**FOX TAIL MILLET: A MAGICAL AND VERSATILE CROP**

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**ABSTRACT:**

Foxtail millet is also known as magical or a miracle crop. These are tiny seeds that covered in a tiny hull and are present in the yellow- brownish color. They have a sweet and a nutty flavor. They are also health friendly and farmer- friendly crop. It has high nutritive value, rich in carbohydrates, essential fatty acids ,proteins, minerals like Calcium, Phosphorous, Magnesium, Sodium and Vitamins like A and E. It has anti-nutrients such as tannin and phytic acid. It is a C4 photosynthetic model crop and can survive in extreme conditions like saline, drought and harsh climate. The millet is cooked in such a way that the maximum nutrients are retained. It has antioxidant properties, anti- carcinogenic properties and glucose-lowering properties, potential to manage the fungal infections and has gastro- protective properties. These Bioactive compounds increase the antioxidant property which is beneficial for the human health. It also present in the gastrointestinal tract for better digestion. It is good for the spleen and the stomach as it is non -allergenic and the most digestive grain. Consumption of the whole grains can pose a number of health factors. It is a boon for the diabetic patients as it helps to reduce the blood glucose levels in the body. Also helps to lower bad cholesterol (HDL and VLDL), aids in the weight loss ,sheds off extra fat by avoiding excess deposition of the fat cells in the body, reduces the risk of CVD ,Colorectal cancer , Hypertension, Peptic Ulcers and Hyperlipidemia. The world is facing nutritional challenges since the agricultural lands have been exploited to the larger extent, the main focus should be to increase the millet grain production.

**KEYWORDS:**

Photosynthetic model

Anti-nutrient

Diabetes

Hypertension

Hyperlipidemia

Obesity

Colorectal cancer

Peptic Ulcers

Nutritional Security

**INTRODUCTION:**

The main aim of the whole project report is to discuss about the phylogeny, nutritive quality, cooking methods, bioavailability, health benefits and the Nutritional Security of the Foxtail millet.

Foxtail millet is known to be a magical and a versatile crop. Its biological name is *Setaria italica*. It is genetically closely related to biofuel grasses, due to C4 photosynthesis, and tolerance to abiotic stresses. Among all the millets, foxtail millet is the only crop that has the genetic and genomic resources. Globally, it is the second most cultivated millet after the pearl millet. It is considerd to be a staple food in almost all the parts of the world including the semi-arid and arid areas of China, parts of Japan and India, and is also being grown for hay and silage in South and North America. Foxtail millet is commonly known in India as Kangni in (Hindi), Kang in (Gujrati), Kaon dana in (Bengali) ,Tenai in (Tamil), Kavalai and Kangam in (Oriya) and Navane in(Kannada).(1) Foxtail millet (Setaria italica) is cheaper and highly nutritional comparable and superior to major cereals. As compared to rice, it is twice richer in protein, thrice richer in calcium and four times richer in fat and mineral (2). World is facing nutritional as well as agrarian challenges. The irrigation facilities and the agricultural lands have been misused to a larger extent that we have to focus on dry lands in order to increase production of the millet grain. As it has low fertility, the utilization of the dry lands, in order to produce sufficient quality grains is quite a challenging issue. These nutri-cereals are a rich source of vitamins, minerals, essential fatty acids, phyto –chemicals and anti-oxidants which help in order to minimize the occurrence of the nutritional deficiency diseases. Millets cultivation can make dry lands productive and enhance the food and nutritional security for future perspective.(3) Millet is the most essential drought-resistant whole grain available in arid and semiarid areas of Asia and Africa. Foxtail millet, when compared to other grains have less glycemic index and starch digestibility. The bioactivated fibers, polyphenols , flavonoids and other phytochemicals in the millet might be contributing to its glucose lowering effect.(4) It is easily cultivated cereal crop and belongs to the genus Setaria of the family Poaceae and Panicoideae subfamily. It is one of the oldest crop cultivated and its earliest archaeological remains are found in the northern China . The chief component of foxtail millet grain is starch. Apart from the grain, protein and fats are found in significant amounts. There are also non-starchy carbohydrates and free sugar available. (26) Anti-nutrients such as tannin and phytic acid are present in this millet can be reduced to minimal levels by applying suitable processing methods. It has hypolipidemic, low-glycemic index and antioxidant characters (5).Morphologically; foxtail millet grains have husk and bran layers, similar to the other millet grains. It is being used as a model crop to study the genomics and genetics of the other millets, cereals and biofuel crops (10).

 **Discussion:**

**Phylogeny:**

An extensive phylogenetic study based on organellar as well as nuclear DNA study was conducted which revealed the foxtail millet to be closely related to the green foxtail. Both the species of genus Setaria are part of a larger monophyletic clade which basically consists of approx 300 species, along with all the identical inflorescence (spikelets and bristles) . Phylogenetic analyses of both the nuclear genes and the choloroplast show that the foxtail and the green millet (Setaria viridis) are close relatives. The foxtail millet , according to the hypothesis shows that it is almost a domesticated version of the green millet. (27) Morphologically the Foxtail millet differs from its wild ancestor in terms of their branching pattern, flowering synchrony, condensed axillary and basal vegetative branching and the loss of seed dormancy and disarticulation. Moreover, it is very closely related to many other biofuel crops (1).

**Nutritional Quality:**

 Several methods have been adapted to improve the nutritional qualities of the cereal-based foods. These include: fortification of amino acid, supplementation of genetic modification and complementation along with the protein-rich sources and the processing techniques which include fermentation, milling and malting. Others include are pressure-cooking, steaming, flaking, micronization and puffing of the cereal starch which increase the digestibility (2). Foxtail millet (*Setaria italica*) is rich in carbohydrates, proteins, fats, vitamins, dietary fiber and minerals. It has some anti-nutritional factors such as tannin and phytic acid. (6, 15)

|  |  |
| --- | --- |
| Nutritional Components | Value per 100 g |
| Energy  | 331kcal |
| Protein | 12.3g |
| Fat | 4.3g |
| Dietary Fibre | 8g |
| Phosphorous | 290mg |
| Calcium | 31mg |
| Magnesium | 81mg |
| Potassium | 250mg |
| Folic acid | 15mg |
| Vitamin A | 32mg |
| Vitamin E | 31mg |
| Niacin | 3.2mg |
| Sodium | 4.6mg |
| Zinc | 2.4mg |
| Iron | 2.8mg |

Table-1: Nutritional value of the Foxtail Millet (15)

Foxtail millet contains high nutritive values when it is compared to the wheat, corn and rice. Maintaining these nutritional qualities is important for the development and processing of healthy foxtail millet-based products The utilization of the foxtail millet for the diversification of food is not in order to replace rice, instead to enrich the different types of food commodities to consume. (6)

**Bioavailability:**

The Foxtail millet is not grown and consumed in all the parts of India.It is also less popular when it comes for its consumption. It is eaten only by the traditional people and the lower economic strata. The utilization of millet as an ingredient in making many cookies is expected to reduce dependency on wheat flour. The increase in foxtail millet consumption must be accompanied by the availability in the market at decent prices. So, foxtail millet cultivation should be expanded. The cultivation is suggested directed on marginal areas, such as shading areas on young plantations. The utilization of young plantations and forestry land is one of the efforts that can be done to maintain national food supplies (7).

**Nutritional Security Of the Foxtail Millet:**

Recently changes in the food habits involving multi-grains have generated massive interest in the nutritional security of the food. People now have started to pay attention to the nutritional uptake of the small millets. Growing children are being provided the processed foods that fulfill the daily nutritional requirement. (19)

Produced by the increase in the urbanization and the industrialization , current years have observed an emission in the expansion of the assessibility of the foods market and breath-taking modifications have taken place both in terms of quantity (variety) and quality of convenience availability and the packaging along with the processing technologies involved. Since the nutritional qualities of the millet have been recorded, (20) its utilization for the food is confined to the local people, due to the non-availability of consumer-friendly, ready-to-eat products, are found for wheat and rice. (21) In the account of the emerging pandemics, the crop scientists have focused on enhancing the immune system of the human with the natural supplements through food modification. The future depends on the development of the smart crops with the higher nutrition, therapeutic traits and climate resilience. The quality of the Foxtail millet can be analyzed from various perceptions, including the nutritional, appearance and eating quality. Foxtail millet has some significant agronomic characteristics such as drought resistance and high water use efficiency, tolerance to the soil of the low nutrient availability, strong adaptability and good yield stability. (21, 22)

**Bioactive compounds present in the foxtail millet:**

Foxtail millet are excellent sources of biologically active compounds such as dietary fibers, bioactive peptides, proteins, minerals, amino acids, phenolic compounds, sterols, tocols, phytic acids, carotenoids, unsaturated fatty acids, and several anti-nutritive compounds . Bioactive compounds of foxtail millet are becoming important functional food ingredients. The phenolics present in the foxtail millet are the most bioavailable in the gastrointestinal digestion. The protein hydrolysate is having the highest antioxidant activity in the hydrophobic form. Bioactive compounds also showed many biological activities and health benefits, including hypertensive prevention , anti-proliferative and hyperglycaemia.(23)

**Micronutrients present in the Foxtail Millet:**

Foxtail millet is an important crop mainly in the underdeveloped countries. However it has low yields. The application of the varied germplasm in a breeding approach is serious for increasing the productivity. Foxtail millet can be cultivated efficiently in a wide range of the environmental circumstances but it is appropriate to the hot and dry climates.  Foxtail millet is a favorable source of protein and micronutrients when it is compared with the other cereals. Foxtail millet grain contain (per 100 g) iron (2.8 mg), protein (12.3%) and calcium (31 mg) when it is compared with the rice (1.8 mg iron and 7.9% protein) according to the Millet Network of India (MINI). (26) It is a C4 photosynthetic model crop. (27)

**Microbial Fermentation in Foxtail Millet:**

In the modern scientific research studies, it have shown that the microbial fermentation is not only does improve the preservation of the food but also enriches the diet of the humans by bringing a change in the quality and flavor of the food . It also helps to improve the proteins, essential amino acids, vitamins and fatty acids content in foods.

The effect of fermentation on the properties and composition of the main components of the foxtail millet is the major factor to determine the products quality. In addition to the starch, fermentation also improves the digestibility of the protein in the foxtail millet and the antioxidant activity.(28)

It provides a important bioactivity like the antioxidants and the nutritional supplementes for the metabolic disorders such as Diabetes Mellitus, Cancer, malnutrition and cardiovascular diseases. (29)Various studies researched on the millets, for example, finger millet and proso millet, Sorghum and foxtail millet have demonstrated their impacts against hyperglycemic and hypolipidemic metabolic disorders. (30)

**Cooking Methods for the better retention of the foxtail millet:**

A present research had been conducted to understand the effect of the pre-treatment on the quality of cooking, the functional properties, organoleptic quality and visual appearance of the other millet grains when compared with the raw foxtail millet grains. Various pre-treatments had been given to the millet grains in various other combination such as soaking, drying, roasting, steaming and cooking.. Pre-treatments reduced percentage solubility (6.72 to 2.08%) and cooking time (11.66 to 5.33 min). Pre-treatment increased cooked weight (28.66 to 37.33 g), swelling power (5.60 to 6.77 g/g) and cooked volume (23.66 to 32.33 ml). Pre-treatments also reduced the visual appearance of the grains. The pre-treated rice grains that had been cooked had an effect in its color, texture and appearance in the organoleptic evaluation. Each of the quality characters mentioned above were ranked and the scores were given. As the dried, cooked and roasted grains got the high total score than other pretreatments, it can be convenient to use as a ready to eat option (9).

**Potential uses of Foxtail Millets on:**

Some of the potential uses of the foxtail millets are described as below:

It is beneficial for the stomach and also for the spleen. It has been put into application for the food therapy for thousands of years. After the shelling and milling, millet is suitable for human consumption. (6) In rural India, this millet is used as a nutritional source for the pregnant women and the lactating mothers, children and sick people. It helps to fight various diseases. It is the most non-allergenic and the most digestive grains among the other millets. It is three times superior to wheat and rice in terms of minerals, vitamins as well as proteins. Nutrients present in the foxtail millet gives a physiological function which prevents the incidence of the non-communicable diseases. (23) It has a high protein and antioxidant content and a low glycemic index value which is suitable for diabetics. It contains a little amount of gluten that means it can be consumed by the people suffering from the celiac disease. (23)

1. **Diabetes:**

 The rate of the diabetes has been increasing over the last 50 years along with the obesity. According to WHO, 346 million people across the globe have been suspected with the diabetes as compared to 285 million people in 2010 and approximately 30 million in 1985 . WHO projects that the deaths due to the diabetes will be double between 2005 to2030. Type 2 diabetes management generally focuses on lifestyle interventions, maintaining blood glucose levels in the normal range and lowering cardiovascular risk factors. (8) Literature studies shows that the occurrence of diabetes can be reduced by including the foxtail millet in the diet. In vitro study and research by Chen et al. in 2003 stated that foxtail millet have a low glycemic index and stimulates the pancreatic cells to produce insulin hormone that regulates blood glucose level in the body. An animal trial was also conducted to improve the responsiveness of the body cells to insulin and exhibits an anti-diabetic effect. This study indicates that on the consumption of foxtail millet can definitely reduce and regulate diabetes. (4) Present guidelines for the people suffering with type-2 diabetes is to lead a healthy and a balanced diet including low GI (Glycaemia index) carbohydrates and high dietary fiber. They both help to reduce the body weight and to regulate the post-prandial hyperglycemia. It has been stated that a high-fiber diet or a low glycaemic carbohydrate diet safely decreases the cholesterol levels in the plasma and improves glucose in the blood of people suffering with type-2 diabetes. (4, 24) The average GI value for the Foxtail Millet was found to be 47.89 and has been categorized as low GI food. (29)

**2. Hypertension:**

Hypertension or the high blood pressure is a risk factor that leads to several other cardiovascular diseases. Hypertension is generally managed by the drugs which belong to a class called “ACE inhibitors.” It basically works to relax the blood vessels which in order help to reduce the blood pressure. ACE inhibitor molecules are available in the Foxtail millet. According to the study which was conducted in 2017 by Chen et al. stated that the consumption of the Foxtail millet by the hypertensive rats reduced their blood pressure. (11)

**3. Colorectal Cancer:**

According to the recent data from the American cancer Society, The Colorectal Cancer (CRC) is the third diagnosed and the second most deadly cancer which threatens the health of the humans (13). It is the cancer of the colon and the rectum. It is located in the lower end of the digestive system (12).The millet dietary treatment has increased the abundance of Bifidobacterium and Bacteroidales\_S24-7 when compared to the rice –treated rats. The Review Literature suggests that the consumption of the whole grains or of the cereals contributes to a reduced risk of the colorectal cancer. In the current years, the mortality and the morbidity of CRC has been increasing continuously, mostly in the developing countries (12, 13).

The rice and the millet are both principal sources of staple foods in China an Asia. The differences in the composition of the nutrients in rice and millet can help to shape the structure of the intestinal flora and the composition of metabolites after human intake. Whether extensive-period dietary intervention can have the effects on the evolution of CAC remains to be determined. A research study had been conducted by Zhang et al. in the year 2020 in order to evaluate the effects of foxtail millets on the colorectal cancer showed that when it is consumed it impacted positively in the colorectal cancer in mice (12).

**4. Peptic Ulcer:**

 Peptic ulcer disease (PUD) is a common disorder which is caused in the gastrointestinal system also called as peptic or gastric ulcers. Gastric mucosal injuries are caused as a result of the imbalance between the aggressive and defensive factors affecting the gastric mucous.

The foxtail millet is having the nutraceutical properties which are in the form of the antioxidants which help to avoid the worsening of the human health. It has been used since a very long time in the traditional Chinese medicine as a remedy for the various diseases. The current study is aimed to examine the gastro protective effect of the adlay processing product (APP) and the foxtail millet diet on water immersion restraint stress (WIRS) induced ulceration in rats. In a research study, the results revealed that the pretreatment with adlay and diets considerably prevented the development of the gastric mucosal lesion. In addition, ulcerated rats showed depletion of Non- protein Sulfhydryl (NPSH ) levels whereas the treatment with adlay and the millet degenerated this decline in the stress-induced rats. The results were confirmed by the histological studies. The result states that the adlay and the millet diets help in the ulcer protection by the reduction in ulcer index, Thiobarbituric acid reactive substances(TBARS) values and increase NPSH concentrations. Since the Millet and adlay diets are a natural product, they protect the gastric mucosa against ulceration. (14)

**5. Fungal Infection:**

Till date, many of the chemical compounds that are being obtained from the plants have positive impacted fungal infections. An experimental research conducted by Wentao et al. in 2011 recognized a novel antifungal protein molecule in foxtail millets, which shows an activity against the fungi like Alternaria alternate and Botryrtis cinerea are responsible for allergies and asthma. Foxtail millets prevent the progression of these fungi by exhibiting an antifungal activity against these species. This indicates that the foxtail millets may have the capability to manage the fungal infections. (15)

**6. Hyperlipidemia:**

Hyperlipidemia, Hypertension, diabetes, and smoking are the major risk factors for the atherosclerotic CVD. The recent review stated on the effect on the blood lipids as an another beneficial outcome of the consumption of the millet. The analysis showed that the ingestion of the low (46.7 ± 12.0%) GI millet-based food had essential reductions in the levels of TC, LDL-C, triacylglycerol and VLDL-C. Among all the other factors, the glucose and the saturated fats levels and inappropriately controlled diabetes and metabolic syndromes are the causes of hyperlipidemia .Millets, being a low-GI food , reduce the blood glucose available for the synthesis of triacylglycerol. If used on a longer period, it could be helpful in controlling the HbA1c levels and the lipid profile in patients. (25).

Moreover, millets also reduced VLDL-cholesterol which is a carrier of triacylglycerol in plasma; thereby it further reduced the triacylglycerol levels. This implies that millets play a key role in reducing triacylglycerol levels. (16)

**7. Obesity:**

Overweight and obesity rates are increasing rapidly in the world. Eating healthy is the most important requirements to reduce weight. Obesity leads to the deposition of the fat cells in the body. The style of living contributes mainly for the obesity. Consumption of the foods that are rich in fats, oil and sugar, fast foods, processed foods , untimely meal , lack of physical activity are some of the factors that contribute to the onset of obesity. (18) Foxtail millet has a rich source of the phenolic compounds like chlorogenic acid, p- coumaric acid , caffeic acid, ferulic acid syringic acid. It also has carotenoids the zeaxanthin and xanthophylls. The phytochemicals in the foxtail millet are having the free radical scavenging capacity. (17)

Obesity is an inflammatory disorder that means the inflammation lead to the production of the free radicals. Antioxidants from foods play a crucial role in scavenging the free radicals and reducing inflammation (18). An article published in the American Chemical Society showed that the foxtail millet have a decent number of the phenolic compounds and have metal chelating ,antioxidant and reducing powers. (17)

The changes in the lifestyle like healthy eating and increased physical activity helps in the treatment of obesity. In the studies, it has shown that on the consumption of the whole grains, it decreases the risk of obesity. Whole grains have the endosperm, germ and the bran from the plant that is intact to the grains. (17, 18) The consumption of the whole grains as part of the healthy eating, reduces the occurrence of cardiovascular disorders , diabetes and obesity. As the grains are the main source of the energy-giving foods, replacing the refined grains with the whole grains is one of the most ecological strategies for the weight loss. (18) It has been stated that the obesity is correlated with the GI or glycaemic load.

**CONCLUSION:**

Foxtail millet has a number of basic essential nutrients that are required for the body’s sustenance and maintenance. They are packed with the richness of carbohydrates, proteins, minerals like Phosphorous, magnesium, Calcium, Sodium etc. and Vitamins like Vitamin A and E. It is cooked in such a way that the nutritional content is not reduced in any way. It has low G.I and low gluten which can be consumed by the celiac patients.. The health-benefiting properties of Foxtail millets have gained importance in nutritional and medicinal research. Foxtail millet is widely used not only as a source of energy but also for reducing the risk of diabetes, Hyperlipidemia (as it helps to reduce the bad cholesterol- LDL AND VLDL), Hypertension (by lowering Blood Pressure), for the dietary treatment of the fungal infections, aids in obesity and weight loss and in the treatment of the Colorectal cancer and the Peptic Ulcer. An antioxidant defense mechanism is important in the protection against the growth and the development of the injury of the acute gastric mucosal, extensive antioxidant effect and the anti-ulcer response of foxtail millet is valuable, which retains the gastro protective effects on the experimental gastric mucosal lesions in rats. Consumption of whole grains has been linked with decreased risk of the development of the major chronic diseases. Being a natural product, the foxtail Millet and the adlay diet have no side effects reported so far. It has an effective protective role in gastric ulcer. It has bioactive compounds like the bioactive peptides, Tocols, Phenols, and Carotenoids. It is beneficial for the malnutrition since it is rich in the micronutrient content and microbial fermentation which helps in the digestion.

Hence it is concluded that as the Foxtail millet is rich in macro and micronutrients, it should be included in the daily diet of the people. Since it is not so globally popular and is restricted only to the traditional people, the cooperation of the national, international and also in the state –level feeding programs will definitely help in overcoming the nutrient deficiencies especially in the developing countries.

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