

MILLETS AS FUTURE FOR FOOD SECURITY

Abstract

Eradication of malnutrition and hunger, the primary agenda for sustainable development has stressed importance of millets in recent years. The increased attention towards millets due to its adaption to climate change and drought resistant properties has proved beneficial to attain many objectives of food security goals. Serving as best medium for fulfilling world over organizations requirement, millets are not only capable of providing good nutritional content but also beneficial in combating many metabolic disorders. Traditional processing of millets helps in increasing bio-availability of many micronutrients as well as improving its aroma and taste. Increased use of traditionally processed millets in formulation of gluten free products is a promising food sector for near future. Development and study of commonly popular snack such as gluten free biscuits, promised for better nutritional alternative in the existing food product market.

Keywords: ethno-botany, multi-omics, nutrition, small millets, therapeutic traits, food security.

Authors

Layam Anitha

Faculty of Food Technology
Department of Microbiology & Food
Technology
S V University
Tirupati, Andhra Pradesh, India.

K. Aruna Lakshmi

Professor
Department of Biotechnology
College of Sciences, GITAM University
Visakhapatnam, Andhra Pradesh, India.

Pooja Mandlik

Doctoral Student
Department of Microbiology & Food
Technology
College of Sciences, GITAM University
Visakhapatnam, Andhra Pradesh, India.

Vinay Chilakapati

Master student
Department of Food Technology
S V University
Tirupati, Andhra Pradesh, India.

I. INTRODUCTION

Millets serve as one of the best medium to fulfil today's requirement of world-over organizations striving to achieve sustainable food security. These drought resistant crops have many advantages over other cereals such as rice and wheat in terms of their utilization for food, feed, bio-ethanol, bio-films. Millets are coarse cereals, grown seasonally in India and have tremendous advantages in the health and nutritional field. Millets have an alkalizing food effect, and are a mood calming food. Researchers have found these cereals are going to give favorable results in long term illness like Cancer, Type II Diabetes, disorders of the heart and stomach. Millets are rich source of manganese, potassium, iron and phosphorus. Finger millet has 38 times more calcium; foxtail millet has twice the amount of protein, whereas pearl millet has ten times more iron, two times more dietary fiber and five times less fat than rice. In addition, pearl millet has proved to be good source of omega 3 fatty acids and thiamine. Millets are still processed by traditional methods in the semi-arid regions of the world. Malting can be used to enhance the quality of millets. It also helps in the formulation of complementary foods and infant diet. Processing such as soaking, germination improved protein digestibility and bioavailability, decreased polyphenol, tannin, and phytic acid and malting increased the fiber, carbohydrate, moisture and protein content and availability of minerals in different millets. Millet flours are Gluten-free, least allergenic, digest slowly and have a low glycemic index. Many researchers studied gluten free products made with different composite flours. But commercialization of these gluten free products is still on a lower scale. Technical superiority and acceptance of sensory attributes are two main problems faced by earlier researchers while developing gluten free products. Composite flours which are made up of only millet flours, are studied less when compared to other composite flours which included other cereals, pulses, protein powders and fruits and vegetable powders. Thus, present study is an attempt to develop gluten free multi millet biscuit. Processing of millets has an effect on physical, functional and rheological characteristics thereby affecting the outcome of gluten free multi millet biscuit.

II. AGRICULTURE, FOOD SECURITY AND SUSTAINABLE DIETS

Agriculture and its allied sectors are major contributors to the growth of national economy in India and many other developing countries around the world. Agricultural development has ensured economic sustainability and fulfilled the food requirement of 1.3 billion Indians so far. The Green Revolution, alongside other agricultural advancements led to a quantum leap in crop production thus enabling the nation in meeting the burgeoning requirements of the 20th century population of around 1.6 billion. During the 21st century, when the population grew to a whopping 6.1 billion people; novel traits have been applied to increase the production of conventional crops with the help of biotechnological applications. However, need of the current day is to ensure increased food supply and eradicate food insecurity by 2050, by when the population is expected to touch 9.2 billion. Increasing the food production by 70 % within the same size of the land and fewer resources to meet the impending burgeoning food requirements of the nation is the biggest challenge (Pretty et al., 2010; FAO 2009a; FAO 2009b; DuPont Advisory Committee, 2016).

Other than required increase in food and agriculture production, combating food security crisis is a major concern. It is pertinent that challenges lie in the availability of acceptable, nutritious, affordable food and its supplementation to the needy population.

Towards this, Public-private partnerships and small-scale farmer organizations for institutional improvement, adoption of environmental practices, technology application with consideration to rural life and market opportunities, and regulatory and taxation methods for sustainable diets will lead to steady growth in agriculture and food security (Lipton, 2006; World Bank, 2006).

III. CROP YIELD - USE OF TECHNOLOGY; CONFLICT, CLIMATIC CONDITIONS AND ECONOMIC DOWNTURN; FOOD SECURITY GOALS:

- 1. Use of Technology:** Developing countries yield only 30 % of their agricultural potential. Hence, there is a substantial space for increase in yields and cropping intensity through technological advancement, and there is a reduced requirement of expansion of arable land with less damage to the environment through use of chemicals and fertilizers (World Bank, 2010; Deninger, 2011; FAO 2009a). Advanced technological applications such as plant breeding, nuclear techniques, GM crops have been incorporated into the agricultural sector to improve production and accessibility. Technological applications in the field of GM Crops and biotechnology are appropriated on a few focused crops (Maize, Wheat and Rice) and only in high income countries (Pingali, 2007, Atlas and Achoth, 2006). Rampant use of chemicals, pesticides and pathogen resistant crops are resulting in evolution of more resistant pathogens which may spread like fire in the current globalization period. Scarcity and/or uneven distribution of nitrogen and phosphorous, which are essential for increased yield of the nutritive agriculture produce, is caused due to increased soil erosion, which in turn resulted in rising prices of nutrient food and growth in food insecurity, thereby further widening the economic rift between developed and developing countries (SCAR, 2011).
- 2. Conflict, Climatic Change and Economic Downturn:** Rising rift between developed countries and countries rich in natural resources has struck a conflict towards gaining upper hand in acquiring energy and further stance one's dominance in the growing world food and geological insecurity (FAO, 2017). Conflict has resulted in a 14 % global increase in undernourishment and stunting in Children (Global Nutrition Report, UNICEF, 2018). Preserving climate is important towards Sustainable Development Goal 2030. Global warming has created an unpredictable climatic condition which in turn adversely affected agricultural systems. Hence, the requirement of food crops that are sustainable to harsh climatic conditions and promote environmental balance is the need of the present situation (Jain et al., 2016, FAO 2018). Climate change has always been a leading concern for food security (Parry et al., 2009). It not only has an effect on food production, but also on its accessibility and utilization. Every year, around 65% of the cropped area is affected by high variability of monsoon in India (Chakrabarty, 2013). Climate change is also a huge threat to the groundwater level, leading to severe drought situations in several regions in India. In general, extremely high stress of water shortage is experienced by 54% of the Indian regions (Shiao et al., 2015). Rice and wheat, which are considered as the central crops for nutrition in India, get affected by the climate change, thermal stress and acute water shortage conditions (Lal et al., 2001 and Easterling et al., 2007), consequently resulting in low food production and food shortage.

3. Food Security Goals: “Food Security is achieved when one has the physical, social and economic reach to food with respect to quantity, safety and nutritive value to meet the bigger objectives of active and healthy life by meeting diet preferences and requirements” (World Food Summit, 1996 and 2009). Food production alone, therefore, is not sufficient to combat the food security problem. Food security depends on accessibility, availability, utilization and stability of food with an integral dimension of nutrition. Food security also depends on eradication of severe poverty and lack of food, which is the first Millennium Development Goal (United Nations, 2009). UNFCCC-COP 25 was held in Madrid, Spain, in December 2019, to re-state Millennium goal of limiting global temperature to 1.5 ° C rise and for continual focus on climate control with regards to natural calamities and wildfires. Primarily, designing social, economic and trade policies and secondly instilling multi-sector inequality for developing safety thresholds for food and nutrition is a step towards fighting global economy problems, food insecurity and malnutrition (FAO, 2019). Figure 1.1 displays the Severity of food insecurity.

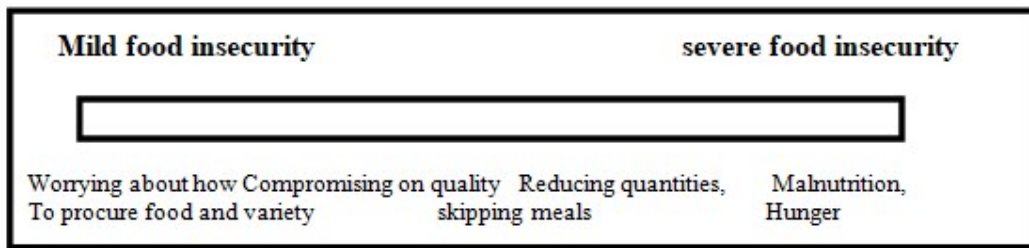


Figure 1: Severity of Food Insecurity - Experience Scale
 (Adapted from FAO– 2019)

Elimination of poverty and thereby attaining food security is possible through sustainable diets. The concept of sustainable diets includes various factors such as well being, health, food nutrients needs, food security, cultural heritage, skills, biodiversity, environment and climate change (Johnston et al., 2014). Promoting sustainable diets is an urgent need for measuring and understanding the role of food systems in nutrition and human health. Sustainable Diets were first defined by Gussow and Clancy in 1986, as ‘a harmony between ecology and food sustainability, for the healthy diet of an individual’. The Sustainable development agenda set up for 2030 is: ‘achieving a world without hunger and malnutrition’ (2030 agenda). Promoting agriculture, ending hunger, improving nutrition status and decreasing food insecurity are some of the essential objectives for the 2nd Sustainable Development Goal (SDG 2) (FAO, 2019). It was aimed to uphold the integrated policy and actions for understanding the positive interrelation between hunger, insecurity, nutritional status and sustainable agriculture. Figure 1.2 displays the determinants and indicators of food insecurity.

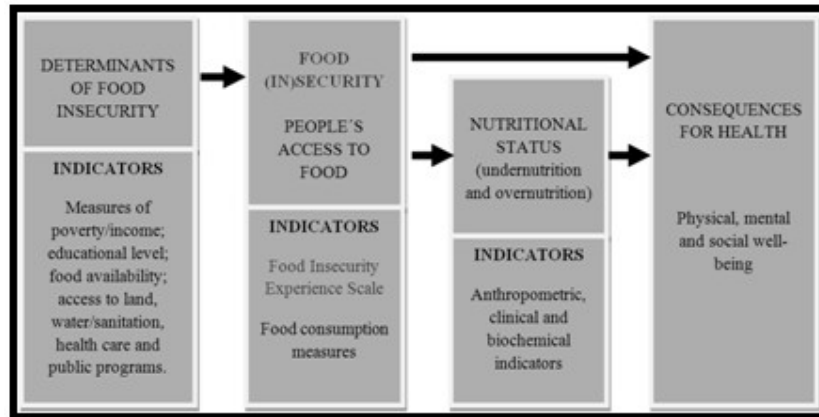


Figure 2: Food Insecurity - Determinants and Consequences
(Adapted from Campbell (1990))

4. Food Insecurity and Malnutrition: Malnutrition is a major obstacle in the developing and underdeveloped countries towards meeting the health goals of people (Phalkey et al., 2015; Global Nutrition Report, 2018). Low availability and accessibility to food nutrients has a long lasting impact on child health. Malnutrition is caused by deficiencies of either macronutrients which are carbohydrates, fats, proteins or micronutrients; vitamins and minerals. These are essential for plugging developmental delays and future cognitive impairment in infants. The Prevalence of Undernourishment (PoU) study suggested that from 2000 to 2013, the percentage of undernourished people is decreased from 14.7 % to 10.8 %. But in 2016, FAO estimates suggested that the prevalence once again rose up to 11 %. As a result of food deprivation and insecurity, people have rampantly fallen prey to eating disorders and stress-induced metabolic responses.

Thus, the diagnosis and incidence of Non-Communicable Diseases (NCD), for example diabetes and heart attack has been integral. Table 1.1 states that a total of 820 Million people were undernourished in 2018 around the world and of which, 278.5 Million were from South Asia. Urbanization, easy access to highly-processed food, high intake of sugar and fat and decreasing importance of traditional diets explains the co-existence of multiple forms of malnourishment, specifically in Low and Middle Income Countries (LMIC) (FAO, 2017; Turner et al., 2019).

Table 1: Number of Undernourished people in the World (2005-2018)

Region	Number of Undernourished People (In Millions)		
	2005	2015	2018
World	947.2	785.4	821.6
Africa	196.0	217.9	256.1
Asia (South Asia)	688.6 (339.8)	518.7 (286.1)	513.9 (278.5)
Latin America and Caribbean	51.1	39.1	42.5

(Source: The State of Food Security and Nutrition in the World, FAO, 2019)

In April 2016, the United Nations declared years 2016 to 2025 as ‘United Nations Decade of Action on Nutrition’ and put a stop to all forms of malnutrition by 2030. Figure 1.3 refers statistics for number of children affected by stunting and overweight during the period from 2000 to 2015. The UN adopted Sustainable Development Goals (SDG) including eradication of stunting, wasting and obesity among children, which are also the indicators of malnutrition in them. In addition, eradication of anemia among women of reproductive age and obesity among adults, improving the percentage of exclusive breastfeeding for infants less than six months of age, are the factors decided upon by the SDG for control over increasing malnutrition (FAO, 2017). FAOSTAT, 2019 defines SDG-12 as responsible consumption and production of food crops by reducing food loss and wastage to fight food insecurity, malnutrition, depleting natural resources and degrading environment.

Nutrition is not only an indicative factor for good health of people and, in turn, the community, but it also indicates the well-being of a country and its economic and social development. This can be achieved through proper nourishment. Chivenge et al., in 2015 stated the potential of the Neglected and Under-utilized Crop Species (NUCS) in mitigating the problems of undernourishment and food accessibility in the water-scarce dry and semi-arid regions of the world. The same was reviewed by Adhikari et al., in 2017 for Pakistan and Nepal and the countries in the Hindukush (HKH) region, which also includes India. These underutilized and neglected groups of crops, also called Orphan or Lost Crops belong to millets (Gupta et al., 2017).

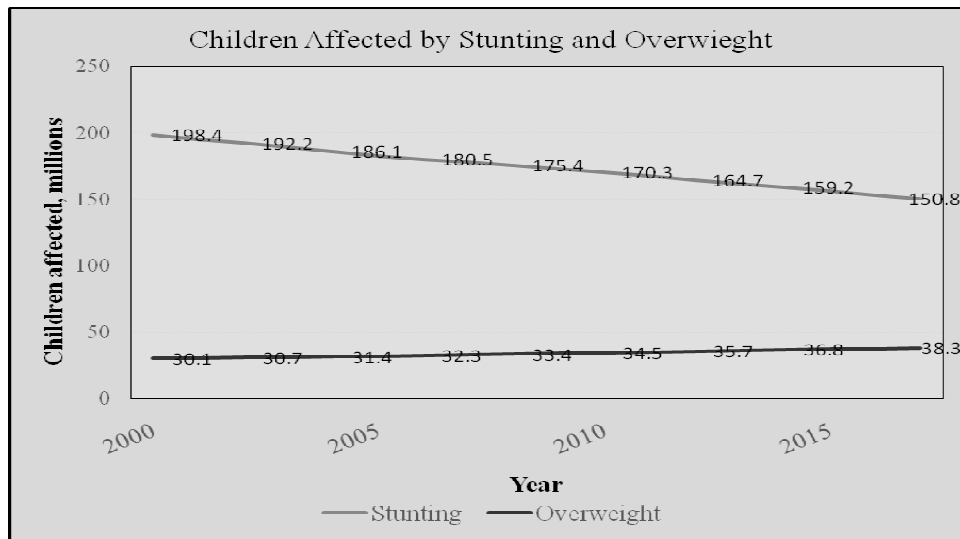


Figure 3: Global Number of Children Affected by Stunting and Overweight

(Source: 2018 Global Nutrition Report. UNICEF / WHO / World Bank Group: Joint child malnutrition estimates)

In order to mitigate the multilevel concerns of climate change, food security and accessibility, undernourishment and metabolic disorders, giving attention to concurrent increase in production and utilization of millets ought to be stressed.

IV. MILLETS

Millets belong to the grass family of Gramineae/ Panaceae and are widespread in approximately 10 genera and 20 kinds in total are used for feed, food and forage (Lata, 2015; Singh et al., 2012). 'Millets' is a common name referring to number of little -seeded annual grasses in dual tribes Paniceae and Chlorideae of the family Poaceae (true grass) (Lu et al., 2009). Widely produced around the world, millets are small seeded grasses which are round and tiny structured and mostly used for food and fodder (Swaminaiduet al., 2015). Millets have shown the capability of growing on infertile land within an extremely wide range of climatic conditions. In adverse agro climatic conditions, the sustainability of millets has proved beneficial (Ushakumariet al., 2004). Countries like America and Europe, where millet is not a daily part of the diet, have realized importance of millets due to their high nutritional content and benefits in many metabolic disorders. However, in the parched/sub-parched regions of Asia, they are known to be a miracle food. In Africa, it is a staple food in many regions; used in many traditional preparations (Chandrasekara and Shahidi, 2011).

Millets serve as one of the best medium to fulfill today's requirement of the organizations, world-over, striving to achieve sustainable food security. These drought resistant crops have many superseding advantages, spanning their utilization for food, feed, bio-ethanol, bio-films etc. Millets are the gluten free coarse cereals which are gaining importance in recent years, not only for their effective role in malnutrition but also in combating major health problems such as diabetes and cardiovascular diseases.

V. PRODUCTION AND CONSUMPTION OF DIFFERENT INDIAN MILLETS

Encompassing 33.6 Million Hectare (M Ha), millet production worldwide was 26.7 Million Tons (MT) in 2009 (FAO statistics, 2009). According to the National Nutrition Monitoring Bureau (NNMB), in India, Gujarat (Pearl millet), Karnataka (Finger millet and Foxtail millet), Maharashtra (Sorghum) lead and Kerala, Orissa and Tamil Nadu lag in the production and consumption of millets (Sarita and Singh, 2016). From the year 2010 to 2014, Asian countries showed significant contribution to the increased production of millets from 48.72% to 52.25 %. FAO data suggests that after maize, paddy, wheat and barley, sorghum is the fifth major crop produced all over the world.

Kulkarni, 2018, stated that, in India, area under millet production reduced from 37 M Ha in 1066 to 14.72 M Ha in 2017, when production of millets itself in 2017 was 16.14 Million Tons (MT). The reduction in Area of Production was attributed to consumption habits, low yield of millets view allotment of irrigation for rice and wheat. Surendranet al., 2019 reported factors affecting low consumption of fruits and vegetables in India. They included proximity to produce, availability and accessibility, occupational shift of farmers, price and affordability, vendor and product properties (Time for which product could be stocked) and desirability. Despite its adaptability and agronomic features of subsistence cereal, only 3 million tonnes of finger millet is produced each year around the world (Opole, 2019). With increased awareness and initiative in Karnataka, India, yield of small millets was increased to 8-12 Quintals per Acre overriding drought like climate and economic slowdown. With organizations such as 'earth 360' in Andhra Pradesh and Indian central government's millet mission, productivity of millets was increased by generating good quality millet seed banks and farm gate decentralized model of primary processing facilities for decreasing

production cost and increasing profit incentive to farmers. To increase the production of millets, IIMR, Hyderabad in 2019 released three Varieties of High Yield (HYV) Sorghum, namely, JaicarHeera, Jaicar Sona and Jaicar Gold, for production in India (Annual Report, IIMR, 2019).

In the current scenario, pearl millets cover 260000 KM² harvested area around the world. This is half the total area used for harvesting all the types of millets. It is pertinent to mention that, above 98% of total global pearl millet market is contributed by Asia and Africa (Nutritional and Health benefits of millets, 2017).

Table 2: Indian Millet Production Year on Year (1998-2018)

Year	Production	Unit of Measure	Growth Rate
1998	10235	(1000 MT)	-1.31 %
1999	8690	(1000 MT)	-15.10 %
2000	10078	(1000 MT)	15.97 %
2001	11235	(1000 MT)	11.48 %
2002	6494	(1000 MT)	-42.20 %
2003	14639	(1000 MT)	125.42 %
2004	10841	(1000 MT)	-25.94 %
2005	10509	(1000 MT)	-3.06 %
2006	10347	(1000 MT)	-1.54 %
2007	12673	(1000 MT)	22.48 %
2008	11372	(1000 MT)	-10.27 %
2009	8777	(1000 MT)	-22.82 %
2010	13005	(1000 MT)	48.17 %
2011	12657	(1000 MT)	-2.68 %
2012	10752	(1000 MT)	-15.05 %
2013	11663	(1000 MT)	8.47 %
2014	11630	(1000 MT)	-0.28 %
2015	10280	(1000 MT)	-11.61 %
2016	11560	(1000 MT)	12.45 %
2017	11550	(1000 MT)	-0.09 %
2018	9400	(1000 MT)	-18.61 %

(Source: United States Department of Agriculture, 2019)

Table 2 shows the history of Indian millet production while table 1.3 estimates the vision for improvement in area of cultivation, production and yield of millets by 2050. This estimate is an important step following the UN report on the state of food security around the world in 2019 towards meeting estimated increase in global demand of food (3 Billion Tonnes) by 2050 (FAO, 2019).

Table 3: Millets Cultivation and Production; Projection up to Year 2050 AD

Millets	Scenario I			Scenario II			Scenario III		
	Area (M Ha)	Yield (Kg/Ha)	Production (MT)	Area (M Ha)	Yield (Kg/Ha)	Production (MT)	Area (M Ha)	Yield (Kg/Ha)	Production (MT)
Sorghum	1.32	1378	1.82	1.32	3000	3.96	2.00	3000	7.00
Pearl Millet	9.00	1214	10.92	9.00	2500	22.50	15.00	2500	37.50
Finger Millet	1.11	1428	1.59	1.11	2500	2.78	4.00	2500	10.00
Foxtail Millet	0.75	750	0.43	0.75	1500	1.13	2.0	1500	3.00

(Source: Vision Document 2050, IIMR Hyderabad, 2014)

Scenario I: Existing situation with current levels of Area, Production and Productivity

Scenario II: Area retained and increased Productivity due to High Yield Varieties

Scenario III: Positive impact on area view supporting policy by government for Production, Processing and Value Addition)

- 1. Production and Consumption of Finger Millet:** The worldwide percentage for area of cultivation of finger millet is 12%. The area of cultivation spreads over 25 countries in Africa and Asia. Area under production for finger millet stands sixth in India following wheat, rice, maize, sorghum and pearl millet (Chandra et al., 2016).

Finger millet is a principal and indispensable food variety in India as well as Eastern and Central Africa. The cultivation area for finger millets in India is 2.65 M Ha. Karnataka is the leading state producing this cereal in India, contributing 58 % of the total produce in the country (Rane et al., 2014; Sarita and Singh, 2016). In Tamil Nadu and Gujarat, finger millet is produced as an irrigated crop. The productivity of the crop is found to be approximately 1500 Kg per Hectare (Kg/Ha) in India (Shukla et al., 2015; Swami et al., 2013). Mandua, as it is better known in India, it can be produced in varying altitudes between Mean Sea Level (MSL) to an altitude of 1800 meters, while in the Himalayas up to 3000 meters above MSL (FAO, 2012; Dida et al., 2006; Bisht and Singh, 2009). The efficiency of yield is, hence, very high due its nil variation towards climatic and environmental conditions (Kumar et al., 2016).

- 2. Production and Consumption of Sorghum:** The production of Sorghum in Africa is among the largest in the world, with a production of 22.5 (M MT) in 2005 (Rosemary et al., 2007). Amongst the producers and exporters of sorghum, the United States was the largest with 20% and 80% of world production and exports, respectively (USDA-FAS, 2003). Major variables affecting Sorghum production are subset of the factors defined by UN Summit on climate change (UNSCC), 2019, for food security by 2050 (Mundia et al., 2019). Consumption wise, sorghum is mostly identified with the African countries. With

respect to the total area of production of sorghum, Africa (59%), Asia (25%), North America (11%), South America (4%) and Europe (1%) stand in that sequence. The total quantity of sorghum produced in the world is 46 % from Asia and North, Middle and South America with 27 %, 21 % and 6 % respectively (Nemeth, 2009). India was the third prominent producer of sorghum in the world with a produce of 6.30 MT in the year 2011, which now slipped to fifth rank behind US, Mexico, Ethiopia and Nigeria preceding it (World Agricultural Production, USDA, 2019).

3. Production and Consumption of Pearl Millet: Pearl Millets are produced on greater than 28 M Ha of ground in the dry tropical regions of Asia (USDA, 2005). The determined production of pearl millet in developing countries is found to be over 95 %. Pearl millet is a traditional cereal produced by cultivators in Maharashtra and Karnataka on the Deccan plateau and in Tamilnadu. India grows around 5 MT of pearl millet per year and contributes around half of the world pearl millet production. Rajasthan, Gujarat and Maharashtra contribute to around 70 % pearl millet production in India. However, the production has been observed to have declined from the year 2007-2011 in these regions and improving thereafter. To improve the production and consumption of this crop with high content of minerals (Iron and Zinc), Pearl Millets are being cross pollinated by fast-track breeding and biofortified breeding pipelines of derived varieties to fight malnutrition in semi-arid regions of India (Govindarajet al., 2019a). Pearl Millet High Yield (HY) Open Pollinated Varieties (OPVs) and Hybrids (03 types) were first introduced in India (Govindarajet al., 2019b). Market opportunities for these crops and thereby consumption is possible by introducing them to Public Distribution System (PDS) and facilitating opportunities.

4. Production and Consumption of Foxtail Millet: Since ancient times, Foxtail Millet, also known as Italian millets, has been cultivated in Eastern Asia. Prasad et al., 1987 suggested that it has been part of central China since 5000 years. Domestication is responsible for spreading this crop to India, Africa and Europe (Pawar and Machewad, 2005). Raxhie, in 1975, reported that yields in China exceeded 11,000 Kg/Ha and Rawat and Tyagi, in 1998, reported that China ranked first in the production of foxtail millet. Foxtail millet was a major rain-fed crop in India, however, presently, continued cultivation is observed only in scattered locations in India. Foxtail millet is produced in different state of India mainly in Karnataka, Maharashtra, Andhra Pradesh, Tamilnadu, Rajasthan (Kusuma, 2011). Patil and Sankangoudar, 2019, studied the consumption pattern of Foxtail Millets in Dharwad amongst Growers and Non-Growers of this crop from same and different village. It was reported that Foxtail Millet is consumed less than 10 % by growers and less than 5 % by Non-Growers from both categories monthly. The percentage of consumption falls below 2% for weekly and daily analysis. However, consumption was reported to be more than 40% on occasions/ festivals. Consumption pattern was defined by difficulty in processing of these crops for food preparation.

VI. NUTRITIONAL SIGNIFICANCE OF MILLETS

Millets are unique among cereals, as they are calcium, dietary fiber, polyphenols and protein rich (Devi et al., 2014) and also contain abundant iron, magnesium, phosphorous and potassium (Stanley et al., 2013). Millets usually contain considerable quantity of necessary amino acids, especially sulphur containing amino acids, methionine and cysteine. They have

higher fat content compared to maize, rice and sorghum (Obilana and Manyasa, 2002). Nutrient opulence of millets has earned them denotation, that is, 'Nutra-cereals' or 'Neutraceuticals' (Stanley et al., 2013). A comparative nutrient composition between wheat, rice, maize and different millets is tabulated in table 1.3. It is observed that, millets are superior in protein, fiber and micronutrient contents when evaluated with wheat, rice and maize.

- 1. Carbohydrate Content in Millets:** Percentage of carbohydrates in **finger millet** was observed within 60.80 to 85% according to McNeill et al., 1975 and comprised of Pentosans (7.2%), cellulose (1.8%) (Wankhede et al., 1979), free sugars (1.04%), starch (65.5%), loose polysaccharides (Malleshiet al., 1986) and dietary fiber (Gopalan et al., 2009). Maximum proportion of carbohydrates was in the form of flexible polysaccharides (Swami et al., 2013). Finger millet is composed of both simple and compound starch sub-constituents and has a large variation in shape and size. The amylose content of starch found by Mohan et al., 2005, was 22%, which was found to be enhanced when compared with the one suggested by Malleshiet al., 1986, that is, 38.6%. The percentage of carbohydrates in **Sorghum** were found to be around 60.80% according to McNeill et al., 1975. Around 94% starch is contained in the endosperm of the sorghum grain kernel and 69.5% average in the grain. Less than 5% amylose is found in the waxy varieties of sorghum whereas 23 to 30% of the amylose content is found in regular endosperm varieties (Leder, 2004).

**Table 4: Nutrient Composition of Millets and Other Cereals
(Per 100 g edible portion; 12% moisture)**

Food	Protein ^a (g)	Fat (g)	Ash (g)	Crude fiber (g)	Carbo- hydrate (g)	Energy (KCal)	Ca (mg)	Fe (mg)	Thiamin (mg)	Riboflavin (mg)	Niacin (mg)
Rice (brown)	7.9	27	1.3	1	76	362	33	1.8	0.41	0.04	4.3
Wheat	11.6	20	1.6	2	71	348	30	3.5	0.41	0.1	5.1
Maize	9.2	4.6	1.2	2.8	73	358	26	2.7	0.38	0.2	3.6
Sorghum	10.4	3.1	1.6	2	70.7	329	25	5.4	0.38	0.15	4.3
Pearl millet	11.8	4.8	2.2	2.3	67	363	42	11	0.38	0.21	2.8
Finger millet	7.7	1.5	2.6	3.6	72.6	336	350	3.9	0.42	0.19	1.1
Foxtail millet	11.2	4	3.3	6.7	63.2	351	31	2.8	0.59	0.11	3.2
Common millet	12.5	3.5	3.1	5.2	63.8	364	8	2.9	0.41	0.28	4.5
Little millet	9.7	5.2	5.4	7.6	60.9	329	17	9.3	0.3	0.09	3.2
Barnyar d millet	11	3.9	4.5	13.6	55	300	22	18.6	0.33	0.1	4.2
Kodo millet	9.8	3.6	3.3	5.2	66.6	353	35	1.7	0.15	0.09	

(Sources: Hulse et al., 1980; United States National Research Council/National Academy of Sciences (1982); USDA/HNIS (1995); FAO (1995). Modified from Gopalan et al., 2004)

(^a - All values except protein are expressed on a dry weight basis) Starch, an essential factor of sorghum, has a very complex structure. Starch digestibility is increased with processing methods such as steaming, puffing, micronization (milling and grinding) due to its release from the protein matrix. Sade, in 2009, found the carbohydrate content in **Pearl Millet** to be around 71%. Pearl millet's amylose percentage spanned 20-21.5%. Swelling power and solubility of pearl millet starch is higher as compared with other millets. Starch in different varieties of pearl millet varies from 62.8 to 70.5%; soluble sugar between 1.2 to 2.6%. In pearl millet grain, non-starch polysaccharide fractions include glucose, arabinose, xylose and uronic acids which are monosaccharide's (Hoseney, 1994; Hadimani et al., 2001; Taylor, 2004). Due to the absence of gluten, carbohydrate percentage is low in pearl millet and thereby, resulting in a low glycemic index (Suma and Urooj, 2014; Singh et al., 2010). Carbohydrate content in **Foxtail Millet** is around 61%, which is comparable to other millets (Kusuma et al., 2013).

2. Protein Content in Millets

- **Finger Millet** grain has the highest percentage of proteins (10%) amongst the cereals and with a range of 5–12% as researched by Srivastava, 2006. Prolamins content found in finger millets is around 35 to 50%, whereas, albumins and globulins around 8 to 15% of total proteins. Finger millets contain high levels of methionine and other amino acids (around 3%, which is exceptionally high for a cereal grain). Amino acid content is found to be good with a total of 44.7% (Mbithiet al., 2000) and the distribution is 2.5% lysine, 13% tryptophan, 3% methionine, 3.1% Threonine and 4% leucine and isoleucine. Other essential amino acids present are Arginine and lecithin.
- **Sorghum** proteins, the second most major nutrient of sorghum, can be classified depending on their solubility into albumins (water soluble), globulins (salt soluble), Kafirins (alcohol soluble) and glutelins (dilute-alkali soluble) (Osborne 1924; Landry and Moureanx, 1970, Abdelhalem, 2006). When compared to wheat proteins, sorghum proteins are found to be superior with regards their solubility. Sorghum is rich in amino acid leucine and has shown good digestibility and biological value (Kazanas and Fields, 1981 and Au and Fields 1981). Sorghum has shown 11 to 13% of protein and even higher values have also been reported (Dendy, 1995).
- **Pearl Millet** showed higher percentage of protein (9 to 13%) when compared to other cereals as stated by Desikachar, 1975. Comparison of the pearl millet to maize brought out that it is enriched with 40% Lysine and Methionine and 30% Theronine. The protein and energy in the crop is one of the highest as reported by Chikwenduet al., 2014. High level of necessary amino acids, amino acid balance and high In Vitro Pepsin Digestibility values in pearl millets proved to be a good source of protein to humans (Ejetaet al., 1987).
- **Foxtail Millet** has a higher percentage of protein content, which is around 12.3%. FAO, 1970 report presented leucine (16.7g /100g of protein) as the highest and Histidine (2.1g /100g of protein) as the lowest by weight in the amino acid composition in foxtail millet. Other amino acids were isoleucine, phenyl alanine and valine. Their fraction in foxtail millets was higher when compared to other amino acids.

3. **Fat Content In Millets:** The percentage of fats in **Finger Millet** is reported to be around 1.2g. Fats in finger millet include fatty acids - oleic (49%), linoleic (25%) and Palmitic acids (25%) (Sridhar and Lakshminarayana, 1994). 72% of total lipids in finger millets exist as glycolipids and phospholipids with 13 % and 6% content, respectively (Mahadevappa et al., 1978). The crude fat content was superior in **Sorghum** when compared to other cereals. Major sources of fat in sorghum kernel structure are the germ and the aleurone layers. The fat content in the germ is proportionate to about 80% of the total fats in sorghum.

Fat percentage of sorghum is higher than that of rice and wheat, i.e. 3%, with high concentrations of Palmitic acid (14%), oleic acid (31%) and linoleic acid (49%) (Leder, 2004). **Pearl Millet** fats contain linoleic acid which is just 0.9% of the total fatty acids and therefore, pearl millets are low in n-3 fatty acid content which plays a characteristic role in undesired physiological activities like platelet gathering, LDL cholesterol increase and damage to the immune system (Kaur et al., 2014).

Foxtail Millet showed fat content ranging from 3.5 to 4.75 gm/100 gm, which is higher compared to other cereals except pearl millet (Geervani and Eggum, 1989; Kusuma et al., 2013). Foxtail and proso millet showed higher acid value and hydroxyl value for oils where stearic and Palmitic acids were found to be highest. Linoleic and oleic acid comprise 80% of the extractable lipids in foxtail millets (Adrian and Jacqoute, 1964).

4. **Fiber Content in Millets:** The fiber in **Finger Millets** is indigestible as finger millet seeds are covered with hulls that are difficult to remove by household processes. These fibers have a lot of health benefits including enhanced digestibility and improved peristaltic movements in intestinal tract (Rane et al., 2014). The percentage of fiber in finger millets is around 2%. Dietary fibers found are of two types, water soluble and insoluble. The percentage of water-insoluble fiber is 13 – 15% more than the counterparts in total dietary fiber content as described by Chethan et al., 2007 and Shobhana et al., 2007. **Sorghum** constitutes different dietary fiber types viz, hemi-cellulose, cellulose and soluble dietary fibers (Ndiaye et al., 2008). Insoluble fiber content in sorghum is found to be 86.2% (Leder, 2004). De-pigmentation of **Pearl Millet** results in better invitro digestibility of soluble dietary fiber, however, it reduces their actual content on ground (Archana et al., 2004). Crude fiber in **Foxtail Millet** was reported to be superior to wheat, rice, little millet and proso millet. It showed 8.0% of crude fiber (Gopalan et al., 2004). Kusuma et al., 2013 stated very high dietary fiber content in foxtail Millet, around 14 %. High fiber content in foxtail millet helps in management of diabetes.

5. **Vitamin and Mineral Content in Millets:** Mineral content in **Finger Millet** constitutes calcium at around 300-350 mg/100g, iron 3.9% and phosphorous around 283mg/100g (Gopalan et al., 2000). The high calcium content in finger millet has no match amongst other cereals (Gari, 2002). Finger millets are a unique source for vitamins, both water-soluble and lipo-soluble. The concentrations of vitamins in finger millet are found to be - thiamine 0.25 mg, VitaminA 6.1 mg, VitaminC 1.2 mg, folic acid and niacin 1.1 mg (Vidyavati et al., 2004; Swaminaidu et al., 2015).

The **Sorghum** grain kernel includes the embryo, approximately 10% of the size of the grain, bran layer (pericarp) around 8% of the grain and the endosperm, the structure of the outermost layer of the sorghum grain, is greater than 80% of the grain. The largest proportion of the architecture endosperm contributes around 50 to 75% B-complex vitamins (Kulamrvaet al., 2009). Other than the B-complex vitamins, sorghum is a source of fat-soluble vitamins like Vitamin D, Vitamin E and Vitamin K, however, does not include Vitamin A and Vitamin C. Thiamin, riboflavin and niacin are present in sorghum in equal measures when compared to other grains. Beta carotene pre-existent of vitamin A is found in traces in sorghum varieties.

Pearl Millets are a rich source for Phosphorous and Iron and a very good source for calcium and zinc as well (Eyzaguirre et al., 2006; Millet Network of India (Deccan Development Society, FIAN, India)). Calcium content in pearl millet is around 300-350 mg/100g, iron 3.9% and phosphorous 283mg/100g (Gopalan et al., 2000). Being a rich source of calcium and phosphorus (Ramanathan et al., 1975),

Foxtail Millet showed a high total mineral content of 3.3%. This accounts higher than the calcium and phosphorous contained in wheat and rice, as reported by Gopalan et al., 2004. The calcium and phosphorous content in foxtail millet were found to be 31 mg and 290 mg per 100 g as observed by Kusuma et al., 2013. Foxtail Millet is a good source of magnesium and thus referred to as a healthy heart food (Reddy, 2017).

6. Micro-Nutrient Content in Millets

- **Iron:** Iron helps in DNA and enzyme-binding oxygen consistency, bodily rate and immunity (Anderson et al., 2012). Classification of iron as it is found in food can be either haem or non-haem. Haem iron exists as hemoglobin and myoglobin. Lack of inclusion of haem iron resulting in low hemoglobin amongst people in progressing countries heightened outcome of Child and Women Iron Deficiency Anemia (IDA) (Young et al., 2018, Mann et al., 2012, Geissler et al., 2011). Haem iron absorption (around 35%) is independent of physiological and dietary factors, whereas, non-haem iron depends on dietary components and health status of individuals. The bioavailability of iron is better in moist heat methods as compared to dry heat methods used for studies (Mounika et al., 2017). Phytates, tannins are the antinutrients which inhibit formation of iron-catalysed hydroxyl radicals. Phytates have an anti-nutritional factor due to significant amounts of inositol hexaphosphates (IP6). Therefore, phytic acid content is reduced in foods, leading to increased absorption of iron. Iron is found to be concentrated in the endosperm and the decortication treatment for a controlled duration removed it approximately 46 to 62% from the grain (Hama et al., 2011).

Pearl millet consists of a good quantity of Fe and Zn and is a crucial grain with regards to breeding based biofortification or enhancing nutrient levels and for a fight against malnutrition in semi-arid tropical region (Kumar et al., 2018). Kodakanyet al., 2013 determined the amalgamation of Fe and Zn in pearl millet (found in abundance in Karnataka) which are deficient in non-fortified plant-based foods worldwide and found it to be superior in pearl millets when compared to **Sorghum** and rice. In the decreasing order, the iron content per 100 g of grain was

observed to be 9.0 mg in pearl millet, 7.0 mg in **Little Millet**, 4.0 mg in sorghum 3.65 mg in **Finger Millet**, 2.6 mg in **Foxtail Millet** and 2.6 mg in **Proso Millet**, while in wheat it was 4.5 g and in rice it was 0.5 mg (Mounika et al., 2017).

- **Zinc:** Zinc ranks sixth among top 10 risk factors for diseases in developing countries (WHO, 2002). Micronutrient malnutrition affects around 66% of the global population as stated by Stein et al., 2010. The mean zinc absorption below the physiological requirements causes stunted growth in children (Brown et al., 2002). Absorption of Iron and Zinc amongst children who were kept on only pearl millet diet was found to be above the physiological requirement of 0.54 mg/g and 2.5 mg/g in that order as given in the Food and Nutrition Board, 2001 (Kodakanyet al., 2013). Zinc content is found to be highest in Prose millet and lowest in finger millet (Mounika et al., 2017).
- **Copper:** As the millet grains are consumed as a whole and are only hand crushed compared to rice and wheat which are refined, the mineral content in millets is found to be high. However, the same is limited due to inhibition from inherent antinutritional factors. Soaking and germination help reduce these factors in millet grains (Jood and Khetarpaul, 2005). **Copper** exists in association with phytic acid in plant foods leading to its poor availability. Soaking and germination causes liberation of the copper ions (Hemalatha et al., 2007). Sorghum copper content was observed to be increased to an order of 2 from 0.19mg/100g to 0.40mg/100g after sprouting due to degradation in phytate, known to hold minerals into low molecules (Azhar et al., 2015). Bioavailable intake rather than the gross intake of minerals appropriately defines the method for assessing the food products. Agteet et al., 1999 reported that percentage capacity of Zinc and Copper to separate by dialysis (also known as dialyzable Zinc and Copper) was found to be higher in rice (10.0 and 35.7 %) than in pearl millet (6.8 and 26.6 %) based foods, however, the total Zinc and Copper content in Pearl millet diets (3.1 and 1.06mg/100g) available for dialysis was upto 10 times higher than rice (1.4 and 0.14 mg/100g) based diets. The decrease in bioavailability of Cu in pearl millet may be due to binding with phytates and tannins whereas the gross high mineral content is due to the grain goiterogenicity (Abdelrahman et al., 2005). It was also found that the bioavailability of minerals including copper differs in composite meals as compared to the individual ingredients of the meal.

7. **Antinutrient Content in Millets:** Antinutrients bring serious consequences by modifying nutrient availability (Abdelhaleem, 2006). Millets consist of tannins (mostly found in finger millets (Ragi) and sorghum), flavonoids, phenolic acids (pearl millets, sorghum and finger millet) and alkyl resorcinol among the phenolic compounds and amides among others. These anti-nutrients are located mostly in the outer endotherm or the bran of the grain which gives the grain its color. Waniska, 2000, stated that tannins help maintain the grain mould of millet and are a good source of anti-carcinogenic, anti-ulcerogenic, gastro-protective and cholesterol lowering contents. Derivatives of Benzoic (11-16) or Cinnamic (17-21) acid are majorly denoted as phenolic acids (PA) of Sorghum. Phenols maintain flavor, texture, color, oxidative stability and taste of food products as researched by Naczka and Shahidi in 2004.

Phytin or phytate is a form of phytic acid, obtained when mixed with magnesium, potassium and calcium salts in seeds. Comprising of 1-3% of legumes, cereals and oil seeds, it acts as a major storehouse for phosphorus (Graf, 1986). Phytic acid forms complex bond with calcium and protein, the latter being multivalent (Haug and Lantzsck, 1983). Protein digestibility and trace minerals availability is, however, reduced by this kind of formation. The structure of phytates is depicted in Figure 1.4 below. Finger millets consist of a considerable amount of Inositol Hexaphosphate (IP6) or phytates (contribution of 150mg/100g as given by Pragya Singh et al., 2011), an anti-nutritional factor affecting the assimilation of Ca, Mg, Zn, Fe, Cu and Mn. Phytates, otherwise, are responsible for chelating reactions forming iron catalysed hydroxyl radicals (Honkeet al., 1998).

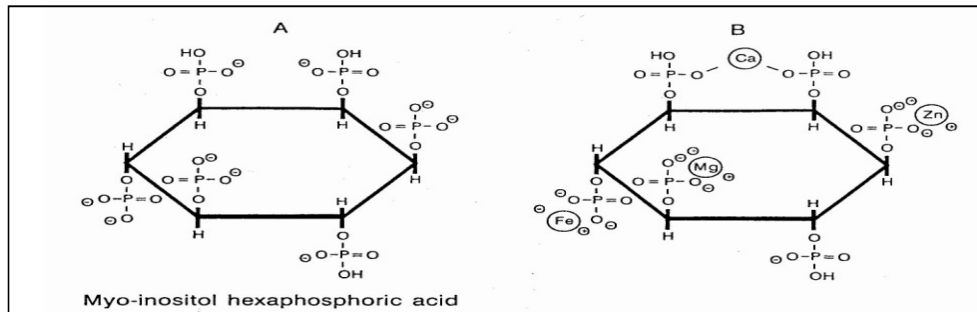


Figure 4: Structure of Phytic Acid and Phytic Acid Chelate

Out of all the phytochemical components in **Sorghum**, tannins have superlative importance as they consist of properties that generate viable and important factors in animal and human health. These viewpoints are explained by the harvest and genus of tannin sorghums. Tannins also reduce the feed value. They bind to nutrients resulting in loss of digestibility of different food/ feed kinds. They have better tolerance to pests and diseases and control the pigmented test a layers using B1 and B2 genes present in them. Tannins are structurally complex which make them hard to isolate and characterize in an effective manner. The shell of a grain, also called bran, consists of the highest percentage of sorghum PA in cereals. PA may be found bound or stuck to cell wall polymers as well (for example – extensively found bound PA in sorghum is Ferulic acid (18) (Hahn et al., 1983) and other grains (Nordkevistet al., 1984; Adam and Liu, 2002).

Phytates and phytic acids form complexes with the nutrients to decrease their bioavailability thus making their absorption difficult. Phytic acid found in **Pearl Millets** is considerably high with 825.7mg per 100g; bringing out a negative effect on its nutritional value (Kumar et al., 1993). The seed coat or endosperm demonstrate high antibacterial and anti fungal action due to the presence of high polyphenol content. Polyphenols hold the nutrients bound to them and the nutrients are, then, not bio-available. The nutrients held include minerals, for example, iron and zinc (Eyzaguirre et al., 2006). Antimicrobial and antioxidant activities are predominant due to the polyphenol content in pearl millet as given by Chethan and Malleshi in (2007).

Foxtail millets are rich in phytochemicals and antinutrients such as polyphenols (Tannins and Phenolic Acids) (0.052mg/100gm), flavonoids, flavones and phytates

(1.94mg/gm). The presence of polyphenols is proved from the testa and the outer pericarp of the whole grain. These anti-nutrients cause lack of IVPD and availability of iron and zinc. The presence of phytochemicals in foxtail millets gives them the brand value of availability of natural antioxidants, thereby, enhancing their market potential.

- 8. Processing of Millets to Reduce Antinutrient Content:** Kayoed, 2006 and Steiner et al., 2007 reported that breakdown of certain nutrients such as phytate and protease inhibitors can be achieved by germination. Nayini and Markakis, 1983 discussed milling, Chang et al., 1977 described soaking and Vidal-Valverde et al., 2001 explained germination, which could lead to decreased phytate level in plant matter. Mahgoub and El Hag, 1998 reported that the natural fermentation of four sorghum cultivars namely Hageen, Fetarita Gezira, FetaritaGadarif and Dabar, for 20 hours in Sudan, showed decrease in phytic acid content by 60%, 58%, 58% and 57 % respectively. Whereas Marfoet al., 1990 found a 52% loss of phytate in red sorghum variety. Malleshi and Desikachar, 1986 and Opuket al., 1981 reported that phytic acid levels reduced in cereals which underwent sprouting.

Addition of malt has reduced phytate content in corn, as given by Fageer and Tinay, 2003 whereas Tangkongchitret al., 1981b, described that denaturation and inhibition of phytase may occur during 48 hours of fermentation. Incubation, germination and fermentation with malt (Salunkheet al., 1977), treating of sorghum grain with formaldehyde (Graf et al., 1982), strong alkalies (Chavan et al., 1979) and ammonia (Price et al., 1978) are a few methods which helped in reduction of tannins in sorghum. Butler, 1982 observed that major assayable tannins in sorghum were eliminated by 5 days of germination.

Dehulling of foxtail millet resulted in reduction of anti-nutrients by 41.49%, while soaking resulted in stripping the anti-nutrients from the grain by just 3.75%, whereas dehulling in combination with soaking and cooking resulted in reduction of polyphenols by 59.02% and phytates from 1.94mg/gm to 0.032mg/gm. It also caused an increase in availability of minerals by 45 % and IVPD by 32 % (Pawar and Machewad, 2005).

VII. EFFECT OF PROCESSING ON MILLETS

Millets such as sorghum and finger millets are still processed by traditional methods in dry regions of the world. The germ, protective pericarp and starch containing endosperm are three major constituents which get affected by the processing methods (Eastman, 1980).

Malting can be used to enhance the quality of millets. It also helps in formulation of complementary foods and infant diet. Soaking of millet and steeping process is often referred to as germination (Roohinejad et al., 2010). Soaking and germination brings about hydration of grains which leads to multiple accelerated chemical reactions. It helps in increasing the availability of minerals and breakdown of complex macronutrients such as carbohydrates, fats and protein (Mayer and Poljakoff, 1963). Bioavailability is increased for vitamins such as vitamin C, niacin and riboflavin (Lay and Fields, 1981).

One of the most valuable effects of germination is conversion of starch to soluble sugars. Amylase and amylopectin are the two enzymes which play a vital role in converting starch into dextrin and maltose (Seenappa, 1987). Germination of soybean and finger millet

was studied by Magala-Nyagoet al., 2005. They observed that soybean, when germinated for 72 hours at 25°C showed increased beta carotene from 1102% to 8316.9 % whereas finger millet showed a rise of 126.9% for 48 hours of germination at 30°C. Griffith and Castel-Perez (1993) studied the effects of malting and roasting on cowpea, peanut and pearl millet with respect to their physicochemical properties. They observed that malting has the most significant effect on the physiological properties. Reduction in viscosity of the flour is also brought about by malting.

Hasan et al., 2006, described that soaking and germination of pearl millet for different sets of hours led to improved protein digestibility and polyphenol, tannin, and phytic acid reduction. Naveena and Bhaskarachary (2013) observed germinated millets and legumes samples, such as finger millet, sorghum, green gram dal, horse gram whole and others for 0, 12, 24, 48 and 72 hours and then analyzed the samples for total polyphenolic content. They concluded that processing improved the bioavailability of proteins and minerals. Laxmi et al., 2015 studied the effect of malting on foxtail millet flour and concluded that malting increased the fiber, carbohydrate, moisture and protein content and availability of minerals. However, it reduced fat, ash and calcium content in foxtail millets.

VIII. HEALTH BENEFITS OF MILLETS

Millets are coarse cereals, grown seasonally in India and have tremendous advantages in the health and nutritional field. Millets have an alkalizing food effect, and are a calming mood food (Sarita and Singh, 2016). Researchers have found these cereals to be giving favorable results in long term illnesses like cancer, type II diabetes, disorders of the heart and stomach. Millet flours are gluten-free, least allergenic and digest slowly and hence, are useful and highly recommended for consumption by diabetic patients in India. They are easy to absorb and do not cause any harm to the lining of the intestine.

Neutraceutical drugs benefiting human health are defined as the food components which support health and supplement dietary health benefits for prevention, treatment and cure of various cardiovascular and lifestyle diseases. Neutraceuticals are used equally in the food industry as well as in factories as pre-processors for the production of different nutrients. This proves them to be of dual benefit to the industry over and above the basic nutrition (Srivastava et al., 2012). Presently, finger and pearl millets are amongst the high potential neutraceuticals available in the market.

1. Cancer: Frequent consumption of sorghum found low cases of esophagus cancer in Africa, India, Russia, China and Iran (Rensburg, 1981). Sorghum tannins and polyphenols (common in tannins and red wine, tea) were found to be anti-carcinogenic (Awika et al., 2003). Sorghum reduces the impact of cancer on human health due to its antioxidant characteristics. Finger millets are used in preventive medicinal health and have been advantageous in reducing fat content in diet and increasing dietary fiber thus preventing colon cancer as researched by Schatzkin et al., 2007 and Lattimer and Haub, 2010. Dietary fiber in finger millets further helps reduce constipation, prevents gallstone formation and intestinal cancer (Usha, 2004). Phytate constituents in finger millet reduce cancer risk. Pearl millets are used for curing high cholesterol and fat content, constipation, preventing diabetes, atherosclerosis and colorectal cancer (Mathangi and Sudha, 2012). Due to the unique, bound composition of phytochemicals in foxtail millets, they sustain stomach and

intestinal reactions to arrive at the colon. This results in prevention of colon, prostate and other digestive system cancers (Suma and Urooj, 2012).

2. **Cardio Vascular Diseases (CVD):** Consumption of whole grain sorghum has a positive cholesterol-lowering effect; it increases the HDL levels without increasing the overall cholesterol (helps reduce occurrence of Cardio Vascular Diseases) due to its composition of tannins, phytochemicals, phytosterols, policosanols and polyphenols. Hegde et al., 2002 confirmed that Vitamins A and B and phosphorous in finger millet help in lowering high cholesterol levels. According to Pradhan et al., 2010, patients with diabetes, heart disease or atherosclerosis benefit the most from finger millets as it lowers blood pressure and heart attack risk. The antioxidant activities in pearl millet help manage cardiovascular and geriatric diseases (Zhang and Liu, 2015). Foxtail millet has cholesterol lowering properties due to its high fiber content (Kusuma et al., 2013).
3. **Obesity:** High percentage of tannins in sorghum has weight-reducing properties. This occurs when the nutritional value of the food is reduced by developing bonds with proteins and carbohydrates into insoluble composites which cannot be biodegraded into enzymes, thereby, increasing capacity of the grain to stay longer in the stomach (offer durable satiety value). Therefore, they are preferred over other cereals in certain regions of Africa by farmers, so that they don't frequently feel hungry and thus allowing longer days at field (Rosemary et al., 2007). Jones et al., in 2000 elucidated the benefits of pearl millet in the treatment of obesity. Kusuma et al., 2013, stated that high dietary fibre content in foxtail millet results in smooth bowel movements reduces constipation and complements digestion and thus is beneficial for weight-reduction.
4. **Diabetes:** Diabetes mellitus is a non-communicable disease which is a result of excess or low insulin secretion and insulin action defects. It has multi-characters, which is, hyperglycemia, lipoprotein abnormalities, raised basal metabolic rate, defect in reactive oxygen species scavenging enzymes and damage to pancreatic cells due to high oxidative stress. As one of the threats for many nations, increasing incidence of diabetes has become major concern all over the world. Statistics suggest that by 2030 number of diabetic persons would reach to 87.0 million from 50.8 million in 2010, in India (Thilagavathi and Kanchana, 2017). Earlier this disease was considered as 'Rich Man's Disease' in India but now it is predominant across all economic classes. India, which is now considered as 'Capital of Diabetes', finds itself second after china. By 2030, it is projected that diabetes can be sixth leading cause of death (WHO, 2017a).

Glycemic Index (GI) is a gauge of rate at which carbohydrate containing food raise blood sugar post two or more hours of food consumption (post prandial response) (Miller et al., 2003b). Diabetes is caused by genetic pre-dispositions, obesity and consumption of foods with high GI (Dias-Martins et al., 2018). Alpha glucosidase and alpha amylase are enzymes present in brush border membrane of small intestine. Alpha Amylase is responsible for hydrolyzing complex carbohydrates to oligosaccharides. Alpha glucosidase breaks down oligosaccharides, disaccharides and disaccharides, that is, sucrose and maltose to monosaccharides which are glucose and fructose (McIver et al., 2020). Controlling enzyme activity in intestine controls blood sugar levels. Reactive hypoglycemia is correlated with symptoms of weakness, nausea, perspiration, hunger, anxiety and tremor post 2 hours of meal intake. It is caused by rapid gastric emptying

(Dumping Syndrome) or digestion of carbohydrates in intestine by breakdown of oligosaccharides into simple monosaccharides (sucrose and fructose) resulting in hyperglycemia and thereby having a rapid insulin secretion or response causing low plasma glucose levels (Sivakumar et al., 2012; Ozgenet al., 1998).

Use of insulin, glycemic drugs and dietary manipulation are major forms of treatment for diabetes. Primary prescription for diabetes is dietary manipulation by increased consumption of fiber, restricted carbohydrate-based diets and controlling intake of processed sugar in addition to physical exercise. Besides regulation by injection of insulin and drugs, the secondary way ahead for diabetes prevention and control is inhibition of glucose release using drugs (Tamura et al., 2006).

Acarbose and Miglitol are blood sugar level controlling drugs, both systemically absorbed and Miglitol has less absorption percentage per dosage (Schmeltz, 2007). Acarbose is a natural microbial complex oligosaccharide drug and an effective alpha-glucosidase enzyme inhibitor causing delay in breakdown of carbohydrates into sucrose and fructose, thereby controlling hyperglycemia or post prandial glucose levels. It also helps to control rate of insulin secretion followed by reactive hypoglycemia (Shibao, 2012). However, acarbose is not an FDA approved drug for type I diabetes mellitus. But it is a potential pharmacological choice to prevent pre-diabetes to type II diabetes mellitus. Side effects of acarbose consumption include nausea and in the long term may cause carbohydrate malabsorption (McIver et al., 2020). Acarbose does not cause hypoglycemia, however, if ingested along with sulfonylurea or insulin, blood sugar drugs, it may reduce glucose levels.

Millets are cereals with low GI (GI range < 55 mg/dl) and thus help control diabetes (Ugareet al., 2014; Vanisha et al., 2011). They, therefore, fall into primary mechanism of diabetes control by dietary manipulation. Low GI food has a virtue of slow rate of gastric emptying, slow digestion and intake of their carbohydrates in intestinal lumen leading to slow increase in insulin levels, slower rate of glucose absorption in portal and systemic circulation and thus, improve glucose tolerance. Therefore, satiety is increased and voluntary food intake is reduced (Bornet et al., 2007). Slow digestible starch in millets are attributed to their characteristics of amylose content, granular structure, amount and type of fatty acids (Oleic acid content) forming complexes with starch molecules, starch-protein-lipid interactions and high content of fibers (Annoret et al., 2017). Millets and resistant starch apparently provide impetus to lower or delay health problems due to diabetes and also lower serum cholesterol levels (Ilamaran et al., 2017). Millets contain high insoluble fibers which cause gradual sugar release thus benefiting diabetic patients (Rathore et al., 2016). Magnesium increases efficiency of insulin and glucose receiving agents produce multiple carbohydrate digesting enzymes which control insulin levels and helps control Type II diabetes (Ambati and Sucharitha, 2019). As India is one of the major producers of millets, these traditional foods can form a good alternative source for replacing simple carbohydrates for diabetics.

- 5. Antioxidants:** Sorghum, finger millet, pearl millet and foxtail millet have high antioxidant properties naturally occurring in the grain aleurone layer, the endosperm and the bran layers. These natural antioxidant properties are attributed to the presence of polyphenols (Tannins and Phenolic acids), flavonoids and free radical scavenging activity

in millets. The above reducing power assay of millets results in metal chelation, free radical termination, single-oxygen quenching and in decreasing the percentage of oxidative minerals such as iron. Antioxidants neutralize free radicals in the food, thereby, resulting in prevention of non-communicable diseases like cancer and diabetes (Hegde et al., 2005; Shobhana et al., 2007).

- 6. Other Health Benefits of Millets:** Sorghum consumption helps reduce Polycystic Ovarian Disorder (PCOD) in women (Klopfenstein and Hosency, 1995; Chavan et al., 2007). Sorghum also shows a protective effect on Red Blood Cells (RBC) by thinning of blood stimulated by tannins present in the grain and by preventing RBC hemolysis induced by hydrogen peroxide (Grinberg et al., 1997; Yang and Koo, 2000). Consumption of finger millets benefits in enhancing folate for child nervous channel defects as stated by Lumley et al., 2001 and Czeizelet al., 2013 and calcium for osteoporosis as given by Srivastava and Deal in 2002 and by Lanham- New in 2008.

Hadimani and Malleshi had researched in 1993 and Malleshireported in 2005 that finger millet seeds meet the nutritional requirements and further enhance the therapeutic value of formulated foods. Its high protein content aids in building the damaged cells and tissues (Swaminaiduet al., 2015). Malted ragi flour is used for unaccustomed and new born foods, drinks and pharmacological preparations (Nirmala et al., 2000). Medicinally, finger millet is diaphoretic, diuretic and vermifuge. Hence, it is used as traditional nutritional supplement for internal treatment of leprosy, liver disease, measles, tuberculosis and pneumonia in the dry regions of India (Wyk and Gericke, 2000). Finger millets help avoid aging by decreasing the glycosylation of body proteins as per Doraiswamy et al., 1969. Phosphorous, a major mineral in finger millets, is a critical component of Adenosine Triphosphate (ATP), a molecule also known as a body energy carrier. Therefore, phosphorous is critical for body cell growth, growth of bones, genetic codes (DNA and RNA). It regulates the metabolism of lipids (Fats) and Fat composition complexes like cell membrane and system of nerves. Containing high amount of magnesium, they help reduce migraine attacks and fight the severity of asthma (Dubey et al, 2013). Glewet et al., 2008 suggested that amino acids in finger millet improve body health by formation of nitric oxide and growth hormone stimulation. Additionally, they curtail male infertility by improving sperm production and motility. Anti-inflammatory, anti-viral and platelet aggregation inhibitor benefits are add-ons with respect to finger millet. They help avoid life-altering allergies like Salmonella Typhimurium and Eschericia Coli (Usha et al., 1998).

Digestive utilization in pearl millets is found to be high. It increases hemoglobin in the body by three times due to high iron content caused by iron balance and retention. Pearl millets are a rich source of iron and zinc which facilitates the growth and cognitive balance in infants (Eyzaguirre et al., 2006). The metabolized energy derived from pearl millets is high and approximately equals to that acquired from maize. Pearl millet is a high exothermic food with high calorific value and energy content. Thus, it is consumed during winters in the boiled form across India (Mathangi and Sudha et al., 2012).

IX. UTILIZATION OF MILLETS

Sprouts prepared out of **ragi/ finger Millet** is recommended for infants and elderly people for its calcium content which helps build bone density. Ragi is used to prepare local drink, ragi soup, in eastern state of Andhra Pradesh in India, which constitutes high calcium, vitamins and nutrient content for recovery of bones and tissues post work-outs. Sprouted finger millets are consumed as it is and, sometimes, ground into a flour to form baked items or flat breads (Bhakri).

In India, **sorghum** is used to prepare local delicacies like idli and dosa (steamed and leavened products, respectively) and thus helping in gaining brand value in the sorghum-growing central and southern states. Papads prepared from sorghum by drying in the sun may be a cheap, effective and durable (shelf life of over one year) manufacturing option for the Indian people, thus bringing in the regional strategy for food products prepared from sorghum (Chavan et al., 2015). Partial and/or complete substitution of other cereals by whole-grain sorghum may be considered in various baked food products including snacks and breakfast cereals. Sorghum usage improves phytonutrient content, dietary fibre and sensory properties. Pigmented sorghum (pigmented testa type of tannins in sorghum) provides a wide range of options in color and texture of sorghum products, thus making it commercially attractive (Awika et al., 2003). Sorghum is also used for generating animal feed. It is a component of alcoholic beverages and other secondary industrial products as well. A range of porridges, thick or soft, can be prepared from sorghum. Dibou or Oto or Oka-Baba as it is called in Bevin, Burkina Faso and Nigeria, respectively, is a concentrated sorghum porridge consumed during afternoon and night meals in the main course, served with okra or soup in a non-vegetarian dish depending on the financial capacity to spend.

Sorghum is used for extraction of starch by wet milling process to produce dextrose from it; later to be used in foods. It is used for cattle and poultry feed mainly in the United States. Juice extracted from the sorghum stem is an excellent source for production of sugar with 15–17% of saccharose. Sorghum can be used for production of snack foods and tortillas and noodles (Taylor et al., 2006). As given by NDRI news in 2011, iron and protein augmented biscuits can be prepared from lightened and germinated **pearl millet** flour, combined cereal flours and whey protein concentrate (Singh et al., 2006). More crunches may be added to the food when pearl millet grates and flour are used as an addition to it. Pearl millet is processed with other food items such as soya and protein rich ingredients, for example, legumes or groundnut cakes, to provide very well-balanced nutritional eatables (Malleshiet al., 1996). Indian traditional food-uses of pearl millet are characterized by cooking snack foods like noodles, papads, semiyan, laddoos (from popped pearl millet, as experimented by Singh and Sehgal in the year 2008) and daily meal food like chapati (Indian flat bread). Processed dried secondary food is cooked from composition of pearl millet, corn and whey – skim milk as given by NAIP, 2010.

With its hygroscopic properties upon germination, the pearl Millet grain has a contention for pasta production. Therefore, pearl millets are well-suited for bakery products (Rathi et al., 2004). Malting catalyses increase in Water Absorption Capacity (WAC) of pearl Millets which helps in preparation of chapatis as stated by Poongodiet al., 2009. Chapatis may be prepared after heat treating the pearl millet for better overall benefit and acceptability (Kaur et al., 2014). Iron-fortified processing increased the fat and carbohydrate

content of the food by many times and the iron content found was 6.5mg per 100g (Kaur et al., 2014). Laddoos and biscuits prepared using pearl millets were found to have more mineral (Calcium, Iron, Manganese and Phosphorous) content.

Foxtail millets are used in traditional foodpreparation in India. They are used in preparation of rice in North Karnataka to prevent and fight diabetes. Value-Added (VA) papad and timbittu were prepared from foxtail millets; their economical analysis for preparation and marketing was conducted by Kusuma et al., 2013. Due to their very low Glycemic Index and resistance to any kind of storage pests (high duration of storage –upto 60 days), they are ideally suited for preparation of VA products. Foxtail millet was used to produce biscuits and were successfully analysed for the nutritional and sensory properties (Anju and Sarita, 2010). On the other hand, constant progress is being achieved in standardizing the Ready-To-Cook (RTC), value-added food products from foxtail millet; indicated in recent studies undertaken by Prabhakar, 2006, by Manju et al in 2014 and by Aigal and Chimmad in 2017. RTC flakes prepared from foxtail millet had a higher water absorption capacity, low cooking time (only 32 seconds against 83 seconds for rice flakes), better consistency in cooking and a better nutritional composition when compared to rice and oat flakes.

1. Gluten Free Foods: Gluten provides textural and processing qualities to baked foods. Gliadines and Glutenins are the two components of gluten. They provide elasticity and viscosity to the dough when mixed with water. Available gluten-based foods showed that there are difference innutritional compositions when compared to non-gluten containing products (Miranda et al., 2014, Mazzeo et al., 2015). In recent years, gluten-free products are gaining popularity due to an increased incidence of celiac disease caused by gluten foods and awareness of gluten-free products. An increase in gluten-related disorders is also contributed by a new variety of wheat which is produced through mechanized farming and excessive use of pesticides (Volta et al., 2013). Low permeability of the gastric cells to proteins leads to gastric resistance thus developing celiac or non-celiac sensitivity in some individuals. Gluten ingestion is completely restricted in patients with celiac diseases. Common food products such as bakery products, biscuits, cakes etc made with wheat and wheat by-products are restricted for consumption by celiac patients (Lovis, 2003). Exclusion of gluten from diet helps celiac patients in remission of the disorder and when gluten products are reintroduced in their diets, the relapse of the condition occurs (Bernado et al., 2012). Celiac Disease (CD) is understood as a multisystem immunological disorder than a genetic one. Broad flat villi and intestinal cell abnormalities lead to indigestion of gluten included in the diet (Paulley, 1954, and Marsh, 1992). Research has shown that the prevalence of CD in children is 1.06%, and in adults, it is 0.18-1.2% (Barker, 2008, Fasano et al., 2003, Dube et al., 2005). The pathogenesis of CD exhibited the involvement of auto-antigen, interactions between intestinal epithelium and gluten peptides (Dieterich et al., 1997).

CD is also called Autoimmune Enteropathy. CD results in constant inflammation of the intestine and its degeneration. As cereals such as wheat, barley and rye which play a crucial role in daily diet contain gluten, it is difficult for patients with CD to go by gluten-free diet. Also, the available gluten-rich products lack important nutrients which lead to deficiency of macro and micronutrients. High level of fats in processed cereals account for other metabolic disorders. Gluten-free products often contain other

ingredients which may complement the above benefits; awareness of these ingredients among patients is another important parameter to study. Hence, for a positive and healthy outcome, maintenance of a strict gluten-free diet is very essential. Use of millets has been increasingly on the rise in the development of healthy gluten-free products for a number of reasons. Sorghum has a bland taste, good starch properties and light color. It is now being used in many-gluten free product formulations (Jonas and Dahlberg, 2004). Finger millets are not considered to be allergenic and are thus best suited for patients with CD being gluten-free. They are the most easily digestible grains due to their non-acid forming characteristics. Celiac patients, who are prescribed gluten-free diet, are helped by consuming pearl millets (Shahidi and Chandrashekara, 2013).

- 2. Biscuits:** Biscuits or cookies manufacturing is contributing to the fastest growing industry in the food processing sector. A turnover of around Rs. 3000 Crores is reported by Indian biscuit industries, which stands at the second place, after USA. The biscuit manufacturing industry is a part of the diverse Indian food market. Going by the production statistics in the biscuit industry, 60% of the biscuits are produced in the unorganized sector and 40% in the organized sector. In 1997, the equation suggested that the ratio of unorganized to organized sector was 66:34. However, in 2007, it shifted to 60:40 (NIIR, 2007). In developed countries, utilisation of biscuits is 10-50 kg per annum against mere 1-2 kg per annum in India. With the growing population and boost in the use of convenience food, a rising need for snack items has been felt. Therefore, with lifestyle changes and growing income, the biscuit industry is expected to grow by 25% by 2020 (RNCOS – Indian food processing report 2006). Bakery industry stood third in generating revenue in the processed food sector thereby becoming one of the largest industries in the food processing sector (NIIR, 2007). Due to low cost, biscuits are treated as cheapest snack products for all socio-economic groups.

The bakery sector has also been making a mark in e-retailing. Hence, more international brands are interested in future investment in this sector. Abundant raw material supply, a larger target population and increased requirements for low capital investments are some of the advantages for investors to increase their interest in the Indian bakery sector (NPCS, 2012). Major biscuit brands in India viz Parle, ITC, Cadbury and Britannia cover around 75% of the total revenue in the biscuit sector. About 81% of the bakery market accounts for biscuits and bread (Kumar and Kumar, 2016). Biscuit consumption was recorded at par with bread at 35%. Small scale production of bakery items has been largely accepted and adopted in India, especially in the unorganized sector. The availability of raw materials, comparatively easy manufacturing process and low investment in the production has been pivotal to the popularity of this sector. Urbanization and a booming domestic market compel new producers to invest here. Technological progress paves the way to and contributes for rapid improvement. Certain limitations still need to be addressed such as high purchase and packaging cost, taxation, national and international competition etc. Nevertheless, it has an immense scope to improve on various factors (Jegan, et al., 2013).

- 3. Dough Rheology:** Changing the original dimension by an external force is called deformation. The study of matter deformation/flow is called Rheology (Bourne, 2002). Unit for measurement of deformation in Rheometry is called Strain. The exerted force leads to deformation of the material and achieved deformation is, thus, measured.

Classification of dough rheology in cereal research is divided into fundamental and empirical. Viscosity and elasticity properties are provided by fundamental tests. Fundamental properties are affected by the type of material and the type of ingredients. Hence, understanding the role of these materials and ingredients is an important part of the study of dough rheology to describe the end-product quality (Khatinget al., 2014).

Bakery products have been successfully manufactured with the help of positive research in the field of deformation and flow behavior of dough. These studies have become central for continuous improvement of bakery products. Better understanding of factors responsible for dough rheology help in the formulation and manufacturing of new products during optimization stage and hence, result in consistent and innovative production. Bakery is an interdisciplinary field which includes many factors such as rheology, fluid mechanics, process engineering, polymer science, cereal chemistry and colloid science (Faridi and Faubion, 1990). Studying rheology is important to enhance efficiency of processes as well as quality of the food product. As the baking industry is becoming more and more automated, it is imperative that the science behind dough rheology is understood and applied.

During mixing, torque is applied on dough by the mixing blades. This torque is measured and recorded by using Farinograph. Farinograph is considered to be an important instrument in dough rheology because it estimates rheometry features such as water absorption, dough development and its stability. Farinograph results are used for determining dough consistency, processing and over-mixing. Even dough texture can be adjudged from the farinographic results (AACC, 2000).

Farinographic tests can be conducted in steps such as Absorption, Peak Time, Arrival Time, Departure Time, Stability Time and Mixing Tolerance Index (MTI). Absorption defines water required for the dough preparation from flour so as to process end-products. Peak time, under standard conditions, is the time required for optimum mixing of dough from addition of water up till retention of dough maximum consistency. Arrival time is measured in Minutes. It expresses the rate at which the flour takes up the water. Dough consistency and beginning of the dough breakdown is measured by departure time (minutes). Dough strength equals to its consistency which the dough can maintain for a longer time. This period of consistency is expressed in minutes and is termed as stability time. During mixing, the degree of softening of the dough is indicated by mixing tolerance index.

Extensograph determines the gluten strength of the flour along with effect of additives and fermentation time on bread dough. When dough is stretched, resistance to certain dough parameters is measured and recorded by Extensograph. It is measured into various factors such as resistance to extension, extensibility, their ratio and area under the curve. Resistance is the height of the curve and curve length describes extensibility. Ratio of resistance and extensibility indicates balance of dough strength and extensibility of dough before breaking (AACC, 2000).

REFERENCES

- [1] AACC, "Approved methods of analysis, Approved Methods of the American Association of Cereal Chemists(Formerly Cereal Laboratory Methods)",7th Edition, Method No. 76-10, St. Paul, MN, U.S.A., (2000).
- [2] Abdel Rahman, S.M., Babiker, E.E., Abdullahi, H.E., Effect of fermentation on antinutritional factors and HCL extractability of minerals of pearl millet cultivars,J. Food. Sci. Tech.,Vol. 3, pp. 516-522, (2005).
- [3] Adhikari, L., Hussain, A., & Rasul, G., Tapping the potential of neglected and underutilized food crops for sustainable nutrition security in the mountains of Pakistan and Nepal, Sustainability, Vol. 9, No. 2, pp. 291, (2017).
- [4] Adlas, J. and Achoth, L., Is the green revolution vanishing? Empirical evidence from TFP analysis for rice, International Association of Agricultural Economics Conference, Australia, (2006).
- [5] Adrian, J. and Jacquot, R., Le Sorgho et les Mils en Alimentation Humaine et Animale, CentreRecherches sur la Nutrition Du C.N.R.S. Bellevue (Seine-Et-Orse), Vigot Freres, Editeurs, Paris, pp, 189, (1964).
- [6] Agte, V.V., Khot, S., Girigosavi, S.T., Paknikar, K.M., Chiplonkar, S.A., Comparative performance of pearl millet and sorghum based diets vs. wheat and rice based diets for trace metal bioavailability,J Trace Elem Med Biol. Vol. 13, No. 4, pp. 215–9, (1999).
- [7] Aigal, S. S. and Chimmad, B. V., Physicochemical and Nutrient Composition of Ready to Cook (RTC) Foxtail Millet (*Setariaitalica* L.) Flakes in Comparison to Rice and Oat Flakes, International Journal of Current Microbiology and Applied Sciences, Vol. 6, No. 10, pp. 19-24, (2017).
- [8] Anderson, G.J. and McLaren, G.D., Iron Physiology and Pathophysiology in Humans, Nutrition and Health, First Edition, Humana Press, pp. 704, (2012).
- [9] Anju, T., & Sarita, S., Suitability of foxtail millet (*Setariaitalica*) and barnyard millet (*Echinochloafrumentacea*) for development of low glycemic index biscuits, Malays, Journal Nutrition, Vol. 16, No. 3, pp. 361-368, (2010).
- [10] Annor, George Amponsah,Tyl, Catrin&Marcone, Massimo &Ragae, Sanaa & Marti, Alessandra, Why do millets have slower starch and protein digestibility than other cereals?, Trends in food science & technology, Vol. 66, pp. 73-83, (2017).
- [11] Annor, George Amponsah,Tyl, Catrin&Marcone, Massimo &Ragae, Sanaa & Marti, Alessandra, Why do millets have slower starch and protein digestibility than other cereals?, Trends in food science & technology, Vol. 66, pp. 73-83, (2017).
- [12] Archana, S.S., Sehgal S, Kawatra A., Reduction of polyphenols and phytic acid content of pearl millet grains by malting and blanching, Plant Foods for Human Nutrition, Vol. 53, pp. 93–98, (1998).
- [13] Au, P.M. and Fields, M.L., Nutritive quality of fermented sorghum, Journal of food science, Vol. 46, No. 2, pp. 652-654, (1981).
- [14] Awika, J. M., & Rooney, L. W., Sorghum phytochemicals and their potential impact on human health, Phytochemistry, Vol. 65, No. 9, pp. 1199-1221, (2004).
- [15] Awika, J.M., Rooney, L.W., Wu, X., Prior, R.L., Cisneros-Zevallos, L., Screening methods to measure antioxidant activity of sorghum (*Sorghum bicolor*) and sorghum products, Journal of Agricultural and Food Chemistry, Vol. 51, pp. 6657–6662, (2003).
- [16] Azhari, A., Mohammed Nour., Mohamed, A. E. M., Ibrahim ,Eman, E., Abdelrhman, Eman, F., Osman, Khadir E., Khadir, Nazik, F. Hussain, Nahla, A., Abdallatif, Amir A. Eldirany., Effect of Processing Methods on Nutritional Value of Sorghum (*Sorghum bicolor* L. Moench), Cultivar American Journal of Food Science and Health,Vol. 1, No. 4, pp. 104-108, (2015).
- [17] Barker, Jennifer M., and Edwin Liu. Celiac disease: Path physiology, clinical manifestations, and associated autoimmune conditions, Advances in Pediatrics, Vol. 55, pp. 349-365, (2008).
- [18] Bernardo, D. and A. S. Peña,Developing strategies to improve the quality of life of patients with gluten intolerance in patients with and without celiac disease, European Journal of Internal Medicine, Vol. 23, No. 1, pp. 6-8, (2012).
- [19] Bernardo, D., Garrote, J.A., Allegretti, Y., León, A., Gómez, E., Bermejo-Martin, J.F., Calvo, C., Riestra, S., Fernández-Salazar, L., Blanco-Quirós, A., Higher constitutive IL15R alpha expression and lower IL-15 response threshold in coeliac disease patients, Clinical Experimental Immunology,Vol. 154, No. 1, pp. 64–73, (2008).
- [20] Bisht, B.S. and Singh, D.P., Agriculture in Uttarakhand hills. Directorate of Experiment Station, G.B.Pant University of Agriculture & Technology, Pantnagar, pp.11-17, (2009).
- [21] Bornet, Francis, R.J., Glycemic response to foods: impact on satiety and long-term weight regulation, Appetite, Vol. 49, No. 3, pp. 535-553, (2007).
- [22] Bourne, M. C., Texture Profile analysis, Food Technology,Vol. 32, No. 7, pp. 62-66, (1978).

- [23] Bourne, M., Food texture and viscosity: concept and measurement, 2nd Edition Academic Press, Elsevier, (2002).
- [24] Brown, Kenneth, H., Peerson, J.M., Rivera, J., Allen, L.H., Effect of supplemental zinc on the growth and serum zinc concentrations of prepubertal children: a meta-analysis of randomized controlled trials, *The American journal of clinical nutrition*, Vol. 75, No. 6, pp. 1062-1071, (2002).
- [25] Butler, L.G., Relative degree of polymerization of sorghum tannin during seed development and maturation, *Journal of Agricultural and Food Chemistry*, Vol. 30, pp. 1090-1094, (1982).
- [26] Chakrabarty, Subrata, and Liang Wang, Climate change mitigation and internationalization: The competitiveness of multinational corporations, *Thunderbird International Business Review*, Vol. 55, No. 6, pp. 673-688, (2013).
- [27] Chandra, Dr., Chandra, Satish, Arora, Pallavi & Sharma, A.K., Finger millet (*Eleusine coracana* (L.) Gaertn: A power house of health benefiting nutrients, a review, *Food Science and Human Wellness*, doi: 10.1016/j.fshw.2016.05.004, Vol.5, (2016).
- [28] Chandrasekara, A., & Shahidi, F., Determination of antioxidant activity in free and hydrolyzed fractions of millet grains and characterization of their phenolic profiles by HPLC-DAD-ESI-MSn, *Journal of Functional Foods*, Vol. 3, No. 3, pp. 144-158, (2011).
- [29] Chavan, J. K., Kadam, S. S., Ghonsikar, C. P., & Salunkhe, D. K., Removal of tannins and improvement of in vitro protein digestibility of sorghum seeds by soaking in alkali, *Journal of Food Science*, Vol. 44, No. 5, pp. 1319-1322, (1979).
- [30] Chavan, U. D., Pansare, S. S., Patil, J. V. and Shinde, M. S., Preparation and Nutritional Quality of Sorghum Papads, *International Journal of Current Microbiology and Applied Sciences*, Vol. 4, No. 5, pp. 806-823, (2015).
- [31] Chethan, S., Malleshi, N.G., Finger millet polyphenols: optimization of extraction and the effect of pH on their stability, *Food Chem.*, Vol. 105, No. 2, pp. 862-870, (2007).
- [32] Chikwendu, J. N., Igbatim, A. C., & Obizoba, I. C., Chemical composition of processed cowpea tender leaves and husks, *International Journal of Scientific and Research Publications*, Vol. 4, No. 5, pp. 1-5, (2014).
- [33] Chivenge, Pauline, The Potential Role of Neglected and Underutilised Crop Species as Future Crops under Water Scarce Conditions in Sub-Saharan Africa, *International journal of environmental research and public health*, Vol. 12, No. 6, pp. 5685-711, (2015).
- [34] Czeizel, Andrew E., Folate deficiency and folic acid supplementation: the prevention of neural-tube defects and congenital heart defects, *Nutrients*, Vol. 5, No.11, pp. 4760-4775, (2013).
- [35] David, A. V. Dendy, St. Paul., Sorghum and Millets Chemistry and Technology, Minnesota, American Association of Cereal Chemists, Inc., Minnesota, USA, pp. 406, (1995).
- [36] Dayakar Rao, B., Bhaskarachary, K., Arlene Christina, G. D., Sudha Devi, G., Vilas, A. T., & Tonapi, A., Nutritional and health benefits of millets. ICAR-Indian Institute of Millets Research (IIMR) Rajendranagar, Hyderabad, pp. 112, (2017).
- [37] Desikachar, H. S. R., Processing of maize, sorghum and millets for food uses, *Journal of Scientific and Industrial Research*, Vol. 34, pp. 231-237, (1975).
- [38] Dida, M. M., Devos, K. M., Finger millet. In: Chittarajan, K., *Genome Mapping and Molecular Breeding in Plants*, Springer-Verlag, Vol. 1, pp. 333-344, (2006).
- [39] Dieterich W., Ehnis T., Bauer M., Donner P., Volta U., Riecken E. O., Identification of tissue transglutaminase as the autoantigen of celiac disease, *Nature Medicine*, Vol. 3, pp. 797-801, (1997).
- [40] Doraiswamy, TR., Singh, N., Daniel, V.A., Effects of supplementing ragi (*Eleusine coracana*) diet with lysine or leaf protein on the growth and nitrogen metabolism of children, *British Journal of Nutrition*, Vol. 23, pp. 737-743, (1969).
- [41] Dubé, C., Rostom, A., Sy, R., Cranney, A., Saloojee, N., Garrity, C., & Pan, I., The prevalence of celiac disease in average-risk and at-risk Western European populations: a systematic review, *Gastroenterology*, Vol. 128, No. 4, pp. S57-S67, (2005).
- [42] Dubey, Ashutosh, Tandon, Shishir, Verma and Adarsh, Millets: Good Nutraceutical source, *Indian Farmer Digest*, Vol. 46, pp. 20-21, (2013).
- [43] DuPont Advisory Committee on Agricultural Innovation and Productivity, *The Urban Transition: Implications for Global Food Security*, (2016).
- [44] Easterling, W. E., Aggarwal, P. K., Batima, P., Brander, K. M., Erda, L., Howden, S. M., and Tubiello, F. N., Food, Fibre and Forest products, *Climate change*, pp. 273-313, (2007).
- [45] Eastman, P., An end to pounding, A new mechanical flour milling system in use in Africa, Ottawa, Canada, Centre de recherche pour le développement international, pp. 63, (1980).

- [46] Ejeta, G., Hassen, M. M., & Mertz, E. T., In vitro digestibility and amino acid composition of pearl millet (*Pennisetum typhoides*) and other cereals, Proceedings of the National Academy of Sciences of the United States of America, Vol. 84, No. 17, pp. 6016–6019, (1987).
- [47] Eyzaguirre, R. Z., Nienaltowska, K., De Jong, L. E., Hasenack, B. B., & Nout, M. R., Effect of food processing of pearl millet (*Pennisetum glaucum*) IKMP-5 on the level of phenolics, phytate, iron and zinc, Journal of the Science of Food and Agriculture, Vol.86, No. 9, pp. 1391-1398,(2006).
- [48] Fageer, A.S.M., Babiker, E.E. and El Tinay, A.H., Effect of malt pretreatment and/or cooking on phytate and essential amino acids contents and in vitro protein digestibility of corn flour, Food Chemistry, Vol. 88, No. 2, pp. 261–265, (2004).
- [49] FAO, Amino acid content of foods and biological data on proteins, Nutritional Studies No. 24, Rome: Food and Agriculture Organization, (1970).
- [50] FAO, IFAD, UNICEF, WFP and WHO, Building Resilience for peace and food security, The State of Food Security and Nutrition in The World, Rome FAO,(2017).
- [51] FAO, IFAD, UNICEF, WFP and WHO, Building Resilience for peace and food security, The State of Food Security and Nutrition in The World, Rome FAO,(2017).
- [52] FAO, IFAD, WHO WFP, and UNICEF, Safeguarding against economic slowdowns and downturns, The state of food security and nutrition in the world, (2019).
- [53] Faridi, H. and Faubion, J.M., Dough rheology and baked product texture, Springer, US, New York: Van Nostrand Reinhold, (1990). Vol. 7, pp. 117, (2014).
- [54] Fasano, A., Berti, I., Gerarduzzi, T., Prevalence of Celiac Disease in At-Risk and Not-At-Risk Groups in the United States: A Large Multicenter Study, Archives of internal medicine, Vol. 163, No.3, pp. 286–292,(2003).
- [55] Food and Agriculture Organization of the United Nations, How to Feed the World in 2050, Economic and Social Development Department, Rome, Italy, (2009a).
- [56] Gari, J.A, Review of the African millet diversity, Food and Agriculture Organisation of the United Nations (FAO), In: Paper for the international work-shop on fonio, food security and livelihood among the rural poor in West-Africa, IPGRI / IFAD, Bamako, Mali, 19-22 Nov 2001, Programme for Neglected and Underutilised Species, Rome, Italy, 9, (2002).
- [57] Geervani, P. & Eggum, B.O., Nutrient composition and protein quality of minor millets, Plant Foods Human Nutrition, Vol. 39, No. 2, pp. 201-208, (1989).
- [58] Geissler, C., & Singh, M., Iron, meat and health. Nutrients, Vol. 3. No. 3, pp. 283-316,(2011).
- [59] Glew, S.R., Chuang, L.T., Roberts, J.L., & Glew, R.H., Amino acid, fatty acid and mineral content of black finger millet (*Eleusine coracana*) cultivated on the Jos Plateau of Nigeria, Food Global Science Books, Vol. 2, No. 2, pp. 115- 118, (2008).
- [60] Gopalan C., Ramasastri, B.V. and Balasubramaniam, S.C., (eds) Nutritive Value of Indian Foods, ICMR, New Delhi, (2004).
- [61] Gopalan, C., Rama Sastri, B.V. and Balasubramanian, S. C., Nutrient value of Indian Foods, National Institute of Nutrition, ICMR Hyderabad, (2000).
- [62] Gopalan, C., Rama, S.B.V. and Balasubramanian, S.C., Nutritive value of Indian foods, National Institute of Nutrition, Indian Council of Medical Research, Hyderabad, India, (2009).
- [63] Gopalan, C., Ramasastri, B.V. and Balasubramanian, S.C., Nutritive value of Indian foods, Hyderabad, NIN, ICMR, (2007).
- [64] Gopalan, C., Ramasastri, B.V., Balasubramanian, S.C., Rao, B.S.N., Deosthale, M.Y.G. and Pant, K.C., (eds.) Nutritive value of Indian foods, ICMR, Hyderabad, India, pp. 59 and 68, (1993).
- [65] Gopalan, C., Ramasastri, B.V. and Balasubramanian, S.C., (eds) Nutritive Value of Indian Foods, ICMR, New Delhi, (2004).
- [66] Govindaraj, M., Rai, K. N., Shanmugasundaram, P., Dwivedi, S. L., Sahrawat, K. L., Muthaiah, A. R., & Rao, A. S., Combining ability and heterosis for grain iron and zinc densities in pearl millet, Crop Science, Vol.53, No. 2, pp. 507-517, (2013).
- [67] Graf, E., and Dintzis, F. R., Determination of phytic acid in foods by high-performance liquid chromatography, Journal of Agricultural and Food Chemistry, Vol. 30, No. 6, pp. 1094-1097,(1982).
- [68] Graf, Ernst., Chemistry and applications of phytic acid: an overview, in: Phytic Acid: Chemistry & Applications, Pilatus Press, Minneaolis, pp. 1-21, (1986).
- [69] Griffith, L. D., M. E. Castell-Perez, and M. E. Griffith., Effects of blend and processing method on the nutritional quality of weaning foods made from select cereals and legumes, Cereal chemistry, Vol. 75, No. 1, pp. 105-112, (1998).
- [70] Griffith, L.D. and Castell-Perez, M.E., Effects of roasting and malting on physicochemical properties of select cereals and legumes, The Journal of Cereal Science, Vol. 75, No. 06, pp. 780-784, (1993).

- [71] Grinberg, L.N., Newmark, H., Kitrossky, N., Rahamim, E., Chevion, M., Rachmilewitz, E.A., Protective effect of tea polyphenols against oxidative damage to red blood cell, *Biochem Pharmacol*, Vol. 54, No. 09, pp. 973–978, (1997).
- [72] Gupta, Sanjay Mohan., Arora, S., Mirza, N., Pande, A., Lata, C., Puranik, S., Kumar, J. and Kumar, A., Finger Millet: A Certain Crop for an Uncertain Future and a Solution to Food Insecurity and Hidden Hunger under Stressful Environments, *Frontiers in plant science*, Vol. 8, pp. 643, (2017).
- [73] Gussow, J. D. and Clancy, K. L., Dietary guidelines for sustainability, *Journal of nutrition education (USA)*, Vol. 18, No. 1, pp. 1-5, (1986).
- [74] Hadimani, N.A., Muralikrishna, G., Tharanathan, R.N., and Malleshi, N.G., Nature of carbohydrates and proteins in three pearl millet varieties varying in processing characteristics and kernel texture, *Journal of Cereal Science*, Vol. 33, No. 1, pp. 17 – 25, (2001).
- [75] Hahn, D.H., Faubion, J.M., Rooney, L.W., Sorghum phenolic acids, their high performance liquid chromatographic separations and their relation to fungal resistance, *Cereal Chemistry*, Vol. 60, No. 4, pp. 255–259, (1983).
- [76] Hama, F., Icard-Vernière, C., Guyot, J. P., Picq, C., Diawara, B., & Mouquet-Rivier, C., Changes in micro-and macronutrient composition of pearl millet and white sorghum during in field versus laboratory decortications, *Journal of Cereal Science*, Vol.54, No. 3, pp. 425-433, (2011).
- [77] Hama-Ba, Fatoumata, Study of the Nutritional quality and acceptability of Millet Biscuits (*Pennisetum glaucum* L.) Supplemented with cowpea (*Vigna unguiculata* L.) and Bambara Groundnut (*Vigna subterranea* L.), *Journal of Agricultural Science and Food Research*, Vol. 9, No. 1, pp. 1-4, (2018).
- [78] Haug, W., and Lantzsch, H. J., Sensitive method for the rapid determination of phytate in cereals and cereal products, *Journal of the Science of Food and Agriculture*, Vol. 34, No. 12, pp. 1423-1426, (1983).
- [79] Hegde, P. S., Namakkal, S. R., and Chandra, T. S., Effects of the antioxidant properties of millet species on oxidative stress and glycemic status in alloxan-induced rats. *Nutrition Research*, Vol. 25, No.12, pp. 1109-1120, (2005).
- [80] Hegde, Prashant S., Gowri Chandrakasan, and Chandra, T. S., Inhibition of collagen glycation and crosslinking in vitro by methanolic extracts of Finger millet (*Eleusine coracana*) and Kodo millet (*Paspalum scrobiculatum*), *The Journal of nutritional biochemistry*, Vol. 13, No. 9, pp. 517-521, (2002).
- [81] Hemalatha, S., Platel, K. and Srinivasan, K., Influence of heat processing on the bioaccessibility of zinc and iron from cereals and pulses consumed in India, *Journal of Trace Elements in Medicine and Biology*, Vol. 21, pp. 1–7, (2007b).
- [82] Honke, J., Kozłowska, H., Valverde, V., Frias, J. and Gorecki, R., Changes in quantities of inositol phosphates during maturation and germination of legume seeds, *Zeitschriftfu*, pp.289, (1998).
- [83] Hosoney, R. C., and Rogers, D. E., Mechanism of sugar functionality in cookies. in: *The Science of Cookie and Cracker Production*, H. Faridi, ed., Avi: New York, pp. 203-226, (1994).
- [84] Idowu Jonas Sagbo, Maryna van de Venter, Trevor Koekemoer, and Graeme Bradley, In Vitro Antidiabetic Activity and Mechanism of Action of *Brachylaena elliptica* (Thunb.) DC, *Hindawi, Evidence-Based Complementary and Alternative Medicine*, Article ID 4170372, pp. 13, (2018).
- [85] Ilamaram, M., Nousheen Noorulllyn, I., Kanchana, S. and Sivasankari, B., Anti-Hyperglycemic Effect of Cereal and Millet Based Modified Starch Substituted Pasta Foods, *Chemical Science Review and Letters*, Vol. 6, No. 22, pp. 704-709, (2017).
- [86] Jain, R., Cui, Z. C. and Domen, J. K., Environmental impact of mining and mineral processing, Elsevier, Butterworth-Heinemann Publ., pp. 322, (2016).
- [87] Johnston, J. L., Fanzo, J. C., & Cogill, B., Understanding sustainable diets: a descriptive analysis of the determinants and processes that influence diets and their impact on health, food security, and environmental sustainability, *Advances in nutrition*, Vol.5, No. 4, pp. 418-429, (2014).
- [88] Jood, S. & Khetarpaul, N., Improving nutritional quality of coarse cereals through probiotic fermentation, *Processed Food Industry*, Vol. 9, pp. 7–25, (2005).
- [89] Kaur, K. D., Jha, A., Sabikhi, L., & Singh, A. K., Significance of coarse cereals in health and nutrition: A review, *Journal of Food Science and Technology*, Vol. 51, No. 8, pp. 1429-1441, (2014).
- [90] Kayodé, A.P., Polycarpe, Genetic and environmental impact on iron, zinc, and phytate in food sorghum grown in Benin, *Journal of agricultural and food chemistry*, Vol. 54, No. 1, pp. 256-262, (2006).
- [91] Kazanas, Nuria & Fields, M., Nutritional Improvement of Sorghum by Fermentation. *Journal of Food Science*, Vol. 46, No. 3, pp. 819 – 821, (1981).
- [92] Khating, K. & Kenghe, Rajendra & Yenge, G. & Ingale, V. & Shelar, Shubhangi, Effect of blending sorghum flour on dough rheology of wheat bread, *Journal of Agricultural Engineering Research*,
- [93] Kimeera Ambati and Sucharitha K. V., Millets-Review on Nutritional Profiles and Health Benefits, *International Journal of Recent Scientific Research*, Vol. 10, No. 07(I), pp. 33943-33948, (2019).

- [95] Klopfenstein C.F. and Hoseneey, R., Nutritional properties of sorghum and the millets, In D.A.V. Dendy (ed), Sorghum and Millets: chemistry and Technology, American Association of Cereal Chemist Icn, St. Paul, pp. 125-168, (1995).
- [96] Kodkany, B.S., Bellad, R.M., Mahantshetti, N.S., Westcott, J.E., Krebs, N.F., Kemp, J.F., Hambidge, K.M., Biofortification of pearl millet with iron and zinc in a randomized controlled trial increases absorption of these minerals above physiologic requirements in young children, *The Journal of Nutrition*, Vol.143, No. 9, pp. 1489–1493, (2013).
- [97] Kulamarva, Arun & Sosle, Venkatesh & Raghavan, Vijaya, Nutritional and Rheological Properties of Sorghum, *International Journal of Food Properties*, Vol. 12, pp. 55-69, (2009).
- [98] Kulkarni, A. R., Pokharkar, V. G., & Nimbalkar, C. A., Trends in growth and instability of major Kharif crops in Western Maharashtra, *International Journal of Forestry and Crop Improvement*, Vol. 9, No. 2, pp. 37-43, (2018).
- [99] Kumar, Alpna and Chauhan, B.M., Effects of phytic acid on protein digestibility (in vitro) and HCl-extractability of minerals in pearl millet sprouts, *Cereal chemistry*, Vol. 70, No. 5, pp. 504-504, (1993).
- [100] Kusuma, D.K., Jayashree, A., Handigol. and Kumara, B.R., An economic analysis of production and value addition in foxtail millet in Bellary district of Karnataka, *International Research Journal of Agricultural Economics and Statistics*, Vol. 4, No. 1, pp. 68-72, (2013).
- [101] Kusuma, D.K., Production and value addition in Foxtail millet in Bellary District – an Economic Analysis, Ph.D Thesis, University of Agricultural Sciences (UAS), Dharwad (2011).
- [102] Landry, J., and Therese, M., Distribution and amino acid composition of protein groups located in different histological parts of maize grain, *Journal of Agricultural and Food Chemistry*, Vol. 28, No. 6, pp. 1186-1191, (1980).
- [103] Lanham-New, Susan A., Importance of calcium, vitamin D and vitamin K for osteoporosis prevention and treatment: symposium on ‘diet and bone health’, *Proceedings of the Nutrition Society*, Vol. 67, No. 2, pp. 163-176, (2008).
- [104] Lata, C., Advances in omics for enhancing abiotic stress tolerance in millets. *Proc. Indian Natl. Sci. Acad.* Vol. 81, No. 2, pp. 397–417, (2015).
- [105] Lattimer, James M., and Mark D. Haub, Effects of dietary fiber and its components on metabolic health, *Nutrients*, Vol. 2, No. 12, No. 1266-89, (2010).
- [106] Laxmi, G., Chaturvedi, N. and Richa, S., The impact of malting on nutritional composition of foxtail millet, wheat and chickpea, *Journal of Nutrition and Food Sciences*, Vol. 5, No. 5, pp. 407, (2015).
- [107] Lay M.M-G. and Fields, M.L., Nutritive value of germinated corn and corn fermented after germination, *Journal of Food Science*, Vol. 46, No. 4, pp. 1069–1073, (1981).
- [108] Leder, I., Sorghum and Millets. In: *Cultivated Plants, Primarily as Food Sources*, [Fuleky, G. (Ed.)], in *Encyclopedia of Life Support Systems (EOLSS)*, Developed under the Auspices of the UNESCO, EOLSS Publishers, Oxford, UK., pp: 570-578, (2004).
- [109] Lipton, M., Can Small Farmers Survive, Prosper, or be the Key Channel to Cut Mass Poverty, *Electronic Journal of Agricultural and Development Economics*, Vol 3, No. 1, pp. 58-85, (2006).
- [110] Lumley, J., Watson, L., Watson, M. and Bower, C., Periconceptional supplementation with folate and/or multivitamins for preventing neural tube defects, *Cochrane database of systematic revision*, Vol. 3: CD001056, (2001).
- [111] Magala-Nyago, C.M., Kikafunda, J. K., Mwasaru, M.A. and Connelly, R.K., Evaluation of nutritional value of malted and extruded finger millet based complementary foods, *African crop science conference proceedings*, Vol. 7, pp. 677-686, (2005).
- [112] Mahadevappa, V. G., & Raina, P. L., Lipid profile and fatty acid composition of finger millet (*Eleusine coracana*), *Journal of Food Science and Technology*, Vol. 15, No. 3, pp. 100–102, (1978).
- [113] Mahgoub, Salah, E.O., and Safia, A. Elhag., Effect of milling, soaking, malting, heat-treatment and fermentation on phytate level of four Sudanese sorghum cultivars, *Food chemistry*, Vol. 61, No. 1-2, pp. 77-80, (1998).
- [114] Mallava Patil and Surekha Sankangoudar, Consumption patterns of Minor Millets among Growers and Non-Growers of Minor Millets, *Journal of Pharmacognosy and Phytochemistry*, Vol 8, No. 3, pp. 3726-3729, (2019).
- [115] Malleshi, N. G., Hadimani, N. A., Chinnaswamy, R., & Klopfenstein, C. F., Physical and nutritional qualities of extruded weaning foods containing sorghum, pearl millet, or finger millet blended with mung beans and nonfat dried milk, *Plant foods for human nutrition*, Vol. 49, No. 3, pp. 181-189, (1996).

- [116] Malleshi, N. G., Hadimani, N. A., Chinnaswamy, R., & Klopfenstein, C. F., Physical and nutritional qualities of extruded weaning foods containing sorghum, pearl millet, or finger millet blended with mung beans and nonfat dried milk, *Plant foods for human nutrition*, Vol. 49, No. 3, pp. 181-189, (1996).
- [117] Malleshi, N.G., Hadimani, N.A., Nutritional and technological characteristics of small millets and preparation of value-added products from them. In: K.W. Riley, S.C. Gupta, A.Seetharam, J.N.Mushonga, [Eds]. *Advances in small millets*. Oxford and IBH Publishing Co Pvt. Ltd. New Delhi, pp. 271– 287, (1993).
- [118] Mann, K.G., Orfeo, T., Butenas, S., Undas, A., Brummel-Ziedins, K., Blood coagulation dynamics in haemostasis, *Hamostaseologie*, Vol. 29, No. 1, pp. 7-16, (2009).
- [119] Manoj kumar, Er. Avanish Kumar, Study on Existing Bakery Industries in Allahabad and Sensory Evaluation of Bakery Products, *International Research Journal of Engineering and Technology (IRJET)*, Vol. 03, No. 10, pp. 267-271, (2016).
- [120] Marsh, M.N., Gluten, major histocompatibility complex, and the small intestine: a molecular and immunologic approach to the spectrum of gluten sensitivity (celiac sprue) *Gastroenterology*, Vol. 102, No. 1, pp. 330–354, (1992).
- [121] Martins, Ana Dias, Metabolic Syndrome and Male Fertility, *The World Journal Of Men's Health*, Vol. 37, No. 2, pp. 113-127, (2019).
- [122] Mathanghi, S. K. and K., Sudha, Functional and Phytochemical properties of finger millet (*Eleusine Coracana L.*) for health, *International Journal of Pharmaceutical, Chemical and Biological Sciences*, Vol. 2, No. 4, pp. 431-438, (2012).
- [123] Mayer, A. M. and Poljakoff-Mayber A., *The Germination of Seeds*, Pergamon Press, Oxford, The Macmillan Company, New York, pp. 1-244, (1963).
- [124] Mazzeo, T., Cauzzi, S., Brighenti, F., & Pellegrini, N., The development of a composition database of gluten-free products, *Public health nutrition*, Vol. 18, No. 8, pp. 1353-1357, (2015).
- [125] Mbithi-Mwikya, S., Ooghe, W., Van Camp, J., Nagundi, D., Huyghebaert, A., Amino acid profile after sprouting, Autoclaving and lactic acid fermentation of finger millet (*Elusine coracana*) and kidney beans (*Phaseolus vulgaris L.*), *Journal of Agricultural and Food Chemistry*, Vol. 48, No. 8, pp. 3081–5, (2000).
- [126] Mbithi-Mwikya, S., Van Camp, J., Yiru, Y., Huyghebaert, A., Nutrient and antinutrient changes in finger millet (*Eleusine coracana*) during sprouting, *LWT - Food Science Technology*, Vol. 33, No. 1, pp. 9–14, (2000).
- [127] McIver, Lindsey, A. and Jayson Tripp., *Acarbose*, Treasure Island (FL): StatPearls Publishing, NCBI Bookshelf. A service of the National Library of Medicine, National Institutes of Health, (2020).
- [128] Miller G. L., Use of dinitrosalicylic acid reagent for determination of reducing sugar, *Journal of Analytical Chemistry*, Vol. 31, No. 3, pp. 426-428, (1959).
- [129] Miller, Sharon L., Independent and combined effects of amino acids and glucose after resistance exercise, *Medicine & Science in Sports & Exercise*, Vol. 35, No. 3, pp. 449-455, (2003).
- [130] Millet Network of India (MINI), Deccan Development Society (DDS), Food First Information and Action Network (FIAN), India, Millets- Future of Food and Farming. <https://milletindia.org/wp-content/uploads/2015/07/Milletsfutureoffoodandfarming.pdf>
- [131] Miranda, Jessi., Lasa, A., Bustamante, M.A., Churruca, I., Simón, Edurne., Erratum to: Nutritional Differences Between a Gluten-free Diet and a Diet Containing Equivalent Products with Gluten. *Plant foods for human nutrition (Dordrecht, Netherlands)*, (2014).
- [132] Mounika, M., Devi, K. U., & Devi, S. S., Iron bioavailability from Little Millet and Proso Millet based recipes, *International Journal of Current Microbiology and Applied Sciences*, Vol. 10, No. 6, pp. 2832-2840, (2017).
- [133] Mundia, C. W., Secchi, S., Akamani, K., & Wang, G., A Regional Comparison of Factors Affecting Global Sorghum Production: The Case of North America, Asia and Africa's Sahel, *Sustainability*, Vol. 11, No. 7, pp. 2135. (2019).
- [134] Murari, Lal, Nozawa, T., Emori, S., Harasawa, H., Takahashi, K., Kimoto, M., Abe-Ouchi, A., Nakajima, T., Takemura, T. & Numaguti, A., 'Future climate change: Implications for Indian summer monsoon and its variability', *Current Science*, Vol. 81, No. 9, pp. 1196-1207, (2001).
- [135] Naczki, M. & Shahidi, F., Extraction and analysis of phenolics in food, *Journal of Chromatography A*, Vol. 1054, pp. 95-111, (2004).
- [136] Nada, Fatma A., and Safaa K. Hasan., Preparation and evaluation of gluten free pan bread and noodles, *Sciences*, Vol. 5, No. 04, pp. 1273-1286. (2015).
- [137] Nambiar, Vanisha S., Potential functional implications of pearl millet (*Pennisetum glaucum*) in health and disease, *Journal of Applied Pharmaceutical Science*, Vol. 1, No. 10, pp. 62-67, (2011).

- [138] Naveena, N. and Bhaskarachary, K., Effects of soaking and germination of total and individual polyphenols content in the commonly consumed millets and legumes in India, *International Journal of Food and Nutritional Sciences*, Vol. 2, pp. 12-19, (2013).
- [139] Nayini, N. R. and Markakis, P., Effect of Fermentation Time on the Inositol Phosphates of Bread, *Journal of Food Science*, Vol. 48, No. 1, pp. 262–263, (1983).
- [140] Ndiaye, C., Xu, Shi-Yiug., Ngom, P.M. and Ndoye, A.S., Malting Germination Effect on Rheological Properties and Cooking Time of Millet (*P. typhoides*) and Sorghum (*S. bicolor*) Flours and Rolled Flour Products (Arrow), *American Journal of Food Technology*, Vol. 3, No. 6, pp. 373-383, (2008).
- [141] Nirmala, M., Jyotsna, R., Jeyarani, T., Venkateshwara, R.G., Influence of debittered, defatted fenugreek seed powder and flax seed powder on the rheological characteristics of dough and quality of cookies, *Int. J. Food Sci. Nutr.* Vol. 62, pp. 336–344, (2011).
- [142] Nirmala, M., Rao, S. and Muralikrishna, G., Carbohydrates and their degrading enzymes from native and malted finger millet (*Ragi*, *Eleusine coracana*, Indaf-15), *JFd.Chem*, Vol. 71, No. 2, pp. 293, (2000).
- [143] Nordkvist, E., Salomonsson, A., and Aman, P., Distribution of insoluble bound phenolic acids in barley grain, *Journal of the Science of Food and Agriculture*, Vol. 35, pp. 657-661, (1984).
- [144] O.S.K.Reddy., *Smart Millet and Human Health*, Green Universe Environmental Services Society, (2017).
- [145] Obilana, A. B., Manyasa E. Millets, in *Pseudocereals and Less Common Cereals. Grain Properties and Utilization Potential*, Belton P. S., Taylor J. R. N., editors. (Berlin: Springer-Verlag.), pp. 176–217, (2002).
- [146] Opole, R., Opportunities for enhancing production, utilization and marketing of Finger Millet in Africa, *African Journal of Food, Agriculture, Nutrition and Development*, Vol. 19, No.1, pp. 13863-13882, (2019).
- [147] Opuku, A. R., Ohenhen, S. O. and Ejiofor, N., Nutrient composition of millet (*Pennisetum typhoides*) grains and malts, *Journal of Agricultural and Food Chemistry*, Vol. 29, pp. 1247 & 1248, (1981).
- [148] Osborne, Thomas Burr, *The vegetable proteins*. Longmans, Green and Company, (1924).
- [149] Parry M, Evans A, Rosegrant MW, Wheeler T., *Climate Change and Hunger: Responding to the Challenge*, Rome: World Food Programme, (2009).
- [150] Paulley, J. W., Observations on the aetiology of idiopathic steatorrhoea, jejunal and lymph-node biopsies, *British Medical Journal*, Vol. 2, pp. 1318, (1954).
- [151] Pawar, V.D. and Machewad, G.M., Processing of foxtail millet for improved nutrient availability, *Journal of Food Processing and Preservation*, Vol. 30, pp. 269–279, (2006).
- [152] Phalkey, Revati K., Systematic review of current efforts to quantify the impacts of climate change on under-nutrition, *Proceedings of the National Academy of Sciences*, Vol. 112. No. 33, pp. E4522-E4529. (2015).
- [153] Prabhakar, P., Value Added Products Using Foxtail Millet (*Setaria italica*), Doctoral dissertation, Acharya NG Ranga Agricultural University, Rajendranagar, Hyderabad (2006).
- [154] Prabhu L Pingali, Will the Gene Revolution reach the poor? - Lessons from the Green Revolution Seventh Mansholt Lecture, Wageningen, (2007).
- [155] Pradhan, A., Panda, A.K. & Bhavani, R.V., Finger Millet in Tribal Farming Systems Contributes to Increased Availability of Nutritious Food at Household Level: Insights from India, *Agric Res.* Vol. 8, pp. 540–547, (2019).
- [156] Pradhan, Adikant, Nag, S. K. and Patil. S. K., Dietary management of finger millet (*Eleusine coracana* L. Gaerth) controls diabetes, *Current Science*, Vol. 98, No. 6, pp. 763-765, (2010).
- [157] Pragya, Singh. and Rita, Singh Raghuvanshi, Finger Millet for Food and Nutritional Security, *African Journal of Food Science*, Vol. 6, No. 4, pp. 77-84, (2012).
- [158] Prasada Rao, K. E., Intraspecific variation and systematics of cultivated *Setaria italica*, foxtail millet (*Poaceae*), *Economic Botany*, Vol. 41, No.1, pp. 108-116, (1987).
- [159] Pretty J., Sutherland W.J., Ashby J., Auburn J., The Top 100 Questions for Global Agriculture and Food, *International Journal of Agricultural Sustainability*, Vol. 8, pp. 219-236, (2010).
- [160] Price, M. L., Van Scoyoc, S. and Butler, L. G., A critical evaluation of vanillin reaction as an assay for tannin in sorghum, *Journal of Agricultural and Food Chemistry*, Vol. 26, pp. 1214–1218, (1978).
- [161] Ramanathan, K. M., Subbaiah, S., Francis, S. J. and Krishnamoorthy, K. K., A note on nutritive value of certain minor millets, *Madras agricultural Journal*, Vol. 62, pp. 225-6, (1975).
- [162] Rao, Benhur & Suhasini, Korabandi & Krishna Rao, E., Sarada T., & Seetharama, Nadoor, Baseline Survey on Millets-special reference to Sorghum- NAIP-Millets value chain, (2010).

- [163] Rathi, A., Kawatra, A. & Sehgal, S., Influence of depigmentation of pearl millet (*Pennisetum glaucum* L.) on sensory attributes, nutrient composition, in vitro protein and starch digestibility of pasta, *Food Chemistry*, Vol. 85, pp. 275-280, (2004).
- [164] Roohinejad, S., Omidzadeh, A., Mirhosseini, H., Saari, N., Mustafa, S., Yusof, R. M., Manap, M. Y. A., Effect of pre-germination time of brown rice on serum cholesterol levels of hypercholesterolaemic rats, *Journal of the Science of Food and Agriculture*, Vol. 90, pp. 245– 251, (2010).
- [165] Rosemary, I., Kobue-Lekalake, John, R. N., Taylor and Henriette, de Kock, Effects of Phenolics in Sorghum grain on its bitterness, astringency and other sensory properties, *Journal of the Science of Food and Agriculture*, Vol. 87, pp. 1940-1948, (2007).
- [166] Sade F.O., Proximate, Antinutritional factors and functional properties of processed pearl millet (*Pennisetum glaucum*), *Journal of Food Technology*, Vol. 7, No. 3, pp. 92-97, (2009).
- [167] Salunkhe, D.K., Kadam, S.S. and Chavan, J.K., Nutritional quality of proteins in grain sorghum, *Plant Foods for Human Nutrition*, Vol. 27, pp. 187–205, (1977).
- [168] Schatzkin, A., Mouw, T., Park, Y., Subar, A. F., Kipnis, V., Hollenbeck, A. and Thompson, F. E., Dietary fiber and whole-grain consumption in relation to colorectal cancer in the NIH-AARP Diet and Health Study, *The American Journal of clinical nutrition*, Vol. 85, No. 5, pp. 1353-1360, (2007).
- [169] Schmeltz, Lowell R., Reduction of surgical mortality and morbidity in diabetic patients undergoing cardiac surgery with a combined intravenous and subcutaneous insulin glucose management strategy, *Diabetes care*, Vol. 30, No. 4, pp. 823-828, (2007).
- [170] Seenappa, M., Sorghum and millets in East Africa with reference to their use in weaning foods, Improving young child feeding in eastern and southern Africa: household level food technology, proceedings of a workshop held in Nairobi, Kenya, IDRC, Ottawa, ON, CA, (1988).
- [171] Shahidi, Fereidoon & Chandrasekara, Anoma, Millet grain phenolics and their role in disease risk reduction and health promotion: A review. *Journal of Functional Foods*. Vol. 5, pp. 570-581, (2013).
- [172] Shiao, T., Maddocks, A., Carson, C., & Loizeaux, E., Maps Explain India's Growing Water Risks. World Resources Institute, <https://www.wri.org/blog/2015/02/3-maps-explain-india-s-growing-water-risks>, (2015).
- [173] Shibao, Cyndya, Luis Okamoto, and Italo Biaggioni, Pharmacotherapy of autonomic failure, *Pharmacology & therapeutics*, Vol. 134, No. 3, pp. 279-286, (2012).
- [174] Shobana S, Malleshi NG., Preparation and functional properties of decorticated finger millet (*Eleusine coracana*), *Journal of Food Engineering*, Vol. 79, pp. 529–538, (2007).
- [175] Shobana, S., Usha Kumari, S. R., Malleshi, N. G., & Ali, S. Z., Glycemic response of rice, wheat and finger millet based diabetic food formulations in normoglycemic subjects, *International Journal of food sciences and nutrition*, Vol. 58, No.5, pp. 363-372, (2007).
- [176] Shukla, Anubha, Lalit, Adarsh, Sharma, Vinay, Vats, Dr. Sharad, Alam, Afroz, Pearl and Finger Millets: The Hope Of Food Security Article Info Abstract, *Applied Research Journal*. Vol. 1, pp. 59-66, (2015).
- [177] Singh, J., Dartois, A., Kaur, L., Starch digestibility in food matrix: a review, *Trends in Food Science & Technology*, Vol. 21, pp. 168–180, (2010).
- [178] Sridhar, R., Lakshminarayana, G., Content of total lipids and lipid classes and composition of fatty acids in small millets: foxtail (*Setaria italica*), proso (*Panicum miliaceum*), and finger (*Eleusine coracana*), *Cereal Chem.*, Vol. 71, No. 4, pp. 355-358, (1994).
- [179] Srivastava, Manish, and Chad Deal, Osteoporosis in elderly: prevention and treatment, *Clinics in Geriatric Medicine*, Vol. 18, No. 3, pp. 529-555, (2002).
- [180] Suma, P. F. and Urooj, A., Antioxidant activity of extracts from foxtail millet (*Setaria italica*), *Journal of food science and technology*, Vol. 49, No. 4, pp. 500-504, (2012).
- [181] Sustainable Food Consumption and Production in a Resource Constrained World (SCAR), Third Foresight Exercise, Budapest, (2011).
- [182] Swami, Shrikant & Sawant, A & Thakor, Nayansingh & Divate, A., Physical and sensory characteristics of Ready-To-Eat food prepared from finger millet based composite mixer by extrusion, *Agricultural Engineering International*, Vol. 15, pp. 100-105, (2012).
- [183] Swami, Shrikant Baslingappa, Nayansingh J. Thakor, and Hemant S. Gurav, Effect of soaking and malting on finger millet (*Eleusine Coracana*) grain, *Agricultural Engineering International: CIG*, Vol. 15, No. 1, pp. 194-200, (2013)
- [184] Swaminaidu, N. & Ghosh, & Mallikarjuna, Kokkanti, Millets: The miracle grains, *International Journal of Pharma and Bio Sciences*, Vol.6, pp. B440-B446, (2015).
- [185] Tamas Nemeth, Effect of Nutrient Supply on nutrient uptake, dry matter accumulation and yield of sweet sorghum, Ph.D Thesis, Hankoczy Jenő Doctoral School of Plant Production, Horticulture and Food Science, University of Debrecen, (2009).

- [186] Tamura, Akira & Ishihara, Hisamitsu & Suzuki, Susumu & Hirai, Masashi & Takahashi, Rui & Yamaguchi, Suguru & Satoh, Fumitoshi & Kanno, Noriatsu & Katagiri, Hideki & Oka, Yoshitomo, Hypoglycemia associated with hyperinsulinemia in a subject with type 2 diabetes and liver cirrhosis, *Nihon Naika Gakkai zasshi, The Journal of the Japanese Society of Internal Medicine*, Vol. 95, pp. 1371-4, (2006).
- [187] Tangkongchitr, U., Seib, P.A., and Hosoney, R.C., Phytic Acid. II. Its fate during Breadmaking, *Cereal Chemistry Journal*, Vol. 58, No. 3, pp. 229-234, (1981b).
- [188] Taylor, J. R., Schober, T. J., & Bean, S. R., Novel food and non-food uses for sorghum and millets, *Journal of cereal science*, Vol.44, No. 3, pp. 252-271,(2006).
- [189] Taylor, J.R.N., Millet: Pearl, *Encyclopedia of grain science*, Vol. 2, Wrigley C.W., Corke, H and Walker C.E. edition, Elsevier, Amsterdam, pp. 253 – 261, (2004a).
- [190] Tharsan Sivakumar., Sonya Sivakumar., Leila Chaychi. and Richard J., Comi, A Review of the Use of Acarbose for the Treatment of Post-prandial Syndrome (Reactive Hypoglycemia), *Endocrinol Metabol Syndrome*, Vol. 1, No. 010, pp. 1-5, DOI: 10.4172/2161-1017.S1-010,(2012).
- [191] The World Bank Annual Report, Innovation Policy, A Guide for Developing Countries, Vol. 2, pp. 22, (2010).
- [192] Thilagavathi, T. and Kanchana. S., A Study on the effect of millet and pulse based pasta on blood glucose and lipid profile in alloxan-induced diabetic rats, *International Journal of Pharmaceutical, Chemical & Biological Sciences*, Vol. 7, No. 2, (2017).
- [193] Ugare, Roopashree., Glycemic index and significance of barnyard millet (*Echinochloa frumentacea*) in type II diabetics, *Journal Of Food Science And Technology*, Vol. 51, No. 2, pp. 392-395, (2014).
- [194] UNICEF / WHO / World Bank Group: Joint child malnutrition estimates, Number of children affected by stunting, overweight and wasting, *Global Nutrition Report*, (2018).
- [195] United Nations Children's Fund (UNICEF), *The Global Nutrition Report, The current State of Global Nutrition and Burden of Malnutrition in the World*, (2018).
- [196] United Nations Children's Fund (UNICEF), *The Global Nutrition Report, What People eat and Why it Matters*, Chapter 4, pp. 74-95, (2018).
- [197] USDA, FAS, Foreign Agriculture Service Division, (2003), <http://www.fas.usda.gov/psd>
- [198] USDA, FAS, World Agricultural Production, Circular Series, WAP 12-19, (2019).
- [199] USDA, N., The Plants Database, Version 3.5 (<http://plants.usda.gov>). Data compiled from various sources by Mark W. Skinner, National Plant Data Center, Baton Rouge, LA, 70874-4490,(2005).
- [200] Van Wyk, B.-E. & Gericke, N., *People's plants: a guide to useful plants of southern Africa*. Briza, Arcadia,(2000).
- [201] Vidyavati, H. G., Begum, J., Vijayakumari, J., Gokavi, S. and Begum, S., Utilization of finger millet in preparation of Papad, *Journal of Food Science and Technology*, Vol.41, No. 4, pp. 379-382, (2004).
- [202] Vijayakumar, Poongodi T., and Jemima Beryl Mohankumar., Formulation and characterization of millet flour blend incorporated composite flour, *International Journal of Agriculture Sciences*, Vol. 1, No.2, pp. 46, (2009).
- [203] Volta, U., Caio, G., Tovoli, F., & De Giorgio, R., Non-celiac gluten sensitivity: questions still to be answered despite increasing awareness, *Cellular & molecular immunology*, Vol. 10, No. 5, pp.383–392, (2013).
- [204] World Bank Group, *Enhancing Agricultural Innovation: How to Go Beyond the Strengthening of Research Systems*, Agriculture and Rural Development (ARD), Washington D.C., (2006).
- [205] World Bank Lovis, L.J., Alternatives to wheat flour in baked goods, *Cereal Foods World*, Vol. 48, No. 2, pp. 61-63, (2003).
- [206] World Food Summit, Food and Agriculture Organization of the United Nations, Rome, Italy, 1996 and 2009.
- [207] www.niir.org, Profitable small scale industries,(20 Jan 2012).
- [208] Yang, T.T.C. and Koo, M.W.L., Inhibitory effects of Chinese green tea on endothelial cell-induced LDL oxidation, *Atherosclerosis*, Vol. 148, pp. 67–73, (2000).
- [209] Young, M. F., Oaks, B. M., Tandon, S., Martorell, R., Dewey, K. G., & Wendt, A. S., Maternal hemoglobin concentrations across pregnancy and maternal and child health: a systematic review and meta-analysis, *Annals of the New York Academy of Sciences*, Vol. 1450, No. 1, pp. 47–68, (2019).
- [210] Zhang L. Z., Liu R. H., Phenolic and carotenoid profiles and antiproliferative activity of foxtail millet, *Food Chem*, Vol. 174, pp. 495–501, (2015).
- [211] Christopher, T., Sofia, K., Adam, D., Bharati, K., Sanjay, K. and Suneetha, K., Food Environment Research in Low- and Middle-Income Countries: A Systematic Scoping Review, *Advances in Nutrition*, doi: <https://doi.org/10.1093/advances/nmz031>, Vol. 031, pp. 1-11, (2019).

- [212] Lu, H., Zhang, J., Wu, N., Liu, K., Xu, D., Li, Q., Phytoliths analysis for the discrimination of foxtail millet (*Setaria italica*) and common millet (*Panicum miliaceum*), *PLoS One*, Vol. 4, No. 2, pp. 1–15, (2009).
- [213] Ushakumari, S.R., Shrikantan, L. and Malleshi, N.G., The functional properties of popped, flaked, extruded and roller dried foxtail millet (*Setaria italica*), *International Journal of Food Science and Technology*, Vol. 39, pp. 907-915, (2004).
- [214] Kumar, A., Metwal, M., Kaur, S., Gupta, A. K., Puranik, S., Singh, S., and Yadav, R., Nutraceutical value of finger millet [*Eleusine coracana* (L.) Gaertn.], and their improvement using omics approaches, *Frontiers in plant science*, Vol. 7, pp. 934, (2016).
- [215] <http://www.millets.res.in/vision/vision2050.pdf>
- [216] Mahalingam Govindaraj, Kedar Nath Rai, Binu Cherian, Wolfgang Helmut Pfeiffer, Anand Kanatti and Harshad Shivade, Breeding Biofortified Pearl Millet varieties and Hybrids to enhance millet markets for Human nutrition, *Agriculture*, Vol 9, No 5, pp. 106, (2019b).
- [217] Devi, P. B., Vijayabharathi, R., Sathyabama, S., Malleshi, N. G., and Priyadarisini. V. B., Health benefits of finger millet (*eleusine coracana* l.) polyphenols and dietary fiber: a review, *J. food sci. technology*, Vol. 51, No. 6, pp. 1021-1040, (2014).
- [218] Stanly Joseph Michaelraj, P. and Shanmugam, A., A Study on Millets Based Cultivation And Consumption In India, *International Journal of Marketing, Financial Services & Management Research*, Vol. 2, No. 4, (2013).
- [219] Steiner, T., Distribution of phytase activity, total phosphorus and phytate phosphorus in legume seeds, cereals and cereal by-products as influenced by harvest year and cultivar, *Animal Feed Science and Technology*, Vol. 133, No. 3-4, pp. 320-334. (2007).
- [220] Özgen, A. Gökhan, Long-term treatment with acarbose for the treatment of reactive hypoglycemia, *Eating and Weight Disorders-Studies on Anorexia, Bulimia and Obesity*, Vol. 3, No. 3, pp. 136-140, (1998).