Review Article

International Journal of Food, Nutrition and Dietetics
Volume 12 Number 3, September - December 2024
DOI: http://dx.doi.org/10.21088/ijfnd.2322.0775.12324.6

Millets: A Nutrient-Rich Marvel in Cuisine

Haris Chandra Sahoo[1], Subrata Mishra[2]

How to cite this article:

Haris Chandra Sahoo Subrata Mishra Millets: A Nutrient-Rich Marvel in Cuisine. Int J Food Nutr Diet. 2024;12(3):141-152.

Abstract

Millets, often regarded as ancient grains, have experienced a resurgence in popularity due to their remarkable nutritional profile and versatile applications in modern culinary endeavors. This review explores the diverse uses of millets in food items, shedding light on their health benefits, culinary versatility, and potential contribution to sustainable and inclusive agriculture.

Keywords: Millets, Nutrition, Fibre, Diet, Health Graphical Abstract.

INTRODUCTION

Millets, a group of small-seeded grasses, have been a staple in traditional diets across the globe for centuries. Recently, it has gained renewed attention as a superfood, owing to its rich nutrient content, resilience in diverse growing conditions, and their potential to address global food security issues. The production of millets is gaining increased importance in the nations that are overpopulated, having malnourished population and facing significant climate uncertainties. Factors such as the rising demand for gluten-free products, increasing health consciousness among consumers, and growing vegan population are driving the requirement of the millet-based food products. In asian and african countries millets commonly include Sorghum, Pearl millet, Finger millet, Little millet, Kodo millet, Foxtail/Italian millet, barnyard millet, Proso millet etc (Vetriventhan M. *et al*., 2020). India stands at sixth position globally as a producer of Sorghum (www.smartfood.org). Sorghum is the common millet that are used in the indian cities like Bengaluru, Chennai, Hyderabad, Mumbai, Kolkata and others. Traditionally millets are used to produce several kinds of foods and beverages in different region, which played very important role in the local food culture. In 1960s the per capita consumption of millet drastically decreased due to the several reasons like government policies, rising incomes in wheat and rice production etc. Due to its resilient traits such as ability to survive in high temperature, degraded soils, minimum requirements of water, pesticides and fertilizers (Saleh *et al*., 2013), lower carbon footprint in farming, there is an increase interest in reviving the millets in India and also globally. Giving the background with the example of sorghum.

Sorghum (Sorghum bicolor) is one of the most important cereal crops worldwide, particularly in arid and semi-arid regions. This literature review aims to provide an overview of recent research on sorghum, focusing on its agronomic characteristics, nutritional value, health benefits, and its significance as a sustainable crop. Sorghum

Author's Affiliation: [1]Naturopathic Practitioner, Badarpur, New Delhi 110044, India, [2]Molecular Biology and Biotechnology Department, Tezpur University.

Corresponding Author: Haris Chandra Sahoo, Naturopathic Practitioner, Badarpur, New Delhi 110044, India.

E-mail: haris.sahoohll@gmail.com

Received on: 22-07-2024 **Accepted on:** 23-08-2024

is a highly adaptable crop that can thrive in diverse agro- ecological zones, including regions with low rainfall and poor soil fertility. Recent studies have highlighted the crop's ability to withstand drought, heat, and soil salinity, making it an attractive option for farmers facing climate change-related challenges (Borrell *et al*., 2020; Vadez *et al*., 2013). Research has also focused on developing sorghum varieties with improved traits such as higher yield, resistance to pests and diseases, and enhanced nutritional content. Recent advances in breeding techniques, including marker-assisted selection and genomic selection, have facilitated the development of improved sorghum varieties (Mace *et al*., 2013; Tao *et al*., 2019).

Sorghum is not only a staple food for millions of people worldwide but also a rich source of essential nutrients. It is particularly high in carbohydrates, with a lower glycemic index compared to other cereals, making it suitable for people with diabetes (Taylor *et al*., 2016). Furthermore, sorghum contains significant levels of protein, dietary fiber, vitamins, and minerals, including iron, calcium, and phosphorus (Saleh *et al*., 2013). Recent research has also highlighted the presence of bioactive compounds in sorghum, such as phenolic acids and flavonoids, which have antioxidant and anti-inflammatory properties (Dykes & Rooney, 2006; Awika *et al*., 2004). The sustainability of sorghum production is a key area of research, particularly in the context of climate change and food security. Sorghum's ability to thrive in marginal environments with limited water and nutrients makes it a valuable crop for smallholder farmers in developing countries (Vadez *et al*., 2013).

Furthermore, sorghum has a lower water footprint compared to other cereals such as maize and wheat, making it a more environmentally sustainable option, particularly in water-scarce regions (Chapagain & Raizada, 2017). Recent studies have also explored the potential of sorghum as a biofuel feedstock, with research focusing on improving the crop's biofuel yield and sustainability (Rooney *et al*., 2007; Mullet *et al*., 2014).

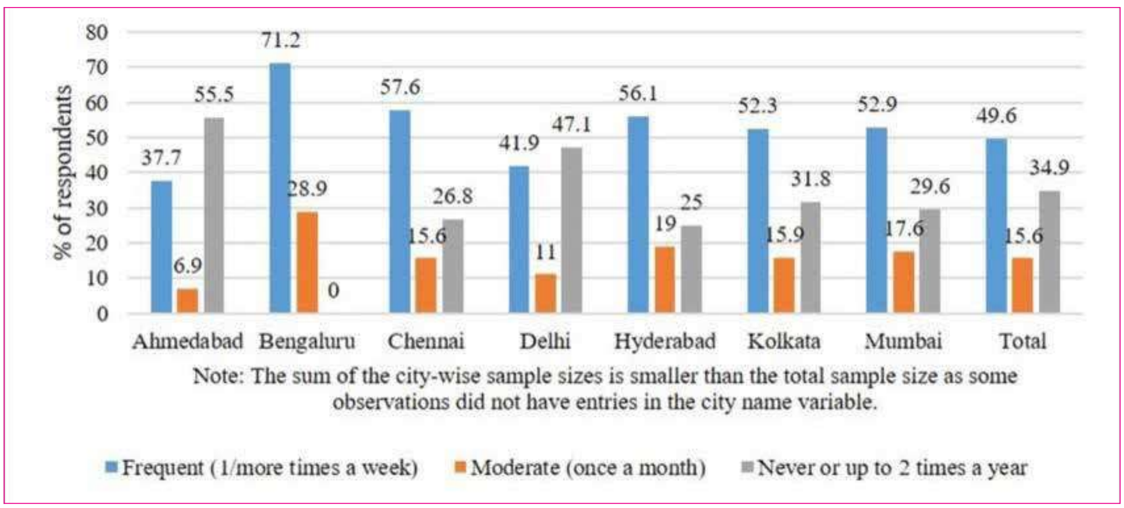


Fig. 1: Frequency of consumption of millets (mainly sorghum) in Indian cities (***Source:*** P.J.Kane *et al*)

Nutritional Bonanza & Health Benefits

One of the primary reasons for the growing interest in millets is their exceptional nutritional content. Millets are rich in essential nutrients such as fiber, proteins, vitamins, and minerals. They are gluten-free, making them an excellent option for individuals with gluten sensitivity or celiac disease. The diverse nutrient profile of millets contributes to their recognition as a valuable addition to a balanced and health-conscious diet. Consuming refined grains specifically, refined white rice has shown to be associated to non-communicable diseases including obesity and type II diabetes mellitus (Radhika G. *et al*., 2009). As a result, eating whole grains is becoming more and more popular throughout the world. This emphasizes how important it is to mainstream nutrient-dense smart food- corps and promote them as staples. One crucial component of therapeutic dietary modification and variety might be offering traditional whole grain and multi grain alternatives to processed carbs that are healthier and more nutrient dense. In the *Table 1* the nutrient composition of different types of millets with other grains are summarized (Indian Food Composition tables 2017).

Table 1: Proximate composition and dietary fibre (per 100g)

Millets and Cereals		Moisture (g)	Protein (g)	Ash (g)	Total Fat (g)	Dietary Fibre (g)			Carb hydrates (g)	Energy (KJ)
						Total	Insoluble	Soluble		
Bajra (*Pennisetum typhoideum*)		08.97 ± 0.60	10.96 ± 0.26	1.37 ± 0.17	6.43 ± 0.64	11.49 ± 0.62	9.14 ± 0.58	2.34 ± 0.42	61.78 ± 0.85	1456 ± 18
Sorghum (*Sorghum vulgare*)		09.01 ± 0.77	09.97 ± 0.43	1.39 ± 0.34	1.73±0.31	10.22± 0.49	8.49 ± 0.40	1.73 ± 0.40	67.68± 1.03	1398 ± 13
Ragi (Eleusine coracana)		10.89 ± 0.61	07.16 ± 0.63	2.04 ± 0.34	1.92 ± 0.14	11.18 ± 1.14	9.51 ± 0.65	1.67 ± 0.55	66.82 ± 0.73	1342 ± 10
Little Millet (*Panicum miliare*)		14.23 ± 0.45	08.92 ± 1.09	1.72 ± 0.27	2.55± 0.13	06.39 ± 0.60	5.45 ± 0.48	2.27 ± 0.52	65.55 ± 1.29	1449 ± 19
Kodo Millet (*Setaria italica*)		14.23 ± 0.45	08.92 ± 1.09	1.72 ± 0.27	2.55 ± 0.13	06.39 ± 0.60	4.29 ± 0.82	2.11 ± 0.34	66.19 ± 1.19	1388 ± 10
Foxtail Millet		-	12.3	-	4.3	-	-	-	60.09	331
Barnyard Millet *		-	6.2	-	2.2	-	-	-	65.55	307
Proso Millet *		-	12.5	-	1.1	-	-	-	70.04	341
Wheat	Whole	10.58 ± 1 .11	10.59 ± 0.60	1.42 ± 0.19	1.47 ± 0.05	11.23 ± 0.77	9.63 ± 0.19	1.60 ± 075	64.72± 1.74	1347 ± 23
	Refined flour	11.34 ± 0.93	10.36 ± 0.29	0.51 ± 0.07	0.76± 0.07	02.76 ± 0.29	2.14 ± 0.30	0.62 ± 0.14	74.27 ± 0.92	1472 ± 16
	Atita	11.10 ± 0.35	10.57 ± 0.37	1.28 ± 0.19	1.53 ± 0.12	11.36 ± 0.29	9.73 ± 0.47	1.63 ± 0.64	64.17 ± 0.32	1340 ± 07
	Semolina	08.94 ± 0.68	11.38 ± 0.37	0.8 ± 0.17	0.74 ± 0.10	09.72 ± 0.74	8.16 ± 0.58	1.55 ± 0.18	68.43 ± 0.99	1396 ± 18
Rice	Raw Brown	09.33 ± 0.39	09.16 ± 0.75	1.04 ± 0.18	1.24 ± 0.08	04.43 ± 0.54	3.60 ± 0.55	0.82 ± 0.15	74.80 ± 0.85	1480 ± 10
	Raw milled	09.93 ± 0.75	07.94 ± 0.58	0.56 ± 0.08	0.52 ± 0.05	02.81 ± 0.42	1.99 ± 0.39	0.82 ± 0.22	78.24 ± 0.68	1491 ± 15
	Parboiled	10.09 ± 0.43	07.89 ± 0.63	0.65 ± 0.8	0.55 ± 0.08	03.74 ± 0.36	2.98 ± 0.35	0.76 ± 0.09	77.16± 0.76	1471 ± 8
Quinoa (Cheno podium quinoa)		10.43	13.11	2.65	5.5	14.66	10.21	4.46	53.65	1374
Amaranth Seed	Black	9.89	14.59	2.78	5.74	7.02	5.76	1.26	59.98	1490
	Pale Brown	09.20 ± 0.40	13.27 ± 0.34	3.05 ± 0.3	5.56 ± 0.3	07.47 ± 0.09	5.80 ± 0.17	1.67 ± 0.21	61.46 ± 0.60	1489 ± 10
Maize	Dry	09.26 ± 0.55	08.80 ± 0.49	1.17 ± 0.16	3.77 ± 0.48	12.24 ± 0.93	11.29 ± 0.85	0.94 ± 0.18	64.77 ± 1.58	1398 ± 25

It's interesting to compare the mineral and trace element content of millets and fine grains. Because millets have a high nutritious profile, they are frequently regarded as preferable in this context. For example, compared to more refined cereals, millets are known to have greater quantities of aluminium, calcium, and iron (www.millets.res.in). In Table 6.2 the mineral and trace elements of different types of millets with other fine cereals are summarized (Indian Food Composition tables 2017).

Table 2: Amount of trace element and minerals in millets and others grains

Millets and Cereals		Aluminium (mg)	Arsenic (mg)	Cadmium (mg)	Calcium (mg)	Chromium (mg)	Cobalt (mg)	Copper (mg)	Iron (mg)	Lead (mg)	Lithium (mg)
Bajra (*Pennisetum typhoideum*)		2.21 ± 0.78	0.97 ± 0.24	0.003 ± 0.001	27.35 ± 2.16	0.025 ± 0.006	0.030 ± 0.015	0.54 ± 0.11	6.42 ± 1.04	0.008 ± 0.002	0.003 ± 0.001
Sorghum (*Sorghum vulgare*)		2.56 ± 0.59	1.53 ± 0.04	0.002 ± 0.002	27.6 ± 3.71	0.010 ± 0.003	0.012 ± 0.007	0.45 ± 0.11	3.95 ± 0.94	0.008 ± 0.003	0.001 ± 0.001
Ragi (*Eleusine coracana*)		3.64 ± 0.69	-	0.004 ± 0.004	364 ± 58	0.032 ± 0.019	0.022 ± 0.009	0.67 ± 0.22	4.62 ± 0.36	0.005 ± 0.002	0.003 ± 0.003
Little Millet (***Panicum miliare***)		-	0.49 ± 0.15	0.001 ± 0.000	16.06 ± 154	0.016 ± 0.006	0.001 ± 0	0.34 ± 0.08	1.26 ± 0.44	-	-
Kodo Millet (*Setaria italica*)		1.07 ± 0.83	-	-	15.27 ± 1.28	0.021 ± 0.027	0.005 ± 0.003	0.26 ± 0.05	2.34 ± 0.46	-	0.027 ± 0.003
Foxtail Millet *		-	-	-	-	0.03	-	1.4			
Barnyard Millet *		-	-	-	-	0.09	-	0.6			
Proso Millet *		-	-	-	-	0.02	-	1.6			
	Whole	0.55 ± 0.23	-	0.002 ± 0.001	39.36 ± 5.65	0.006 ± 0.003	0.003 ± 0.002	0.49 ± 0.12	3.97 ± 0.78	-	0.005 ± 0.004

table cont....

Millets and Cereals		Aluminium (mg)	Arsenic (mg)	Cadmium (mg)	Calcium (mg)	Chromium (mg)	Cobalt (mg)	Copper (mg)	Iron (mg)	Lead (mg)	Lithium (mg)
Wheat	Refined flour	0.94 ± 0.33	-	0.001 ± 0.000	20.4 ± 2.46	0.005 ± 0.002	0.001 ± 0.001	0.17 ± 0.02	1.77 ± 0.38	0.004 ± 0.002	0.003 ± 0.003
	Atta	1.54 ± 0.53	-	0.01 ± 0.001	30.94 ± 3.65	0.006 ± 0.005	0.006 ± 0.003	0.48 ± 0.11	4.10 ± 0.67	0.006 ± 0.003	0.002 ± 0.001
	Semolina	0.64 ± 0.19	-	0.002 ± 0.001	29.38 ± 2.11	0.006 ± 0.003	0.003 ± 0.002	0.46 ± 0.11	2.98 ± 0.34	0.004 ± 0	0.002 ± 0.002
Rice	Raw Brown	0.6 ± 0.18	-	0.002 ± 0.001	10.93 ± 1.79	0.005 ± 0.002	0.011 ± 0.003	0.37 ± 0.14	1.02 ± 0.35	0.002 ± 0.001	-
	Raw milled	0.44 ± 0.3	-	0.002 ± 0.002	7.49 ± 1.26	0.005 ± 0.003	0.003 ± 0.002	0.23 ± 0.06	0.002 ±0.66	0.002 ± 0.66	0.002 ± 0.66
	Parboiled	0.2 ± 0.06	-	0.002 ± 0.003	8.11 ± 1.01	0.005 ± 0.002	0.003 ± 0.001	0.27 ± 0.12	0.72 ± 0.20	0.006 ± 0.002	0.005 ± 0.002
Quinoa (Chenopodium quinoa)		-	0.03	0.002	198	0.004	-	0.48	751	-	-
Amaranth Seed	Black	3.32	-	-	181	1.227	0.059	0.81	9.33	0.013	0.028
	Pale Brown	2.73 ± 0.47	-	0.001 ± 0	162±15.7	0.092 ± 0.045	0.021 ± 0.005	0.56 ± 0.09	8.02 ± 0.93	0.018 ± 0.012	0.008 ± 0.008
Maize, Dry		2.82±0.16	-	-	8.94 ± 0.61	0.010 ± 0.006	0.010 ±0.003	0.45 ± 0.23	2.49 ± 0.32	-	0.002 ± 0.001

Regarding the nutritional qualities, millets are not only on par with other main grains but also excellent providers of vitamins, carbs, and phytochemicals with nutraceutical qualities. 7–12% protein, 2-4% fat, 65-75% carbs, and 15-20% dietary fibre are included in millets. Of these, finger millet has lower levels of fat (1.5-2%) and protein (6-8%) than pearl millet, which has a comparatively large proportion of proteins (12-16%) and lipids (4-6%). Millet protein has superior essential amino acid profiles compared to maize protein. Pearl millet has more niacin than any other cereal, however finger millet proteins are special due to their high sulphur concentration of amino acids.

Millets include a variety of water-soluble vitamins, including vitamin B6, folate (vitamin B9), thiamine (vitamin B1), and niacin (vitamin B3). A serving of millet provides around 0.11 mg of thiamin,r 9% of the recommended daily intake. Thiamin is essential for nerve function maintenance and energy metabolism. Niacin from millet makes up around 1.3 mg per serving, or 8% of the daily requirement1. The synthesis of cellular energy and general health depends on niacin. Although millet has less vitamin B6, it is still beneficial to nutrition in general. Numerous metabolic processes, including protein synthesis and neurotransmitter activity, are impacted by vitamin B6. Folate (vitamin B9), which is found in millet, is necessary for cell division, DNA synthesis, and general health maintenance. The precise quantity of folate in millet, however, might differ. Although it is not specifically stated in the literature, millet is likely to contain riboflavin (vitamin B2) as well. The synthesis of energy and the preservation of healthy skin, eyes, and red blood cells depend on riboflavin. *Table 3* is showing the water-soluble vitamins profile of millets and other cereals (Indian Food Composition tables 2017).

Table 3: Water-soluble vitamins profile of millet and other cereals

Millets and Cereals	Thiamine B1 (mg)	Riboflavin B2 (mg)	Niacin-B3 (mg)	Pantothenic Acid-B5 (mg)	Total B6 (mg)	Biotin-B7 (pg)	Total Folates-B9 (pg)	Total Ascorbic acid (mg)
Bajra (*Pennisetum typhoideum*)	0.25 ± 0.044	0.20 ± 0.038	0.86 ± 0.1	0.5 ± 0.05	0.27 ± 0.09	0.64 ± 0.05	36.11 ± 5.05	-
Sorghum (*Sorghum vulgare*)	0.35 ± 0.039	0.14 ± 0.014	2.1 ± 0.09	0.27 ± 0.02	0.28 ± 0.023	0.70 ± 0.06	39.42 ± 3.13	-
Ragi (*Eleusine coracana*)	0.37 ± 0.041	0.17 ± 0.008	1.34 ± 0.02	0.29 ± 0.19	0.05 ± 0.007	0.88 ± 0.05	34.66 ± 4.97	-
Little Millet (*Panicum miwe*)	0.26 ± 0.042	0.05 ± 0.008	1.29 ± 0.02	0.6 ± 0.07	0.04 ± 0.005	6.03 ± 0.57	36.2 ± 7.04	-
Kodo Millet (*Setaria itaJica*)	0.29 ± 0.054	0.20 ± 0.018	1.49 ± 0.08	0.63 ± 0.07	0.07 ± 0.017	1.49 ± 0.18	39.49 ± 4.52	-
Foxtail Millet *	0.59	0.11	3.2	0.82	-	-	-	-
Barnyard Millet	0.33	0.1	4.2	-	-	-	-	-

table cont....

Millets and Cereals		Thiamine B1 (mg)	Riboflavin B2 (mg)	Niacin-B3 (mg)	Pantothenic Acid-B5 (mg)	Total B6 (mg)	Biotin-B7 (pg)	Total Folates-B9 (pg)	Total Ascorbic acid (mg)
Proso Millet *		0.41	0.28	4.5	1.2	-	-	-	-
Wheat	Whole	0.46 ± 0.067	0.15 ± 0.041	2.68 ± 0.19	1.08 ± 0.21	0.26 ± 0.036	1.03 ± 0.58	30.09 ± 3.79	-
	Refined flour	0.15 ± 0.017	0.06 ± 0.08	0.77 ± 0.07	0.72 ± 0.08	0.08 ± 0.008	0.58 ± 0.09	16.25 ± 2.62	-
	Atta	0.42 ± 0.044	0.15 ± 0.010	2.37 ± 0.1	0.87 ± 0.04	0.25 ± 0.032	0.76 ± 0.12	29.22 ± 1.92	-
	Semolina	0.29 ± 0.025	0.04 ± 0.004	1.13 ± 0.1	0.75 ± 0.08	0.11 ± 0.010	0.44 ± 0.04	25.68 ± 3.64	-
Rice	Raw Brown	0.27 ± 0.023	0.06 ± 0.011	3.4 ± 0.12	0.16 ± 0.04	0.37 ± 0.035	1.38 ± 0.21	11.51 ± 1.69	-
	Raw milled	0.05 ± 0.019	0.05 ± 0.006	1.69 ± 0.13	0.57 ± 0.05	0.12± 0.012	0.6 ± 0.12	9.32 ± 1.93	-
	Parboiled	0.17 ± 0.023	0.06 ± 0.018	2.51 ± 0.49	0.55 ± 0.06	0.22 ± 0.017	0.31 ± 0.02	9.75 ± 2.1	-
Quinoa (*Chenopodium quinoa*)		0.83	0.22	1.7	0.62	0.21	0.62	1.73	-
Amaranth Seed	Black	0.04	0.04	0.45	0.24	0.5	1.92	27.44	-
	Pale Brown	0.04 ± 0.007	0.04 ± 0.07	0.52 ± 0.05	0.28 ± 0.03	0.33 ± 0.023	1.87 ± 0.24	24.65 ± 3.21	-
Maize, Dry		0.33 ± 0.32	0.09 ± 0.009	2.69 ± 0.06	0.34 ± 0.03	0.34 ± 0.017	0.49 ± 0.05	25.81 ± 1.44	-

Millets are a good source of fat-soluble vitamins including A and K. Beta-carotene, a substance found in millets, is a precursor to vitamin A, which is necessary for skin health, vision, and immune systems. Vitamin E, which functions as an antioxidant and aids in preventing cell damage, is abundant in millets. Vitamin K, which is necessary for healthy bones and blood clotting, is also present in millets. Although the precise amount of these vitamins varies according to the kind of millet, millets aregenerally thought to be a wholesome source of these fat-soluble vitamins. The fat-soluble vitamins profile of millets and other cereals are summarized in *table 4* (Indian Food Composition tables 2017).

Table 4: Fat-soluble vitamins profile of millet and other cereals

table cont....

Millets and Cereals		Ergocalciferol (pg) Alpha	Tocopherols (mg)			Tocotrienols (mg)				α-Tocopherol (mg)	Phylloquinoes K1 (µg)
			Beta	Gamma	Delta	Alpha	Gamma	Delta			
Bajra (*Pennisetum typhodeum*)		5.65 ± 0.27	0.1 ± 0.01	-	1.42 ± 0.20	-		-	-	0.24 ± 0.02	2.85 ± 0.63
Sorghum (*Sorghum vulgare*)		3.96 ± 0.03	0.04 ± 0.01	-	0.27 ± 0.03	-		-	-	0.06 ± 0.01	43.82 ± 4.84
Ragi (E/eusine coracana)		41.46 ± 3.12	0.09 ± 0.01	-	0.66 ± 0.06	-	-	-	-	0.16 ± 0.01	3.0 ± 0.44
Little Millet (*Panicum miliare*)		3.75 ± 0.8	0.28 ± 0.14	0.67 ± 0.40	-	-	-	0.28 ± 0.09	-	0.55 ± 0.16	4.47 ± 0.38
Kodo Millet (*Setaria italica*)		-	0.03 ± 0.01	-	0.43 ± 0.12	-		0.19 ± 0.05	-	0.07 ± 0.02	3.75 ± 0.63
Foxtail Milet *		-	-	-	-	-	-	-	-	-	-
Barnyard Millet *		-	-	-	-	-	-	-	-	-	-
Proso Millet *		-	-	-	-	-	-	-	-	-	-
Wheat	Whole	17.49 ± 0.07	0.6 ± 0.33	0.37 ± 0.12	-	-	0.07 ± 0.03	1.03 ± 0.58	30.09 ± 3.79	0.77 ± 0.35	1.75 ± 0.26
	Refined flour	6.73 ± 0.96	0.05 ± 0.01	-	-	-	-	-	-	0.05 ± 0.01	1.0 ± 0.46
	Atta	13.42 ± 1.77	0.21 ± 0.09	0.06 ± 0.01	-	-	0.06 ± 0.03	-	-	0.26 ± 0.09	1.5 ± 0.47
	Semolina	0.290 ± 0.03	0.04 ± 0.004	1.13 ± 0.1	0.75 ± 0.08	0.11 ± 0.010		0.44 ± 0.04	25.68 ± 3.64	0.69 ± 0.12	2.0 ± 0.83
Rice	Raw Brown	-	0.62 ± 0.08	0.05 ± 0.02	0.42 ± 0.57	-	0.03 ± 0.02	-	0.05 ± 0.02	-	
	Raw milled	-	0.04 ± 0.03	-	0.06 ± 0.02	-	0.03 ± 0.02	-	0.05 ± 0.02	0.06 ± 0.03	1.5 ± 0.4
	Parboiled	-	0.06 ± 0.04	-	0.13 ± 0.12	-	0.05 ± 0.02	-	-	0.09 ± 0.04	1.5 ± 0.5
Quinoa (*Chenopodium quinoa*)		-	2.08	0.06	2.85	-	-	-	-	2.08	2
Amaranth Seed	Black	0.04	0.04	0.45	0.24	0.5	-	1.92	27.44	-	
	Pale Brown	53.98 ± 3.38	0.06 ± 0.00	0.22 ± 0.1	0.03 ± 0.01	-	-	-	-	0.15 ± 0.03	2.5 ± 0.87
Maize, Dry		33.60 ± 2.82	0.21 ± 0.04		1.29 ± 0.17	0.38 ± 0.05	0.05	-	-	0.36 ± 0.03	2.5 ± 0.76

Millets also show high levels of alanine and leucine, and the methionine concentration varies greatly throughout samples, indicating that choosing particular cultivars may be necessary to guarantee a high content. Furthermore, compared to other gluten-free grains, millets have been discovered to possess more important amino acids. It is noteworthy that dehulling does not substantially alter the amino acid content, meaning that both whole and dehulled millets have a healthy amino acid profile. Because of this, millets are a beneficial addition to any diet, particularly for individuals trying to cut back on gluten or up their consumption of important amino acids. The amino acid profile of millets and other cereals are summarized in *Table 5* (Indian Food Composition tables 2017).

Table 5: Amino acid profile of millets and other cereals

Millets and Cereals		Histidine	Isoleucine	Luecine	Lysine	Methionine	Cystine	Phenylalanine	Threonine	Tyrptophan	Valine
Bajra (*Pennisetum typhoideum*)		2.15 ± 0.37	3.45 ± 0.74	0.8.52± 0.86	3.19± 0.49	2.11 ±0.50	1.23 ± 0.33	4.82± 1.18	3.55 ± 0.40	1.33 ± 0.30	4.79 ± 1.04
Sorghum (*Sorghum vulgare*)		2.07 ± 0.20	3.45 ± 0.63	12.03 ± 1.51	2.31 ± 0.40	1.52 ± 0.50	1.06 ± 0.30	5.10± 0.50	2.96 ± 0.17	1 .03 ± 0.21	4.51 ± 0.71
Ragi (*Eusina coracana*)		2.37 ± 0.46	3.70 ± 0.44	08.86 ± 0.54	2.83 ± 0,34	2.74 ± 0.27	1.48 ± 0.23	5.70 ± 1.27	3.84 ± 0.45	0.91 ± 0.30	5.65 ± 0.44
Little Millet (*Panicum millare*)		2.35 ± 0.18	4.14 ± 0.08	08.08± 0.06	2.42 ± 0.10	2.21 ± 0.10	1.85 ± 0.14	6.14 ± 0.10	4.24 ± 0.12	1. 35 ± 0.10	5.31 ± 0.16
Kodo Millet (*Setaria italica*)		2.14 ± 0.07	4.55 ± 0.22	11.96 ± 1.65	1.42± 0.17	2.69 ± 0.16	1.92± 0.05	6.27 ± 0.34	3.89 ± 0.16	1.32 ± 0.19	5.49 ± 0.23
Foxtail millet											
Barnyard millet											
Proso millet											
Wheat	Whole	2.65 ± 0.31	3.83 ± 0.20	06.81 ± 0.33	3.13± 0.26	1.75 ± 0.21	2.35 ± 0.23	4.75± 0.38	3.01 ± 0.17	1.40 ± 1.10	5.11± 0.05
	Refined flour	1.95 ± 0.23	3. 19 ± 0.27	06.2 2 ± 0.46	2.05± 0.18	1.64 ± 0.20	2.03± 0.27	4.29 ± 0.28	2.34 ±0.08	1 .04 ± 0.16	4.01 ± 0.44
	Atta	2.56 ± 0. 25	3.78 ± 0.21	06.13 ± 0.48	2.42 ± 0.22	1.77 ± 19.4	2.24 ± 0.18	5.03±0.14	2.58 ± 0.14	0.99 ± 0.16	5.12 ± 0.48
	Semolina	2.38 ± 4.28	3.43 ± 0.26	06.71 ± 0.59	2.54± 0.13	1,57 ± 0.23	1.79 ± 0.03	4.77 ± 0.32	2.71 ± 0.15	1.04 ±0.12	4.47 ± 0.39
Rice	Raw Brown	2.36 ± 0.18	4.08± 0.05	08.40 ± 0.55	3.63 ± 0.29	2.39 ± 0.26	2.02 ± 0.12	5.50 ± 0.49	3.38 ± 0.25	1.00 ± 0.17	6.72 ± 0.36
	Raw milled	2.45 ± 0.30	4.29 ± 0.23	08.09 ± 0.40	3.70 ± 0.39	2.6 0 ± 0.34	1.84 ± 0.18	5.36 ± 0.43	3.28 ± 0.27	1.27 ± 0.14	6.06 ± 0.02
	Par boiled	2.35 ± 0.18	4.14 ± 0.08	08.08 ± 0.06	3. 42± 0.10	2.48 ± 0.24	2.15 ± 0.08	5.14 ± 0.10	3.24± 0.12	1.15± 0.06	6.26 ± 0.13
Quinoa (*Cheno podium quinoa*)		2.98	3.75	6.08	5.55	2.24	1.85	4.35	3.01	1.25	4.55
Amaranth Seed	Black	1.86	2.82	4.83	5.45	1.86	1.6	3.98	3.02	1.05	4.34
	Pale brown	1.98 ± 0.50	2.85 ± 0.04	04.94 ± 0.17	5.5 ± 0.35	1.95 ± 0.12	1.51 ± 0.15	4.75 ±0_.41	2.99± 0.21	1.69 ± 0.10	4.30± 0.27
Maize, Dry		2.70 ± 0.21	3.67 ± 0.22	12.24 ± 0.57	2.64 ± 0.18	2.10 ± 0.17	1.55± 0.14	5.14 ± 0.29	3.23 ± 0.29	0.57 ± 0.12	5.41 ± 0.71

Because of its high nutritional value, the carotenoid profile of millet, and especially foxtail millet (*Setaria italica*), has been widely researched. The yellow hue of the grains can be attributed to chemicals called carotenoids, which comprise lutein and β-carotene[(4)]. The two main carotenoid metabolites in foxtail millet panicles are lutein and β-carotene. During stage 1 of panicle development, the contents of these carotenoids drastically drop. The levels of lutein and β-carotene were determined to be 11.474 μg/100 mg and 12.524 μg/100 mg, respectively, during the S1 stage of development. An investigation into the impact of ultraviolet B (UV-B) radiation on foxtail millet revealed that carotenoid synthesis-related genes might be expressed more often at optimal UV-B intensities.[5] In *Table 6* the carotenoids profile of millets and other cereals are summarized (Indian Food Composition tables 2017).

Table 6: Carotenoids profile of millets and other cereals

Millets and Cereals	Lutein (μg)	Zeaxanthin (μg)	Lycopene (μg)	β-Cryptoxanthin	γ-Carotene	β-Carotene	Total Carotenoids
Bajra (*Pennisetum typhoideum*)	29.69 ± 08.72	9.30 ± 1.23	-	-	-	28.23 ± 9.42	293 ± 55.7
Sorghum (*Sorghum vulgare*)	09.08 ± 01.77	7.48 ± 2.41	-	-	-	08.29 ± 1.30	212 ± 48.9
Ragi (*Eleusine coracana*)	25.53 ± 05.82	1.45 ± 0.23	-	-	-	01.53 ± 0.25	154 ± 25.6
Little Millet (*Panicum miliare*)	07.82 ± 01.76	5.24 ± 1.66	-	-	-	01.91 ± 0.89	120 ± 09.0
Kodo Millet (*Setaria italica*)	59.40 ± 07.01	3.91 ± 1.08	-	-	-	01.41 ± 0.29	272 ± 25.1

Millets and Cereals		Lutein (µg)	Zeaxanthin (µg)	Lycopene (µg)	β-Cryptoxanthin	γ-Carotene	β-Carotene	Total Carotenoids
Foxtail Millet *		-	-	-	-	-	-	-
Barnyard Millet *		-	-	-	-	-	-	-
Proso Millet *		-	-	-	-	-	-	-
Wheat	Whole	52.56 ± 05.67	1.47 ± 0.68	-	-	-	01.03 ± 0.58	30.1 ± 3.79
	Refined flour	24.41 ± 09.21	1.30 ± 0.72	-	-	-	03.03 ± 2.13	287 ± 40.0
	Atta	42.12 ± 11.27	1.31 ± 0.69	-	-	-	02.67 ± 1.29	284 ± 31.9
	Semolina	29.94 ± 07.39	1.13 ± 0.66	-	-	-	01.60 ± 0.59	276 ± 29.9
Rice	Raw Brown	13.15 ± 04.03	-	-	-	-	-	159 ± 13.9
	Raw milled	01.49 ± 00.46	-	-	-	-	-	16.9 ± 5.61
	Parboiled	01.46 ± 00.72	-	-	-	-	-	46.9 ± 8.29
Quinoa (*Chenopodium quinoa*)		11.88	10.05	-	-	-	5.12	153
Amaranth Seed	Black	0.25	-	-	-	-	-	121
	Pale Brown	04.11 ± 01.16	-	-	-	-	-	59.7 ± 3.09
Maize, Dry		186.0 ± 19.40	42.4 ± 15.70	-	110 ± 10.1	-	186.0 ±19.2	893 ± 154

Millets typically contain a small amount of fat, and the fatty acid composition can vary between different types of millets. However, the predominant fatty acids in millets are usually Oleic Acid (Omega-9), Linoleic Acid (Omega-6), Palmitic Acid, Stearic Acid. Millets are rich in carbohydrates, primarily in the form of starch. The starch content in millets can range from 60% to 75% of their dry weight. The fatty acid profile of millets and other cereals are summarized in the *Table 6* (Indian Food Composition tables 2017).

The starch in millets is mostly composed of amylose and amylopectin, with the ratio varying depending on the type of millet. Millets typically contain around 20-25% amylose in their starch composition. The remaining starch content in millets consists of amylopectin. The starch profile of millets and other cereals are summarized in *Table 7* (Indian Food Composition tables 2017).

Table 7: Fatty acid profile of millets and other cereals

Millets and Cereals		Palmitic (mg)	Stearic (mg)	Palmitoleic (mg)	Oleic (mg)	Linoleic (mg)	Total Saturated Fatty Acids (mg)	Total Mono Saturated Fatty Acids (mg)
Bajra (*Pennisetum typhoideum*)		729 ± 21.3	128 ± 19.6	6.97 ± 0.45	1040 ± 39.8	1844 ± 56.7	875 ± 34.5	1047 ± 39.9
Sorghum (*Sorghum vulgare*)		149 ± 5.6	14.22 ± 0.79	-	30.14 ± 13.7	508 ± 18.3	163 ± 6.2	314 ± 13.7
Ragi (*Eleusine coracana*)		290 ± 15.4	27.86 ± 2.43	-	585 ± 36.3	362 ± 15.3	317 ± 17.0	585 ± 36.3
Little Millet (*Panicum miliare*)		487 ± 26.1	102 ± 11.9	-	868 ± 24.2	1230 ± 42.9	589 ± 31.9	868 ± 24.2
Kodo Millet (*Setaria italica*)		211 ± 0.9	28.40 ± 1.22	3.21 ± 0.11	291 ± 7.2	576 ± 17.8	246 ± 2.3	297 ± 6.8
Foxtail Millet*		6.4	6.3		13	66.5	-	-
Barnyard Millet *		10.8	-		53.8	34.9	-	-
Proso Millet*		-	-	-	-	-	-	-
Wheat	Whole	176 ± 7.4	14.83 ± 2.25	-	141 ± 9.4	616 ± 22.1	191 ± 8.0	141 ± 9.4
	Refined flour	91.24 ± 1.50	7.31 ± 0.73	-	50.64 ± 2.98	325 ± 6.8	98.55 ± 1.87	50.64 ± 2.98
	Atta	191± 5.6	14.55 ± 3.10	-	149 ± 7.5	697 ± 19.4	206 ± 82	149 ± 7.5
	Semolina	81.63 ± 4.28	7.24 ± 1.49	-	67.34 ± 3.25	306 ± 3.0	88.87 ± 5.16	67.34 ± 3.25
Rice	Raw Brown	273 ± 14.99	33.01 ± 4.34	2.77± 0.46	197 ± 15.4	490 ± 33.2	346 ± 20.3	203 ± 15.7
	Raw milled	143 ± 28.0	14.50 ± 3.27	1.49 ± 0.47	109 ± 21.2	234 ± 45.8	184 ± 8.9	117 ± 6.6
	Parboiled	120 ± 8.0	13.83 ± 1.67	1.19 ± 0.21	84.09 ± 6.47	209 ± 12.8	150± 10.2	86.66 ± 6.38

Quinoa (chenopodium quinoa)	434	52.88	56.79	1323	2203	570	1424
Amaranth Seed, Black	1043	155	-	1020	2259	1280	1033
Amaranth Seed, Pale Brown	891 ± 54.5	172 ± 14.1	-	1030 ± 64.3	2223 ± 129	1140 ± 70.05	1043 ± 65.8
Maize, Dry	363 ± 4.6	42.45 ± 2.76	-	700 ± 17.9	1565 ± 18.2	413 ± 5.6	706 ± 17.4

Table 8: Starch and individual sugar profile of millets and others cereals

Millets and Cereals		Total Available CHO (g)	Total Starch (g)	Fructose (g)	Glucose (g)	Sucrose (g)	Maltose (g)	Total Free Sugars (g)
Bajra (*Pennisetum typhoideum*)		56.02 ± 2.57	55.21 ± 2.57	0.21 ± 0.01	0.60 ± 0.02	-	-	0.81 ± 0.01
Sorghum (*Sorghum vulgare*)		60.96 ± 1.70	59.70 ± 1.70	0.57 ± 0.07	0.1 ± 0.01	0.6 ± 0.04	-	1.27 ± 0.05
Ragi (*Eleusine coracana*)		62.47 ± 1.24	62.13 ± 1.13	-	0.25 ± 0.06	0.12 ± 0.02	-	034 ± 0.06
Little Millet (*Panicum miliare*)		56.43 ± 4.09	56.07 ± 4.12	-	0.24 ± 0.10	0.13 ± 0.01	-	0.37 ± 0.09
Kodo Millet (*Setaria italica*)		66.25 ± 2.90	64.96 ± 2.93		0.89 ± 0.11	0.4 ± 0.02	-	1.29 ± 0.10
Foxtail Millet *		-	-	-	-	-	-	-
Barnyard Millet *		-	-	-	-	-	-	-
Proso Millet *		-	-	-	-	-	-	-
Wheat	Whole	58.60 ± 2.68	56.82 ± 2.69	0.72 ± 0.03	0.78 ± 0.05	0.3 ± 0.02	-	1.80 ± 0.06
	Refined flour	71.82 ± 1.07	70.03 ± 1.01	0.64 ± 0.03	0.75 ± 0.02	0.4 ± 0.05	-	1.79 ± 0.08
	Atta	58.62 ± 2.68	56.82 ± 2.69	0.72 ± 0.03	0.78 ± 0.05	0.30 ± 0.02	-	1.80 ± 0.06
	Semolina	59.85 ± 2.99	58.20 ± 2.95	0.60 ± 0.04	0.55 ± 0.03	0.50 ± 0.04	-	1.65 ± 0.08
Rice	Raw Brown	72.00 ± 1.87	71.31 ± 1.91	-	0.55 ± 0.08	0.14 ± 0.02	-	0.69 ± 0.08
	Raw milled	76.39 ± 2.76	75.70 ± 2.70	-	0.54 ± 0.25	0.15 ± 0.06	-	0.69 ± 0.28
	Parboiled	76.80 ± 5.71	76.14 ± 5.73	-	0.51 ± 0.24	0.16 ± 0.06	-	0.67 ± 0.25
Quinoa (*Chenopodium quinoa*)		49.825	48.41	-	1.41	-	-	1.41
Amaranth Seed, Black		56.71	55.83	0.1	0.22	0.46	0.1	0.88
Amaranth Seed, Pale Brown		60.13 ± 1.30	59.33 ± 1.31	0.10 ± 0.01	0.22 ± 0.04	0.48 ± 0.04	-	0.80 ± 0.07
Maize, Dry		61.01 ± 0.76	59.35 ± 0.83	0.16 ± 0.03	0.8 ± 0.01	0.7 ± 0.03	-	1.66 ±0.04

Consuming millets regularly is associated with several health benefits. The high fiber content aids digestion and helps regulate blood sugar levels. makes them an ideal choice for individuals aiming to Millets also contain antioxidants that contribute to overall well-being by neutralizing free radicals in the body. Additionally, the low glycemic index of millets manage weight and prevent diabetes.

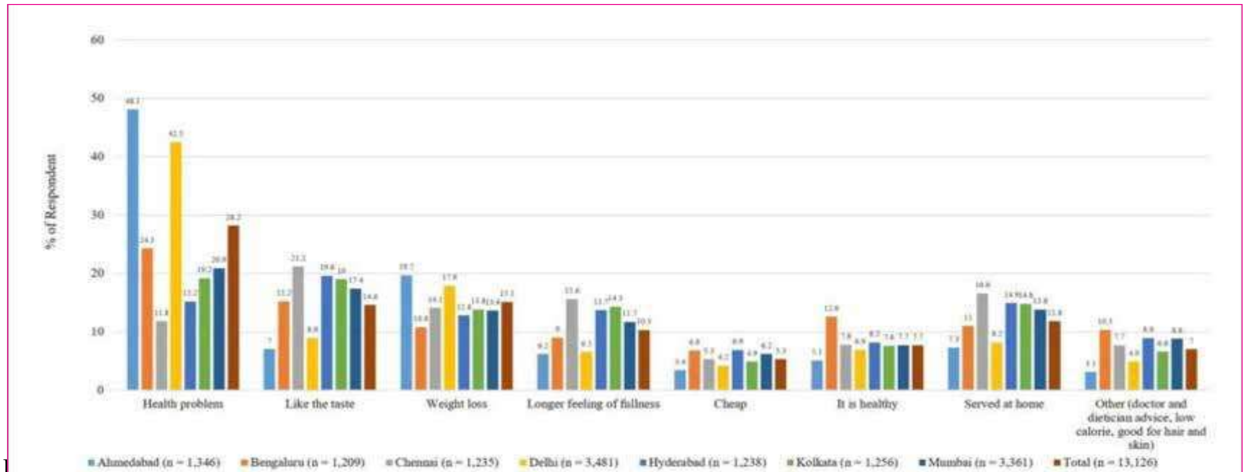
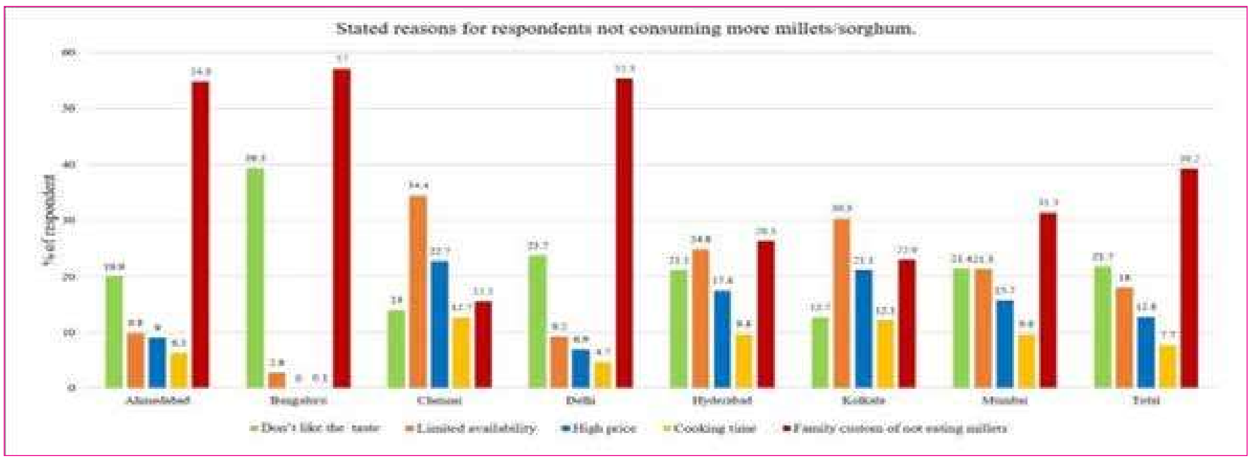


Fig. 2: Respondents' reasons for consuming millets and sorghum in indian cities (Source: P.J.Kane *et al.*)

Culinary Versatility

Millets exhibit remarkable versatility in the kitchen, adapting well to various culinary techniques. From savory dishes to desserts, millets can be incorporated into a myriad of recipes. Their mild, nutty flavor complements both sweet and savory preparations, making them a favorite among chefs experimenting with diverse cuisines. Millet flour, for example, can be used to prepare flatbreads, pancakes, and baked goods, providing a nutritious alternative to refined flours. Millets are very versatile grains that have a wide range of culinary uses. Like rice or quinoa, millets may be cooked and used as a side dish or as the basis for a variety of dishes. They can be prepared in a rice cooker, steamer, or boiling. When millets are boiled in either water or milk, they become a creamy porridge. You may add spices, nuts, and fruits to this porridge to flavor and sweeten it.

It may be combined with other gluten-free flours, such as sorghum or rice flour, or used on its own. Cooked millet is a healthy, gluten-free substitute for grains like bulgur wheat or couscous in salads. They may be mixed with other veggies, herbs, and dressings to give salads structure and taste. To give texture and thickness to soups and stews, millets can be used. They provide the meal more nutritious value while absorbing the tastes of the veggies and broth. Before cooked with broth or water, millets can be sautéed with onions, garlic, and spices to form pilafs. They may be added to vegetables, dried fruits, and nuts to create a tasty and nourishing feast.



You can load veggies like peppers, tomatoes, and squash with millets. They may be used to create a tasty filling by mixing them with items like cheese, nuts, and herbs. Sweet recipes like puddings, cakes, and cookies can be made using millet. In dessert dishes, millet flour can be used as a gluten-free substitute for wheat flour. Traditional dishes like idli, dosa, and fermented drinks may be made with millet. Products made from fermented millet are both simple to digest and nutritive. All things considered, millets are

incr gra in a con a g any

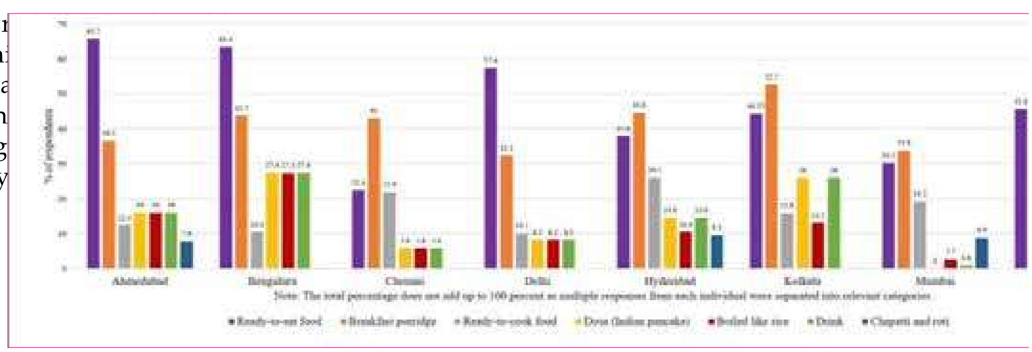


Fig. 3: Common forms in which millets are eaten in different Indian cities (Source: P.J.Kane *et al.*)

Innovative Millet-Based Products

The food industry has embraced millets, leading to the creation of innovative products that cater to modern dietary preferences. Millet-based snacks, cereals, and beverages have become popular choices for health-conscious consumers seeking nutritious alternatives. Additionally, the incorporation of millets into ready-to-eat meals addresses the demand for convenience without compromising on nutritional value. Pasta made from millet is a gluten-free substitute for regular wheat pasta. It is created using a blend of gluten-free flours and millet flour and works well in a variety of pasta recipes. Another increasingly well-liked gluten-free substitute is millet bread. It may be used to create toast, sandwiches, and other things. It's prepared from a blend of millet flour and other gluten-free flours. There are a variety of millet-based foods on the market, including crackers, puffs, and chips. These snacks are higher in nutrients and a better option than regular potato chips. Nutritious breakfast cereals can be made with millet flakes or puffs. For extra taste and nutrition, they can be consumed with milk or yogurt and garnished with nuts and fruits. When baking, millet flour can be used as a gluten-free substitute for wheat flour. Bread, muffins, pancakes, and other baked goods can be made using it. In several regions of the world, beer is also made from millet. Gluten-free and with a distinct taste character is millet beer. Energy bars made from millet are a quick, easy, and wholesome snack choice for folks on the go. Typically, a blend of millet, nuts, seeds, and dried fruits are used to make them. These are but a handful of the inventive items manufactured from millet.

There will probably be a further growth in the market for items made from millet as more people become aware of its health advantages. People in the Indian cities consume less millets just because of there were no family custom of eating millets.

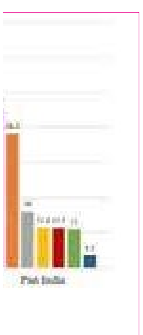


Fig. 4: Stated reasons for respondents not consuming more millets (Source: P.J.Kane *et al*)

Sustainability and Inclusive Agriculture

Millets are known for their adaptability to diverse agro-climatic conditions, making them a resilient crop that can thrive in arid regions with minimal water requirements. The cultivation of millets contributes to sustainable agriculture by promoting biodiversity, reducing the reliance on water- intensive crops, and enhancing soil health. Moreover, the cultivation of millets can provide a livelihood for small-scale farmers, promoting inclusive and sustainable agricultural practices.

CONCLUSION

In conclusion, millets have transitioned from being traditional staples to contemporary superfoods, gaining recognition for their nutritional richness, culinary adaptability, and positive impact on sustainable agriculture. As the world continues to seek wholesome and sustainable food choices, millets emerge as a promising solution that bridges the gap between nutrition, culinary innovation, and environmental consciousness. Integrating millets into our diets not only enriches our plates but also contributes to the broader goals of global food security and sustainable agriculture.

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