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Nutrient rich Kodo millet, importance and value addition: An overview

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Abstract
Kodo millets are suitable for people who are gluten intolerant because they don't contain gluten. Because it has a higher level of lecithin, which is important for the health of the neurological system, Kodo millet is very simple to digest. Postmenopausal women with signs of cardiovascular illness, such as high blood pressure and excessive cholesterol, can benefit greatly from regular use of Kodo millet. It contains more antioxidants, which protect against oxidative stress and keep type 2 diabetes patients' glucose levels stable. Asthma, migraines, high blood pressure, heart attacks, atherosclerosis, and diabetic heart disease can all be treated with Kodo millet. As a result, research on millet-based goods is becoming more and more important in order to take advantage of their positive effects in light of the growing population in developing nations.

Keywords: Millet, people, problem, yield, women

Introduction
One of the largest problems facing the modern world is feeding everyone on the planet. The lack of micro- and macronutrients, shortages in food production that cause supply-demand mismatches, and conflicts that destabilize different regions of the world are all factors that contribute to this problem. Even though some of these causes of hunger can be addressed, the threat of climate change and global warming still exists. As a result, the number of people who experience hunger and malnutrition has decreased slightly from approximately one billion in the years 1990–1992 to 850 million in the years 2010–2012 (FAO, 2012) [30]. 2-3 billion people may experience nutritional insecurity as a result of reduced food production rates and the additional strain of feeding a population that will top 9 billion by 2050 (Wheelker and Braun, 2013; Godfray *et al*. 2010) [33]. Land productivity, crop production, and the overall sustainability of our food systems are all said to be directly impacted by climate change and rising world average temperatures. Although predictions suggest that some regions may benefit from climate change through increased productivity and yields, this will not be sufficient to feed the expanding global population (Kang *et al*. 2009) Furthermore, the majority of scientists concur that crop output would be severely decreased under the influence of climate change and greenhouse gas emissions. Therefore, ensuring food security depends greatly on reducing greenhouse gas emissions in order to control global temperatures. However, one of the main sources of greenhouse gases like methane in the environment is the agriculture industry Intensive farming practices, which are practiced in various parts of the world, typically result in higher emissions (Downing *et al*. 2000; Olesen and Bindi, 2002) [28, 56].

Millets are forage grasses which belong to family *Poaceae*. Millets are one of the cereals asides the major wheat, rice, and maize. These are key agriculture produce on a global level having significant contribution for the people having low income especially in developing countries. Millets can be grown in a short period, can sustain drought condition crop and have long storage period without insect damage (Adekunle, 2012) [1]. They are small to medium size crops that are cultivated throughout the tropics and subtropical region. The millets belonging to genus *Poaceae* (true grass) can be classified as major millets and minor millets which are cultivated in India, China, Malaysia, Srilanka, Australia and some parts of Africa since ancient times (Baltensperger, 1996) [12]. The major millets are Pearl millet (*Pennisetum glaucum*), Foxtail millet (*Setariait alica*), Proso millet or white millet (*Panicum miliaceum*), and Finger Millet (*Eleusine coracana*). Minor millets includes Barnyard millet (Echinochloa spp.), Kodo millet (*Paspalum scrobiculatum*), little millet (*Panicum sumatrense*), Guinea millet (*Brachiaria deflexa*), and Browntop millet (*Urochloa ramose/Brachiaria ramose/ Panicum*

ramosum) (Chinchole *et al.*, 2017; ICRISAT, 2017; Yang *et al.*, 2012, Nithiyanantham *et al.*, 2019) [19, 42, 81]. Millets are small annual grains of cereals seed. These plants are very hardy and can be effectively cultivated in lands of infertility. Diseases and pests are less susceptible to these plants. It is stable like wheat and rice. Some of them exceed the average protein, fat and mineral content (Gopalan and Shastri, 2009) [3]. All the millets are rich in calcium, iron, folic acid, niacin, potassium, magnesium and zinc (Parvathy and Thayumanavan, 1995) [57].

Coarse cereals are primarily used as animal feed in advanced nations, whereas 68-98% of coarse cereals are used for human consumption in developing nations. Depending on the taste and cultural preferences, they are placed to many uses in our diet. Millets are currently produced in Northern China, India, Africa and Southern Russia, with about 80% of the crop being consumed directly as food (Sindhu and Khetarpaul, 2001) [69]. The word "millet" applies to different plants of grass whose seeds are harvested for human consumption or animal feed (Crawford and Lee, 2003) [21]. Compared to other cereal grains, millet production in India is very small. Throughout the year, minor millets such as foxtail, *Kodo*and small millets are readily accessible. It is cheaper than other significant millets and cereals. Millets are especially low in phytic acid and high in dietary fiber, iron, calcium and B-vitamins. It also includes greater proportions of unavailable carbohydrates. Due to poverty, moving consumption patterns from a balanced diet, extensive incidence of nutritional deficiencies and also low consumption of nutritious cereals, nutritional deficiencies have decreased considerably over the previous three decades (Malathi *et al.*, 2012) [50]. The growing population of world needs food which is a great challenge for governments and policy makers. Therefore, it is important to explore plants such as millets that are grown locally and consumed by low income households in places like India and the Sahel zone (Obiana, 2003). Cereals especially millet based foods and beverages are used throughout the world and are still part of the major diet in most African countries (Obilana and Manyasa, 2002; Amadou *et al.*, 2013) [55, 4]. The present review summarizes the nutritional composition of Kodo millets, some health benefits, and the use of it in the food industry.

History of Origin and Distribution of Kodo millet

Kodo millet (*Paspalum scrobiculatum* L.) is an annual grain that is grown primarily in India. It is a highly drought tolerant crop and is the coarsest of all food grains. It is also found in the Philippines, Indonesia, Vietnam, Thailand and in West Africa. It is harvested as a wild cereal in West Africa and India apart from being cultivated. It is grown as a minor food crop in most of the areas in India. Kodo millet is also grown in hot arid regions of Asia, New Zealand and USA as a pasture crop. It is a self-pollinating grass (2n = 4x = 40) belonging to Family *Poaceae*and Subfamily *Panicoideae*. It grows wild as a perennial in the west of Africa, where it is eaten as a famine food. Often it grows as a weed in rice fields, and farmers do not weed it out as it can be harvested as an alternative crop if their primary crop fails. India is known as the country where Kodo millet was originated. It is assumed that domestication of Araka or Kodo millet (*Paspalum scrobiculatum L.*) was took place about 3000 years ago (House *et al.*, 1995; Arendt and Dal, 2011) [40, 7]. The tropical and sub-tropical regions are best suited for its cultivation (Hulse, 1980; Saxena *et al.*, 2018) [41, 64]. It is grown on poor soils and it is widely distributed in arid and semi-arid regions of India an African Countries. In India, it is a small grain crop and a significant crop in the plateau of Deccan. In India, its cultivation is usually limited to Gujarat, Karnataka, Chhattisgarh, Eastern Madhya Pradesh and parts of Tamil Nadu. It is an annual grass species that grows to around 90 cm height. The Kodo millet grain color varies from light red to dark grey which is bounded in a tough husk that is difficult to remove. In latest years, millets have been acknowledged as significant replacements for main cereals in order to deal with global food shortages and satisfy the demand from developing and developed nations for a growing population. Kodo millet is categorized as coarse grain and is mainly grown in India, China, Russia, Japan and Africa. *Kodo*grains are readily maintained and demonstrated to be a good reserve for starvation. *Kodo*grains comprise protein 8.35%, fat 1.45%, carbohydrate 65.65% and ash 2.95%. It can be regarded a cereal-nutrient. Kodo millet belongs to the *Poaceae*family and is also known as cow grass, ditch millet. Kodo millet is cultivated mainly in India and Madhya Pradesh ranks first in its cultivation in the country. It contributes about 50% area and 35% production of total millet in the country (Bhat *et al*., 2017; Balasubramanian, 2013; Devi *et al*., 2014) [14, 10, 25]. It is monocot crop and smaller size seeds, 1.5 mm in width, 2 mm in length and light brown to dark gray in color and it is covered in a husk which is hard to remove (Nithiyanantham *et al.*, 2019). Kodo millet is well known for the highest drought resistance among all minor millets and said to produce good yield with in less growing period i.e. 80-135 days (Ravi, 2004, Saxena *et al.*, 2018) [64, 60].

Nutritional parameters of Kodo millet

Millets are unique among the cereals because of their richness in calcium, dietary fibre, polyphenols and protein (Devi *et al.*, 2011) [27]. Millets are good sources of magnesium and phosphorus. Magnesium has the ability to help reduce the effects of migraine and heart attacks, while, phosphorus is an essential component of adenosine triphosphate (ATP) a precursor to energy in the body (Badau *et al.*, 2005; Liang *et al.*, 2010; Devi *et al.*, 2011) [9, 27, 49]. Kodo millet is rich in vitamins, minerals, and phytochemicals containing sulfur, so it is called "nutria-cereals. It is also rich in essential amino acids, like lysine, threonine, valine, sulphur containing amino acids and the ratio of leucine to isoleucine is about 2.0 (Ravindran, 1992; Antony *et al.*, 1996) [61, 6], but it is deficient in tryptophan amino acid. Kodo millet*s* are rich in vitamin B3, vitamin B6 and folic acid as well as minerals such as calcium, potassium, magnesium and zinc. Kodo millet grain contains 8.3 per cent protein in which major protein is glutelin (Sudharshana *et al.*, 1988) [73]. It contains high amount of crude fiber (9%) as compared to wheat (1.2%). It provides 353 Kcal energy per for 100 gm of grain. Kodo millet contains 66.6% carbohydrate, 2.4% minerals, 1.4% fat and 2% ash. The range of iron content in Kodo millet is 25.86 ppm to 39.60 ppm (Chandel *et al.*, 2014) [16]. The overall average nutrient composition of Kodo millet is given below in table 1.

Medicinal Values of Kodo millet

Millets for diabetes

Diabetes occurrences have been found to be lower among millet eaters. By partially suppressing the enzymatic digestion

of complex carbs, millet's phenolic content, which includes alpha glucosidase and pancreatic amylase, lowers postprandial hyperglycemia (Shobana *et al*., 2009) [68]. Aldose reductase inhibitors, for example, stop sorbital build up and lessen the risk of cataract illnesses brought on by diabetes (Chethan and Malleshi, 2007).

Millets and aging

The chemical reaction between the amino group of proteins and the aldehyde reduction group of sugars, known as non-enzymatic glycosylation, is primarily responsible for diabetes and ageing. According to Hegde *et al*. (2005) [38], Kodo millet is one of many millets that are high in antioxidants and phenolics such phytates, phenols, and tannins that may have a significant antioxidant effect on ageing, metabolic syndrome, and general health.

Millets against cancer and celiac disease

Millets are high in phytes, tannins, and phenolic acids, which act as "anti-nutrients." However, in animals, these anti-nutrients reduce the risk of breast and colon cancer. According to Chandrasekara *et al*. (2010), the phenolics found in millet are effective at halting the development of cancer in both *vitro* and *vivo*. A new business of cereal goods made from grains other than wheat and rye has emerged in tandem with the rise in celiac disease cases and the general increased demand for inventive, delectable, and "healthy" foods. When patients with a hereditary predisposition to celiac disease consume gluten, it results in an immune-mediated enteropathy. However, given that millets are gluten-free, they have a considerable potential in foods and beverages that may be suitable for those who have celiac disease (Taylor, 2006; Ezeogu *et al.*, 2008) [74, 29]. Therefore, millet grains and their functions have the ability to be helpful in the prevention of cancer and in the production of celiac food products.

Millets for cardiovascular disease

The risk of heart attack and stroke is increased by obesity, smoking, bad eating, and inactivity. The majority of the world's countries are dealing with high and rising rates of cardiovascular disease. According to Hegde and Chandra (2005) [38], millets have a higher level of free radical scavenging activity, which lowers the risk of cardiovascular illnesses.

Traditional use of Kodo millet

Millets are referred to as nutri-cereals since they are full of vitamins, minerals, phytochemicals, and sulphur-containing amino acids. Additionally, millets are suggested for people with celiac disease because they don't contain gluten (Chandrasekara and Shahidi, 2010). Foods and beverages made from millet are particularly well-liked over the world and continue to play a significant role in the diets of most African nations (Obilana and Manyasa, 2002; Amadou *et al*., 2011) [55, 4]. Porridge with milk and other liquids is typically made with millet and its flour. In many developing nations in Asia and Africa, where millet is widely farmed, it is a staple grain. According to Chandrasekara and Shahidi (2011), millets are used to make traditional dishes and drinks such Idli, Dosa, Papad, chakli, porridge, bread, infant formula, and snacks Sorghum/millet flour is frequently used to make flat, thin cakes known as Roti in the Maharashtra state, which are then used as the foundation for meals. For Rotis, Idlies, Dosa, and chakli (Veena *et al*., 2004) [76], foxtail millet is used for navanesampali, huggi, burfi, or kabab; little millet is used for samaidosa, porridge, paddu, and paysam as per traditional recipes in various millet-growing states in India (Jayabhae *et al*. For large portions of the tribal population in Central India, Kodo millet is a crucial food crop. The people in Himalayan foothills use millet as a cereal, in soups, and for making dense, whole grain bread called Chapatti. One of the popular alcoholic fermented beverage used in Darjeeling hills and Sikkim in India known as =*Kodo*ko jaanr‘ is manufactured by using dry seeds of finger millet. *Chhang*is also a fermented finger millet beverage popular in Ladakh region in India. *Koozh*is another fermented beverage made with pearl or finger millet flour and rice, and consumed by ethnic communities in Tamil Nadu (Ilango and Antony, 2014) [43]. Although many traditional foods can be prepared in the domestic household, but limited large-scale commercial use of millet discourages the farmers to grow millets (Subramanian and Viswanathan, 2003) [72]. Therefore, there is an emerging need for the world to produce industrial products using millets.

Development of Value-Added products Using Kodo millet

In many places of the world, millet is a staple food. The processing of millet grains is thought to be acceptable for both residential and industrial levels (Obilana and Manyasa, 2002; Millets, 1995) [55]. Millet grains are currently gaining increased attention from food technologists and nutritionists due to their potential health benefits and ability to combat numerous diseases (Shahidi and Chandrasekara, 2013) [66]. Millets are not used to their full potential in many developed nations. Millet grains have a huge potential for being transformed into high-value foods and beverages in underdeveloped countries. Therefore, research into and development of advanced processing technologies at the industrial level for better nutritive value and functionality to satisfy the needs of the consumer was initiated and accelerated in many nations across the world.

Blended flour

Millets are more nutrient-dense than cereals, but their use is still underutilised. To boost utilisation, millets can be blended with wheat flour after going through the required processing steps (Singh and Raghuvanshi, 2012) [70]. The physico-chemical, nutritional value, and functional properties of the blended product would change when millets flour was added to other goods (Jaybhaye *et al*., 2014) [47]. In affluent nations, a variety of convenience foods, including extruded goods, are commonly consumed. In comparison to weaning foods of acceptable quality, extruded goods made from millets have a better nutritional content (Almeida-Dominguez *et al*., 1993) [3]. Using pearl millet, Balasubramanian *et al*. (2012) [11] reported on the manufacturing of inexpensive snacks. A lot of researcher have tried to prepare composite millet flours by substituting generally used cereal flours to manufacture various food products like ready-to-use foods, pasta preparation etc. This approach is very convenient technique to get nutritionally improved with increased functionality.

Baked products

Due to their diverse taste profiles, low cost, variable texture profiles, long shelf lives, and appealing packaging options, bakery products are becoming more and more popular on a

global scale (Bunkar *et al*. 2012) [15]. Millets will be superior in terms of fibre content and micronutrients when used in bakery products, and they will also create a fantastic opportunity for millets to enter the baking industry for a variety of value-added products (Verma and Patel, 2013) [78]. Although they are often manufactured with wheat flour, efforts are being undertaken to replace a small percentage of it with millets in order to offer a substitute, lessen our reliance on wheat, and create gluten-free bread. It is possible to use finger millet and foxtail millet flour in baked goods including cookies, nan-khatai, chocolate, cheese, cakes, muffins, and more. According to research results, finger millet flour may replace 40% of the wheat flour used in baked goods like cake and cookies (Begum *et al*., 2003; Yenagi *et al*., 2013) [13]. The finger millet-based muffins, soup sticks, rusks, masala cake, carrot cake, and chocolate cup-cakes all received high marks for look, texture, flavour, and general appeal. Malted finger millet flour has been added to cakes in an effort to increase their nutritional value in terms of their mineral and fibre content (Desai *et al*., 2010) [23].

Fermented products

The most popular fermented dishes in South India include delicacies like dosa and idli. Due to their importance as human food, fermented foods made from grain are highly well-liked and utilised all over the world (Mugocha *et al*., 2000; Gotcheva *et al*., 2001) [53, 35]. Due to its advantages, such as improving *in vitro* protein digestibility and lowering the levels of anti-nutrients in dietary grains, millet-based fermented products are also employed (Chavan and Kadam, 1989; Begum *et al*., 2003; Verma and Patel, 2013) [18, 78]. The ground germinated pearl millet grains undergo chemical changes during fermentation that result in a high protein digestibility that makes up 90% of the final product (Ahmed *et al*., 2009) [2]. Pearl millet was fermented by inoculating S. *diacetylactis, S. cerevisiae, L. brevis and L. fermentum* which increased the starch digestibility of flour significantly (Khetarpaul *et al*., 1990) [48]. The various recipes of acceptable quality were prepared using naturally and mixed fermented pearl millet flour including cutlets, weaning mixtures, vermicelli and biscuits. Based on scientific literature, it can be suggested that production of millet based fermented products including Kodo millet can be a profit making formula using fermentation and enzymatic hydrolysis processes to enhance nutritive value and decrease of anti-nutritive factors.

Puffed/popped and flaked millets

A long-standing custom of boiling grains for consumption as a snack or breakfast cereal, either plain or with some spices, salt, or sweeteners, is the use of cereal-based puffed products (Jaybhaye *et al*., 2014) [47]. By submitting native grains (12% mc) to HTST treatment at 230+/- 5oC, the cereal processing technologies were successfully applied to foxtail millet to generate RTE or ready to use products in the form of flaked, extruded, roller dried decorticated, and popped grains (Ilango, and Antony, 2014) [43]. In order to create ready-to-eat (RTE) barnyard millet-based snacks, Jaybhyae and Srivastav (2010a; 2010b) formed thin rectangular-shaped, steam-cooked cold extrudate (cut pieces of dough) samples and puffed them using the HTST puffing technique.

Extruded products: Extruded products cooked at high temperature with less holding time which leads to gelatinization of starch and denaturation of protein. This process improves digestibility and causes inactivation of anti-nutrient factors (Awika and Rooney, 2004) [8]. Extrusion process have many advantage like improved and consistent quality, high production, variety in products, enhanced *in vitro* digestibility of proteins (Dahlin and Lorenz, 1993) [22]. This process improves the availability of iron in extruded foods (Cisse *et al*., 1998) [20]. Millet based extruded snack foods are prepared using twin-screw extruder from Kodo millet-chickpea flour blend (70:30) (Geetha *et al*., 2014) [32]; pearl millet, finger millet and soybean flour blend (Balasubramanian *et al*., 2012) [11] or ragi, sorghum, soy and rice (42.03, 14.95, 12.97 and 30%) flour blend (Seth and Rajamanickam, 2012) [65] with desired quality. Devi and Narayanasamy (2013) [26] explored the possibility of preparation of composite millets milk powder with the combination of finger millet and pearl millet to prepare RTC extruded product from composite of millet powder and maida (50:50) within the acceptable range in terms of nutrient content, color, texture and cooking quality and sensory characteristics

Healthy and functional foods

Millets have received attention for their potential role as functional foods due to health promoting phytochemicals. Small millets are important coarse grains and rich in nutrients. Epidemiological studies reflect that persons on millet based diet suffer less from degenerative diseases such as heart diseases, diabetics, hypertension, etc. (Jaybhaye *et al*., 2014) [47]. Millets and millet based products are the safe food for the patients having celiac disease and gluten allergy due to its characteristic of not producing acids and anti-allergic properties (Saleh *et al*., 2013) [62]. The various healthy products were prepared blending millets including Kodo millet with other cereals like low glycaemic index biscuits (Srivastava and Singh, 2003), diabetic food formulations (Shobana *et al.* 2007) [67], roti, upma and idli with low glycaemic index (Thakkar and Kapoor, 2007) [75]. However, no such product is commercially produced and reported which is entirely based on millet.

Effect of processing on nutritional quality of Kodo millet

Kodo millets contain higher amounts of polyphenols, phosphorous, antioxidants, and phytic acids. These anti-nutrients make complexes of micronutrients like calcium and zinc, which reduce their solubility and bioavailability. Techniques like soaking, cooking and fermentation of millet-based foods reduce tannin and phytate levels, which enhance availability of amino acids and minerals and also improve digestibility of protein and starch. Chandrasekher *et al.* (1981) [17] studied millet varieties for preventive action against human salivary amylase and discovered no detectable activity in Kodo millet verities. The antioxidant activity of Kodo millets decreases when the whole grain is dehulled and cooked. Hegde and Chandra (2005) [38] show that Kodo millet has a higher free radical scavenging property as compared to other millets such as finger millet, small millet, foxtail millet, barnyard millet and large millet. It was also seen that the activity was also decreased by fractionation of husk and endosperm of Kodo millet. Chandrasekara *et al.* (2012) indicates that the antioxidant activity of whole *Kodo* decreased from 32.4 to 6.86 in dehulled one, while only 6.06

in dehulled boiled Kodo millet. Approximately 112 (µmol ferulic acid equ/g defatted meal) are also included in the bran. Annor *et al.* (2013) [5], study revealed that the anticipated glycemic index (AGI) of whole Kodo millet starch is lower than that of rice starch. Furthermore, the entire *Kodo*grain has decreased starch and AGI digestibility than the decorated grains (Yadav *et al*., 2013) [80].

Table 1: Nutritional composition of Kodo millet

Nutrient	Quantity (100gm)
Moisture	11.6 gm
Protein	10.6 gm
Fat	4.2 gm
Fiber	10.2 gm
Ash	2.95 gm
Calorific value	346 kcal
Carbohydrate	59.2 gm
Minerals	4.4 gm
Calcium	27 mg
Phosphorus	188 mg
Iron	0.5 mg
Riboflavin	0.09 mg
Niacin	2.0 mg

Conclusion

In conclusion, millets have historically been consumed as a cereal because of their nutritive and health-promoting qualities. Millets, such as Kodo millet, offer a lot of potential for usage as raw materials in industrial goods. Although millets have comparable health advantages and nutritional value to other popular cereals like rice, wheat, and maize, the limited technical advancements work to increase their acceptance among customers in terms of quality, nutrition, and functionality. The scientific investigations completed to date for processing improvements are included in the current review. To produce high-quality, reasonably priced products, it is required to switch processing and equipment from conventional to current ways. The food processing sector now has a number of options to produce high-quality millet-based goods that are more widely accepted by consumers thanks to the increased efficiency in post-harvesting and value addition capabilities. Therefore, there is a great opportunity to do in-depth research to find millet goods of higher quality that are also accessible for customers of all income levels, flavourful, and health-promoting.

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