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Barnyard millet: The underutilized nutraceutical minor millet crop

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Abstract
Barnyard millet (*Echinochloa species*) has become one of the most important small millet plants in Asia, reflecting strong growth in global production. The genus *Echinochloa* includes two major species, *Echinochloa esculenta* and *Echinochloa frumentacea*, which are widely grown for human consumption and fodder. Barnyard millet is a good source of protein, carbohydrates, fiber, and, in particular, contains more micronutrients (iron and zinc) than other major grains, and has a lower glycemic Index and gluten-free grains adds additional benefits, against various health issues such as obesity, diabetes, blood pressure control, cardiovascular disease and celiac disease. The carbohydrate content in barnyard millet is low and digested slowly, making barnyard millet a natural gift for busy modern humanity. In barnyard millet the fatty acids are linoleic acid followed by palmitic and oleic acid. It also exhibits a high rate of amylase reuptake, facilitating the formation of high levels of resistant starch. The present study highlights the importance of millets in terms of its nutritional values, pharmacological benefits, biological activities and applications of barnyard millet.

Keywords: Phytic acid, CVD, obesity, anthocyanin, celiac disease, antinutrients

1. Introduction

Barnyard millet (*Echinochloa spp*.) is emerging as one of the most significant minor millet crops in Asia (Renganathan *et al*., 2020) [64]. Amid various distinct, wild and cultivated spices of *Echinochloa*, the two mainly grown and popular spices are, *Echinochloa esculenta* (Japanese based barnyard millet) and *Echinochloa frumentacea* (Indian based barnyard millet). Moreover, *Echinochloa* genus constitutes of 20-35 annual and perennial species spread all over and have the potential to grow in any given climatic and agricultural condition. It has always been the staple cereal for the areas having unsuited climatic and soil conditions for cultivation of rice (Sood *et al*., 2015) [77-78].

Barnyard millet has wide range of adaptability even in the span of short life cycle, moreover, with the ongoing researches it's been proven that this crop is considered as a functional food as it has high nutrient and antioxidant value shown in table 1, therefore, demand for the crop cultivation has increased extremely in recent years (Khulbe *et al*., 2015) [77]. The grains of barnyard millet are used as food and can be consumed by cooking like rice and also can be used as functional food for people suffering from allergic diseases and atopic dermatitis (Sharma *et al*., 2016) [73]. The grain does contain all the macronutrients that too in acceptable quantity but above all, it contains more micronutrients mainly iron and zinc (table 2) as compared to other major cereals (Renganathan *et al*., 2020) [64]. In addition to this, since the grain contains almost no gluten therefore it is one of the most suited cereals for the ones suffering from celiac disease, in which patients are intolerant to gluten (Gomashe *et al*., 2017) [33].

Indian based Barnyard millet is grown up to 2300 from the mean sea level (MSL) predominantly in kharif season in the elevation of Uttarakhand and Tamil Nadu States (Gomashe *et al*., 2017) [33]. Conventionally it was used instead of rice in Northern India. It has been in recent times only that the grain is gaining attention from the health point of view and is modified into some worthful outcomes such as multi grain flour biscuits, sweet, vermicelli table -5 (Goel *et al*., 2021) [32]. It has rich source of sulphur containing amino acids, proteins, fats, vitamins, minerals (table -1) and nutritionally had a higher profile than other staple crops like rice, maize and wheat (Bora *et al*., 2019) [14].

Amongst 35 species of *Echinochloa*, there are only 2 species that are grown as a crop while rest all grows vigorously as weeds (Gomashe *et al*., 2017) [33]. The 2 cultivated species are

Echinochloa crus- galli (L.) (Japanese barnyard millet), is a temperate grass having an awn, indigenous to Eurasia and is cultivated in Japan in the past 4000 years ago. The second species, *Echinochloa colona* (L.) (Indian barnyard millet) is an awn less crop and is suitable in tropical and subtropical regions (Wallace *et al*., 2015) [91].

Barnyard millet has a potential to tackle and inhibit the protein glycation and prevent the formation of AGE (advanced glycation end products) (Anis *et al*., 2020) [7]. This inhibition of protein glycation can be done through 7 steps, as glycation includes many steps it can be inhibited at each and every step as shown in the figure -1. This inhibition is mainly initiated by the phenols of barnyard millet and this phenolics avoids formation of AGE products and helps to prevent many biological impairments and diseases (Yeh *et al*., 2017) [93]. The Anti-oxidant mechanism of barnyard millet includes several steps like scavenging activity, chelating of metal ions, inhibition of lipid peroxidation reaction and activation of anti-oxidant defence system of body as shown in the figure 2 (Wen *et al*., 2020) [92]. The barnyard mill*et al*so helps in many immunological functions like cataract genesis inhibition etc. (Chauhan *et al*., 2018) [97].

In this review paper a detailed description of Barnyard millet's history, habitat, taxonomy, chemical composition, medicinal benefits, biological benefits, pharmacological activities activities, inhibition of protein glycoxidation and its mechanism of action, antioxidant activity, utilization of millet, toxicology, application of barnyard millet, and future perspectives is discussed.

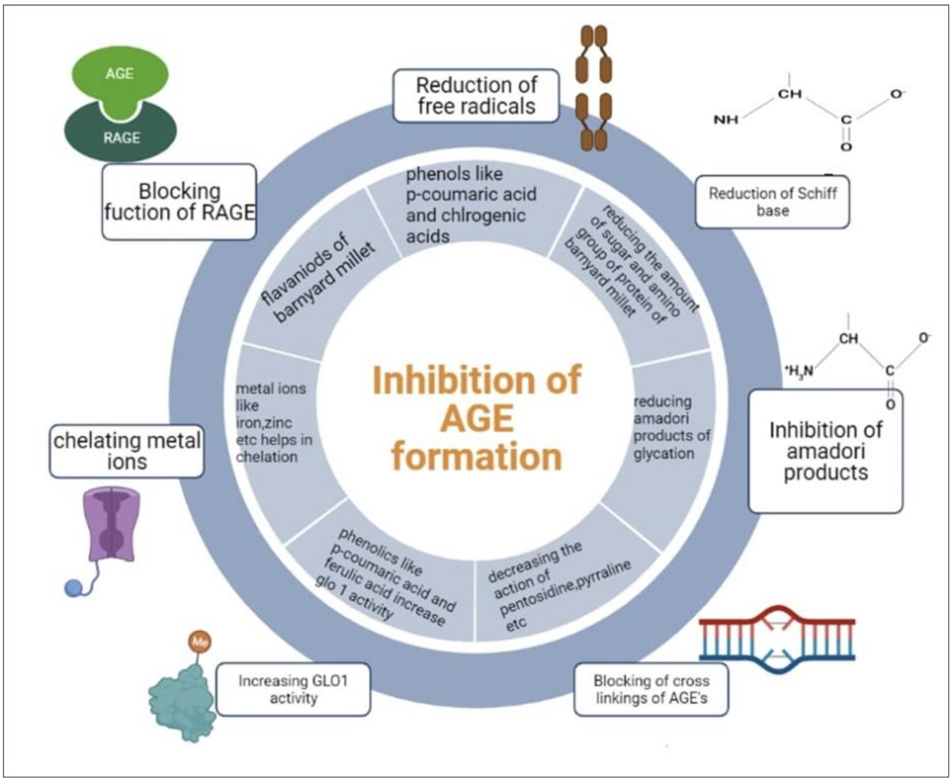

Fig 1: Inhibition of AGE formation at different levels (Anis *et al*., 2020; Yeh *et al*; 2017).

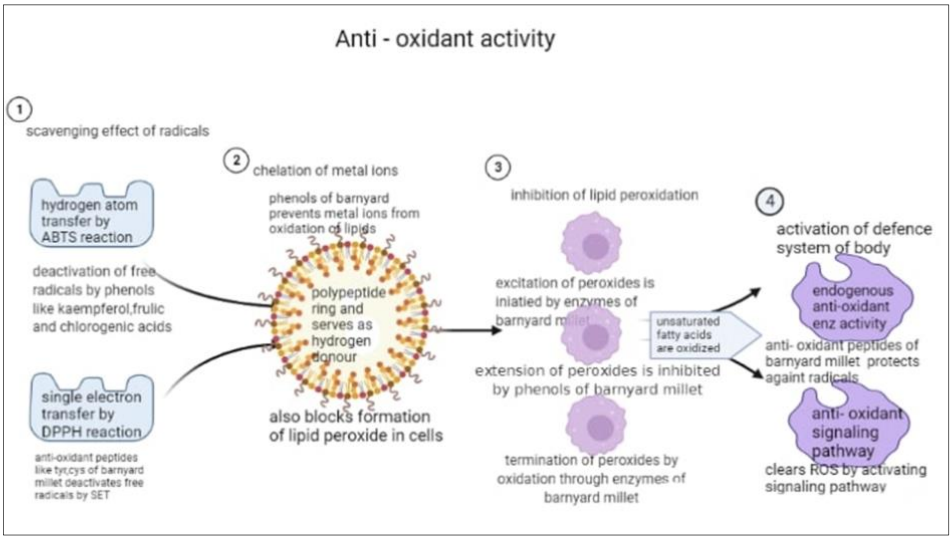

Fig 2: Anti-oxidant mechanism (Anis *et al*, 2020; Wen *et al*., 2020)

2. History and Origin

The Barnyard crop is one of the most archaic crops cultivated in warm and temperate regions (Renganathan *et al*., 2020) [64] across the world, especially in the semi-arid tropics of Asia and Africa (Sreerama *et al*., 2020) [7] including the countries like India, China, Japan and Korea (Renganathan *et al*., 2020) [64]. Talking about India the millet is grown in Himalayan region from North to the Deccan plateau in south i.e., from hilly areas to marginal areas (Sood *et al*., 2015) [77-78]. *Echinochloa* genus includes 35 species that are out there in warmer and temperate regions and Barnyard millet is the usual name given to the most of these species, all of them being native to Southern or eastern Asia (Upadhyaya *et al*., 2015) [91]. It is believed that the Indian based millet was originated from undomesticated species of *Echinochloa* i.e., *Echinochloa Colona* (jungle rice) and displays a simultaneous evolution in India and Africa (Renganathan *et al*., 2020) [64].

Regardless of barnyard millet being an ancient crop, there are no evidence till date that shows genetic source or origin of this crop (Mitsui *et al*., 2020) [51] and this obscurity hinders the way of having better understanding of this species through morphological perspective, because there are almost negligible mutants phenotypically (Renganathan *et al*., 2020) [64].

Rice, in general was regarded as a staple food in Japanese diet but unfortunately the agronomical and climatic conditions in Japan does not support rice farming (due to cold weather in winters and cold sea wind in summers) therefore barnyard millet (Japanese based) which is capable of surviving in harsh conditions, eventually became the staple food for Japanese. Back in1920's barnyard millet production and consumption was at its peak and, rice there was meant as a luxurious food item. People over their preferred millet over rice on daily basis consumption or mixed equal portions of both millet and rice and this was continued religiously till 1940's. But with the innovations and growing technology, tools and techniques were developed in such a way that benefitted the rice cultivation in Japan, with which there was a gradual decrement in the production of barnyard millet. The stats mentioned in their study makes it evident that with increase in the years, barnyard millet production was decreased. Japanese barnyard millet production decreased from 103,600 ha in 1880 to 5090 ha in 1969 to 285 ha in 1984 (Mitsui *et al*., 2020) [51].

Amongst the minor millets barnyard millet have managed to be in top 4 most produced millet globally (Renganathan *et al*., 2020) [64]. India being in the top position in growing barnyard millet not only with regard to area (o.146 m/ha) but also in cultivation (0.147 MT) with average productivity (1034 kg/ha) since last 3 years (IIMR, 2018) [11].

Fundamentally, barnyard millet is grown for human consumption but at times, it is also utilized as fodder (Renganathan *et al*., 2020) [64]. In India barnyard millet stands to be the 2nd most significant minor millet following the finger millet, with the production and productivity of 87thousand tons and 875kg/ha (Sood *et al*., 2015) [77-78].

3. Taxonomy

Barnyard millet belongs to Domain Eukaryota, kingdom Plantae, Phylum spermatophyta, sub–Phylum Angiospermae, class Monocotyledonae, order Cyperales, family Poaceae, genus *Echinochloa* and 35 other species (Sayani *et al*., 2017) out of those 35 species as shown in table 1,2 were only cultivated for food remaining are mostly problematic weeds (Renganathan *et al*., 2020) [64]. Under the genus *Echinochloa* on the basis of inflorescence it is divided into two species, four subspecies and eight races and its inflorescence pattern is simple and reliable and it aids us to understand not only patterns of variation but also helps in knowing their evolutionary paths (Khulbe *et al*., 2015) [78]

4. Chemical and Nutritional Composition

Barnyard millet grain is a good source of protein, carbohydrate, fibre, and most importantly it contains high quantity of micronutrients i.e., iron and zinc (Ranganathan *et al*., 2020) [64]. Despite its agronomical and nutritional benefits, barnyard millet has remain an underutilized crop. It contains protein (6-13g), carbohydrates (55 - 65.5g), fat (2 - 4g), crude fibre (9.5 - 14g), mineral matter (3.8- 4.5g), calcium (11-27.1mg), phosphorous (280 - 340 mg), iron (15 – 19.5 mg) table -1 starch (51-62%). Starch is the primary source of energy. Starch composed of two polymeric molecules i.e., amylose and amylopectin. Starch consists 20.0% of amylose (Vipin *et al*., 2021**)** [47]. The barnyard millet grain contains about 65% carbohydrate which is present in the form of non-starchy polysaccharide and dietary fibre (Sood *et al*., 2015**)** [77-78]. The three antioxidative phenolic compounds isolated i.e., one serotonin derivative and two flavonoids from Japanese barnyard millet grains. The essential amino acids present in barnyard millet are lysine, methionine, threonine, isoleucine, leucine, histidine, tryptophan and the non-essential amino acids are aspartic acid, glutamic acid, arginine, alanine, cysteine, glycine, and proline are shown in the table-4 (Muthamilasaran *et al*., 2015; Kim *et al*., 2011) [52, 45].

5. Antinutritional Content of Barnyard Millet

Barnyard millet contain antinutritional compounds such as α-amylase inhibitor, trypsin inhibitors, phytate and tannins. Phytates or phytic acid protects them against oxidative stress by chelating the iron which is involved in Fenton's reaction and some phenolics and tannins act as antioxidants (Panwar *et al*., 2016) [57]. Humans neither absorb phytate nor have the ability to hydrolyze this molecule, resulting in its involvement in making minerals less bioavailable. Phytate being negatively charged ion works in pH-sensitive areas and negatively affects the bioavailability of positively divalent and trivalent mineral ions like Zn^{2+}, $Fe^{2+/3+}$, Ca^{2+}, Mg^{2+} (Dhewa *et al*., 2021) [19]. These antinutrients form complexes with dietary minerals such as zinc, calcium and iron which lead to a marked reduction in its bioavailability and make them biologically unavailable to human organism (Sood *et al*., 2015) [77-78]. Phytic acid content in seeds of barnyard millet has ability to bind and decrease the availability of di and trivalent cationic mineral (Panwar *et al*., 2016) [57]. Thus, lower level of phytic acid is a desirable trait.

Tannin compounds are concentrated in the bran and affect *in vitro* protein digestibility. Tannin is a polyphenolic biomolecule and having an astringent and bitter taste. Tannin combined with protein and makes a complex which lower food efficiency, growth, and iron absorption in human body. Other severe side effects caused from excessive tannin consumption are damage to the gastrointestinal tract and the elimination of specific tissues, proteins, and essential amino acids. Therefore, they should be reduced to a safe level before being consumed by humans. According to analysis, the daily intake of tannin in India is 1500-2500 mg. Daily consumption of less than 1.5 to 2.5g tannin does not show any side effects. However, consumption beyond this range leads to diseases like anemia and osteoporosis and worsens cancer (Dhewa *et al*., 2021) [19].

Amylase inhibitors can behave as endogenous, mammalian and insect alpha-amylases, which bind to alpha-amylase to make them non-functional. Proteinaceous and non-proteinaceous inhibitors are the two classes of alpha-amylase inhibitors (Dhewa *et al*., 2021) [19].

6. Antinutrients Reduction Strategies

Several processing methods have been used to reduce the concentration of anti-nutrients which include decortication/dehulling, soaking, germination and fermentation.

Decortication is the process of removal of pericarp i.e., outer covering of grains. Earlier it was done manually with the help of mortar and pestle but nowadays huller/milling machine is used. Basically, decortication reduce phytic acid and polyphenolic content from barnyard millet. De-hulling reduce anti-nutrient content present in the bran. The concentration of condensed tannins was also found to be lowered by dehulling. In a recent investigation, this method decreased phytic phosphorus content by 23% in barnyard millet. It is clear from that the removal of the pericarp and aleurone layer (peripheral parts) of grains reduces the content of anti-nutritional factors. Therefore, decortication is a suitable method for eliminating phytates and tannins (Dhewa *et al*., 2021) [19].

Soaking is the easiest way to reduce anti-nutrient content. Some studies reported that soaking in water for 12 to 18 hrs are quite effective in reducing level of soluble phytic acid and proteolytic enzyme inhibitors. According to Fernandes *et al*., and Nithya *et al*., soaking and discarding water can remove a significant anti-nutrients by leaching out polyphenol. Singh *et al*., study shows that reduction of up to 70% of polyphenol when millet was treated with soaking, germination, microwave treatment and fermentation (Dhewa *et al*., 2021) [19].

Germination is an active phase of metabolism in which anti-nutrients are reduced. Masud., *et al*. stated that germination is one the best way to reduce phytic acid by up to 40%. The phytic acid content in different varieties of pearl millet varies from 588 to 1382 mg/100. When pearl millet grains are germinated for 24 hrs at 30°C it leads to reduction of phytates by more than 50%. It hydrolyzes phytic acid during the process of germination and eventually reduces phytic acid content. Germination also reduced tannin content from 22.66-35.22% and phytic content from 25.87-32.84%. Azeke., *et al*. concluded that germination reduces phytate content in millet from 5.7 to 0.85mg/g. Thus, germination gives good result by removing anti-nutrient content (Dhewa *et al*., 2021) [19].

Fermentation eliminates anti-nutritional factor. Rasane., *et al*. observed that non-fermented roasted and germinated pearl millet have high phytic acid content than fermented, roasted, and germinated pearl millet (Dhewa *et al*., 2021) [19].

7. Medicinal benefits of Barnyard millet

Millet is abundant source to bioactive compounds and antioxidant, which contribute in weight control and prevent from various health issue. The role of phenolic compounds such as flavonoids, anthocyanin and phenolic acid in millet act as an antioxidant and play crucial role in strengthening the body's immune system. Millets are considered as rich source of fibre content which help out in maintaining the amount of sugar release in the blood stream and also prevent from constipation, bloating and cramping. Likewise, alkaloids, steroids, glycosides, tannins are also present in adequate amount in barnyard millet and thus contribute to various medical benefits like being anticarcinogenic, anti-inflammatory, antimicrobial, having a wound healing capacity & constipation associated disease (Pandey *et al*., 2021) [56]. They are highly popular for their low glycaemic index which help in facilitating the formation of resistant starch and therefore recommended for patients suffering with diabetes mellitus Phenolics present in millet inhibits like alpha-glucosidase, pancreatic amylase reduce postprandial hyperglycemia by partially inhibiting the enzymatic hydrolysis of complex carbohydrates. Inhibitors like aldose reductase prevents the accumulation of sorbitol and reduce the risk of diabetes induced cataract diseases (Prasad *et al*., 2016) [35].

Barnyard millet considered as a functional food which has a beneficial effect towards human health. As consumption of functional food in our diet improves immune system, prevent from lifestyle disease and maintain good physical and mental health (Chandraprabha *et al*., 2017) [21]. The presence of alpha-amino butyric acid which is a free amino acid help in inhibiting cancerous cell proliferation and also reduces blood pressure (Sharma *et al*., 2016) [73]. The presence of dietary fibre exerts beneficial effects is through undergoing fermentation in the large intestine (colon) and producing short-chain fatty acids such as butyrate, propionate and acetate. Some of the short-chain fatty-acid (butyrate) helps in the regeneration of colon mucosal cells by serving as a source of energy, thereby reducing the risk of colon cancer and inflammatory bowel disease. Some of the short-chain fatty acids produced are absorbed (especially propionate and acetate) into splenic circulation and transported to the liver where they are known to inhibit cholesterol synthesis by hepatocytes and also glucose release from the liver, due to which it contributing partly to the hypocholesterolaemia and hypoglycaemic effects of dietary fibre. Micronutrient present in millet play essential role for overall cellular function as in pregnant and nursing mothers, young children and the elderly population to prevent malnutrition, reduces the incidence of osteoporosis and osteopenia (Prasad *et al*., 2020) [35]. Being non- glutinous and non- acid forming they are excellent nutraceuticals for people with digestive disorder.

Millet possesses anti- hypertensive properties due to the presence of polyphenols and also tannins, which prevent from certain types of cancer. The renin released from the millet bioactive peptides ultimately leads to elevated blood pressure of the body The therapeutic compounds present in phytocyanin's, phytosterols and polyphenols acts as antioxidants and detoxifying system to reduce the risk of degenerative ailments such as Parkinson's disease and certain another metabolic syndrome (Gautam *et al*., 2020) [60]. Besides this, millets contain fewer cross-linked prolamins, which may be an additional factor contributing to higher digestibility of the millet proteins. Presence of plant lignans in millets have the ability to convert into animal lignans in presence of microflora in digestive system and protect against certain cancers and heart disease. Millets plays a major role in lowering the cholesterol as it has good amount of fibre which help in eliminating LDL from the system and increasing the effects of HDL (Rao *et al*., 2017) [26].

8. Biological Activities

Barnyard millet is a multi-purpose plant. Also nutritious, it is a good source of protein, very digestible and is an excellent source of dietary fiber with a good amount of soluble and insoluble components. The carbohydrate content in barnyard millet is low and digested slowly. In barnyard millet the fatty acids are linoleic acid followed by palmitic and oleic acid. It shows high degree of retrogradation of amylase which facilitates the formation of high levels of resistant starch. It can therefore be recommended for patients with heart disease and diabetes mellitus, obesity etc. It is very effective in lowering blood sugar and lipid levels (sood *et al*, 2015) [77-78].

9. Diabetes Mellitus

Diabetes mellitus is an incurable disease characterized by hyperglycaemia associated with changes in carbohydrates, proteins, and lipid metabolism. It is considered to be the most common endocrine disorder and results in poor insulin production (type 1) or combined resistance to insulin action and insulin- secretory reaction (type 2) (Roopashree *et al*., 2014) [86]. The effectiveness of insulin and glucose receptors in the body is increased by the important levels of magnesium content and helps prevent diabetes. Barnyard millet-based diets have shown a low glycaemic response due to their high fibre content and alpha amylase inhibitory properties known to reduce starch digestion and absorption.

Barnyard millet: Millet has shown effects by reducing α-glucosidase and pancreatic amylase thereby reducing postprandial hyperglycaemia by reducing enzymatic hydrolysis of complex carbohydrates. Enzymes such as aldose reductase help prevent sorbitol accumulation and reduce the risk of diabetes mellitus. Eating millets therefore helps control blood sugar levels and aids in wound healing with the help of antioxidants (Rajasekaran, *et al*., 2021) [17].

The National Institute of Nutrition (ICMR) in 2010 evaluated the Glycaemic (GI) Index of barnyard millet- based foods in collaboration with the Indian Institute of Millets Research, Hyderabad under the National Agricultural Innovation Project (NAIP). The results reveal that barnyard millet-based diets have lower GI and lower postprandial glucose levels in the blood, glycosylated haemoglobin. Other studies also point to the fact that blood sugar levels in noncommunicable patients with noninsulin-dependent diabetes (NIDDM), who consumed millets based products, have shown a significant decrease. Barnyard millet has been reported to be beneficial for people with type 2 diabetes especially extinct species, as the glycaemic index of dehulled millet (50.0) and heat treatment was 41.7 (Ugarte *et al*., 2019) [87].

Diabetes is a disease found in millions of people around the world. Millet helps prevent type 2 diabetes because of its important levels of magnesium. Magnesium is an important mineral that helps increase the efficiency of insulin and glucose receptors by producing more digestive enzymes of carbohydrates, which regulate insulin activity. (Reddy *et al* 2017) [13].

10. Obesity

Obesity is a major problem in India and is closely linked to a number of chronic illnesses, including diabetes and CVD. Strong evidence suggests that high-fibre diets reduce the incidence of obesity (Kim *et al*., 2017) [15]. Diet rich in dietary fibre improves the function of the large intestine and reduces the digestive and digestive processes, thereby reducing the risk of chronic diseases (Agrawal *et al*., 2021) [3]. Millet is rich in dietary fibre and has unique chemical and physical properties (food content, viscosity, water retention and absorption capacity) that determine the body's subsequent behaviour. It helps to satisfy hunger, increases appetite and thus reduces the risk of obesity.

Celiac disease (CD) is one of the most common genetic disorders, by which genetically predisposed people suffer a reaction to gluten proteins found in wheat and other cereal. The disease is caused by an adverse immune response to gluten and can lead to severe abdominal pain. Millet can be a healthy food for those with celiac disease as it is gluten free. Millet products were unable to alter the level of anti- transglutaminase antibodies after prolonged use (Carolina *et al*., 2016) [76]. When people with celiac disease eat gluten, their body triggers an immune response that attacks the small intestine. This attack leads to damage to the villi, a small finger-like speculation that runs through the small intestines, which develops nutrients absorption. When the villi are damaged, the nutrients cannot be absorbed by the body. So, the only way to cure this disease is to stick your whole life to a gluten free diet provided by barnyard millet, replacing wheat which is our country's food. Barnyard millet provides all the major nutrients that make it a complete diet for a celiac patient as it is gluten free and provides all the major and small nutrients in the right amount for our body's needs.

11. Pharmacological Studies

Pharmacological studies have reported that millet is an active ingredient and exhibits nutritional properties mainly due to its antioxidant power. Bioactive compounds of millets are responsible for reducing the risk of developing a number of degenerative diseases such as cardiovascular disease, diabetes, several types of cancer, high blood pressure, heart attacks and tumours (Tiwari *et al*, 2019) [71]. Millet health benefits have been studied primarily in terms of hypoglycaemic effects, prebiotic potency, anti-inflammatory properties and prevention of heart disease and cancer. Diabetes control has been well established through dietary changes, especially with foods with a low glycaemic index. The hypoglycaemic reaction of millet is associated with a high protein and fibre content that reduces the rate of digestive starch; thus, postprandial hyperglycaemia is controlled (Geetha *et al*., 2020) [30] found that a millet-based dietary supplement showed a moderate glycaemic load (less than 20) and a lower glycaemic index (less than 55) compared with other particles that caused a significant decrease in blood sugar levels in people with diabetes.

Vedamanickam *et al*., (2020) [88] also reported that millet controls blood sugar levels in diabetic patients in addition to changes in lipid profile, systolic and diastolic levels. (Sharma *et al*, 2021) [72] found that starch digestion has a strong negative affinity for starchy starch, dietary fibre, phenolic acids and flavonoids. Natural polyphenols create an anti-diabetic effect as a result of the inhibition of the activity of a-amylase and a-glycosidase. Therefore, carbohydrate digestion and metabolism are delayed and glucose absorption is influenced by the digestive tract (Taslimi *et al*, 2017) [83]. Several prebiotic compounds such as arabinoxylans, inulin and xylo-oligosaccharides are isolated in the bran and seed coat of different millet (Prashanth *et al*., 2016) [61]. Shakya *et al*., (2020)[8] investigated the prebiotic potency of the active millet beverage and reported that millet implants stimulated the growth of the gut microflora which appears to be a result of prebiotic activity.

Palaniappan *et al*. (2017) [55] found significant prebiotic activity of xylo-oligosaccharides extracted from the millet of Lactobacillus plantarum and inhibition of four pathogenic micro-organisms due to the production of short-chain fatty acids. Prebiotics benefit the health of hosts by stimulating the colonic microflora which strengthens the immune response and limits the growth of pathogenic microorganisms. Chronic inflammation has been termed the novel malignant phenotype in which tumours begin Phenolic compounds from millet have been reported to show anti-inflammatory properties under vivo and *in vitro* experimental models (Shi *et al*., 2017) [74].

Bioactive peptides from foxtail millet prolamin inhibit inflammatory cytokines and suppress other similar metabolites in murine macrophages (Ji *et al*., 2020) [43]. Similarly, Jakubczyk *et al*. (2019) also confirmed the anti-inflammatory effect of bioactive peptides of millet grains submerged in water in controlled *in vitro* gastrointestinal conditions. In addition, Hu *et al*. (2020) [40] reported that foxtail millet peptide exhibits anti- inflammatory activity characterized by inhibition of nitric oxide and proinflammatory cytokinetion of nitric oxide and pro-inflammatory cytokines including interleukin6 and tumour necrosis factor a RAW264.7 cells.

12. Inhibition of protein glycoxidation of barnyard phenolics

Protein glycation, reactions between sugar reduction and amino groups of proteins occur at different stages. The first stage represents the construction of the Schiff base and Amadori products. In the final stages, Amadori products are oxidized, dehydrated, and thickened to produce high-quality glycation products (Vistoli *et al*., 2013) [90]. This glycation of protein is associated with glycoxidation and the production of oxygen and active carbonyl intermediates. In addition, certain specific Glycation End (AGE) products such as pentosidine, pyrraline, crossline, argpyrimidine, and pentolysine increase oxidative damage in cells and alter their normal biological functions. *In vivo* accumulation of AGEs also accelerates aging and causes diabetic complications such as retinopathy, neuropathy, nephropathy, protein denaturation, inflammation, and oxidative stress as shown in figure -1 (Delgado *et al*., 2018) [27].

Blocking the protein glycation process is one of the main ways to prevent glycation-mediated diabetes problems. Synthetic inhibitors such as aminoguanidine (AG) (Synvista Therapeutics, Inc.), pyridoxamine (Bio Stratum, Inc.), N-phenacylthiazolium bromide (Prime Organics, Inc.) and amlodipine (Pfizer, Inc.) used clinically to prevent protein glycation.

Although these synthetic drugs have strong antiglycation properties, they have been found to have many side effects such as gastrointestinal disturbances, rare vasculitis, anaemia and flulike symptoms. Thus, in recent years, natural phytochemicals from plants that effectively block glycation with minimal side effects have been of great interest to researchers. Phenolic compounds are the second metabolites of plants and have been processed for their *in vitro* antioxidant properties and antiglycation. These bioactive compounds may provide protection by free radicals, chelating transition metals and / or by incorporating carbonyl intermediate during the glycation reaction, thereby preventing the formation of AGEs (Hosseini *et al*, 2015) [38].

Phenolic cells have a strong function in preventing collagen cross-linking and glycation separated from the fingers and kudo millets (Hegde *et al*, 2002) [37]. These millet phenols are reported to have various biological functions such as antioxidative, antihypertensive, antitumor functions and prevent the formation of AGEs (Hou *et al*., 2018) [39]. In addition, phenols from small millets (barnyard, foxtail, and proso) have shown antioxidant potential in various ways and have shown strong inhibition of important enzymes associated with postprandial hyperglycaemia (αamylase and αglucosidase).) (Sreerama *et al*., 2012) [79].

Barnyard millet (*Echinochloa frumentacea*) is one of the oldest traditional millet plants in the tropics of Africa and Asia. This millet has the distinct advantage of being a drought-tolerant plant and serves as food for the people living in these regions. However, it is rarely used in processed food products and food systems. It is a rich source of amino acids containing sulphur, proteins, fats, vitamins and minerals and is rich in basic grains such as rice, corn and wheat (Bora *et al*., 2019) [14].

In addition to its nutritional value, the bioactive phytochemicals present in this millet may have health-beneficial effects in reducing the risk of various oxidative stress-mediated disorders (Ugare *et al*., 2014) [86]. In addition, barnyard millet grains have been reported to have potent antioxidant activity (Kim *et al*., 2011) [45]. Therefore, these millet antioxidant compounds may be promising agents in preventing oxidative- induced protein glycation and AGE formation. Natural protein glycation inhibitors from barnyard millet can be a very effective strategy to regulate protein glycoxidation and AGE formation and provide benefits without the side effects associated with synthetic drugs. However, there is no systematic study of the antiglycation components of barnyard millet. Therefore, this study aimed to evaluate the inhibitory effects of barnyard millet phenolics on fructose mediated protein glycation, AGE formation and its ability to protect against protein glycoxidation. In addition, it has been investigated for the effects of extracting active agents at different stages of glycation (early, mid-, and late) and its role in reducing structural changes in proteins.

Protein glycation plays an important role in the development of various diabetic complications. Therefore, inhibition of protein glycation may be an important strategy to prevent this disorder. Evaluation of phenolic compounds and their antiglycation activity revealed that p-coumaric and chlorogenic acids were the main phenolic acid in barnyard millet. These phenols exhibit many antioxidant activities in a variety of ways and protect against DNA oxidative damage and degradation of hydroxyl radical-induced protein.

Millet phenolics were very effective in extracting> 78% carbonyl intermediate active reaction and protein thiol oxidation group protection. In addition, 68.3% inhibition of protein glycation and decreased protein aggregate formation was also observed with millet phenolics. In addition, fluorescence strength measurements showed a significant decrease in glycated end products and protection against changes in glycoxidation protein conversion at 100 µg / ml phenolics. These results suggest the potential use of barnyard millet as an ingredient in an effective diet to control protein glycation associated with diabetic complications (Fogliano *et al*., 2018) [27].

13. Utililization of barnyard millet

Traditional food items from millets have been a staple food of Central America, Africa, and the Indian subcontinent. Many traditional products are based on flour, and this includes cakes made from fermented or unfermented dough, porridge or mudde, snacks, fried products, sweet or sour local beverages, non-alcoholic beverages, grains, cooked like rice by boiling (Taylor *et al*., 2017, Bhat *et al*., 2018) [85, 11]. Based on their nutritional components and nutritional characteristics, different types of millets are used in different seasons, generally. Almost all of these grains are a good source of both soluble and insoluble food fibers, provided by both the seed coat and the walls of the endosperm cells, unlike rice, where the layers of the bran often account for its fiber content (kumar *et al*.,2016) [46].

Millet is considered important because of its nutritional and nutraceutical power. It is a rich source of minerals, dietary fiber, and phenolic compounds and provides health benefits such as antimicrobial, antidiabetic, anticancer, antiartherosclerogenic effects, antioxidant, and structural properties. And aging (Kumar *et al*, 2016) [46]. Among the various types of millets, barnyard millet is known to have the highest number of healthy foods (Taylor, 2017) [85]. The first anti-aging effect of millet grains have also reported by various studies, in the past (Pei *et al*., 2016). It is often a major risk factor for non-communicable chronic diseases (NCDs) such as heart disease, type 2 diabetes, certain cancers, obstructive pulmonary disease, osteoporosis, dementia, etc. (Shlisky *et al*,2017) [75]. It is a complex process with many features, and many ideas have been proposed to explain it. These theories include free aging theory that was later transformed into mitochondrial theory, telomere shortening theory as proposed by (Lu *et al*., 2010) [49], and protein modification theory as proposed by Lindner and santos (2017) [68]. Dietary supplements such as antioxidants and protein-binding compounds influence different factors as proposed in these concepts and help delay and in conditions overcome aging.

Ribarič (2012) [65] described epigenetic mutations by dietary factors that include a direct effect on gene expression by influencing DNA methylation, histone modification, activation of nuclear receptors by ligands, and modification of membrane receptor signalling cascades. In addition the effect of calorie restriction on aging is reviewed in the article with increasing clarity in molecular pathways such as the target mammals rapamycin (mTOR), sirtuin pathway, and insulin / insulin like growth factor signalling (IIS) all involved in aging (Altintas *et al*., 2016) [4], (Chen *et al*., 2020; Yu *et al*., 2021) [24, 94]. How these components are influenced by dietary components has helped us to establish a major impact on dietary components in the aging process. As a complete source of nutrients especially minerals, vitamins, dietary fiber, and phytochemicals, millets provide many health benefits. They are nutritious as they have a high content of calcium (0.38%), and phenolic compounds (0.3-3%), calcium, roughage or dietary fiber (18%) (Rao *et al*., 2017) [26]. Apart from this, the protein found in millet is rich in essential amino acids such as tryptophan, threonine, and amino acids containing sulfur other than lysine and threonine. They have a higher fat content compared to other grains especially fatty acids (Nithiyanantham *et al*, 2019) [54]. Millet contains 7-12% protein, between 65-75% carbohydrates, 2 to 5% fat, and a dietary fiber of 15-20%. In different types of millet, pearl millet is rich in both protein (12-16%) and lipids (4-6%). Millet protein contains a large number of healthy essential amino acids (Bhat *et al*., 2018; Shah *et al*, 2021) [11, 70].

Barnyard millet starch-rich amylose has now attracted the attention of the decaying film industry as an antioxidant packaging material (Cao *et al*., 2017) [18]. The incorporation of borage seed oil into barnyard millet starch increases the range and reduces the strength, water penetration, and properties of starch moisture content, making it suitable for biofilm production. These biofilms are found to be resistant to various microbes and block free light and free radical formation in the food industry (Cao *et al*., 2017) [18]. Nanoparticle research by Kumar *et al*. (2016) [46] suggested the use of aqueous extract in the atmospheric components of *E. colona* plant in the synthesis of silver nanoparticles (AgNPs) as a new eco-friendly method for the synthesis of bio-synthesizing nanoparticles in plants. Such a combination of AgNPs derived from plant extracts could be a safe and environmentally friendly alternative to future medical use in the fields of medicine, engineering, and agriculture.

14. Application of barnyard millet

Various products from barnyard millet have been developed and barnyard millet has shown the value addition in many of the products, as mentioned in the table 1.Nishad *et al*, 2017) [50] prepared cupcakes by adding barnyard millet different concentration. Their results have shown that the sensory evaluation of millet-based cupcakes revealed a good overall acceptability and had a higher content of total dietary fibre. Crust and crumb structure and taste/flavor characteristics were 81-84%. Cupcakes from millet flour had the lowest glycaemic index (GI) of 50.8, table -5.

(Patel *et al*. 2015) [58] prepared idli. In this experiment very soft textured products were developed, the consistency of the fermented batter was thick. But taste and flavour quality was slight bitter to bland and visual appearance of the products showed well cooked apperance and soft products. Bhosale *et al*., (2015) [12] prepared kheer. This experiment was mainly based on sensory evaluation by various tests for sensory quality like color, appearance, texture, flavor, sweetness and overall acceptance. It was done to consider the physico-chemical properties of kheer. And all the parmaeters like mass thickness, molecule thickness and cooking time were explored and it was found that the expanded millet coarseness in kheer and reduces the particle thickness and porosity rate.

Jaybhaye *et al*, (2014) [42] conducted an experiment on a millet-based snack food where barnyard millet, potato mash and tapioca powder were used in a ratio of 60:37: 3. The dough was formed into small rectangular cold samples, steamed and coated with a HTST absorption process at high temperature and time (238 °C / 39.35 s). The puffed product had a moisture content of 9% and an elasticity rate of 2.05. After puffing, the product was heated in the oven at 116.26 °C for 2023 minutes. Visual extrudate structures such as density, fragment density, expansion rate and moisture retention were also analyzed. There was also a significant decrease in the moisture content, color and hardness of the toasted product with an increase in toasting temperature and time while there was a higher increase in crispiness at low levels but a slight increase in the high level of toasting parameters.

Swathi *et al*, (2017) [44] prepared dosa by using barnyard millet. The overall sensitivity was initially 8.10 and there was a significant decrease (p<0.01) in color appearance, texture and overall acceptance. As the millet flour increased the thickness of dosa decreased and diameter increased. Millet dosa stored in food grade aluminium foil pouches at ambient temperature can be stored for four and half months. The dosa level of barnyard millet in terms of nutrient density and sensory point of view was good.

Goswami *et al*., (2015) [34] worked on barnyard millet bases muffins they have taken many flour blends for making muffins and determined the pasting properties of flour blends, specific gravity of batter, proximate analysis and gluten content, instrumental analysis, sensory evaluation, oxidation and microbiological properties. The hardness (274.02), cohesiveness (0.80), resilience (0.60), springiness (1.20). The overall acceptability of the muffins is above 7 and as gluten is not included in this product it is considered as gluten free product.

Karuna *et al*., (2016) [53] they prepared rusks by using barnyard millet for that they conducted experiments on pre-treatment of barnyard millet bran, analysis of anti-nutritional and nutrient analysis for raw and chemical treated barnyard millet bran, sensory evaluation Texture profile analysis (TPA) and statistical analysis. The rusks showed higher protein and dietary fibre and while barnyard millet bran is treated with chemicals the anti-nutrient factors were significantly decreased the overall sensorial acceptance of the rusk is in the ratio 85:15 and is been highly accepted by the panel members but barnyard millet has increased hardness of rusk it can be used as substitute for wheat in bakery products as in table-5.

Chakraborty *et al*., (2016) [20] they conducted experiment on making barnyard millet bread and on its properties like Textural properties, bread quality parameters, colour, specific volume and data analysis. From this experiment of making bread from Barnyard millet show that leavened bread can be made from Barnyard millet the hardness value of the bread is 161.8 in the cohesiveness of the bread is 0.812, resilience is 0.594 and springiness of bread is 1.0.

Salunke *et al*., (2019) [67] they prepared cookies from barnyard millet by determining physical characteristics, chemical properties, physico-chemical analysis, sensory evaluation, statistical analysis, packaging and storage of barnyard cookies with these they concluded that the cookies which are made from the barnyard millet and from other flour mixtures are well accepted till 90th day of its baking. The overall Sensorial score was above 7 and this sensorial score is increased while the quantity of Barnyard millet flour is increased.

Goel *et al*., (2021) [32] they conducted experiment on making vermicelli from barnyard millet for this they conducted analysis on various aspects like optimization, statistical analysis, proximate analysis and concluded that that vermicelli that is made with 64.25% of barnyard millets floor 22.3% of rice flour and 2.36% of XG resulted in vermicelli that can replace 100% refined wheat flour. Usage of barnyard millet increased amount of iron (3.81 mg/100g) and beta carotene content (1039µg/100g) thus this product showed that barnyard millet has ample scope for the commercial utilisation.

Sruthi *et al*., (2018) [80] they prepared wafers by incorporating barnyard millet by analysing the proximate analysis of different formulations, microbial analysis and sensory characteristics. Form these different formulations of wafers they concluded that combinations of wheat flour, pearl mint floor and barnyard millet floor the highest content of ash (1.6) is seen in 50% of barnyard millet combination and higher content of crude fiber (12.8) is seen in 70% of Barnyard millet composition. The overall sensorial acceptance of wafers is above 7 as shown in table -5.

Amrita *et al*., (2021) [19] they conducted experiment on barnyard millet ice cream by performing analysis on Nutrition, statistical analysis and concluded that barnyard millet ice cream has higher amounts of carbohydrates, protein, fat, calcium and phosphorus. The overall acceptability score is also high. This ice cream is very beneficial for people who are suffering from lactose intolerance, cow milk protein allergy and the people who are preferring vegan diet. Thus, this product also has a good potential in future for the commercialization.

15. Toxicology and recommendation of barnyard millet

With respect to nutritive value, barnyard millet have significant nutritional importance and in last few decades the millet is gaining attention for its fibre content and bioactive compounds, but still there's scope to draw the attention of barnyard millet in terms of phytochemicals and antioxidants. Therefore, a study was done to prove the proliferative activity of free and bound extract of proso millet against the human breast cancer cell and human lung cancer cell line. So, (Ramadoss *et al*., 2019) [62] extracted the bioactive compounds from proso and barnyard millet and purified those compounds using SFE (Supercritical fluid extraction) technique. With the help of their study it was proved that when HT-29 cells were treated against the extracted bioactive compounds of barnyard millet having concentration of 250 micro gram/ml for 48hrs, then the proliferation of the cells were inhibited. Later, through the cytotoxic activity it was confirmed that those particular extracted bioactive compounds were not toxic upto the concentration of 250 micro gram/ml (Ramadoss *et al*., 2019) [62].

16. Future perspective

Barnyard millet is an underrated grain, with a high percentage of crude fiber and minerals in it, which can be used in bakery sectors for muffins. According to this paper, muffins prepared by barnyard millet flour (BMF) were relatively leading in fiber (2.1g/100g) and mineral (1.75g/100g) composition rather than the ones prepared with refined wheat flour. Moreover, the BMF muffins were having a longer shelf-life than the normal ones (Goswami *et al*., 2015) [34]. Puffing of grains is a long-established way of preparing grains as snacks or morning meal either plain or with flavors (Lehmann *et al*., 2007) [96]. The average carbohydrate content of Barnyard millet varies from 51.5- 62.0 gm/100gm (Saleh *et al*., 2013) which is quite a satisfactory quantity to start the first meal of the day with.

Noodles are produced using the flours of grains. The dried food items are utilized as ready-to eat; thus, the shelf life of the millet and taste is enhanced as well as it's economical value also expands. Moreover, noodles are a quick food which can be prepared in a very less time (Devaraju *et al*., 2006) [28]. Above all this, the fact that noodles are accepted openly by people of all age group makes this product commercially good product. This particular millet has comparatively low sugar concentration (58.56%). In a research project (Ugare *et al*. 2014) [86] they confirmed, a lower glycemic index in type II diabetic groups during regular consumption of Barnyard millet meal. So, noodles made from barnyard millet flour can be consumed by a diabetic person without feeling guilty.

Millet was utilized by formulated low glycemic index noodles from barnyard millet flour with the combination of sago flour, pulse flour and Bengal gram leaf powder at various levels to create plain, pulse and vegetable noodles separately (Surekha *et al*., 2013) [81].

The millets are considered as underutilized cereal i.e. They possess antioxidant properties as millet is rich in phenolic compounds but the only defect in this grain is that the bioactive compounds are not fully available due to which the grain loses its significance and therefore to overcome this shortcoming they have come out with a new way. According to this research the end result of independent variables like soaking time, germination temperature and germination time have different retort on total individual phenolic, flavonoid contents and antioxidant activity. The results suggested soaking time, germination time as well as germination temperature are directly proportional to the antioxidant activity, total phenolic and flavonoid contents i.e., on increasing the factors (time and temperature of seeds) we can have huge difference in the composition of barnyard millet flour. On comparison there was a significant quantitative difference in the phenolic extract of raw and optimized germinated barnyard millet that revealed high amount of Hexadecenoic acid (5.59%), Octadecadienoic acid (14.5 9%), 9, 12 Octadecadienoic acid, ethyl ester (11%), Lupeol (5.18%), campesterol (7.59%) in optimized germinated flour as compared to raw flour. Dietary fiber and minerals increased whereas phytates decreased significantly due to germination (Sharma *et al*., 2016) [73].

Table 1: Taxonomical classification

Domain	Eukaryota
Kingdom	Plantae
Phylum	Spermatophyta
Sub phylum	Angiospermae
Class	Monocotyledonae
Order	Cyperales
Family	Poaceae
Genus	*Echinochloa*
Species	*Echinochloa* species

Table 2: Nutritional composition

Nutrient	Composition (Per 100 g)	Reference
Carbohydrates	55 - 65.5 g	Gomashe *et al*., 2017 [33]. Muthamilasaran *et al*., 2015 Chauhan *et al*., 2018
Protein	6 - 13 g	Gomashe *et al*., 2017 [33]. Muthamilasaran *et al*., 2015 Nithiyanantham *et al*., 2019 [54].
Fat	2 - 4 g	Gomashe *et al*., 2017 [33]. Muthamilasaran *et al*., 2015 Chauhan *et al*., 2018
Energy	300 - 310 Kcal	Muthamilasaran *et al*., 2015 Chauhan *et al*., 2018
Crude fibre	9.5 - 14 g	Gomashe *et al*., 2017 [33]. Muthamilasaran *et al*., 2015 Chauhan *et al*., 2018
Thiamine	0.30 mg	Muthamilasaran *et al*., 2015
Riboflavin	0.09 mg	Muthamilasaran *et al*., 2015
Calcium	11- 27.1 mg	Panwar *et al*., 2016 [57]. Nithiyanantham *et al*., 2019 [54]. Gomashe *et al*., 2017 [33].
Iron	15 – 19.5 mg	Panwar *et al*., 2016 [57]. Nithiyanantham *et al*., 2019 [54]. Gomashe *et al*., 2017 [33].
Ash	3.8 -4.5 mg	Gomashe *et al*., 2017 [33]. Muthamilasaran *et al*., 2015 Chauhan *et al*., 2018 Pasha *et al*., 2017
Phosphate	280 - 340 mg	Gomashe *et al*., 2017 [33]. Muthamilasaran *et al*., 2015
Zinc	2.6 – 4.75 mg	Panwar *et al*., 2016 [57]. Muthamilasaran *et al*., 2015
Copper	0.013 - 1.30 mg	Panwar *et al*., 2016 [57]. Muthamilasaran *et al*., 2015
Manganese	1.33 – 3.13mg	Panwar *et al*., 2016 [57]. Muthamilasaran *et al*., 2015
Magnesium	82 mg	Muthamilasaran *et al*., 2015

Table 3: Bio active compounds

Bio Active compound	Composition (per 100g)	Reference
Total phenol	20.3 - 27.80 mg	Panwar *et al*., 201
Tannins	3.96 mg	
Saponins	10.26 mg	
Orthodihydroxyphenol	107.14 mg	

Table 4: Anti – nutritional factors

Anti – Nutrient	Composition (per 100 g)	Reference
Phytic acid	3.37 - 3.70 mg	Panwar *et al*., 2016 [57].
Trypsic inhibition	8.07 mg	Sharma *et al*., 2021 [72].

Table 5: Amino acid content

Amino acid	Composition (mg / g)	Reference
Isoleucine	288 - 372 mg	Muthamilasaran *et al*., 2015 Lim *et al*., 2011
Leucine	725 - 762 mg	
Lysine	106 - 136 mg	
Methionine	131 - 133 mg	
Cysteine	175 - 210 mg	
Phenylalanine	362 - 430 mg	
Tyrosine	119 - 150 mg	
Threonine	35 – 263 mg	
Tryptophan	63 mg	
Valine	388 - 415 mg	

Table 6: Applications of barnyard millet

Product	Composition	Optimization		Findings and Results	Reference
Cup cakes	Wheat flour 75g, jaggery powder Barnyard millet flour 75g 180g, butter 60g, milk 125 ml, baking powder 5 g, baking soda 2g, vanilla essence 2 ml.	Grease cupcake mould and filled 3/4th cake batter then preheat the oven and place the mould for 20- 25 min at 180 °C.		The quality attributes which affected the acceptability were flavor, color, texture e, overall acceptability and taste. And the order of preference of attributes were OAA> taste> flavor> texture> color. Thus, analysis indicates that taste, OAA, and flavour were major quality attributes while texture and colour were least important.	Nishad *et al*., (2021) [50]
Idli	2 cups barnyard millet, ¾ cup Sabu dana (Tapioca pearls), ¾ white urad dal, ½ cup (flattened rice), 2 teaspoon methi seeds.	Consistency of the fermented batter, cooking quality and visual appearance were determined.		Very soft textured products were developed but taste and flavor quality was slight bitter to bland and crisp texture was 81. s42.	Patel *et al*., (2015)
Kheer	tbsp barnyard millet, 1 cup milk,2- 3 spoon sugar,¼ tsp cardamom powder and TBSP chopped almond cashews.	To test the Timeframe of kheer blend powder was put away at 30-35°C to demonstrates different physiochemical changes.		Sensory evaluation by various tests for sensory quality like color, appearance, texture, flavor, sweetness and overall acceptance were good. It was done to consider the physicochemical propertiesof kheer.	Bhosale *et al*., (2015)
Snack foods	Barnyard millet half cup, half cup onion chopped, half cup mashed potato, tapioca powder ¼ tsp, oil as needed.	Product had a moisture content of 9% and an expansion ratio of 2.05.		The extrudate physical properties like bulk density, piece density, expansion ratio and moisture retention were analysed.	Jaybhaye *et al*., (2017).
Dosa	2 cups barnyard millet,½ cup urad dal, ¼ tsp methi, salt –as needed	Soak millets and dal separately for 3 hours. Kept it in fridge for an hour, it prevents the mixier jar getting heated. Consistency should be thick		As the millet flour increased, the thickness of dosa decreased and diameter increased. Millet dosa stored in food grade aluminium foil pouches at ambient temperature can be stored for four and half months	Swathi *et al*., (2017)
Muffins	Barnyard millet flour 26 g, sugar 26 g, egg 21 g full fat milk 13 g shortening agent 12 g sodium	Grain polisher– Rice polisher Millet grinder – sieve mesh no. 65 Muffin batter – spar quart mini mixer		Replacing barnyard millet in flour blends led to enhancement of overall quality like pasting properties, physical, textural and colour properties. Due to lack of gluten in millet it affected baked height, springiness, resilience, cohesiveness and chewiness of muffins.	Goswami *et al*., (2015) [34]
	bicarbonat e1.1 g citric acid 0.8 g and salt 0.1 g				
Rusk	Wheat flour 100g 10g Barnyard millet bran Sugar Shortenin g agent Salt	Bran removal by milling Grinding by manually Sieved manually through 60 mesh		Sensory evaluation was done by 7 point hedonic scale As more Barnyard millet bran is added the fibre and protein content was increased The Sensorial attributes of rusk are in the ratio of 85:15 The overall acceptance of rusk is ranged from 7.4 to 8.4	Karuna *et al*., (2016)
Bread	Dehusked	Cleaning	of	Response surface analysis is used for data generation after experiments. Soy flour has effected texture, colour and specific (2.963 cm³/ g) Colour changes was due to protein present in soy flour Hardness (274.02) Cohesiveness (0.80) Resilience (0.60) Springiness (1.20)	Chakraborty *et al*., (2016)
	Barnyard	Millet by			
	millet –	laboratory			
	variable Fat	attrition mill			
	soy flour –	Sieved by			
	variable	140 mesh			
	Compress ed	Storage done	I.S		
	yeast-	In	is		

	variable Salt – Variable Sugar –1.5 g Water - 40ml	polythene Bags		
Cookies	Barnyard millet flour-variable Wheat flour-variable Vegetable fat Powdered sugar Sodium bicarbonate Ammonium bicarbonate	Bran removal by decorticator Sieved by 80 mesh Physical characteristics were determined Chemical properties were determined Physico chemical Properties were analysed Sensory evaluation of cookies is done by 9 point hedonic scale	The percent porosity of barnyard millet was 70.59 percent. The overall acceptance of Maida and barnyard millet cookies is from 8 to 9 And for wheat and barnyard millet cookies is from 6.5 to 9 The cookies which were made from 50 percent wheat, Maida and barnyard millet cookies has good quality and can be stored till 90 days in LDPE Package	Salunke *et al.*, (2019) [67]

17. Conclusion
As paper is all about Barnyard millet as an under-utilized minor millet crop and therefore in the paper we have given an elaborated account of the barnyard millet. In the introduction there are some common points about the millet for instance, it's scientific name, popularly grown species, climatic and agronomic conditions it requires, it's health benefits over rice and the areas where it is cultivated. Since, Barnyard millet is an ancient crop therefore it's history and origination is also covered in detail. We have mentioned the classification and categorization of barnyard plant. This millet in particular is one of the most underrated minor millets as it contains Protein, Carbohydrates, Fat, Crude fibre, Mineral matter, Calcium, Phosphorous, Iron, Starch etc. The essential amino acids present in barnyard millet are lysine, methionine, threonine, isoleucine, leucine, histidine, tryptophan and the non-essential amino acids are Aspartic acid, Glutamic acid, Arginine, Alanine, Cysteine, Glycine, and Proline. It contains antinutrient constituents such as α-amylase inhibitor, trypsin inhibitors, ortho-dihydroxy phenol content phytate and tannins. The presence of antinutrients such as polyphenols, phytates, oxalates and tannins affect the mineral bioavailability. Barnyard millet is categorised under the neutraceutical grains as it have varied number of health benefits. In this study the effect of echinochloa on diabetic patients, weight gain and metabolic disorder is discussed in detail. Also, not only the positive side is considered but also the toxic effect and recommended amount of barnyard millet is cited. As of now, we can see a great future for barnyard millet in food line therefore we have discussed some of the products of barnyard millet that have an excellent time ahead.

18. References

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