster of cardiovascular risk factors including obesity, insulin resistance, impaired glucose tolerance and hypertriglyceridemia which can further lead to CAD (coronary artery diseases), complications related to diabetes, hypertension, cerebral hemorrhage etc. In many studies millets are found to have promising results in weight reduction, blood glucose control, lowering blood pressure and protective effect on preventing complications of diabetes.

According to Ayurveda, the symptoms can be classified as *Santarpanjanya vyadhi*, i.e. diseases caused by overnutrition. Millets are dry, *Kaphahara* (reduces *kapha dosha*) and *Lekhana* (scraping of fat) and can be useful as a dietary modification in the treatment of MetS.

### **Distraughting scenario of metabolic syndrome (MetS):**

Which first started in western countries, has now spread all over the world, with the spread of western diet & lifestyle. A rapid increase in non-communicable diseases is observed in developing countries, putting burden on the healthcare system. According to WHO's report 2002, in developing countries, 79% of deaths are attributed by non-communicable diseases and India and China carry the most burden even more than other industrialised countries<sup>2</sup>. The prevalence of metabolic syndrome has escalated in both urban and rural India from 11% to 41%<sup>3</sup>. Prasad et al noted that a significantly higher prevalence of metabolic syndrome is seen in females (52.2%) than males (34.2%). This prevalence increases with increasing age in both males and females.<sup>4</sup>

Higher incidence of type 2 DM and cardiovascular diseases are observed in Asian Indians at lower BMIs than the existing WHO cut-off point for overweight (BMI-  $\geq 25\text{kg/m}^2$ ).<sup>5</sup>

For the diagnosis of MetS, three out of five cardiovascular risk factors have to be abnormal in Asian Indians.<sup>6</sup>

1. Increased waist circumference (Males  $\geq$  90cm and for females  $\geq$  80cm)
2. Hypertriglyceridemia  $\geq$  150mg/dl (1.7 mmol/l)
3. Low HDL - Males  $\leq$  40mg/dl (1mmol/l), Females  $\leq$  50mg/dl (1.3mmol/l)
4. Elevated blood pressure (Systolic blood pressure  $>$ 130mmHg and/or diastolic blood pressure  $\geq$  85mmHg or on drug treatment for Hypertension.
5. Elevated blood sugar (Fasting blood sugar  $\geq$  100mg/dl (5.6mmol/l) or drug treatment for Diabetes mellitus.

High-calorie diet intake and sedentary lifestyle are two major causative factors for MetS.

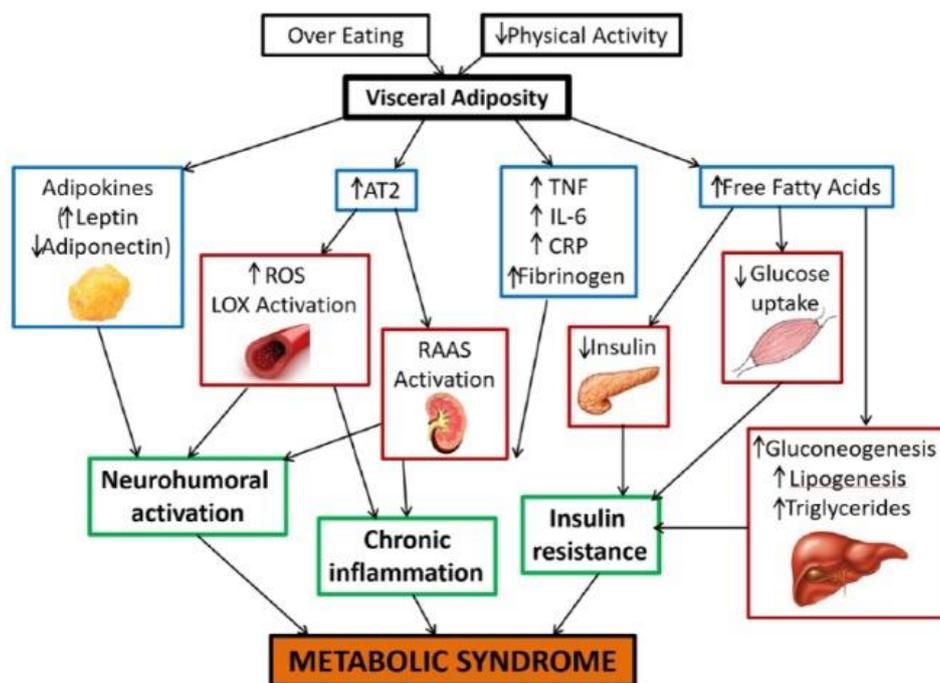


Fig.1-Pathophysiological mechanism in MetS<sup>7</sup>

### Change in Indian diet:

Ancient Indian diet was very diverse, which included cereals, pulses, a variety of seasonal vegetables, fruits, whole grains, spices like turmeric, cumin, etc. Indian diet is considered superior for being cardio-protective.<sup>8</sup> In India there is a lot of diversity in culture, food habits etc. In different parts of India, traditionally, seasonal foods are consumed, like at the time of Uttarayana (northward movement of Sun) laddoos made from sesame seeds and jaggary are

eaten. Sesame seeds are hot, oil-bearing seeds that give warmth and increase unctuousness in the body. Different festivals are celebrated around the harvesting season. This is a part of culture that has food at its core.

With modernization and westernization, fast foods have become food of choice for everyone. Fast foods, bakery items, deep fried foods and processed foods are increasingly consumed at Indian households. While part of India is still struggling with undernourishment, over-nourishment is rising in both urban and rural India. Overnutrition is also a form of malnourishment and is a reason for obesity and MetS.<sup>9</sup>

### **Ayurvedic wisdom for maintaining health:**

*Aahar, Nidra, Bramhacharya* along with *Vyayam* are pillars of healthy life. Ayurveda has a prime focus on prevention of diseases and the maintenance of health. By taking care of these pillars of healthy life many of the disease conditions can be taken care of. Out of which food is the major influencing factor. Food is the source of energy to life. Food has both physiological and psychological effect on our body and mind respectively. Proper dietary correction (*pathya seven*) can be as effective as a medicine itself.<sup>10</sup>

In Ayurveda, proper digestion of food is considered very important and indigestion is considered as a root cause of most diseases. So, proper functioning of digestive fire i.e. *jatharagni* and *dhatvangi* is very important for maintaining health. Excessive consumption of heavy, nutritious foods (*Bhrinhana*) can cause *Dhatvagnimandya*, leading to the accumulation of *asara dhatu* and further obesity and related diseases.

### **Millets:**

As compared to common cereals, millets are nutritionally comparable and provide number of health benefits. The structure of millet grain includes outer bran (pericarp) which protects the inner structures from sunlight, pests and other diseases. The germ/embryo can grow into a new plant when fertilized and endosperm, the largest part which contains carbohydrates, proteins, vitamins and minerals<sup>11</sup>. The bran contains anti-oxidants, vitamin B, Iron, Zinc, Copper, Magnesium and Fibre. Sorghum and millets provide good energy by the virtue of 51-81% of grain weight being starch. All millets are a good source of protein. They are low in lipid and majorly contain insoluble, non-starchy polysaccharides and dietary fiber. They also contain phenols, flavonoids, carotenoids (pro-vitamin-A). Millets are good sources of fat-soluble vitamins like A, D, E, K and also B vitamins except Vit B12. Millets are also high in

phenolic and flavonoids which are anti-oxidants and have potential health benefits against chronic diseases and cancer.<sup>12</sup>

**Table 1: Nutritional profile of millets in comparison with cereals (per 100 g)<sup>13</sup>.**

Grains	Energy (kcal)	Protein (g)	Carbohydrate rate (g)	Starch (g)	Fat(g)	Dietary Fiber (g)	Minerals (g)	Ca (mg)	P (mg)
Sorghum	334	10.4	67.6	59	1.9	10.2	1.6	27	222
Pearl millet	363	11.6	61.7	55	5	11.4	2.3	27	296
Finger millet	320	7.3	66.8	62	1.3	11.1	2.7	364	283
Proso millet	341	12.5	70.0	-	1.1	-	1.9	14	206
Foxtail millet	331	12.3	60.0	-	4.3	-	3.3	31	290
Kodo millet	353	8.3	66.1	64	1.4	6.3	2.6	15	188
Little millet	329	8.7	65.5	56	5.3	6.3	1.7	17	220
Barnyard millet	307	11.6	65.5	-	5.8	-	4.7	14	121
Maize	334	11.5	64.7	59	3.6	12.2	1.5	8.9	348
Wheat	321	11.8	64.7	56	1.5	11.2	1.5	39	306
Rice	353	6.8	74.8	71	0.5	4.4	0.6	10	160

**Millets listed in Ayurveda:**<sup>14,15,16,17</sup>

*Kangu* (Priyangu) - Foxtail millet

*Shyamaka* - Barnyard millet

*Koradusha* (Kodrava) - Kodo millet

*Cheenaka* - Proso millet

*Nartaki* - Finger millet

*Gaveduka* - Adlay millet

*Yavanaala* - Sorghum

**The general qualities and functions of millet as per Ayurveda are-**

In Ayurveda millets are called *Kudhanya* as they are not considered much nourishing.

*Rasa- Kashaya-Madhura* (Sweet, astringent taste)

*Virya-Ushna* (Hot potency)(*Sushrut sutra 46/22*) *Shita* (Cold potency)(*Ch. Sutra 27/16*)

*Vipaka- Katu* (After digestion effect)

*Guna- Laghu* (Light to digest), *Ruksha* (dry)

*Doshaghata- Kaphahara* (reduces *Kapha dosha*), *Vata-Pitta prakopaka* (Increases *Vata* and *Pitta dosha*)

*Karma- Sangrahi, Lekhana, Kledashoshana, Avashtambhi* (constipating), *Avrishya* (Ant aphrodisiac)

***Priyangu/Kangu: (Setaria italica – Foxtail millet)***

It is *Guru* (heavy to digest), *Brinhana* (nourishes the body), *Bhagnasandhankara* (fracture healing), *Durjara* (difficult/heavy to digest), *Ruksha* (dry, ununctious), *Vatavardhaka* (increases *vata dosha*) and *Kaphahara* (decreases *Kapha dosha*), *Shoshana* (absorbs/dries out unctuous *dhatu*s like *mansa* and *meda*), *Vajikaran* (aphrodisiac)

***Shyamaka: (Echinochloa frumentacea- Barnyard millet)***

It is *Kashaya-Madhura* in taste, *Laghu* (light to digest), *Shitavirya* (cold potency), *Pittahara* (reduces *pitta dosha*), increases *Vata dosha*, *Grahi* (absorbs excess liquid from stool and facilitate digestion) and *Dhatushoshana* (creates dryness and dries secretions), *Vishaghna* (anti-poison), indicated in diseases like *Prameha* (Diabetes mellitus), *sthoulya* and *medoroga* (Obesity, dyslipidemia)

***Kodrava / Kordusha: (Paspalum scrobiculatum- Kodo millet)***

It has *Ushna virya* (hot potency), *Laghu* (light to digest), and *Grahi* (absorbs excessive fluids, helps to form formed stools and improves digestion). *Vishaghna* (anti-poisonous), *Pittahara* (reduces *Pitta dosha*), *Kaphahara* (reduces *Kapha dosha*), *Vatakara* (increases *vata dosha*).

***Cheenaka (Panicum miliaceum- Proso millet)***

It is *Guru* (heavy to digest), *Brinhana* (nourishes the body), *Durjara* (difficult to digest) and *Bhagnasandhankara* (fracture healing).

***Nartaki/Ragi (Eleusine caracana- Finger millet):***

It is *Shita* (cold potency), Increases *Kapha dosha*, *Pitta shamaka* (decreases *pitta dosha*), *Snigdha* (increases unctuousness), *Balya* (increases the strength of body), *Vrishya* (increases potency).

***Gaveduka – (Coix lachryma jobi- Adlay millet):***

*Katu-Madhura rasa* (pungent, sweet taste), *Kaphahara*, *karshyakara* (good for weight loss)

***Yavanaala – (Sorghum vulgare- Sorghum):***

*Kashaya-Madhura rasa* (sweet, astringent taste), *rakta*, *pitta*, *kaphahara*, *dry*, *cold*, *Vatakopana* (vitiates *vata dosha*), *Avrishya* (reduces potency), *Kledaghna* (lowers the excess moisture in the body)

**DISCUSSION:**

Foods that have health benefits are advised as a part of medical nutritional therapy and are called as nutraceuticals. Millets are one of them. Millets are source of carbohydrate, protein, fibre, vitamins, minerals, etc. They provide better nutrition than commonly consumed cereals like wheat, rice, maize etc.<sup>13,18</sup>

Millets are grown in countries like India, and Africa since centuries, consumed in rural parts but mostly used as fodder crop. In India, Karnataka is the largest millet growing state, there after comes Maharashtra and Gujrat. It is observed that other than these states, in the rest of the states of India, less amount of millets is consumed, the main reason being, not cooked at home and not in culture. Most of people consume millets because of some health condition i.e., as a nutraceutical.<sup>19</sup>

MetS is characterized by insulin resistance, impaired glucose tolerance, hypertriglyceridemia and visceral adiposity, further leading to obesity, diabetes and its complications, hypertension, coronary artery disease, etc. The main reason for MetS is imbalance of diet.

The accumulation of adipose tissue is associated with low-grade chronic inflammation.<sup>20</sup> The adipocytes secrete certain pro-inflammatory molecules like TNF-  $\alpha$ , IL-6, CRP, ACE etc. which may lead further to MetS and cardiovascular diseases. Higher intake of whole grains, fruits, vegetable, legumes, fish and poultry are inversely related with plasma CRP levels.<sup>21</sup> Consumption of whole grains intact, ground, cracked or flaked consisting of endosperm, bran and germ is associated with decrease in stroke, CVD, MetS, Type-2 Diabetes and Cancer. Consumption of whole grains is also considered as a marker of healthy choices of diet and lifestyle.<sup>22</sup> Diet rich in dietary fibre is inversely related with obesity and associated disorders. Whole grains like millet lower the risk of weight gain. With 1 kg weight loss there is 16% reduced risk of getting diabetes. Millets are high in soluble and resistant starch which has positive role against diabetes and in improving insulin resistance in MetS.<sup>23</sup>

Millets like adlay, finger millet, Proso millet etc. have anti-oxidant and anti-inflammatory properties and have proven to be effective in inhibiting reactive Oxygen species and pro-inflammatory substances in vitro.<sup>24</sup> Excessive accumulation of fat leads to increased oxidative stress and high oxidative stress is associated with MetS<sup>25</sup>. Millets are anti-oxidants owing to their polyphenol content.<sup>26</sup>

Transition of food choices over the years include foods made from refined wheat & milled white rice which are free from husk, bran and germ, and high in GI. Consumption of refined grains is directly associated with MetS and diabetes. Wheat and rice are main part of diet of the poor people of India. In a questionnaire-based cross-sectional study carried out in Chennai, Radhika et al noted that in people on a diet consisting low sugar and fat but high in refined grains, still had high BMI and MetS.<sup>27</sup>

Post prandial hyperglycemia is proven to be a crucial factor for development of diabetic complications, endothelial dysfunction, inflammation and an increase in oxidative stress. Post prandial hyperglycaemia is also been suggested as an independent risk factor for cardiovascular diseases.<sup>28</sup> The hyperglycaemic spike during this period is affected by amount and glycaemic index (GI) of carbohydrates consumed.<sup>29</sup> High glycaemic diet can also cause hyperinsulinemia which is a feature of MetS and is associated with increased cardiac risk by its direct effect on serum lipids, blood pressure, endothelial dysfunction and coagulation factors. Whereas low glycaemic diet is observed to be associated with low triglyceride levels, low-low density lipoprotein and lower ratio of total to high density lipoprotein (HDL).<sup>30</sup> Millets and sorghum have significantly lower GI than rice and refined wheat. The mean GI of

millet is  $52.7 \pm 10.3$ , while that of milled rice is  $71.7 \pm 14.4$  and that of refined wheat is  $74.2 \pm 14.9$ . Foxtail millet and Barnyard millet have low GI ( $<55$ ), Pearl millet, Finger millet, Kodo millet, little millet and Sorghum have intermediate GI (55-69).<sup>31</sup>

According to Ayurveda, the features of insulin resistance like obesity, and hyperlipidaemia can be correlated with *medovaha strotodushti*. These diseases are mentioned as *Santarpana janya vyadhi* and more consumption of heavy, nourishing foods and sedentary lifestyle is considered as cause of *Santarpanajanya vyadhi*.<sup>33</sup> *Medodhatvagni mandya* and accumulation of *ama*, *meda* and *kapha* is the reason behind *medovaha strotodushti*. According to Ayurveda, initial stage of MetS can be correlated to *Medovaha strotodushti* and *Prameha Purvarupa*. During next stage there is appearance of *lakshana* of *Sthula Pramehi* (*Apathya nimittaja*-Type-2 DM). In the later/chronic stage there are *Upadrava* (complications) related to *Prameha* and *Sthoulya* (obesity).<sup>34</sup>

The treatment guideline for *Santarpanajanya vyadhi* includes *Shodhana*, *Basti*, use of *lekhana Dravya*, *Guru*, *Aptarpana*, *Kapha-Medohara anna-pana* etc. depending upon stage of the disease.<sup>35</sup> Millets are dry, hot, increase *vata* in the body, which leads to absorption of *kleda* (unctuousness from body elements) and lesser nourishment/depletion of *snigdha dhatus* like *meda* and *mansa* leading to weight loss. Prominent taste being *Kashaya*, *katu* and *Katu vipaka*, these foods carry out *dhatu apakarshana*.

**Shyamaka (Barnyard millet)** is *Kashaya-Madhura* in taste, *Laghu* (light to digest), *Shitavirya* (cold potency), increases *Vata dosha*, *Grahi* (absorbs excess liquid from stool and facilitate digestion) and *Dhatushoshana* (creates dryness and dries secretions) and is indicated in diseases like *Prameha* (Diabetes mellitus), *Sthoulya* and *Medoroga* (Obesity, dyslipidemia)<sup>17</sup>. Barnyard millet has low GI and showed improved carbohydrate tolerance in both diabetic and non-diabetic subjects with a significant reduction in Fasting plasma glucose levels. It also showed a significant decrease in total cholesterol level.<sup>36</sup> In animal study, Barnyard millet was found effective as faecal bulking, hypoglycaemic and hypolipidemic agent owing to the presence of complex carbohydrates and fibres.<sup>37</sup> **Priyangu/Kangu: (Foxtail millet)** is *Guru* (heavy to digest), *Brinhana* (nourishes the body), *Durjara* (difficult/heavy to digest), *Ruksha* (dry, ununctious), *Vatavardhaka* (increases *vata dosha*) and *Kaphahara* (decreases *Kapha dosha*) and *Shoshana* (absorbs/dries out unctuous *Dhatus* like *Mansa* and *Meda*). Its properties are especially effective to treat *Sthoulya* (obesity) and *Prameha* (diabetes)<sup>16</sup>. In in-vivo studies, it is found that Priyangu (Foxtail millet) has

excellent anti-hyperglycemic and hypolipidemic properties.<sup>38</sup> In another study it was found that daily consumption of Foxtail millet significantly reduced blood pressure (SBP/DBP, 4.13/3.49 mm of Hg), BMI, body fat percentage and fat mass in mildly hypertensive subjects.<sup>39</sup>

**Cheenaka (Proso millet)** is *Guru* (heavy to digest), *Brinhana* (nourishes the body), *Durjara* (difficult to digest) and is recommended in *Santarpanajanya vyadhi*.<sup>16</sup> In epidemiological studies proso millets are seen to reduce serum cholesterol<sup>40</sup>, effective in cardiovascular diseases, type-2 DM and liver injury. Proso millet also has anti-oxidant and anti-proliferative (Anti-cancer) properties.<sup>41</sup>

**Kodrava / Kordusha (Kodo millet)** has *Ushna virya* (hot potency), *Laghu* (light to digest), *Grahi* (absorbs excessive fluids, helps to form formed stools and improves digestion), *Kaphahara* (reduces *Kapha dosha*), and *Vatakara* (increases *vata dosha*) properties. Kodo millets are high in B-complex vitamins, Iron, Calcium, Magnesium, Zinc and Potassium. It has protective effect against diabetes and hyperlipidemia owing to low glycaemic index and high fibre content.<sup>42</sup>

**Nartaki/Ragi (Finger millet)** is *Shita* (cold potency), Increases *kapha dosha*, *Pitta shamaka* (decreases *pitta dosha*), *Snigdha* (increases unctuousness), *Balya* (increases strength of body), *Vrishya* (increases potency). It contains maximum Calcium (364mg/100g) among cereal group.<sup>13</sup> Being rich in polyphenols, finger millet delays the absorption of glucose and ultimately controls the post-prandial glucose levels.<sup>43</sup> Supplementation of diet with ragi showed higher reduction in both fasting and post prandial glucose levels than supplementation with other millets.<sup>44</sup>

**Gaveduka – (Coix lachryma jobi- Adlay millet)** is especially indicated for *Sthoulya* (obesity) and *Sthula Pramehi* (Type-2 DM). It was exhibited that millets and Adlay to have anti-oxidant properties in animal studies.<sup>45</sup> Wei-Yi-Cheng et al. suggest that daily 60g adlay millet has beneficial effect on blood lipids and is effective in chronic inflammation in obese people.<sup>46</sup>

**Yavanaala – (Sorghum vulgare- Sorghum):** It has *Kashaya-Madhura rasa* (sweet, astringent taste), *rakta*, *pitta*, *kaphahara*, *dry*, *cold*, *Kledaghna* (lowers the excess moisture in body). Whole sorghum flour is proven to improve glucose tolerance, insulin resistance and lower the liver fat. Sorghum bran contains maximum phenolic content which exhibits anti-oxidant

properties.<sup>47</sup> Anunciacao et al. suggested that daily 40g consumption of Sorghum is effective in weight loss and in reducing body fat in obese individuals. Sorghum flour also has acute effect on oxidative stress markers in healthy individuals.<sup>48</sup>

## CONCLUSION:

We are in an era in which non-communicable diseases are on their peak. With the increasing number of people suffering with obesity, diabetes, and MetS, it is important to develop preventive measures involving healthy diet and exercise. Millets have advantage over common cereals as they are rich in phytochemicals, polyphenols, fibre, vitamins and trace elements and millets can be effective in treatment, preventing complications and improving quality of life as a nutraceutical. In Ayurvedic literature and various scientific studies, millets are proven to be effective in reducing blood glucose level, reducing blood pressure, anti-hyperlipidaemic, anti-inflammatory and anti-oxidant. So, supplementing diet with millets and eliminating refined grains is an important requirement in the treatment of diabetes and MetS.

There is future scope for clinical studies focusing on the dietary inclusion of millets in preventing and in treatment of diabetes and MetS.

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