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Comparison study of starch from Kodo millet and other millets.

Estudio comparativo del almidón del mijo Kodo y de otros mijos

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ABSTRACT

Background: Kodo millet or *Paspalum scrobiculatum* belongs to the family Poaceae.The cultivation of kodo millets started in India about 3000 years ago.The Food and Agriculture Organization (FAO) estimate millet output as 28,371,792 tonnes in India. Kodo millets are packed with the goodness of carbohydrates, proteins, and dietary fibres. Main body of the Abstract: The main component of millet grain is starch, the characteristics of millet starch include 0.38-28.40% amylose, 7.64-11.48% moisture, 0.39-1.60% ash, and 0.31-0.58% protein. Kodo and little millets are produced widely and consumed in various states of India, Madhya Pradesh has the largest area for small millet cultivation followed by Chhattisgarh. Conclusion: Kodo millet can help avoid diseases like insulin resistance, heart disease, diabetes, ischemic stroke, obesity, breast cancer, childhood asthma, and early mortality. The major constituent of the millet is its starch which contributes about 70% of total millet grain and decides the quality of millet-based food products. The application of starch for various purposes is dependent upon its physicochemical, structural, and functional properties. All this makes this a miracle millet.

Key Words: Kodo Millet, Starch, Food Grain, anti-diabetic, anticancer

RESUMEN

Antecedentes: el mijo kodo o pertenece a la familia Poaceae. El cultivo del mijo kodo comenzó en la India hace unos 3.000 años. La Organización para la Alimentación y la Agricultura (FAO) estima la producción de mijo en 28.371.792 toneladas en la India. El mijo Kodo está repleto de las bondades de los carbohidratos, las proteínas y las fibras dietéticas. Cuerpo principal del resumen: El componente principal del grano de mijo es el almidón, las características del almidón de mijo incluyen 0,38-28,40% de amilosa, 7,64-11,48% de humedad, 0,39-1,60% de ceniza y 0,31-0,58% de proteína. Kodo y mijo pequeño Se producen ampliamente y se consumen en varios estados de la India. Madhya Pradesh tiene la mayor superficie para el cultivo pequeño de mijo, seguida de Chhattisgarh. Conclusión: El mijo Kodo puede ayudar a evitar enfermedades como la resistencia a la insulina, enfermedades cardíacas, diabetes, accidente cerebrovascular isquémico, obesidad, cáncer de mama, asma infantil y mortalidad temprana. El componente principal del mijo es su almidón, que constituye aproximadamente el 70% del grano total de mijo y decide la calidad de los productos alimenticios a base de mijo. La aplicación del almidón para diversos fines depende de sus propiedades fisicoquímicas, estructurales y funcionales. Todo esto hace de este un mijo milagroso.

Palabras clave: mijo Kodo, almidón, cereales alimentarios, antidiabético, anticancerígeno.

BACKGROUND

Millets are one of the oldest food grains known to mankind and possibly the first cereal grain used for domestic purposes. Millets are the most important cereals of the semi-arid zones of the world. For centuries, millets have been the staple diet for nearly 1/3rd of the world's population. Millet crop primarily constitute a diverse group of small grains. Millets are classified into major millets and minor millets or small millets.

Kodo millets or magical millets are the must-have millets in your meals. Kodo millet or Paspalum scrobiculatum belongs to the family Poaceae, and is locally known as rice grass, ditch millet, cow grass in English, araka in Telugu and kodra in Marathi. Kodo millet grains are annual grains ranging from light red to dark grey. The cultivation of kodo millets started in India about 3000 years ago.[1]

In comparison to other cereals like maize, wheat, and rice, millets are underutilised crops with untapped potential. The FAO estimates that millet output reached 28,371,792 tonnes globally in 2019 whereas only 10,235,830 tonnes were produced in India. Due to the quantity of several of its components, such as starch, B vitamins, minerals, lysine, polysaccharides (antioxidants), and dietary fibres, it is a very valuable supplemental nutrition source for people [2].

Many scientists have conducted proximate analyses of millets and reported the amounts of crude protein (4.48 to 12.49 g/100 g), crude fat (1.2 to 7.2 g/100 g), ash (0.6 to 4.78 g/100 g), crude fibre (0.49 to 8.72 g/100 g), and carbohydrate (62.25 to 81.69 g/100 g), respectively. [3–6].

Millets' usefulness for particular applications is mostly determined by starch, which makes up the majority of fully ripened grains [7]. The most prevalent polysaccharide in nature, starch is cheap, a significant source of energy in foods for humans, and is widely used for both food and non-food applications [8].

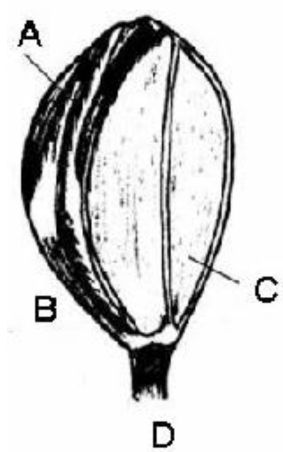
The main component of millet grain is starch, which is frequently used in a variety of culinary products, including breakfast cereals, bakery goods, and nutritional foods. The characteristics of millet starch include 0.38-28.40% amylose, 7.64-11.48% moisture, 0.39-1.60% ash, and 0.31-0.58% protein [9].

In addition to being high in calories, kodo millet is also high in fibre, carbohydrates, fats, minerals, and iron, with relative amounts of 9%, 66.6 g, 1.4%, 2.6%, 25.86-39.60 ppm, and 353 Kcal/100 g. Kodo contains less phosphorus than other millets[10]. Additionally, this millet possesses significant DPPH scavenging abilities. Kodo millet flour's gelatinization temperature range was discovered to be 76.6–90°C. This demonstrates that kodo millet is less gelatinization-resistant and can therefore be utilised in baking. Kodo grains are processed into flour in India and used to make puddings. Due to its lack of gluten, its use as a gluten-free ingredient is growing dail[11].

MAIN TEXT

Kodo Millet Inflorescence And its Parts.

Kodo millet infloresence.(fig 1)



Kodo millet parts : (A) Upper floret, (B) Second glum, (C) Lemma of lower floret, (D) Spikelet; (E) Floret.(fig 2)

Since ancient times, cereal grains have aided in the expansion of human races and are an essential component of billions of people's daily diets worldwide. However, due to climate change, crop failure brought on by variable weather producing flood and draught conditions, poorer productivity as a result of soil nutrient depletion, and chemical residues deteriorating soil health, production of the major cereal crops has been declining in recent years. The agricultural and food industries are under pressure as a result. Additionally, the global agricultural sector and food security are under threat from the growing global population, rising prices for food and other key commodities, and other socioeconomic effects. People who live in arid and sub-arid areas with few resources would be most affected[12].

To address hunger and poverty, scientists working in the fields of production, processing, storage, and nutrition face enormous challenges. Millets are regarded as ancient grains because they were domesticated at the dawn of human civilisation thousands of years ago[13].

The main source of sustenance for those who live in rural areas is millets, one of the most drought-resistant crops that is widely grown across Asia, Africa, and the Indian subcontinent. Because they contain a far higher concentration of antioxidants than the major cereal crops, these millets are employed as nutraceuticals. They are said to be helpful in preventing heart attacks, migraines, blood pressure, diabetic heart disease, and atherosclerosis. Millets' high fibre content prevents the development of gallstones. Consuming whole grains can help avoid diseases like insulin resistance, heart disease, diabetes, ischemic stroke, obesity, breast cancer, childhood asthma, and early mortality [14].

EPIDEMIOLOGY

Kodo and little millets are produced widely and consumed in various states of India. ,e production pattern and their consumption show that millets are gaining their importance and people are trying to follow healthy diet charts.

Madhya Pradesh has the largest area for small millet cultivation followed by Chhattisgarh, which covers 19.5% of land, Uttarakhand 8%, Maharashtra 7.8%, Gujarat 5.3%, and Tamil Nadu 3.9%. ,e productivity of millets is higher in Uttarakhand, which accounts to be 1174 kg/ha, followed by Tamil Nadu (1067 kg/ha) and then Gujarat (1056 kg/ha). ,e state of Karnataka has the most land and produces the most finger millet, followed by Tamil Nadu. Karnataka alone accounted for roughly 66% of overall production, whereas other states in India produce very little.

However, Tamil Nadu has the highest finger millet production (2464 kg/ha), followed by Karnataka (1782 kg/ha), both of which are higher than the national average yield (1580 kg/ha) [15].

Found that the average yield of kodo and little was 2.77 and 2.71 quintal per acre, respectively, as compared to 0.14 and 0.12 quintal per acre in the year 2018. A regular farmer used around 40% of the total produce of both crops. In the case of kodo and little, farmers preserved 5.42 and 3.69 percent of total yield for seed and 0.72 and 0.55percent for animal feed, respectively, and wastage of kodo and little millets was determined to be 1.81 and 3.95 percent of total production, respectively. According to the analysis, the marketable excess is greater than the marketed surplus.

Disposal pattern of kodo and little for marketed surplus was observed during 2015–16, with data showing that an average manufacturer sold 78.30% kodo and 72.14% little of marketed surplus in the peak periods from September 2015 to March 2016 with an average cost of Rs. 18.71 and Rs. 19.47 per kg, respectively. During the lean period, the remaining 21.70% kodo and 19.47% little were sold at average costs of Rs. 22.36 and Rs. 23.40 per kilo, respectively. ,e selling cost of kodo and little millet was determined to be Rs. 20.23 for kodo and Rs. 21.11 for little millet per kilogram, with prices ranging from Rs. 15 to Rs. 24 and Rs. 7 to Rs. 25 per kilogram. ,is suggested that the price and quantity of kodo and little millet sold in the market were inversely related [16].

ORIGIN AND DISTRIBUTION OF KODO MILLET.

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 [17].

The tropical and subtropical regions are best suited for its cultivation .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[18].

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 [19].

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 [20].

Nutritional Value of Kodo Millets: The goodness of carbohydrates, proteins, and dietary fibres are abundant in kodo millets. It includes minerals like calcium, iron, and phosphorus as well as vitamins like niacin and riboflavin. Antioxidants and phenolic compounds like vanillic acid, gallic acid, tannins, ferulic acid, etc. are among the phytochemicals present in kodo millets. The chart below lists the kodo millets' nutritional components:

Table 1: Nutritional value of kodo millets[21]

Sr No.	Nutritional components	value per 100g
1	Carbohydrate	59.2g
2	Protein	10.6 g
3	Fibre	10.2 g
4	Fats	4.2 g
5	Phosphorus	188 mg
6	Potassium	107.8 mg
7	Calcium	27.0 mg
8	Sodium	3.48 mg
9	Vitamin B3	2.0 mg
10	Zinc	1.58 mg

Effect of processing on nutritional quality of kodo millet: Kodo millets have increased concentrations of phytic acids, phosphorus, antioxidants, and polyphenols. Micronutrients like calcium and zinc become complexed by these anti-nutrients, which lowers their solubility and bioavailability. Techniques including soaking, boiling, and fermentation of millet-based diets lower tannin and phytate levels, which improve amino acid and mineral availability and protein and carbohydrate digestibility. [22]

In comparison to other millets including finger millet, tiny millet, foxtail millet, barnyard millet, and giant millet, kodo millet has a better capacity to scavenge free radicals. Additionally, it was observed that fractionating the husk and endosperm of kodo millet significantly reduced activity.[23]

Properties of Kodo Millets:

The following are a few of the numerous, experimentally verified benefits that kodo millets exhibit:

1. It may reduce blood glucose levels and possess antioxidant properties [21].
2. It could reduce arterial pressure[21].
3. It might possess anti-allergic qualities[21].
4. It might be able to stop cells from growing in an aberrant way[26].
5. It might be able to lower excessively elevated lipid levels[27].
6. It might possess antimicrobial qualities[26].

USES OF KODO MILLETS.

In Ayurveda, kodo millets are used to relieve joint pain. For women who experience irregular menstrual periods, kodo millets may be helpful. The high potassium concentration of kodo millets may help women's period cramps. But the exact mechanism underlying these benefits is still poorly understood. [27]

Because they are an excellent source of dietary fibre, kodo millets may help with bowel movements and the treatment of constipation. Kodo millets also assist in weight loss by enhancing satiety, which reduces overeating, because they are high in protein and fibre. Kodo millets contain large amounts of prebiotic fibres, which may improve gastrointestinal health[27].

Kodo millets contain large amounts of collagen, a protein that encourages skin elasticity and may help with wrinkle reduction[28].

Constituents of Kodo Millet: Kodo millet's potential effects on lipid profiles Increased amounts of triglycerides, total cholesterol, and low levels of high-density lipoprotein are referred to as hyperlipidemia. In order to evaluate the effects of kodo millets on hyperlipidemia in rats. Performed a study in 2013. According to the study's findings, kodo millets significantly increased high-density lipoprotein while lowering overall cholesterol, triglycerides, and low-density lipoprotein. This suggests that kodo millets may have a favourable effect on lipid composition. However, more clinical research is required to back up these assertions in human subjects. [28]

Kodo millets may prevent the development of bacteria that cause diarrhoea, uti, and other illnesses, such as S. aureus, Bacillus cereus, Leuconostoc mesenteroides, and Enterococcus faecalis. Kodo millets could thus aid in the treatment of bacterial illnesses. More research is required to substantiate these assertions, though. [29]

Health Benefit of Kodo Millet:

1. Antibacterial.

Kodo millets may be used to treat bacterial illnesses.Kodo millets have been shown in the literature to have the ability to treat bacterial infections.

2. Antidiabetic

A metabolic condition known as type-2 diabetes is characterised by an increase in blood glucose as a result of decreased insulin production or insulin resistance. According to a study done in 2022 by Han et al., kodo millets may be able to lower blood sugar levels. Polyphenols, which block the enzymes that break down carbohydrates into simpler sugars and raise blood sugar, are thought to be responsible for this impact. Kodo millets also have a low glucose index. Kodo millets may therefore be able to treat type 2 diabetes. These assertions are not, however, sufficiently supported by research. [28]

3. Anticancer

Kodo millets have been linked to a lower chance of cancer in literature studies. In 2010, Chandrasekara et al. published a study in which they suggested that kodo millets might possibly slow the development and spread of cancer. The phenolic acids, phytic acids, and tannins found in the grain are thought to be responsible for this anti-cancer impact. This suggests that kodo millets may lower the chance of developing specific cancers. To back up these assertions, we need more scientific data, though. [21]

4. Antianaemic.

Malnutrition is characterised by a lack, an excess, or an unbalanced consumption of nutrients and/or energy. Three major categories of conditions are covered by the word malnutrition:

1. Undernutrition

2. Micronutrient-related malnutrition

3. Overweight

Because they contain elements like calcium, iron, and phosphorus as well as carbohydrates, proteins, and dietary fibres, kodo millets are very nutrient-dense. Antioxidants and phenolic substances like vanillic acid, gallic acid, tannins, ferulic acid, etc. are also abundant in kodo millets. Kodo millets may aid in the management of malnutrition caused by a lack of certain micronutrients. [29]

5. Millets for cardiovascular disease

Obesity, smoking, unhealthy nutrition and physical inactivity boost the risk of heart attack and stroke. Most nations in the globe are facing elevated and rising cardiovascular disease rates. Millets have higher amount of free radical scavenging activity which decreases the risk of cardiovascular diseases [30]

STARCH CONTENT OF KODO MILLET

The two main molecules that make up starch are amylopectin and amylose. A structural component that serves as an intermediary step may be offered, depending on the type of fractionation. Amylopectin has a substantially higher number of branches than amylose, which is linear with many branches, -(1-6) linkage, scattered throughout the linear backbone, -(1-4) linkage. The manufacture, actual granular forms, functionality, and potential applications of starch components are all influenced by their molecular composition.[31]

Like other grains, millets contain between 51% and 79% starch. Pearl and finger millets have starch contents that vary from 71 to 81 percent and 51 to 69 percent, respectively. Most millet starches contain 20 to 30 percent amylose and 70 to 80 percent amylopectin. The performance of starch granules is significantly impacted by the presence of extra contaminants. For instance, the majority of the polar phospholipids in millet starch (89%) is made up of triglycerides, whereas the remaining lipids are nonpolar lipids. These lipids create complexes with the amylose component of starch because to their cohesive nature and Bhydrophobic interactions, which may reduce the flowability and swelling ability of starch. Hydrophobic and hydrophilic links are found in proteins, whereby how well they can attach to both water and oil.

The fibres are known to reduce oil intake, which may reduce their ability to bind oil. It is unknown how polyphenols affect millet starch's ability to operate. However, substantial research has been done on the impact of adding polyphenols from outside sources, such as vanillic acid, gallic acid, and quercetin, to starch and how they affect numerous physicochemical properties. For instance, the maximum viscosity of wheat starch rises when pomegranate peel extract is added. Additionally, it was discovered that black tea extract was more effective than green tea extract at reducing the viscosity of wheat, rice, maize, and potato starch in cold paste.[32]

PROPERTIES OF MILLET STARCH

1.Swelling, solubility and water absorption capacity.

2.Pasting behaviour.

3.Thermal properties.

1.Swelling, solubility and water absorption capacity:

In the presence of heat and water, granules of starch enlarge by absorbing water. Millet starch exhibit swelling power in 50 to 90C temperature range. Millet starches were shown to have a lower swelling power than rye, wheat and potato starch.[33] This concludes that millet starches are more resistant to swelling because of their comparatively high bonding force between granules. The starch granules having short amylopectin chains may readily bind water molecules by hydrogen bonds; but amylose and its lipid complexes and long amylopectin chain create helical boundaries and it hinders the entrance of molecules of water.[34] As a result, low amylose starches may readily find food application where there is a necessity of viscosity, like thickening agent present in soup. Furthermore, the existence of amylose is advantageous in goods that need retrogradation.

The water absorption index of starch-based flour while heating may also be associated to swelling capacity. The porous structure of starch polymers is associated to its highwater absorption capacity, while low values show the structure’s compactness.[35]

2.Pasting behaviour:

Many factors influence the pasting behaviour of starch and its characteristics, including starch composition, concentration, cooling and cooking temperatures, as well as the presence of solutes such as sugar, lipid and pH. Waxy starches may readily bind with water and swell quickly, achieving their peak pasting temperatures in relatively short period of time (2008). Both barnyard and Kodo millet starch had higher SBV (setback viscosity) than proso millets. [36]

3.Thermal properties:

The properties of starch gelatinization differ not only across millet species, but also between genotypes within the same species. They are affected by amylose-amylopectin ratio and size of starch granules.[37]

Isolation of starch from millets

A range of physical, chemical, and enzymatic techniques, including filtering, gravity sedimentation, and centrifugation, can be used to extract starch.[38] Depending on the source and variation, each starch has unique structural and physiochemical characteristics. Granules of starch are closely related to the protein structure of grains. To extract starch from grains, a variety of solubilization procedures are used to solubilize the protein component.[39]

Starch from millets has been mostly isolated using wet-milling based methods. In brief, whole millet kernels (or flour) are steeped in aqueous solution for several hours to facilitate the separation of starch from other components before the kernels are milled. Then the slurry is repeatedly washed with water and sifted to remove protein and fibrous components. The separated starch is recovered by centrifugation before drying [40].

Table 2. Starch yield and chemical composition.[41,42]

Sr No.	Millet Starch	Starch Yield(%)
1	Proso	93.7
2	Pearl	70.4
3	Finger	63.4
4	Kodo	94.18

No., number of genotype analyzed in specific study.

a Different calculation methods.

b Two methods for amylose content determination.

c Two methods for starch extraction.

Applications of Millet Starch: In the food and non-food industries, millet starch is utilised either in its natural form or in modified forms. However, it has limited functioning in its natural state, which limits its industrial applications. Native and modified starches are typically used as a binder, thickeners in baked goods, meat products, snack seasonings, as a fat replacement in ice creams, flavour encapsulating agents, emulsion stabilisers in juices and beverages, gelling agents in gums and gels, foam stabiliser in marshmallows, and as a crisping agent for fried snack items. For the tablet formulation as a medication delivery strategy, pre-gelatinized, acetylated, acid modified, esterified, and native starches are frequently utilised.[43]

Starch Content of Cereals and Millets Germinated for 48h And 96h: A 48-hour germination period caused a 5% loss in starch content, and a 96-hour germination period caused a 10% loss in starch content for the samples.

Table 3. Starch contant of cereals and millets germinated for 48h and 96h: [44]

Sr No.	Millets	Ungerminated control seeds starch	48 h germinated samples starch	96 h germinated samples starch
1	Rice	77	74	70
2	Wheat	71	67	59
3	Maize	66	63	59
4	Sorghum	68	64	58
5	Triticale	70	65	57
6	Finger millet	65	9	53
7	Pearl millet	69	61	57
8	Proso millet	60	57	53
9	Foxtail millet	60	56	52
10	Barnyard millet	57	56	52
11	Kodo millet	54	52	50

Morphology of Millet Starch Granules: Species differences in millet starch granule size can be seen. Although most millet starch granules are polygonal and spherical in form. A handful of them had spherical granule shapes, while the majority had polygonal shapes. [46].

Table 4

Characteristics of various natural and modified starches in terms of morphology.

Sr No.	Millets	Shape Of Starch Granule	Size
1	Proso	Small Spherical	1.3-8.0
2	Foxtail	Small Spherical	0.8-9.6
3	Kodo	Large Polygonal	1.2-9.5
4	Little	Small Spherical	1.0-9.0
5	Kodo(24hr gremination)	Large Polygonal with pores	0.8-9.0

Kodo millet starch granules were mostly polygonal. Occasionally, little spherical and polygonal particles were seen. The protein-induced indentations were present in the large granules. The fraction of small granules was rather low in comparison to other millet starch granules. The size of the granules ranged from 1.2 to 9.5.

Table 5. Morphological Properties of Kodo Millet

Sr.No.	Parameter Dimensions	Mean value±SD
1	Length (mm)	2.61±0.01
2	Width (mm)	1.94±0.01
3	Thickness (mm)	1.31±0.01
4	Thousand kernel weight (g)	2.73±0.20
5	Geometric mean diameter (mm)	1.87
6	Sphericity	0.71
7	Frontal area (mm)	3.97
8	Surface area (mm2)	10.98

Parameter dimension with mean value of morphology properties of kodo millet.[47]

Starch Digestibility of Kodo Millet: The degree to which starch can be digested is regarded as a key nutritional indicator that determines whether or not customers would accept a product. In the marketing of novel food products, the degree and rate of starch digestibility are both very important factors. Rising consumer demand for wholesome food items has sparked the creation of novel processes, tools, and components including resistant starch. Important health advantages of RS include preventing fat buildup, lowering blood glucose and cholesterol levels, inhibiting colon cancer, and reducing gallbladder stone development [48].

For instance, compared to rice, the starch from barnyard millet demonstrated reduced levels of serum cholesterol, triglycerides, and blood sugar. The amylose content of millet has a significant impact on the RS content of starch, which differs between millet species [49]. Amylose-rich starches are ideal for the production of RS [50]. Compared to pearl millet (1.4–2.2%), Kodo millet starch (37.52%) has the greatest RS level. The RS, SDS, and RDS values of a few native and modified millet starches are shown in Tables 5 and 6, respectively. The presence of other components, the kind of millet species, and the treatment or modification applied to the starch all have an impact on how well millets can digest their starch. For instance, the presence of other components (such lipids and proteins) decreases the accessibility of enzymes to starch molecules, slowing down the rate at which starch may be digested [51].

When compared to other millet starches, pearl millet flour was said to have the highest resistant starch [52]. This suggests that the digestibility of starch may be influenced by other food ingredients. The total starch digestibility and GI of finger millet flour were low [53].

Table 6 In vitro digestibility of native starches.

Sr.No.	Millet Starch	RS(%)	SDS(%)
1	Kodo Millet	37	33
2	Foxtail	18	11
3	Pearl	12	37

RS, resistant starch

SDS, slowly digestible starch

Compared to pearl millet (1.4–2.2%), Kodo millet starch (37.52%) has the greatest RS level.[54] [55] [56]

After removing lipids and proteins, millets' in vitro starch digestibility and GI considerably rise. The way the millet is processed also affects how sensitive an enzyme is to its carbohydrates. While some techniques reduced the RS, others improved it. Various processing techniques, such as fermentation by endogenous microflora [57], popping [58], germination and fermentation by yeast [59], malting and blanching [60], frying, toasting, puffing, baking and germination [61], and removal of other constituents like lipid and protein components, increased the enzyme susceptibility or decreased the RS content of starches.

Effect of protein on the hydrolysis of kodo millet starch: The protein components, such as globulins, albumins, and glutenins, form a matrix around the millet starch granules and function as a barrier to the starch hydrolysis enzymes (amylases), inhibiting their activity [6,122]. After the Kodo millet's proteins were removed, the glycemic response grew [62]. The extent and rate of enzymatic starch hydrolysis are often decreased by the presence of protein in the granules.

The rate and amount of the starch hydrolysis in the foxtail millet flour enhanced when the protein was removed using the pepsin enzyme. 50.4% of the starch in the pepsin-treated flour was hydrolyzed, compared to 42.5% in the untreated/undigested millet flour [63]. This suggests that amylase can access or hydrolyze starch more easily when the starch-protein matrix is degraded or removed.

Effect of lipids on millet starch hydrolysis: Lipids slow down the rate of enzymatic starch hydrolysis by building complexes with free fatty acids such amylose lipid complexes (ALC), which slow down the rate of starch hydrolysis [64] and digestion. Kodo millet has a lower GI (49.4) than both rice (75.0) and wheat (58.3) [65]. Rapid hydrolysis of the amorphous area precedes sluggish degradation of the amylose inclusion complex in the process of amylose and lipid complex degradation. About 85% of the overall fatty acid content of millets is made up of the three major fatty acids palmitic, oleic, and linoleic [66].

The rate of enzymatic hydrolysis of starch was shown to be greatly reduced when starch was complexed with lauric and oleic fatty acids, but not significantly lowered when starch and linoleic fatty acids were combined. The instability of the linoleic-starch complex may be to blame for this [67]. Differently unsaturated lipids exhibit varying influences on the rates of starch hydrolysis and their complexes. In comparison to short-chain emulsifiers, long-chain emulsifiers were observed to decrease the starch digestibility.[68]

Starch Modification of Kodo Millet: By manipulating the hydrogen bond in a predictable way, starch modification is the process of changing the structure of the starch molecule. The physical process of heat moisture treatment (HMT) is one of numerous ways to change starch. Hydrothermal modification techniques, such as HMT, have been often investigated to change the physicochemical, digestibility, and functional characteristics of starch with the least possible impact on the granule structure [69].

Acid modification of starch is performed by treating starch below its gel point in an aqueous acid suspension. This results in granular modifications of the native starch. Starch suspensions are subjected to a variety of enzymes during an enzymatic modification, including hydrolyzing enzymes that frequently result in highly functional derivatives. The current study's objectives are to physically alter millet starch and examine the behaviour of both the native and modified starches.[70]

Physical modification for the preparation of modified starch: Kodo millet, small millet, pearl millet, and proso millet were prepared using the usual procedure for the synthesis of modified starch (autoclaving - chilling cycle method) with a minor modification. Kodo millet and pearl millet grains were cleaned, washed separately, and soaked for two hours before being ground and pressurecooked for one hour in an autoclave at 121° C (15 lb/in2). The gelatinized starch mixture underwent one cycle of freezing at 4°C for 24 hours after being brought to room temperature. Following the completion of three more cycles, the product was cabinet-dried for approximately four to six hours at 40°C, according to the starches used, and was then crushed into fine particles and sealed in an airtight container.[71]

RESULT AND DISCUSSION

A 48-hour germination period caused a 5% loss in starch content, while a 96-hour germination period caused a 10% loss in starch content for the samples. The amount of free sugars in the malt samples also increased in lock step. The largest quantities of a-amylase produced during germination were found in the malt samples of triticale, wheat, finger millet, and pearl millet, which also had the highest starch loss and free sugar content. All samples' protein contents slightly decreased after germination for 48 hours.

The protein level of the other 48 and 96 h malts was roughly the same, however the 96 h malt made from finger millet and pearl millet contained considerably less protein than the control. The protein content of devegetated malt may remain the same per se despite the fact that only a little portion of seed nitrogenous matter migrates from seed to growing embryo because of the reduction in seed carbohydrate content.[45]

Kodo millet grain measures 2.61 mm in length, 1.94 mm in breadth, and 1.31 mm in thickness, respectively. The variations in values of size could be brought on by moisture content and diversity. The type of fan and sieve needed to separate the grains from unwanted components can be determined using the millet grains' thousand kernel weights. Kodo millet grains had an average geometric diameter of 1.87 mm.

CONCLUSION

According to the study, kodo millet grains had a good nutritional value due to their high mineral content and moderate protein level. In compared to other millets like finger, pearl, and foxtail, kodo starch showed a higher range of gelatinization temperature.The yield of high-quality starch might, however, still be improved utilising various different techniques.Millets contain a significant amount of starch, but unlike other common sources, it is not used as a raw material for the synthesis of starch.

Kodo millet are a good source of dietary fiber and therefore can be utilized for the utilization for the formulation of prebiotics drinks, which helps in digestion. Not only the acceptability of these millets is scarce, but also the food industry does not utilize these to develop functional foods. Also, antinutrients elimination with less time-consuming process can be explored for their utilization in food sectors. There is a need to optimize the methods for extraction, quantification, and purification of bioactive compounds from kodo. Toxicity, allergen, and microbial studies will be examined for kodo before utilization to develop functional foods. These are the future research area on which studies can be conducted to make available to food sectors to develop functional foods and nutraceuticals.

Millet starches primarily serve as a structural agent, texture modifier, binder, and viscosity regulator, much like other starches.However, their utility is limited because they cannot be produced in huge quantities and are only grown in a small number of places around the world. The smaller size of millet grains, as well as the difficulties in processing and handling them compared to other traditional starch sources, are some of the key issues limiting their widespread use.

Granules of all sizes and shapes can be found in millet starches; spherical and polygonal granules of various sizes were found. Because of the variations in their testing procedures and settings, it can be difficult to directly compare data on specific millet starch qualities .

A 48-hour germination period caused a 5% loss in starch content, while a 96-hour germination period caused a 10% loss in starch content for the samples. A weakness in this field is the molecular characterization of kodo starch and the relationships between its fractions. Additionally, researchers need to pay attention to how this starch interacts with other food ingredients.

The functional properties and phytochemical components of native and modified millet were studied. Results obtained in this study indicated that the millets are a good source of soluble, insoluble and total fibre content. Phenolic compounds and antioxidant activity was high in almost all millets.

List of Abbreviations

HMT- heat moisture treatment

ALC- amylose lipid complexes

RS- Resistant Starch

SDS- Slowly Digestible Starch

GI- Glycemic Index

Food and Agriculture Organization (FAO)

SD- Standard Deviation

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