

# An Overview of Sorghum (*Sorghum bicolor*) and their Health Benefits

Hardeep Kaur

Department of Food Technology, School of Applied and Life Sciences (SALS) Uttarakhand University Prem Nagar Dehradun

**Abstract:** Sorghum (*Sorghum bicolor*) belongs to the family Poaceae and it is king of millet cereals. Sorghum is one of the important coarse-grained and traditional staple food crops in dry lands of tropical Africa, India and China. In India it is cultivated widely across Maharashtra, Madhya Pradesh, Karnataka, Tamil Nadu, Andhra Pradesh, Telangana, Uttar Pradesh, Haryana and in Rajasthan. Sorghum is called as the powerhouse of the nutrition, it is an important source of minerals that is located in the pericarp, aleurone and germ. Sorghum is mainly cultivated in kharif and rabi seasons but sorghum which is harvested in post-rainy season is of superior quality and only used for the food. Sorghum contains about 10.4% protein. Fat content in sorghum is about 1.9% and total dietary fiber is around 8.3%. It is highly rich in antioxidants, protein, fibre, thiamine, riboflavin, folic acid, calcium, phosphorus, iron and  $\beta$ -carotene which help to support the cardiac health, boost the immunity, improve heart and control blood sugar level and helps to control body weight and arthritis.

**Keywords:** Sorghum (*Sorghum bicolor*), therapeutic properties, phenolic compounds, health benefits

## 1. Introduction

Sorghum cereal is supposed to be an important coarse-grained food crop. It is the most drought-tolerant cereal grain crops and it needs little input during growth, as with other crops. Sorghum is known as the *Sorghum bicolor* is the ancient cereal grain belongs to the family Poaceae and also known as a great millet, durra, jowar, jola, cholam, Jonna, juar, jwari, milo. (Ratnavathi and Patil., 2013).



## Sorghum Grain

In India, sorghum are essential crop and associated crops distinctly in the desert areas of Rajasthan, in the eastern region of Rajasthan and Gujarat it is the reverse. Sorghum becomes over a wide scope of latitudes from 0 to 45° North and South of the equator. Likewise, sorghum is planted as significant crop in the Telangana, Andhra Pradesh, Maharashtra and parts of central India, while it is considered as feed crop in a few of the Southern districts. (Rao et al., 2017).

Sorghum is mainly cultivated in kharif and rabi seasons, sorghum leads in those areas receiving annual rainfall capacity of 400 mm, but sorghum which is harvested in post-rainy season is of superior quality and only used for the food. At present a large portion of the sorghum delivered in India is devoured in the type of roti or chapatti (unleavened level bread). Kharif sorghum grain can be cleaned with pearling machine and utilized for other food items like nibble nourishments and heated nourishments. (Ratnavathi and Patil., 2013)

**Table:** Actual harvested area, production and yield of sorghum in India.

Year	Harvesting Area	Growth rate%	Production/1000 MT	Growth rate%	Distribution/1000 MT	Growth rate%
2010	7382	- 5.20%	7003	4.55%	7188	3.99%
2011	6245	- 15.4%	5979	- 14.6%	6340	- 11.8%
2012	6214	- 0.50%	5281	- 11.6%	5487	- 13.4%
2013	5793	- 6.78%	5542	4.94%	5651	2.99%
2014	6161	6.35%	5445	- 1.75%	5809	2.80%
2015	6077	- 1.36%	4238	- 22.1%	4825	- 16.9%
2016	5624	- 7.45%	4568	7.79%	4719	- 2.20%
2017	5024	- 10.6%	4803	5.14%	4999	5.93%
2018	4041	- 20.1%	3760	- 21.7%	4034	- 19.3%
2019	5000	24.5%	4500	19.6%	4683	16.0%

Source: Govt. and Agriculture ministry of India and USDA, 2019.

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The table highlights that there is decrease in the harvested area in year 2010, 2011, 2012, 2013, 2015, 2016, 2017 and 2018, in year 2014 and 2019 there is increase in the area of harvesting. The production is decreased in the year 2011, 2012, 2014, 2015 and 2018, in year 2010, 2013, 2016, 2017 and 2019 there is rise in the production. The distribution is decrease in the year 2011, 2012, 2015, 2016 and 2018 and in year 2010, 2013, 2014, 2017 and 2019 there is rise in the distribution.

The grain comprises of an exposed caryopsis, comprised of a pericarp, endosperm and germ. Despite the fact that there is an enormous scope of physical assorted variety, sorghums are classed into one of four gatherings – (a) grain sorghum; (b) rummage sorghum; (c) grass sorghum; or (d) Sudan sorghums and broomcorn. Sorghums are assembled utilizing the accompanying attributes:

- The coloration of the pericarp (white, yellow or red)
- Nonappearance of pigmented testa (with/without tannins)
- Endosperm shading (white, heteroyellow or yellow)
- Thickness of pericarp
- Type of endosperm (typical, heterowaxy or waxy) (Macrae *et al.*, 1993)

Sorghum is called as the powerhouse of the nutrition. Sorghum is rich in protein, iron and dietary fiber. It is highly rich in antioxidants which help to support the cardiac health, boost the immunity, improve heart and control blood sugar level. (Samuel Ayofemi., 2016). Nutritional composition of sorghum in per 100gm is; 10.0% protein, 1.7% fat, 67.7% carbohydrates, 1.4% minerals, 3.95% iron. Total dietary fiber content in sorghum is 10.2% including 8.5% insoluble dietary content and 1.7% soluble dietary content. (IFCT., 2017 and nutritive value of Indian foods., 2009)

**Table:** Nutrition composition of sorghum per 100g

Compositions	Values
Moisture	11.9%
Ash	1.60%
Protein	10.40%
Fat	1.90%
Crude fiber	3.2%
Total minerals	1.5%
Carbohydrate	72.60%
Total dietary fiber	10.3%
Insoluble dietary fiber	8.4%
Soluble dietary fiber	1.8%
Phosphorus	275mg
Iron	4.10mg
Magnesium	1.35mg
Calcium	25.00mg
Zinc	1.60mg
Riboflavin	0.13mg
Energy	349 k cal

Source: IFCT 2017, Nutritive value of Indian Foods, 2009 and Data generated under NAIP subproject on Creation of demand for sorghum foods through PCS value chain, 2008 - 2012.

The proximate composition and nutritional composition of sorghum grain have been substantially reviewed. Sorghum grain is understood for its hardness in comparison to other food grain. The hardness of the grain is because of higher content of protein prolamine. (Husle *et al.*, 1980). Sorghum

can be milled to supply starch or grits (semolina) from which many ethnic and traditional dishes may be made. The most not usual products are leavened and unleavened breads, porridges, biscuits, boiled grains and steamed cooked products together with couscous. (Vannalli *et al.*, 2008).

In spite of the fact that sorghum is known for its nourishing quality, the utilization of this grain is diminishing because of simple accessibility of rice and wheat through open dispersion system and simple strategies for preparing and cooking of fine grains, (for example, rice). The special skills are required for preparing the sorghum rotis and non - accessibility of readymade sorghum flour and semolina in the market are obstructions for more extensive use of sorghum as food. Other hand, the sorghum that is harvested in the post - rainy season is of predominant quality and utilized distinctly for food. At present a large portion of the sorghum delivered in India is devoured in the type of *roti* or chapatti (unleavened level bread). Kharif sorghum grain can be cleaned with pearling machine and utilized for other food items like nibble nourishments and heated nourishments. Sorghum is utilized in preparation of many conventional meals and in bakery arrangements like bread, disserts and biscuits. Dough prepared with cold water has terrible adhesiveness and is tough to roll thin. Technologies for manufacturing of shelf - strong refined flour, semolina and grits from sorghum have been developed and laboratory studies have tested a hit utilization and incorporation into diverse conventional meals and more recent convenience health products. (Ratnavathi and Patil., 2013)

Sorghum is enriched in potassium, phosphorus and calcium with adequate measures of iron, zinc and sodium. Because of this, it is being focused as a way to decrease malnutritionall over the world. It assists with controlling heart issues, obesity and joint pain. Including sorghum routinely in the diet of pregnant ladies booststhe dietary mineral and nutrient necessities in them. Sorghum also helps to controlling the heart issues, body weight and joint pain. (Hariprasanna *et al.*, 2018).

**THERAPEUTIC NUTRITION:** Nutritional composition of sorghum differs from variety to variety. Mainly carbohydrate, proteins and lipids are the fundamental constituent of the grain (Hill *et al.*, 2012). Besides, most sorghum varieties are wealthy in phenolic compounds, particularly 3 - deoxyanthocyanidins and tannins. The outcome attained in vitro and in animals have indicated that phenolics content and fat - soluble content (polycosanols) isolated from sorghum advantage the gut microbiota and parameters associated with overweightness, oxidative pressure, irritation, diabetes, dyslipidemia, hypertension and cancer. (Cardoso *et al.*, 2017).

- **Protein:** Protein substance and composition of sorghum changes from cultivar to cultivar due to the genotype and agronomic conditions such as water accessibility, soil fruitfulness, temperatures and ecological conditions during grain development. Sorghum proteins are predominantly sited in the endosperm (80%), germ (16%) and pericarp (3%) of the grain (Taylor and Schussler, 1986). The protein present in sorghum can be broadly categorized into

prolamin protein or kafirins and non-prolamin proteins glutelins. Kafirins are the chief kind of protein storage in sorghum grain and 70% of the total protein in sorghum entire grain is recorded, while the rest of the are inglutelins. The four types of kafirins are founded on molecular weight which are  $\alpha$  - ,  $\beta$  - ,  $\gamma$  - and  $\delta$  - kafirins, these proteins are located in endosperm while glutelins are located in germ of the grain. (Belton *et al.*, 2006). The protein present in sorghum have low digestibility. The low digestibility of protein makes the sorghum a capable food source for people suffer from diabetes and obesity. (Da Silva *et al.*, 2011)

- **Carbohydrates:** The carbohydrate content in sorghum is made out of starch, fiber and soluble sugar. The carbohydrates present in sorghum are grouped into non - structural such as sugars, starch and fructosans and structural are such as cellulose, hemicelluloses and gelatin substances. Starch present in sorghum is the dominant carbohydrate and is stored in the form of granules in the endosperm. Sorghum contains (SDS) slow digestible starch in great sums, which has utilitarian property, extend digestion and ingestion of carbohydrate in digestive tract. This slow digestible starch is good for dietary administration and likewise for metabolic issues, for example, diabetes and hyperlipidemia (Wursch., 1997). Sorghum is enriched of fiber as the non - starch carbohydrate content present in sorghum which is primarily composed of 70 - 90% insoluble fiber and 10 - 25% soluble fiber, present in the pericarp and cell walls of endosperm (Martino *et al.*, 2012). Sorghum contain great measure of dietary fiber that is 9.7 - 14.3g and also plays the important role of binding agent of cholesterol, rise the transit time and retards absorption of carbohydrates (Narasinga Rao, 2003).

- **Lipids:** Lipid substance of Sorghum grain is minor and situated in the scutellar zone of the germ. The lipid in sorghum grain is established of primarily unsaturated fatty acids, with the polyunsaturated fatty acids being the maximum rich. The essential unsaturated fatty acids in sorghum are oleic, linoleic, palmitic, linolenic and stearic acids; the lipid profile is like that of maize however is more unsaturated (USDA., 2019). Sorghum lipid has potential to bring down the cholesterol. Further research finding that sorghum grain contains components that could be utilized as food elements or dietary supplements to control cholesterol levels in people (Carr *et al.*, 2005).

- **Vitamins and Minerals:** Sorghum is a good source of nutrients and minerals. It is generally situated in aleurone layer and germ of the sorghum grain. The vitamin B complex (pyridoxine, riboflavin and thiamin) and some fat - dissolvable vitamins (vitamins A, D, E and K) are the major vitamins in sorghum. (Martino *et al.*, 2012). Sorghum is poor in vitamin C, but it can be synthesized by the process of soaking and germination. The detectable measures of other different vitamins E, K and D are found to be available in sorghum. Sorghum grain is also a good source of potassium and other minerals such as Mg, Fe, Zn and Cu but poor in calcium and sodium. (Gazzaz *et al.*, 1989).

- **Phenolic acid:** Phenolic acids are the simple but also abundant phenolic compounds that are found in all sorghum grain, with an aggregate amount of 445 to 2, 850  $\mu\text{g}$  per gram (Girard and Awika, 2018). The primary phenolic

acids present in sorghum grain are gallic, vanillic, cinnamic, p - coumaric, protocatechuic, syringic, ferulic, caffeic, p - hydroxybenzoic, and sinapic acids (Vanamala *et al.*, 2018). The phenolic acids are existing in the endosperm, testa and pericarp of the sorghum grain, and exist in both free and bound structures. The free phenolic acids, which are extractable by natural solvents, are not bound to the cell wall and generally present in the pericarp and testa. Nonetheless, the bound phenolic acids are joined to the cell wall (lignin) by means of covalent bonds and as well part of the cell wall structure, and the extraction requires acidic or soluble conditions, high temperature to break the covalent bonds (Wu *et al.*, 2017). The mostly the phenolic acids about 70 - 95% in sorghum are in the bound structure, among them, ferulic acid (100 - 500  $\mu\text{g}$  per g in the grain) is the most plentiful one and can represent up to 90% of the over - all bound phenolic acids. Because of the bound phenolic acids are a part of the cell wall segments, the concentration of bound phenolic acids is directly connected to the hardness of grain, with the higher concentration being related with harder grain (Chiremba *et al.*, 2012).

- **Flavonoids:** Flavonoids are mostly found in the sorghum grain. The types and concentration of the flavonoids are related with the pericarp color, thickness and presences of the pigmented testa (Awika *et al.*, 2005). A wide range of flavonoids have been found in sorghum including the flavones, flavanones, anthocyanins (3 - deoxyanthocyanidins), flavan - 3 - ols, flavan - 4 - ols, dihydroflavonols and flavonols (Awika., 2017). Among the flavonoids, 3 - deoxyanthocyanidins, flavones, flavanones and 3 - deoxyanthocyanidins, are the prevailing mixes in sorghum.

**Flavones:** The flavone content in the grain of sorghum is around 20 - 390  $\mu\text{g}$  per gram, generally low compared with other flavonoids (Girard and Awika., 2018). A few flavonoids exist organically in the form of as glycosides, for example, luteolin, yet others like apigenin exist essentially as aglycone structures (Yanget *et al.*, 2015). Usually, both luteolin and apigenin are the dominant flavones present in sorghum. Sorghum flavones are more plentiful than other different cereals with higher bioavailability. The varieties of sorghum with red and yellow pericarp are accounted high levels of flavones (Dykes *et al.*, 2011).

**Flavanones:** They are the major intermediates in the biosynthesis of flavonoids, yet their existence in cereal grains is commonly rare. Sorghum and their some varieties seem to be exceptional case have been accounted for the most significant levels of flavanones among food plants (Awika., 2017). The flavanone content in sorghum ranges from 0 - 2, 000  $\mu\text{g}$  per g. The minimal level is accounted in white sorghum, and the maximal level is found in sorghum with a yellow pericarp (Bhagwat *et al.*, 2014). The naringenin and eriodictyol glycosides are the primary flavanones in sorghum. Like the flavones, the glycosides of flavanones are mainly the O - glycosides, which are delicate to low pH, simply hydrolysable and have high bioavailability (Yang *et al.*, 2015).

**3 - Deoxyanthocyanidins:** The exceptional element of sorghum flavonoids is its anthocyanin content. The

anthocyanins found in sorghum are only the C - 3 - deoxylated analogs that is, 3 - deoxyanthocyanidins which are an intermittent subclass of anthocyanins (Xiong *et al.*, 2019). The major 3 - deoxyanthocyanidins in sorghum are apigeninidin and luteolinidin aglycones. 3 - Deoxyanthocyanidins are one of the larger flavonoids in sorghum, with a total amount of 200 - 4, 500 µg per g, in certain sorghums, the 3 - deoxyanthocyanidin content can represent up to 80% of the absolute flavonoids in the grain (Girard and Awika, 2018). Deoxyanthocyanidins are concentrated in the bran layer in the sorghum grain which is up to 4 - 5 times higher than in the entire grain. 3 - deoxyanthocyanidins are effective antioxidants with antimicrobial movement and several other advantages. Sorghum is considered as the major dietary source for 3 - deoxyanthocyanidins for people, which turn to good use as commercial natural dyes, pigments or colorants for food (Xiong *et al.*, 2019).

- **Condensed tannins:** Tannins have been one of the most researched polyphenols in sorghum. sorghum tannins (proanthocyanidins) are in the dense structure with high molecular weight and great degree of polymerization, which are usually found among most of cereals (Wu *et al.*, 2012). The tannin content in sorghums varies from variety to variety. On the basis of tannin concentration, genotype and extractability, sorghums are characterized into three kinds. Type I sorghums have recessive B1 & B2 gene and have no pigmented testa, and have extremely low level of tannins. In type II sorghum have predominant B1 & B2 yet homozygous recessive S gene and have pigmented testa with modest levels of tannins, the tannins are found in the vesicles inside the testa. The type III sorghums have pigmented testa, all B1, B2 and S genes are being predominant with high levels of tannins; the tannins are located in the testa cell wall and also in pericarp (Dykes and Rooney, 2006). Overall, sorghums with pigmented testa have significant levels of condensed tannin substance, and type III sorghums are among the most elevated with the concentration of 10 times higher than other tannin - containing cereals (Girard and Awika, 2018). Sorghums with high tannin content have agronomical benefits of shielding the plant against birds and pathogens (Kil *et al.*, 2009).

**Health Benefits:** Sorghum has certain properties which makes it suitable for the patients suffered from chronic disorders, celiac disease, diabetes, obesity, celiac disease, oxidative stress and cancer.

- **Celiac diseases:** In other words, celiac disease is also known as celiac sprue, nontropical sprue, and gluten - delicate enteropathy. The specific reason of celiac ailment isn't clear, yet it known to have a hereditary (inherited) segment. Celiac illness is an autoimmune system illness, where the immune system attacking the ordinary tissue, especially the inward lining tissue of the small intestine, because of eating gluten, the wheat protein. The particular response that prompts irritation is called prolamins. They are found in specific grains; such as gliadin in wheat, secalin in rye, horedin in grain, and avenin in oats (Pontieri *et al.*, 2013). According to Ciacciet *et al.*, 2007 Sorghum can be a solid diet for the individuals who are suffered from celiac illness as it is gluten - free because of gliadin-like peptides. Sorghum

items could not adjust the level of anti - transglutaminase antibodies later prolonged consumption.

- **Obesity:** Obesity has arrived at worldwide pandemic extents with additional than one billion grown - ups influenced by this incessant issue. Obesity is also a rising issue in India and it is positively connected with a numerous chronic illness including Coronary artery disease, stroke, insulin obstruction, type 2 diabetes, hypertension, and metabolic condition are well known clinical co - morbidities related with overabundance body weight. Experimental confirmations recommend that admission of high dietary fiber diminishes the occurrence of heftiness (Alfieri *et al.*, 1995). Sorghum is a high source of dietary fiber, has novel substance and physical qualities like viscosity, water holding and absorption limit which establish the successive physiological conduct. It helps to the appetite fulfillment, builds satiety and subsequently decreasing the threat of obesity. (Shils *et al.*, 2006).
- **Diabetes:** Diabetes is a complex metabolic illness a significant health worry in numerous countries. The occurrence of diabetes type 2 is increasing all over the world at a disturbing rate, particularly in India where the occurrence of diabetes has arrived at 14.3%. Anticipation of type 2 diabetes will expect measures to advance health dietary form and way of life which incorporates balance diet and physical action. Individuals who eat at least three servings of entire grains in a day, particularly from high - fiber oats, are more averse to create insulin obstruction and the metabolic condition (Mckeown *et al.*, 2004). According to Montonen *et al.*, 2003 Sorghum is enriched in dietary fiber and has low glycemic index, which could help in counteraction and control of type 2 diabetes among Indians. The fiber, magnesium, vitamin E, phenolic compounds and tannins present in food decreases the risk of diabetes as they slower the abrupt rise of blood glucose and insulin levels
- **Cardiovascular disease:** Cardiovascular illness generally indicates to conditions that include narrowed or blocked veins that can lead to a cardiovascular failure, chest pain or stroke. Other heart conditions, for example, those that influence the heart's muscle, valves and rhythm, also viewed as types of heart problems. Overall world statistics have measured the increase of chronic diseases in developed countries. Of these, cardiovascular diseases (CVD) remains the most persistent. Sorghum reduce the risk of Coronary Heart Disease. In the year of 2004, Harvard University professionals examined the eating routine records of 27, 000 men lies between the age of 40 - 75 years for a time of 14 years and discovered that consumption of entire grains 40g/every day lessen the risk of Coronary Heart disease by 20%. (Jensen *et al.*, 2004)
- **Cancer:** The word cancer is gotten from carcinoma - a crab. This is because of development of cells. Without a particular treatment, it is incurring significant damage of human life. Though, if it is defected at initial stage then treatment is possible. Cancer research institute UK says an unhealthy diet is connected to six kinds of cancer - mouth, upper throat, larynx, lung, stomach and gut. Overweightness has been connected to malignant growths of the throat, liver, upper stomach, gallbladder, pancreas, colon, bosom (after menopause) endometrium,

uterus, ovaries and kidneys. Sorghum have an anti - carcinogenic property. The In Vivo and In Vitro investigations have demonstrated utilization of sorghum has positive wellbeing impacts on growth of cancer. The polyphenols and tannins present in sorghum have anti mutagenic and anti - cancer - causing properties and can act against human melanoma cells, also as positive melanogenic action. (Gomez - Cordovez *et al.*, 2001). The anti - carcinogenic compounds exist in sorghum reduced the threat of oesophageal cancer. (Van Rensburg, 1981)

- **Oxidative stress:** The free radicals are reason for the oxidative pressure related pathogenesis of different diseases, for example, Alzheimer's sickness, myocardial infarction, atherosclerosis, Parkinson so on. Antioxidant agents play a significant role in to stop the oxidation process, along with reducing the cellular damage. Sorghum has an antioxidant property which can act against receptive oxidative species. (Dayakar Rao *et al.*, 2017)

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