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66

Role of Millets in Nutritional Security of India

NAAS

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Preface

After almost 67 years of Independence, malnutrition continues to plague India. Even while vast segments of resource-poor people suffer from undernutrition, particularly micronutrient deficiencies (hidden hunger), there is a growing incidence of obesity and chronic diseases like diabetes, cardiovascular diseases, cancer etc. Both the ends of this grim spectrum are at least partly due to changing food habits, loss of millets from the diet being one of them. Millets offer unique advantage for health being rich in micronutrients, particularly minerals and B vitamins as well as nutraceuticals. These phytochemicals have been shown to mitigate above mentioned chronic diseases. Millets can also withstand environmental stress being resistant to drought and warming. Thus, these are grains for the future and "harbingers for evergreen revolution". Currently, they sustain the livelihood of over 60% of small and marginal farmers.

Time trends show marked reduction in area under millet cultivation due to variety of reasons. Thanks to technological breakthroughs, productivity and production have shown some increase despite erosion in farm area.

Growing realisation of the importance of millets has prompted the National Academy of Agricultural Sciences (NAAS) to organise a brainstorming session on "*Role of Millets in Nutritional Security of India*" with Dr. Mahtab S. Bamji – a nutrition scientist (formerly NIN, Hyderabad) as the convener on October 19, 2013. She received help from other scientists in drafting the policy paper. Presentations by experts included agricultural, nutritional, post harvest technological and policy aspects. Some successful initiatives for value chain development were also presented. It was concluded that for nutrition, health and environment security of India, millets have to be revalorised through technological and behavioural engineering, and right policy initiatives. This will demand a concerted effort of agriculture scientists, food technologists, nutrition scientists, industry, NGOs, government and stake holders - farmers, entrepreneurs and homemakers.

Grateful thanks are due to all distinguished participants of the brainstorming, Convener, Co-conveners, Reviewers and the Editors of the Policy Paper.

(R.B. Singh)
President, NAAS

Role of Millets in Nutritional Security of India

1.0 INTRODUCTION

The term millet includes a number of small-grained cereal grasses. Based on the grain size, millets have been classified as major millets which include sorghum and pearl millet and several small grain millets which include finger millet (*ragi*), foxtail millet (*kangni*), kodo millet (*kodo*), proso millet (*cheena*), barnyard millet (*sawan*) and little millet (*kutki*).

The advantages of cultivation of these crops include drought tolerance, crop sturdiness, short to medium duration, low labour requirement, minimal purchased inputs, resistance to pests and diseases. Millets are C_4 crops and hence are climate change compliant. There are varieties particularly in little millet and proso millet which mature in 60-70 days; yet providing reasonable and assured harvests even under most adverse conditions. India is a store-house of highly valuable genetic variability. Millets sequestrate carbon and thereby reduce the burden of green house gas. Millets have been called nutri-grains since they are rich in micronutrients like minerals and B-complex vitamins. Additionally millets are also rich in health promoting phytochemicals, and can be used as functional foods.

Millet cultivation is the mainstay of rain-fed farming on which 60% of Indian farmers depend. They provide food as well as fodder and can be mix-cultivated (polyculture) with pulses and vegetables. Despite these attributes, millets are losing their pride of place in production and consumption in India. In recent years, there has been some effort towards reviving millets.

2.0 ISSUES PERTAINING TO PRODUCTION

Sustained production of millets

Though India is the largest producer of millets in the world, between 1961 and 2012, there has been drastic reduction in the area under cultivation of millets but due to productivity gains in some varieties, total production of millets showed some increase despite shrinkage of area.

Reasons for decline in area

Almost 50% area under millets has been diverted largely to soybean, maize, cotton, sugarcane and sunflower. A combination of factors like low remuneration as compared to other food crops, lack of input subsidies and price incentives, subsidised supply of fine cereals through Public Distribution System (PDS), and change in consumer preference (difficulty in processing, low shelflife of flour and low social status attached to millets), have led to shift from production of millets to other competing crops. There is a vast gap

Table 1. Area, Production and Yield of Millets during last 50 years.

Crop/ Year	Indicator	1955-56	1965-66	1975-76	1985-86	1995-96	2005-06	2008-09	2011-12
Jowar	Area	17.36	17.68	16.09	16.10	11.33	8.68	7.53	6.25
	Production	6.73	7.58	9.50	10.20	9.33	7.63	7.27	5.98
	Yield	387	429	591	633	823	880	962	962
Bajra	Area	11.34	11.97	11.57	10.65	9.32	9.58	8.75	8.78
	Production	3.43	3.75	5.74	3.66	5.38	7.68	8.88	10.27
	Yield	302	314	496	344	577	802	1015	1171
Ragi	Area	2.30	2.70	2.63	2.41	1.77	1.53	1.38	1.18
	Production	1.85	1.33	2.80	2.52	2.50	2.35	2.04	1.92
	Yield	800	492	1064	1049	1410	1534	1477	1641
Small millets	Area	5.34	4.56	4.67	3.16	1.66	1.06	0..91	0.80
	Production	2.07	1.56	1.92	1.22	0.78	0.47	0.45	0.46
	Yield	388	341	412	386	469	443	491	565
Total millets	Area	36.34	36.91	34.96	32.30	24.08	22.08	18.57	18.6
	Production	14.07	14.21	19.96	17.59	17.98	18.14	18.61	18.63
	Yield	387	385	571	545	747	870	1003	1096

Note: Area : Million ha; Production : Million tonnes; Yield: Kg/ha
Source: Agricultural Census, Directorate of Economics and Statistics, Department of Agriculture and Cooperation, Government of India

between productivity of millets in field demonstrations vs. farmers' field pointing to the need for robust extension activities, and transfer of state of the art farming practices, as well as access to good quality seeds to the farmers. Increasing marginalised cultivation is also an impediment to productivity.

Demand for millets can be increased by: (i) Creating awareness regarding their environmental sustainability, nutritional and other health benefits, (ii) Making them available through PDS, (iii) Value addition, and (iv) Inclusion under feeding programmes like mid-day meal, Integrated Child Development Services (ICDS) feeding, and adolescent girls nutrition scheme (now under consideration of Ministry of Women and Child Welfare)

Estimates on production potential versus demand

Estimated demand for millets by 2025 is 30 million tonnes. This has to be met by increasing productivity through choice of better varieties, good agronomic practices, effective extension activities and robust policy initiatives.

A study by ICRISAT using CERES-sorghum and CERES-pearl millet crop growth models and historical weather data, rain-fed potential yields and water balance of sorghum (*kharif* and *rabi*) in different locations, showed that the total yield gap (simulated rain-fed potential yield - farmers' yield) in production zones ranged from 2130 to 2560 kg ha^{-1} for *kharif* sorghum, 280 to 830 kg ha^{-1} for *rabi* sorghum and 680 to 1040 kg ha^{-1} for pearl millet. This indicates that productivity of *kharif* sorghum can be increased by 3.0 to 4.0 times, *rabi* sorghum by 1.4 to 2.7 times and pearl millet by 1.8 to 2.3 times from their current levels of productivity (Murthy *et al.* 2007). Thus assuming an average of 2.5 to 3.0 times potential yield increase as a whole for millets, and current area coverage, the achievable production potential can be three times i.e 45-55 million tonnes. This production potential is achievable by bridging the yield gaps not only through supply side factors such as high yielding crop cultivars, nutrient management and integrated pest management but also addressing demand side issues - value addition by processing, nutritional labelling, alternate industrial utilization and policy measures so as to make millets cultivation more remunerative. Breeding strategies should be redesigned to orient product-specific cultivars. With increased demand and profitability, there will be incentive for farmers to shift to millet cultivation even on better lands. Such a shift will be environmentally and nutritionally beneficial.

Biofortification

Bio-fortification means enrichment/ value addition in crop through genetic manipulations. This seed-based approach is farmer-empowering and can go a long way in reducing deficiency of micronutrients, particularly iron, zinc and vitamin A (Beta carotene) in Indian diets.

Priority is needed for research in biofortification, preferably using conventional breeding and molecular breeding methodologies. A case in point is the ongoing bio-fortification research in pearl millet at ICRISAT, Hyderabad and participating NARS centres. A major thrust is given to bio-fortification under CGIAR funded research programme by ICRISAT. The aim of bio-fortification in pearl millet is to develop varieties/hybrids with high iron and zinc content.

Seed production

There should be an adequate support for seed production of hybrids/ varieties of both public and private sector through public-private partnership (PPP). This should be initiated through signing of MoU between State Departments of agriculture, seed agencies (NSC/ SFCI/SSCs) and private sector seed companies. The State Seed Committees may identify the varieties/hybrids as per State-specific needs. Participation of All India Coordinated Research Projects on pearl millet/sorghum/small millets may be made mandatory in such committees. To promote cultivation of millets as industrial crops, seed delivery systems, community-based services, post-harvest processing, input supply and marketing, coupled with awareness regarding advantages of millet cultivation need to be strengthened.

3.0 NUTRITIONAL AND HEALTH VALUE OF MILLETS

Nutrients in millets and cereals

Nutrient content of cereals and millets is given in Table 2. These old data on the basis of analysis done at the National Institute of Nutrition many years ago may be updated with incorporation of information on varietal variations. Millets in general are rich source of fibre, minerals and B- complex vitamins.

Among the millets, pearl millet (*Bajra*) has the highest content of macronutrients, and micronutrients such as iron, zinc, Mg, P, folic acid and riboflavin. Finger millet (*ragi*) is an extraordinary source of calcium. Though low in fat content, it is high in PUFA (polyunsaturated fatty acids) (Antony *et al.* 1996). It is also rich in essential amino acids, like lysine, threonine, valine, sulphur containing amino acids and the ratio of leucine to isoleucine is about 2 (Ravindran, 1992; Antony *et al.* 1996, Indira and Naik, 1971). The chemical score (percentage of the most limiting amino acid compared to a standard protein like egg protein) of finger millet is about 50 which is relatively better than other millets, *Jowar* (34) and pearl millet (43) (FAO,1970, Eggum *et al.* 1982).

Surveys conducted by the National Nutrition Monitoring Bureau (NNMB 2009), ICMR, show steady reduction in the dietary intake of all food groups including cereals (millets) since 1975. Since mid-90s, the consumption of even cereals falls short of requirement. There has also been a sharp reduction in the intake of energy, protein, calcium and iron.

Table 2. Nutrient content of cereals and millets per 100 g (Gopalan et al. 1989)

Grain/ nutrient	Bajra	Jowar	Ragi	Fox tail millet	Proso millet	Barnyard millet	Kodo millet	Rice-milled	Maize	Wheat-flour
Energy	361	349	328	331	341	397	309	345	342	346
Protein (g)	11.6	10.4	7.3	12.3	7.7	6.2	8.3	6.8	11.1	12.1
Fat (g)	5.0	1.9	1.3	4.3	4.7	2.2	1.4	0.4	3.6	1.7
Calcium (mg)	42.0	25.0	344	31.0	17.0	20.0	27.0	10.0	10.0	48.0
Iron (mg)	8.0	4.1	3.9	2.8	9.3	5.0	0.5	3.2	2.3	4.9
Zinc (mg)	3.1	1.6	2.3	2.4	3.7	3.0	0.7	1.4	2.8	2.2
Thiamine (Vit. B1) (mg)	0.33	0.37	0.42	0.59	0.21`	0.33	0.33	0.06	0.42	0.49
Riboflavin Vit. B2 (mg)	0.25	0.13	0.19	0.11	0.01	0.10	0.09	0.06	0.10	0.17
Folic acid mg	45.5	20	18.3	15.0	9.0	-	23.1	8.0	20	36.6
Fibre g	1.2	1.6	3.6	8.0	7.6	9.8	9.0	0.2	2.7	1.2

Unfortunately earlier NNMB survey reports pooled cereals and millets. It is probable to infer that the sharp reduction in the intake of iron and calcium is due to declining trends in the production and consumption of millets.

Bioavailability of nutrients from millets

High fibre content and presence of some anti-nutritional factors like phytates and tannins in millets affect bioavailability of minerals. Few studies in humans have suggested that absorption of iron tends to be lower from millets than from rice or even wheat. (Rao *et al.* 1983). Thus, the advantage of having higher content of micronutrients may to some extent be nullified by lower bioavailability. More studies using state of art techniques and different methods of cooking are needed to examine the bioavailability of micronutrients including minerals and B-vitamins to assess their nutritional advantage *in vivo*. Effects of physiological status (pregnancy, lactation), age, and nutritional status should also be investigated. Absorption of vitamins and minerals tends to respond to body's demand.

Dietary fibre has health benefits like good bowel movement, and reduction in blood cholesterol and sugar. Besides fibre, millets are also rich in health-promoting phytochemicals like polyphenols, lignans, phytosterols, phyto-oestrogens, phytocyanins. These function as antioxidants, immune modulators, detoxifying agents etc. and hence protect against age-related degenerative diseases like cardiovascular diseases (CVD), diabetes, cancer etc. (Rao *et al*. 2011).

Effect of processing on nutrients

Milling, roasting, soaking and malting: Milling, roasting, soaking, malting, germination and fermentation have been found to reduce phytic acid and tannin contents of millets (Rao and Prabhavathi, 1982, Mammiro *et al*. 2001). The nutrient content of millet grain is relatively poor after milling but the bioavailability of certain nutrients, such as iron improves considerably (Rao and Prabhavathi, 1978). Weaning foods prepared by roasting of finger millet have higher iron bioavailability (Gahlawat and Sehgal, 1994). Popping or puffing of finger millet enhances protein and carbohydrate digestibility (Nirmala *et al*. 2000). Soaking of millet flour prior to heating can activate phytases and thereby improve zinc availability (Agte and Joshi 1997). Malting, finger millet reduces tannin content (brown millet) and phytate and improves ionisable iron and soluble zinc significantly. Malting of pearl millet and finger millet reduces protein content, but improves protein efficiency ratio (PER), bioavailability and has pronounced effect in lowering anti-nutrients (Desai *et al*. 2010).

Fermentation and germination: Enhancement of biological value (BV), net protein utilization (NPU) and contents of thiamine, riboflavin and niacin have been shown in fermented finger millet (Aliya and Geervani, 1981; Rajyalakshmi and Geervani, 1990, Basappa *et al*. 1997). Sprouting has been shown to increase methionine and cysteine content of finger millet (Mibithi *et al*. 2000). Fermentation of finger millet flour using endogenous grain microflora showed a significant reduction in phytates by 20%, tannins by 52% and trypsin inhibitor activity by 32% at the end of 24 h resulting in increase in percent mineral availability of calcium (20%), phosphorous (26%), iron (27%) and zinc (26%) (Antony and Chandra 1998). Fermentation for longer periods of time resulted in a mean decrease of phytic acid by 64.8% after 96 hours and 39.0% after 72 hours in sorghum grain (Makokha *et al*. 2002). In finger millet, there was a mean decrease of 72.3% and 54.3% of phytate after 96 and 72 hours, respectively. Other studies have reported decrease in phytate content by 49.2 %, 66.5% and 33% during milling, germination and fermentation respectively in finger millets (Deosthale, 2002 and Mamrio *et al*. 2001).

Feeding trials in rats have shown superiority of pearl millet-based foods as compared to wheat and rice-based complementary foods (Dahiya and Kapoor *et al*. 1993). Similarly feeding isocaloric diets differing only in the type of cereal, i.e. pearl millet, sorghum, wheat and rice to rats showed significantly higher absorption and liver zinc and iron for the pearl millet and wheat-diet fed groups, than rice or sorghum fed groups. The weight gain was also the highest in the pearl millet group compared to sorghum, wheat and rice-fed groups (Agte and Joshi, 1997).

As functional foods

In recent years, the term functional foods has been used for foods that promote health through prevention of specific degenerative diseases like diabetes, CVD, cancer, Parkinson's disease, cataract etc. This effect is due to the presence of health-promoting and bioactive phytochemicals in plant foods. Some of the known nutrients- vitamins, minerals, essential fatty acids also have benefits in terms of prevention of degenerative diseases, besides their known functions of preventing nutritional deficiency diseases. The term nutraceuticals (like pharmaceuticals) is used for such bioactive compounds having protective effect against degenerative diseases, in isolated form. It is now recognised that harmful oxygen species like free radicals, and peroxides damage cells and initiate the process of diseases.

Epidemiological studies have shown that diets rich in plant foods, including whole grains are protective against the above mentioned non-communicable diseases, due to protective effects of health promoting phytochemicals and some nutrients. Millets which are a treasure trove of health-promotive phytochemicals, have received attention for their potential role as functional foods. Being non-glutinous, millets are safe for people suffering from gluten allergy and celiac disease. They are non-acid forming, and hence easy to digest. They are also non-allergenic (Saleh *et al*. 2013). Processing methods like soaking, malting, decortication, and cooking affect anti-oxidant content and activity (Saleh *et al.* 2013).

Millet and diabetes: Epidemiologically lower incidence of diabetes is reported in millet-consuming populations (Saleh *et al*. 2013). The diabetes preventing effect of millets is primarily attributed to high fibre content. Some antioxidant phenols in millets also tend to have anti-diabetic effect. Reports from India are sporadic. Sorghum is rich in phenolic compounds and antioxidants (Awika *et al.* 2004). Among minor millets, fox tail and barnyard millet have low glycaemic index (40-50). University of Agriculture Sciences Dharwad (and others) have prepared ready to eat foods from these minor millets and demonstrated their anti-diabetic effects. Many processed traditional foods have been prepared from minor millets and pearl millets. However systematic studies to validate their glycemic index are needed.

Millets and other degenerative diseases: Diets high in fibre and antioxidants have been shown to have beneficial effect on serum lipid profile besides blood sugar. Some forms of cancer are also prevented by high fibre diets. Millets being high in fibre, antioxidants and complex carbohydrates are potential candidates for having beneficial effects against diseases like CVD, cancer and ageing in general. Few *in vitro* and animal studies support this view but well controlled studies in human are needed.

In conclusion, millets have potential for protection against age-onset degenerative diseases. This is an area where more work is needed since these diseases are increasing in India. As the largest producer of millets, India can capture world market with appropriate validated functional foods.

4.0 POST-HARVEST PROCESSING TECHNOLOGIES FOR SORGHUM AND MILLETS (SAM)

Commonly used processing technologies for SAM are: milling including decortication or seed coat separation and size gradation into semolina and flour, popping, malting, fermentation and cold extrusion. In recent years, contemporary food processing technologies such as extrusion cooking for Ready to Eat (RTE) foods and breakfast cereals, pasta and vermicelli-noodles and bakery products, malting & brewing, wet milling for starch preparation are employed for these grains. Cost effective dehuller for SAM has not been developed though small prototype models are available. Development of simple technologies for preparation of semolina and flours; composite mini malting unit, Hot-air-based High Temperature Short Time (HTST) unit for sand less popping are some of the areas of future research. Central Institute of Agricultural Engineering (CIAE), Bhopal has developed a millet mill for small millets which can be popularised in millet catchment areas.

Milling to separate seed coat or decortication reduces fibre and nutrients but improves consumer acceptability. Bran is a good source of dietary fibre and edible oil. Deoiled bran from millets has the advantage of having lesser silica than rice bran. Products involving heat treatment (popping, flaking, expanded grains (murmura type) par boiling have better shelf life, since heating deactivates lipase. They also have better aroma and texture, and can be converted in to a variety of products which can be used as snacks or made into complementary food for feeding programmes. Grains like barley and finger millet are amenable to malting (sprouting). Malting increases the bioavailability of micronutrients and amylase, and reduces bulk by breaking down starch. Amylase-rich foods (ARF) like finger millet malt are used in industry. Incorporation of 5% ARF is mandatory for energy-rich formulations used in states sponsored nutrition programmes. Texture and digestibility are also improved.

SAM flours singly are not suitable for bakery products, but they can be mixed with wheat and converted to bakery products. Traditional foods like *roti* cannot be reheated but Mexican Tortillas can be. There is a tremendous scope for promoting SAM-based traditional (*papad*, *murukku* etc.) and contemporary foods (extrusion cooking-pasta, vermicelli, RTE foods etc.) as health foods because of their high nutrient and phytochemicals content. Several Home Science Colleges, industries, Directorates under ICAR, and NGOs are attempting to prepare and market traditional and contemporary millet-based foods. R&D work on parboiling of SAM is scanty even though the potential has been established.

Other commercial uses of SAM

Sorghum and millets are basically starchy grains and have potential for industrial level production of starches, dextrin and ethanol for food and allied applications. In most of the developed countries, SAM finds extensive usage as feed components for bird, cattle and pigs.

5.0 RECENT INITIATIVES – A VALUE CHAIN APPROACH

Initiative for nutritional security through intensive millets promotion (INSIMP)

To promote cultivation and consumption of millets and millets-based products, the Government of India announced an allocation of Rs 300 crores in the budget of 2011-12, under Rashtriya Krishi Vikas Yojna (RKVY), for INSIMP. The aim is to demonstrate improved production and post-harvest technologies in an integrated manner. The scheme is being continued in 2012-13 and 2013-14, with allocation of Rs 175 crores and 100 crores respectively and implemented in 16 states. Major millets such as sorghum, pearl millet and finger millet are covered under Minimum Support Price (MSP) with increase of 42, 55 and 67% in respective MSP of 2010-11 to 2013-14. Apart from bringing more land under cultivation of millets, about 300 Post-Harvesting units have been established in the Andhra Pradesh, Gujarat, Madhya Pradesh, Mahrashtra, Tamil Nadu and UP. These units have increased the supply of raw material for value added products.

Creation of demand for millet foods through production to consumption system value chain - A consortium approach

The major objectives of this Public Private Partnership (PPP) project, mooted by the Directorate of Sorghum Research (DSR), Hyderabad include : (i) Market-driven millets cultivation for specific end products, procurement and primary processing for continuous supply-chain management, (ii) Fine-tuning the technologies for development of millet food products and up-scaling, (iii) Nutritional evaluation and safety of selected millet foods, (iv) Consumer acceptability, price and market strategies and social and policy imperatives, and (v) Entrepreneurship and appropriate strategies to promote and popularize millets for commercialization through value-addition, branding as health foods. The consortium partners are National Institute of Nutrition (NIN), Sate agriculture universities (SAU's), private partners such as ITC and linkages with Defence Food Research Laboratory (DFRL), Central Food Technological Research Institute (CFTRI), CIAE, Central Institute of Post-Harvest Engineering and Technology (CIPHET) and Home Science Colleges.

The e-*choupal* infrastructure of ITC was leveraged by DSR to network hundreds of farmers in Andhra Pradesh and Maharashtra as stakeholders for technology transfer, and improvement of product-specific millets, and primary processing at farm level to value addition. Some entrepreneurship-driven manufacturing units were also set-up. Marketing was facilitated by ITC and nutritional and health studies were done at NIN. A host of sorghum based products were developed and entrepreneurship promoted. This is a promising approach which can generate income and improve access to products made from nutri-cereals.

Employment generation for women through production and marketing of millet-based processed foods

Some Home Science Colleges have involved Self Help Groups (SHGs) in preparing traditional millet-based products, teaching quality control measures, packaging and labelling and hand-holding for local marketing. A successful case study is from the University of Dharwad, where women of North Karnataka are making *roti* (salted pancakes) from sorghum, and pearl millet, and supplying to hotels "Kharnavalis" retail and wholesale dealers, beside supplying to marriage and other social parties at the cost of Rs. 3-5 per *roti*. On an average each woman can prepare 50-60 *rotis.*

A variety of other traditional and contemporary (noodles) millet-based products including small millets have been developed under projects like NAIP and IDRC. SHG women have been trained in their production and help is being given for direct marketing as quality control and market are major challenges. Such a venture can be successful if either a government institution or NGO provides supervision and marketing.

Millet-based food security and women empowerment

Deccan Development Society (DDS) is conducting a unique experiment of empowering many '*dalit*' rural women by organizing them into '*Sanghams*' (Voluntary village-level association of poor) and involving them in dryland agriculture using green methods of farming. Location is Zahirabad mandal of Medak District of Andhra Pradesh. A variety of minor millets besides SAM, as well as pulses, vegetables, medicinal plants etc. are cultivated on own or leased land. Seeds using scientific methods are being preserved. A millet-based, decentralised Public Distribution System (PDS), and food outlet are being run. The results in terms of ensuring household food security for the poorest families, preserving biodiversity and empowering women are remarkable. DDS has also started a virtual Millet Network (*www.ddsindia.com*) for sharing experiences.

National Food Security Bill (NFSB)

The recently passed NFSB has included millets in the basket of food grains to be given at subsidized rate. Concern has been expressed about inadequacy of production to meet this new demand. According to one calculation (Banerjee, 2011), availability should not be a problem even for universal PDS.

6.0 RESEARCH PRIORITIES AND POLICY INITIATIVES

The challenge is to accelerate demand for millets for human consumption and ensure supply through scientific, technological and behavioural engineering.

Strategies for creating demand

1. The production and consumption of millets must be augmented with appropriate policy initiatives.
2. Consortium-mode research may be pursued for validating the advantages of millets as health and functional foods.
3. Traditional and non-traditional, ready to use, convenience foods and foods that can be used for complementary feeding programmes may be developed with proven nutrient content and bioavailability mapping.
4. Millet-based complementary foods such as *khichdi*, *upama, roti* etc. in feeding should be introduced in feeding programmes such as MDM, ICDS etc.
5. R&D on millets as fodder and forage for livestock feed security may be strengthened.
6. Commercialise and promote millet-based processed Ready to eat snacks and convenience foods through public private partnership.
7. Awareness regarding nutritional, health and environmental advantages may be created thorough known communication strategies.

Strategies for enhancing supply

1. Development of varieties/hybrids of SAM with better recovery capacity on reversal of dry spell for harsh environment/drought prone areas.
2. Exploration of zero tillage for millets under rice fallows particularly for southern States.

3. Development of hybrids/varieties resistant/tolerant to salt/high temperature. Strengthening breeding programmes through conventional breeding, marker-assisted breeding as well as biotechnology for biofortification and other traits such as varieties with better root architecture.

4. Validation of high productive technology under real farming situations.

5. Effective deployment of trait-specific germ plasm available in gene banks for genetic enhancement.

6. Evolving strategies for better seed production with public, private, NGO partnership and establishment of seed villages.

7. Research for better post-harvest management for enhancing the shelflife of millets and prevention of wastage.

8. R&D for integrated toolkit for farm mechanisation. CIAE Bhopal has developed a millet mill suitable for small millets. This should be tested in millet catchment area. Retro fitting of machinery used for rice/wheat/maize for millet foods processing.

9. Markets and entrepreneurship development through modern and innovative approaches.

10. Generation of scientific data to substantiate the claim of conservation of biological resources, low water consumption, agro-climatic limitations and high nutritious value of millets and their derivatives.

11. Promote production and consumption of millets through mixed/ relay cropping with legumes and vegetables in homestead gardens.

12. R&D work to generate evidence-based information on the phytochemicals with nutraceutical characteristics and authenticate their health potential including anti-diabetes, anti-inflammatory and hypo-cholesterolemic properties, through clinical trials and nutritional studies. Functional foods for diabetes and obese populations based on SAM will have good market. Measurements of glycemic index should be done using specified WHO-FAO protocol. Such studies must be extended to the best preparations/recipes from millets with functional properties, through proper clinical trials.

13. Studies to examine the bioavailability of micronutrients from different preparations of millets.

14. Breeding to improve the levels of lysine and tryptophan and also screening the germplasms for specific end uses such as milling, popping, malting and vermicelli noodles etc.

15. Setting up of a training-cum-demonstration centre for integrated processing of sorghum and millets.

16. Undertaking surveys of sorghum and millets foods and allied industries, for bringing out a directory and share knowledge base for modernization of the SAM processing industries.

7.0 CONCLUDING REMARKS

Nutrition security implies awareness and access at affordable cost to balanced diet, safe environment and drinking water and health care outreach. Millets contribute towards balanced diet as well as safe environment. They are nature's gift to humankind. Millets are a treasure-trove of micronutrients like B-complex vitamins and minerals whose deficiencies in India are rampant. They also contain fibre and health promoting phytochemicals which function as antioxidants, immune stimulants etc., and thus have potential to mitigate degenerative diseases such as diabetes, CVD, cancer etc. whose incidence is rising in India. This makes millets important candidates as functional foods. Unfortunately some of these phytochemicals like fibre, phytates and tannins interfere with the bioavailability of micronutrients particularly minerals. Processing can improve the bioavailability of nutrients as well as functionality. Limited studies show that bioavailability as well as functionality differ with the type of processing and preparation. More work is needed to optimise both of these.

Millets are drought, temperature and pest tolerant and hence are grains for the future in an environment of climate change and global warming. Despite these attributes, millets are losing their pride of place both in terms of production and consumption, for a variety of reasons, including policy initiatives which favour cereals. Though they have not enjoyed technological breakthroughs like the green revolution for cereals, their productivity has increased. Confined to poor lands, productivity is further affected and there is a wide gap between potential productivity and productivity in farmers' fields.

Unlike cereals, primary processing of millets poses some problems for want of proper machinery, particularly for small and medium scale enterprises. In recent years, a variety of traditional and non-traditional, millet-based processed foods and complementary foods have been developed. These can become income-generation activity for women in household industry. Even while commercialisation is needed, primary effort should be to see that millets are consumed by the poor and they are cultivated as mixed/relay cropping with legumes and vegetables in homestead gardens for home consumption to ensure household food and nutrition security.

Scientific, technological and behavioural engineering involving convergence of efforts of agriculture scientists, food technologists, home scientists, policy makers, and media is needed to revalorise millets. Some recent initiatives to rejuvenate millets from production to Consumption, include: "Initiative for Nutritional Security through Intensive Millets Promotion" (INSIMP), under the Rashtriya Krishi Vikas Yojna of Government of India, "Revalorising Small Millets in the Rain-fed regions of South Asia (RESMISA) funded by International Development Research Centre (IDRC) and CIDA (Canadian funds), and

DSR-led value chain development approach for commercialisation of millets. Millets are an important component of the National Agriculture Innovation Projects of ICAR, and All India Coordinated Project in Home Science, Other policy initiatives include: price and procurement support for millets, inclusion of millets in the Mid day meal programme and, promotion of Nutrifarms.

8.0 SUPPLEMENTARY NOTES

The following materials provided by the authors have been used in developing this Policy Paper:

- *Millets for Nutrition security:* Dr. B. Dayakar Rao, Dr. J.P. Singh and Dr. J.V. Patil
- *Pearl Millet: Processing and Value Addition* by Dr. A. Kawatre
- *Post-harvest Processing Technologies for Millets: Traditional Practices and Contemporary Methods* by Dr. N.G. Malleshi
- *Millets: Potential Functional Foods* by Dr. R.K. Naik, Dr. M.V. Jali, and Dr. D.R. Megana
- *Nutrient Composition and Availability of Nutrients from Millets* by Dr. M.K. Nair and Dr. K. Archana
- *Sorghum as A Functional Food and Relevance to Human Health* by Dr. C.V. Ratnavathi and Dr. J.V. Patil
- *Improving Productivity and Enhancing Consumption - The Twin Approaches - For Promotion of Millets In India* by Dr. A. Seetharam

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