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Research Article

Value Addition Influenced in Millet Products - A Review

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Abstract

The intervention was aimed at reversing the declining consumption of millet, which was primarily due to inconvenience in its preparation as direct food. Thus diversifications of processing technologies related to millet products were attempted, to remove the inconveniences and to develop, fine-tune and standardize millet product technologies. For this purpose, the new trends of food processing involved the primary processing and secondary processing methods have been developed more products, such as extruded products (vermicelli and pasta), flakes, savouries, nutribar, and biscuits etc. These products were made ready for commercialization with improved shelf life. Processing interventions in millet products were good acceptability with improved nutritional value, convenience and shelf life. They are being continued for invention of innovative products of millet and target both niche markets such as gluten-free products; health mix products for mass-markets at the national level. One of the most relevant millet interventions was promotion; creating awareness of the health and nutritional merits of millet products and reinventing them as popular, convenient and healthy foods.

Keywords: Diversification; Millet products; Commercialization; Convenience; Healthy foods

Introduction

Millets are important crops for dry land farmers; they are highly nutritious and are a climate-compliant crop. Overall millets consumption in India has declined over the years. In order to revive the demand for millets in India, government and non-government is the led a consortium funding to undertake interventions to bridge the gaps identified in the millet value chain: at on-farm production, processing diversification, nutritional certification, promotion and marketing. It brought together all the stakeholders in the Production-to-Consumption System (PCS) value chain, linking them with poor dry land farmers. India is still one of the major global producers of millets. This is due to productivity gains in some varieties, with the production of millets showing some increase despite shrinkage of area. Thanks to the Green Revolution in 1965-66, which led to an increase in per capita availability of food grains, cereals at the national level kept pace with population growth. However, millet cultivation has reduced drastically; during 1955-56, it was 36.34 million ha and by 2012-13, it had reduced to 15.40 million ha (Table 1). The production of millets in India has risen marginally between 1955 and 2013(Table 2) ;rising from 14.07 million t in 1955-56, to a peak at 19.96 million t in 1975-76, but subsequently reducing to 16.03 million t in 2012–13. This overall rise in millet production occurs despite a decline in area under millet cultivation from 36.34 million ha (1955-56) to 15.40 million ha (2012-13).

Reasons for the Decline in Area under Millet

Demand-led factors

- Rapid urbanization.
- Changing consumer tastes and preferences due to rising per capita income.
- Government policies favouring other crops such as output price incentives and input subsidies.
- Supply of Public Distribution System (PDS) rice and wheat at cheaper price introduced in
- Non-traditional areas of fine cereals.
- Poor social status and inconvenience in their preparation (especially sorghum).
- Low shelf life of grain and flour.

Supply-led factors

- Increasing marginalized cultivation.
- Low profitability/low remuneration for millets vis-à-vis competing crops.
- More remunerative crop alternatives in kharif competing with millets.
- Decline in production and quality (as in kharif sorghum because of poor quality of grains due to blackening of grains, fetching low price for the farmers).
- Lack of incentives for millet production.

The adoption of improved management/technologies is a key to making agriculture more profitable. Therefore, the availability of improved technology-including seeds of new varieties/hybrids-is of paramount importance for the farmers. Millet Improvement Project is entrusted with the responsibility of improvement of these crops at the national level in coordination with research institution. The Ministry of Agriculture is entrusted with responsibility for the development of these crops at the national level in coordination with the many research institution and the State Department of Agriculture. The state extension agencies work as a bridge between

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Table 1: Cultivated area of millet compared with other crops in India, pre- and post-Green Revolution [79].

Crop/year	Pre-Green Revolution				Post-Green Revolution				
	1955-56	1965-66	1975-76	1985-86	1995-96	2005-06	2008-09	2011-12	2012-13
Sorghum	17.36	17.68	16.09	16.10	11.33	8.67	7.53	6.25	6.21
Pearl millet	11.34	11.97	11.57	10.65	9.32	9.58	8.75	8.78	7.30
Finger millet	2.31	2.70	2.63	2.40	1.77	1.53	1.38	1.18	1.13
Small millet	5.34	4.56	4.67	3.16	1.66	1.06	0.91	0.80	0.75
Total millet	36.34	36.91	34.96	32.31	24.09	20.85	18.57	17.00	15.40
Rice	31.52	35.47	39.48	41.14	42.84	43.66	45.54	42.86	42.75
Wheat	12.37	12.57	20.45	23.00	25.01	26.48	27.75	29.87	30.00
Maize	3.70	4.80	6.03	5.80	5.98	7.59	8.17	8.78	8.67
Total cereals other than millets	51.01	55.48	68.76	71.31	74.65	78.36	82.17	82.15	82.12
Total cereals	87.35	92.39	103.72	103.62	98.74	99.21	100.74	99.15	97.52
Share of millets (%)	42.00	40.00	34.00	31.00	24.00	21.00	18.00	17.00	15.00

Note: Area in million ha.

Table 2: Production of millet compared with other crops in India, pre- and post-Green Revolution [79].

Crop/year	Pre-Green Revolution				Post-Green Revolution				
	1955-56	1965-66	1975-76	1985-86	1995-96	2005-06	2008-09	2011-12	2012-13
Sorghum	6.73	7.58	9.5	10.2	9.33	7.63	7.25	6.01	5.28
Pearl millet	3.43	3.75	5.74	3.66	5.38	7.68	8.89	10.28	8.74
Finger millet	1.85	1.33	2.8	2.52	2.5	2.35	2.04	1.93	1.57
Small millet	2.07	1.56	1.92	1.22	0.78	0.47	0.45	0.45	0.44
Total millet	14.07	14.22	19.96	17.6	17.99	18.14	18.62	18.66	16.03
Rice	41.34	45.88	73.35	95.82	115.57	91.79	99.18	105.31	105.23
Wheat	8.76	10.39	28.85	47.05	62.1	69.36	80.68	94.88	93.50
Maize	2.6	4.82	7.26	6.64	9.53	14.71	19.73	21.76	22.26
Total cereals other than millets	55.45	63.48	112.65	151.48	188.71	177.08	201.28	223.57	222.74
Total cereals	69.52	77.7	132.61	169.07	206.7	195.22	220	242.24	238.78
Share of millets (%)	20.00	18.00	15.00	10.00	9.00	9.00	8.00	8.00	6.70

Note: Production in million t.

Table 3: Utilization of millets in industries.

Millet	Industrial products
Sorghum	Malting, high fructose syrup, starch, jaggery (unrefined sugar), bakery, value- added products for diabetics, poultry and animal feed.
Pearl millet	Malting and brewing, starch, bakery, poultry and animal feed.
Finger millet	Malting and brewing, baby foods, bakery and food for diabetics.
Other millets	Value-added food for devotees (barnyard millet), feed, value-added food products for diabetics and bird feeds

the research institution and farmers. The government of India has extensively taken up a number of initiatives to strengthen the Research- Extension-Farmer (R-E-F) linkages. In pursuance of an effective linkage between research and technology, transfer provides assistance for organizing the national interface between research, extension, industry and trade activities on millets.

Millet is a versatile crop providing food, feed, fodder and fuel. The entire plant is utilized and hence recognized as a high biomass crop. It has been an important staple food for millions of poor people in the dry and rainfed regions of the world. The pattern of utilization for millets varies across countries/regions. In most of the developing countries such as in Africa and Asia, these crops are used primarily for human consumption while in developed countries such as the USA; millets are primarily used for fodder and bird feed. Nearly 10% of total millet production is used in industries to produce various products, while livestock and feed consumption accounts for the lion's share of almost 42.5% (27 million t).The seed demand of millet grains accounts for 6.33% and food consumption accounts for 41.02%. The various industrial products of millets are given in Table 3. And the utilization of millet grain in various industries is increasing, given the limited prospects of the rainy-season , reduced the intake of whole millet for human consumption. Important millet-derived traditional and fast foods are given in Table 4.

Uses of millets in India in addition to the major food products are: Here some of the Technological innovations products developed the listed below.

Table 4: Important millet-derived food products in India.

Millets	Food products
Sorghum	*Roti, ugali*, popped sorghum, malt food, snack/roasted mix grains.
Pearl millet	*Roti, ugali*, fermented food products, pizza, roasted mix grains.
Finger millet	*Roti*, dumpling, popped millet, malt food.
Other millets	*Roti*, cooked cereals.

Decortication, Milling, puffing, Puffed/Popped and Flaked Millets Pasta, Noodles and Other Products Baked Products Extruded Products Fermented Products Malting and Weaning Foods Health and Functional Foods Traditional Foods and Beverages.

Methods for Development of Millet Products

Decortications/Dehulling

Millets were earlier decorticated at household level by hand pounding. Now a day these are milled in rice milling machinery with slight modification of the process. Centrifugal sheller can be used to dehull/decorticate the small millets. The fractions of husk in pearl millet and small millet varied from 1.5 to 29.3% [1]. Soaking of pearl millet grain in 300 ml (w/v) 0.2 N HCL for 15 hr. and washing twice with water helps in removing the hull. Then grains are scarified in laboratory scarifier (Osawa make) for 1-3 min can remove 8.10-15.84% hull [2]. The polyphenolic pigments and phytate phosphorus were reduced to 66.9-71.3% and 60.0-74.0% respectively. Decortication decreases the total mineral contents, but increases the bio-accessibility of calcium, iron and zinc by 15, 26 and 24 g/100 g respectively [3]. It significantly decreases total phytic acid, polyphenols, dietary fibre and the amount of tannins with corresponding increase in protein digestibility. Dehulling coupled with hydrothermal treatment affect the phenolic content and antioxidant potential of millet grains. Antioxidant activity of phenolic extracts was in the order of hull > whole grain >dehulled grain > cooked dehulled grain [4].

Milling

Most of the millets produced in India are used as staple food and less in ready-to-use and convenient food products due to non-availability of proper milling technology. The major constraints for widespread utilization of millet are its coarse fibrous seed coat, coloured pigments, astringent flavour and poor keeping quality of the processed products [5].Pearling, debranning and chemical treatments of millets overcome some of these constraints; improve nutritional quality and consumer acceptability [6]. In milling, the milling efficiency and shelling index are the important parameters that influence the head yield and further processing.

Hadimani et al. [7] milled thirty eight cultivars of pearl millet in McGill mill for 30 s under 1.4 kg pressure and glumes separated by aspiration. The yield of pearled grains and brokens varied from 80.0 to 96.8% and 0.9 to 30.3%, respectively. Similar studies on head yield and bran of minor millets and pearl millet grains found to vary from 63.2 to 90.0%, and 5.0 to 11.0%, respectively. Millet contain appreciable amount of dietary fibre (9-16%) even after removal of husk and major portion of bran [1]. There is significant and positive correlation between milling breakage and thousand-kernel weight, which indicates that bolder grains and varieties of lower protein contents break easily during milling.

Composite flour

Although millets are nutritionally superior to cereals, yet their utilization is not wide spread. One possible way of extending their utilization could be by blending them with wheat flour after suitable processing [8]. On addition of millet flour there would be changes in physico-chemical, nutritional and functional characteristics. In developed countries, many convenience products including extruded products are popularly consumed. Extruded products include spaghetti, macaroni, vermicelli and noodles, pasta, etc. The products are made using refined durum wheat flours or semolina as their main ingredient. Many research workers have attempted to produce composite millet flours by replacing conventional cereal flours to some extent in making the traditional foods, ready-to-use or RTE food products or in the production of pasta. Multi-grain flour by combining wheat and finger millet in the ratio of 7:3 is one of the simple semi-finished products suitable for making chapatti (roti). Kamaraddi and Shanthakumar [9] incorporated the small millet flours to commercial wheat flour and studied the effect of incorporation of refined millet flours on chemical, rheological and baking characteristics. It was found that substitution of wheat flour with millet flours was possible from 10 to 20% level. Barnyard millet and proso millet can be added 20 and 15% respectively. The optimum level of addition of finger millet, foxtail millet and little millet was 10%. The increase in level of millets in blends increased the ash content and decreased the gluten and sedimentation value; loaf volume of dough; per cent damaged starch and protein whereas crust Colour and shape of bread remained unaffected but colour of crumb changed from creamish white to dull brown. Singh et al. [8] prepared composite flours of foxtail, barnyard and finger millet with wheat flour by adding 10-30% millet flour and observed that addition of milled millet flour to wheat flour increased the concentration of protein, fat and ash but decreased the carbohydrates. Addition of milled barnyard millet flour increased significantly ($p<0.01$) the level of protein, crude fat and total ash contents but whole barnyard flour decreased significantly ($p<0.01$) the level of protein. With the increase in the level of finger millet flour in the blend, protein content decreased from 11.59 to 10.99% whereas fat and ash contents increased from 1.06 to 1.37 and 0.55 to 1.37% respectively with no significant variation in carbohydrate content.

Puffed/Popped and flaked millets

Puffing or popping of cereals is an old traditional practice of cooking grains to be used as snack or breakfast cereal either plain or with some spices/salt/sweeteners. Starch is the main carbohydrate in human nutrition and offers a range of desired technological properties. The nutritional quality of starch strongly depends on starch structure and on its processing [10].Puffing or popping process brings about such structural changes in starch or starch-protein matrix of the millet grain or preconditioned pasta that leads to expansion of the grain or pasta pieces and produce a puffed product with high crisp and other textural attributes. The High Temperature Short Time (HTST) treatment exploits the thermo-physical properties of starch and prepares expanded grains or flakes. During this process the Millard reaction takes place in which the sugars present in the aleurone layer react with amino acids of the millet and gives a pleasant and highly desired aroma to the puffed product. In also reduces anti-nutrients like phytates, tannins, etc., increase bioavailability of minerals, give pleasing texture to the product, and enhances protein and carbohydrate digestibility [11]. The engineering properties like moisture, porosity, bulk density, kernel size and ingredient like salt or sugar used in popping affect popping volume and ratio.

Ushakumari et al. [12] prepared expanded finger millet as ready-to-eat new generation product using HTST. Flattening the grains to desired shape factor and moisture content are the critical factors for maximum expansion ratio. The optimal conditions for expansion are moisture content of about 40%, shape factor 0.52 to 0.58, drying time136 to 150 min. The expanded millet had expansion ratio of ≥4.6, hardness ≤5.0 N and with overall acceptability of ≥ 7.2.

The cereal processing technologies can be successfully applied to foxtail millet to prepared RTE or ready to use products in the form of flaked, extruded and roller dried decorticated and popped grains by subjecting native grains (12% mc) to HTST treatment at 230+/- 5 °C [13]. The degree of starch gelatinization was the highest in the case of roller-dried millet followed by popped, flaked and extruded products. The microstructure of puffed starch granules becomes spherical [14] and that of popped and extruded product a honey comb like structure. The cooking of finger millet and foxtail millet flour at 80-100 °C at different levels of water(100-130 ml) and time (1-3 min) to form dough and extrusion through hand extruder and then flaking to a thickness of 0.6 mm, roasting at 90-110°C for 5–15 min can be used to prepare expanded flakes [15].

Popping of conditioned pearl millet using heated sand (250 °C) resulted with yield and expansion ratio of popped grains ranging from 8.3-77.1% and 2.3-11.3% respectively [7]. Puffing process reduces phytic acid (21-50 %) and tannins (3-18 %) [16] whereas popping significantly increases bio-accessibility of Zn (18 g/100 g) in native millet [3].The varietal effect of finger millet on puffing quality shown that brown seeded varieties are more suitable for puffing whereas white seeded varieties yielded organoleptically superior quality puff [17]. The brown seeded variety ‘PR 202’ gave the maximum puffing yield followed by ‘JNR 852’with medium expansion. Premavalli et al. [18] studied the effect of hydration and pan roasting pretreatments on the puffing characteristics of ragi (finger millet) variety ‘MR1’ and found that water and buttermilk hydration influenced puffing yield and bulk density but water conditioning was more economical.

Jaybhyae and Srivastav [19,20] prepared a Ready-to-Eat (RTE) barnyard millet (Echinochloa frumentacea) based snack food by forming thin rectangular shaped, steam cooked cold extrudate (cut pieces of dough) samples and puffing them with HTST puffing process. It was observed that proper level of ingredients and moisture content were the critical factors for forming and cutting the dough in desired shape through dolly pasta machine. The samples prepared from barnyard millet, potato mash and tapioca powder dough in the proportion of 60:37:3 were steam cooked and puffed in hot air at optimum temperature (238 °C) and time (39.35 s) to produce puffed product with an expansion ratio of 2.05 having moisture content of 0.09 kg/kg dry matter. After puffing the product was oven toasted at optimum toasting temperature and time combination of 116.26 °C and 20.23 min respectively to obtain toasted snack food with moisture content (0.0464 kg/kg), Colour (L value - 69.79), crispness (18.45 +ve peaks) and hardness (362.64 g). During the process popped/puffed grains/products are dehydrated to the extremely low level of moisture content (3-5%), which helps to enhance the shelf-life. Now days modern air puffing machines have been developed which can be used for mass production of puffed or popped millet grains [21].

Here some of the product preparations are explained, as below

Preparation of flakes: Raw materials were soaked with water separately. Draining the water and roasting it. The moisture of raw material mixture was adjusted to 10-15 %.the grains were put into flaking machine .the flaked to drying at 50 °C and packaging:

- Raw material-Conditioning-Water-Roasting the grains-Rollerflaker machine-Extruded flakes-Drying at 50°C-Packaging
- In this process, the material comes into contact with the hot surface of the roaster and heat is transferred to the core of the grain. The process is continued until the grains get cooked or the starch content is gelatinized. During this time, the moisture content drops to about 20%.
- The flattened sorghum or the flakes of desired thickness are collected manually.
- The duration of flattening depends on the kind of flakes to be produced, i.e. thin or thick flakes.
- The flaked material will be fairly circular in shape but generally fissured at the edges, and it is screened over perforated decks to separate out finer brokens.
- The thickness of the flakes will be in the order of <1 mm. The flakes are further dried by spreading in an open place or using a mechanical dryer, and then packed (Figure 1).
- Sometimes, the flakes are graded to obtain high value, uniform-sized flakes.
- The seed coat along with the pulverized endosperm material forms the byproduct. Normally, the yield of high quality flakes will be about 60% of the mass of sorghum used for flaking [22].

Preparation of savories from flakes:

- Sorghum flakes are soft textured and hydrate easily just after sprinkling with cold or hot water and could be seasoned with spice and garnishing to prepare very tasty snacks or breakfast items (Figure 2).
- They can be consumed after mixing with milk and sugar and also with buttermilk or curd. Thinner flakes can just be seasoned with a little oil and spice and may be used as delicious dry snacks.

Preparation of museli from flakes:

Figure 1: Flakes.

Figure 2: Savouries.

Figure 3: Museli.

Figure 4: Choco flakes.

Figure 5: Popped grain.

Figure 6: Spicy coated popped grain.

Figure 7: Nutri bar.

- Flakes are soft textured and hydrate easily just after sprinkling with cold or hot water Where to prepare Breakfast Muesli mix, thick flakes were dry roasted and then coated with honey and could be seasoned with dry fruits, fruit candy jaggery /honey and roasted nuts garnishing to prepare very tasty snacks or breakfast items (Figure 3).

Preparation of choco flakes:

- Flakes are coated with melted chocolate with icing sugar (Figure 4).

Preparation of popped sorghum:

- Preparation of pop sorghum is a HTST treatment and is a simple and dry process.
- The process involves the grains are exposed to a hot air stream; the resulting popped grain comes out of the popping machine (Figure 5) and is lighter due to moisture absorption as a result of hot air stream injection; this produces a product with desirable taste and texture similar to popped corn.
- Popped sorghum produced using these methods will a have milky white colour, crunchy texture and highly desirable and characteristic aroma.
- The gelatinized starchy endosperm exhibits a spongy texture with continuous air cells [23,24].

Preparation of spicy/honey coated popped sorghum:

- Popped sorghum coated with honey/spicy mixture
- It is highly desirable and characteristic aroma (Figure 6).

Preparation of nutribar:

- Blending of different types of flakes/popped grains such as sorghum, ragi, pearl millet, dry roasted nuts. Then these blends are pulverized and mixed with sugar syrup and it mixing and shaping cutting and packed with aluminum foil. (Figure 7).

Pasta, Noodles and Other Products

Pasta or papad are made from the flours of cereals or legumes as main ingredient and the dried products are used as RTC. Noodles are the pasta products also known as convenience foods prepared

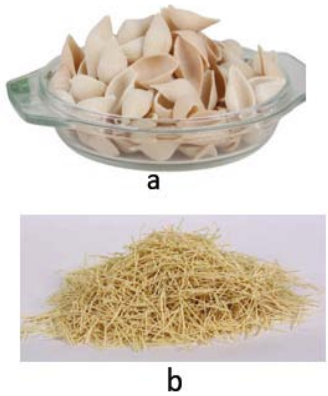

Figure 8: a) Millet pasta, b) Pasta products.

through cold extrusion system which become hard and brittle after drying. The cooking of these noodles is very convenient and requires few minutes. Noodles of different combinations are prepared such as noodles exclusively made of finger millet, finger millet and wheat in the ratio of 1:1 and finger millet blended with wheat and soy flour in the ratio of 5:4:1. Pasta can be prepared with finger millet, refined wheat and soy flour/whey protein concentrate composite flour formulated (50, 40 and 10%) [25] or proso millet and wheat flour blend with appreciable shelf life [26]. Pasta was extracted in dolly pasta machine.

Noodles are one of the most preferred food items among all age groups having longer shelf life and good commercial importance. Barnyard millet has relatively low carbohydrate content (58.56%) having slow digestibility of 25.88% [27]. This health benefit of millet was exploited by preparing value added low glycaemic index noodles from barnyard millet flour by incorporating sago flour, pulse flour and bengal gram leaf powder at different levels to develop plain, pulse and vegetable noodles respectively [28]. The findings indicated significant increase in nutrient composition in pulse and vegetable noodles. The glycemic index of pulse noodles (35.65) and vegetable noodles (38.02) were significantly less than plain noodles (42.07).

Preparation of pasta:

- The flour or fine grits of wheat flour is mixed with cold water to raise the moisture content (to about 30%), allowed to stand for about 30 min and subjected to cold extrusion. (Figure 8).
- The machine is fitted with dies of different sized perforations or
- Of different shapes that determine the diameter of the vermicelli strands or shape/size of pasta products, respectively [29].
- The cold-extruded products are normally steamed for a few minutes to stabilize the vermicelli/pasta and then dried.

Other products: Prepared ladoo (sweet balls) and shankarpara (from dough and formed into flakes) from kanagini or foxtail millet (Setaria italica) by substituting maida with 50% kangini flour and observed that kangini ladoo had protein 13.13%, ash 4.92% and iron and zinc13.83 and 2.35 mg/100 g respectively. It was also found that both the products prepared were acceptable and appearance, texture, and taste of the product were in the category of 'liked very much'. Srivastava et al. [30] prepared popped grains from barnyard, foxtail and little millet using common salt as heating medium in an open iron pan containing sample and salt in the ratio 1:20 at 240-260 °C for 15-25 s. Two types of ladoos (sweet balls of 5 cm dia) first one using individual popped millet grains and jaggery and second type by using millets, roasted groundnut and coconut powder were prepared. The sensory scores on nine point hedonic scales for first and second type ladoo were 5.0-6.9 and 7.2-8.1 respectively. Products based on foxtail millet had higher values of protein and calcium than those based on barnyard millet. Incorporation of groundnut and coconut in the formulation increased the contents twice in protein (7.27-8.39 g/100 g), energy, calcium and iron compared to those containing only millets and jaggery (made from sugarcane juice) in the first type of ladoo.

Geervani and Eggum [31] prepared fortified minor millets by supplementing with lysine to overcome deficiency of amino acid on heat treatment. The italian, french, barnyard, kodo and little millet grains were autoclaved and then supplemented with lysine at 0.6 g/100 g dry matter and observed an increase of both Biological Value (BV) and Net Protein Utilization (NPU). The beneficial effect of supplementation was demonstrated by Eggum et al. [32] who reported an average increase of 0.016 in True Digestibility (TD), 0.154 in BV and >144 in NPU values with the provision of methionine to diets based on casein, skim milk powder, meat and brown beans. In a rat bioassay Ifon [33] observed much improvement in the nutritive value of millet porridge after fortification with soy proteins as reflected in the significant increases in PER (protein efficiency ratio), NPR, NPU and BV.

Jowar crunch, a snack food with a light crunchy texture, prepared by deep-fat frying of dried kernels (pellets) of alkaline-cooked whole sorghum was developed by Suhendro et al. [34]. The optimized process for sorghum were autoclaving for 60 min at 120° C, rinsing, drying to 9% moisture content (room temperature and then 50 °C) and deep fat frying at 220 °C.

Preparation of laddu:

- Millet flours, nuts are roasted in dry pan and mixed with cardamom powder and groundnut powder and to add the powdered jaggery/sugar syrup and melted the ghee mix it and to make a delicious laddu (Figure 9).

Preparation of millet snack:

- Millet flour mixed with Bengal gram flour water and salt to form dough which is extruded through different die and fry it on oil. It should be seasoned with spice and garnishing to prepare very tasty snacks (Figure 10).

Preparation of millet milk: The millet to water mix and ground for 20min in grinding mixer. The millet milk slurry of was stirred well, filtered through sieves, then the slurries were dried in dryer to standard procedure. The dried millet milk powder was collected from stainless steel cyclone in a glass jar. It was packed in glass bottle and stored at room temperature for

- Further analysis. Or the filtered milk slurry were heated at

Figure 9: Millet laddu.

Figure 10: Millet mixture.

Figure 11: Millet Milk.

85ºC for 15min and stored in refrigeration temperature for further analysis (Figure 11).

Bakery products

Bakery products are popular all over the world and the production has risen by many folds due to their low cost, varied taste and textured profiles with attractive package and longer shelf-life to suit easy marketing [35]. The use of millets in bakery products will not only be superior in terms of fibre content, micronutrients but also create a good potential for millets to enter in the bakery world for series of value added products [21]. These are mostly prepared from the wheat flour but efforts are being made to replace few portion of it with millets in order to provide an alternative and reduce over dependence on wheat and make gluten free bread. Finger millet and foxtail millet flour can be incorporated in bakery items like biscuits, nan-khatai, chocolate, cheese, cakes, muffins, etc. (Figure 12).

Figure 12: Bakery products.

Research findings have revealed that substitution of 40% wheat flour with finger millet flour in baked products like cake and biscuits is possible [36,37]. The chocolate cup cake, gel cake, masala cake, carrot cake, soup sticks, rusk and muffins prepared with finger millet have good appearance, texture, flavour and overall acceptability scores. Attempts have been made to improve the nutritional quality of cakes with respect to the minerals and fibre content by supplementing with malted finger millet flour [38].

Sehgal and Kawatra [39] prepared sweet, salty and cheese biscuits using pearl millet flour (40-80%), refined wheat flour (10-50%) and green gram flour (10%) and found highly acceptable with nonsignificant difference. Biscuits prepared from maida finger millet flour blend (80:20) can have shelf life period of 120 days at 65% RH at 27ºC when packed in double pack of polypropylene/pearlised BOPP and metalised polyester/polylaminate packs [40]. More nutritious sweet and salty biscuits prepared from refined wheat flour, blanched pearl millet and green gram in the ratio of 50:40:10 (Type I) and 30:60:10 (Type II) than those with refined wheat flour alone but with higher anti-nutrient (polyphenol and phytic acid) content in Type II biscuits [39]. Saha et al. [41] prepared biscuits from flour composites containing 60:40 and 70:30 (w/w) finger millet: wheat flour and found that hardness of biscuit dough was more in 60:40 combinations than in 70:30 levels. The adhesiveness and resistance of biscuit dough increased with the increasing levels of wheat flour but expansion of biscuit and breaking strength after baking was more in 70:30 composite than in 60:40. Wheat composite flour (40 g/100 g) had higher water absorption capacity than in 30 g/100 g composite.

Krishnan et al. [42] tried to explore the possibility of using Seed Coat Matter (SCM) of finger millet in preparation of biscuits using the composite flour with comparable crisp texture, breaking strength (1480-1690 g), higher protein, dietary fibre and calcium contents compared to control biscuits (1560 g). The sensory evaluation of the biscuits indicated that 10% of SCM from native and hydrothermally processed millet and 20% from malted millet could be used in composite biscuit flour. Production of wheat-free sorghum or millet bread remains the challenge [43].

Some researcher also tried production of cookies from 100% sorghum or pearl millet. Such cookies could be produced, but were tough, hard, gritty, and mealy in texture and taste. These products also lacked spread and top surface cracks, both traits being regarded as desirable. The lipid composition may be partly responsible for this inferior quality.

Extruded products

A majority of world population suffers from qualitative and quantitative insufficiency of dietary protein and calories intake. In all such cases physiological maintenance and growth are impaired and malnutrition results. In this context, extrusion is a beneficial process. Extrusion cooking is a HTST cooking process, which could be used for processing of starchy as well as proteinaceous materials. The use of extrusion cooking has distinct advantages like versatility, high productivity, high product quality, increase in in-vitro protein digestibility [44] and production of new food without effluents. Extrusion Cooking is accomplished through the application of heat either directly by steam injection or indirectly through jacket or by dissipation of mechanical energy through shearing occurring within the blend.

Used lactic and citric acids as alternatives to backslop fermentation in the manufacture of extruded uji (a thin porridge of maize finger millet from eastern Africa). Acidity of the blends was reduced by fermentation or progressively lowered with 0.1, 0.5, and 1.0 mol/l lactic or citric acids before extrusion. The extrusion solubilizes starch without formation of maltodextrins. In vitro starch digestibility increased from 20 mg maltose/g in the raw blend to about 200 mg/g after extrusion. Fermentation of lactic/citric acid treated blends before extrusion increased in-vitro protein digestibility and the nitrogen solubility index (by 20%). The tannin content decreased from 1677 mg/100 g in the raw blend to between 551 and 1093 mg/100 g in the extrudates whereas phytate content remained unaffected by extrusion (248-286 mg/100 g). Extrusion process increases the iron availability of the extruded weaning foods based on pearl millet, cowpea and peanut or milk powder by 3.5 to 6.5 times higher than the corresponding roasted weaning foods [45].

Millet based extruded snack foods are prepared using twin-screw extruder from kodo millet-chickpea flour blend (70:30) [46]; pearl millet, finger millet and soybean flour blend [47] or ragi, sorghum, soy and rice (42.03,14.95,12.97 and 30%) flour blend [48] with desired quality.

Expansion index (2.31) and sectional expansion index (5.39) was found to be maximum for feed rate and screw speed combination of 9.5 kg/h and 250 rpm for pearl millet (81.68%), finger millet (7.02%) and decorticated soy bean (11.29%) composite flour. The barrel temperature significantly affects all the product attributes like expansion ratio, bulk density, hardness and crispiness significantly. Kodo-chickpea flour blend gives desirable crispy extrudates at higher screw speed of 280 rpm, lower feeder speed 20 rpm, and medium to high temperature of 123 °C. About 15% moisture content of the millet-pulse or millet-soy feed at 10 to 15% blend ratio appears to be acceptable level microwave cold extrudated puffed barnyard millet based ready to eat fasting foods with comparable sensory quality was developed by Dhumal et al., [49].

Pelembe et al. [50] developed a protein rich composite Sorghum-Cowpea porridge by extrusion cooking at 1300 C and water content of 200 g/kg and was similar to commercial instant maize–soy porridge in terms of functional properties. Increase in cowpea resulted in increase in protein content, Water Absorption Index (WAI) and decrease in Expansion Ratio (ER). Sumathi et al. [51] blended pearl millet with grain legumes (30%) and also with defatted soy (15%) separately and prepared nutritious extruded ready-to eat food. The foods based on millet and the millet-soy blend contained 14.5% and 16% protein with 2.0 and 2.1 protein efficiency ratio values, respectively. Devi and Narayanasamy [52] explored the possibility of preparation of composite millets milk powder with the combination of finger millet and pearl millet to prepare RTC extruded product from composite of millet powder and maida (50:50) within the acceptable range in terms of nutrient content, color, texture and cooking quality and sensory characteristics.

Fermented products

Fermented foods like Dosa and Idli are popular and common breakfast foods and even as the evening meals in many parts of India. Millets are good source of protein but the protein quality in terms of lysine and tryptophan content is low, hence there is growing emphasis on the improvement of protein quality.

Fermentation not only improves the taste but at the same time enriches the food value in terms of protein, calcium and fibre, B vitamins, in vitro protein digestibility and decreases the levels of anti-nutrients in food grain [21,53,54]. Fermentation of the ground germinated pearl millet grains gives higher protein digestibility (>90%). Khetarpaul [55] fermented the pearl millet by inoculating the micro flora namely, S. diastaticus, S. cerevisiae, L. brevis and L. fermentation and incubated at 30 °C for 72 h in single culture, mixed culture and sequential culture fermentation. The samples were oven dried and ground to fine flour and found that controlled pure culture fermentation did not change the protein and ash content of pearl millet (sprouted and flour) and increased the starch digestibility of flour significantly. High dietary calcium and phytic acid reduces bio-availability of zinc by Zn-Ca-phytate or Zn-phytate complex. Fermentation is one of the most economic and effective measure for reducing polyphenols and phytic acid significantly and improves HCL-extractability of zinc [56,57], iron, copper, calcium and manganese but maximum reduction is brought out by sequential fermentation. Dry heating and acid treatment of pearl millet also increases the mineral availability significantly [58].

Germination and probiotic fermentation causes significant improvement in the contents of thiamine, niacin, total lysine, protein fractions, sugars, soluble dietary fibre and in vitro availability of Ca, Fe and Zn of food blends [59].

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%) [60]. The various recipes were prepared including cutlets, weaning mixtures, vermicelli and biscuits from naturally and mixed fermented pearl millet flour and were highly acceptable. The findings indicated that pure culture fermented products can be safely included in the diet of the people for improving starch digestibility, increase bioavailability of minerals and proteins. The availability of zinc during pure culture fermentation was found to be more effective than natural fermentation. A highly significant ($p \leq 0.05$) improvement in the in vitro protein digestibility of pearl millet genotypes can be achieved if fermented for 14 h [54].

Onyango et al. [61] prepared high energy density fermented uji from different combinations of maize, finger millet, sorghum and cassava using alpha amylase and extrusion. It was observed that fermentation alone was not able to reduce viscosity of uji but addition of 0.1-2.1 ml/100 ml alpha-amylase to the fermented slurry or extrusion of the fermented and dried flour at 150-180 °C and a screw speed of 200 rpm reduced viscosity of uji from 6000-7000 to 1000-2000 cp with acceptable energy densities (0.6-0.8 kcal/g) for child feeding.

Malting and weaning foods

Traditionally, the millet malt is utilized for infant feeding purpose. Finger millet possesses good malting characteristics and its malting is popular in Karnataka and part of Tamil Nadu. Malting helps to increase significantly the nutrient composition, fibre, crude fat, vitamins B, C and their availability, minerals [62], improve the bioavailability of nutrients, sensory attributes of the grains. Millet malt is used as a cereal base for low dietary bulk and calorie dense weaning foods, supplementary foods, health foods and also amylase rich foods. Malting reduce paste viscosity of flour than many other heat treatments [63].

In malting germination is an important unit operation that needs greater attention. The germination temperature normally suggested is greater than 22 °C. Pelembe et al. [50] found 25-30 °C to be optimal with a germination period of 3-5 days. Malting finger millet reduces tannin (brown millet) and phytic acid content, and improves ionisable iron and soluble zinc significantly but malting, steaming and roasting of little millet increase the nutraceutical and antioxidant properties in terms of total phenolic, flavonoid and tannin contents [64]. The amylase activity of malt flour from brown finger millet seed was higher than white seed varieties [65]. Malting of pearl millet and finger millet reduces protein content, but improves Protein Efficiency Ratio (PER), bioavailability of all minerals and has pronounced effect in lowering anti-nutrients [3,38].

Asma et al., [66] prepared weaning blends composed of 42% sorghum supplemented with 20 % legumes, 10 % oil seeds, and 28% additives (sugar, oil, skim milk powder, and vanillin) as per FAO/WHO/UNU recommendations and processed in a twin-roller drum dryer. The blends were found to contain good proportion of protein 16.6% to 19.3%, fair fiber content of 0.9% to 1.3%, satisfactory energy level 405.8 to 413.2 kcal per 100 g and a healthy iron content of 5.3 to 9.1 mg/100 g. The calcium content ranged from 150 to 220 mg/100 g and lysine content improved considerably ($p <$ or $= 0.05$) for all blends.

The paste of this blend was comparable to commercial weaning foods in terms of water-holding capacity, wettability and bulk density. Malleshi and Klopfenstein [67] tried to use seed germination as a tool to improve the nutrient potential of millets.

Preparation of breakfast cereal:

- Millet based-based breakfast cereals can be prepared using in the form of blending of different types of prepared roasted malt flour and pulse flour in appropriate proportions and mixed with fruit candy, and roasted dry nuts added with jaggary and pulverized to flour then to blend it thoroughly.
- It is RTE and is generally taken as a breakfast cereal along with cold or warm milk. This type of cereal would be nutritionally superior to single flakes alone. They are also normally fortified with the necessary vitamins and minerals to enhance their nutritional value. This type of food is of high value and a convenience food (Figure 13).

Figure 13: Breakfast cereal.

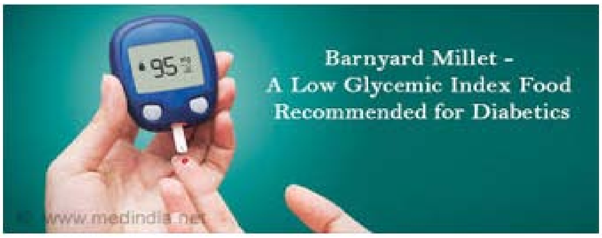

Figure 14: Millet Low GI.

Health and functional foods

Small millets are important coarse grains and rich in nutrients. The term functional foods has been commonly used for foods that promote health through prevention of specific degenerative diseases like diabetes, cancer, Parkinson's disease, cataract etc. due to the effect of health-promoting and bioactive phytochemicals in plant foods. The term nutraceuticals (like pharmaceuticals) is used for such bioactive compounds like vitamins, minerals, essential fatty acids having protective effect against degenerative diseases, in isolated form. Epidemiological studies reflect that persons on millet based diet suffer less from degenerative diseases such as heart diseases, diabetics, hypertension, etc. Millets have received attention for their potential role as functional foods due to health promotive phytochemicals (Figure 14). Millets are safe for people suffering from gluten allergy and celiac disease. They are non-acid forming and non-allergenic hence easy to digest [68].

Finger millet, foxtail millet, pearl millet and sorghum are the potential sources of antioxidant compounds which can quench the free radicals [69]. The total phenolics and tannin content of pigmented type of finger millet; moderate reducing ability and high free radical scavenging activity of pearl millet serve as a source of antioxidants in our diets [70]. The presence of flavonoids, like tricin, acacetin, 3, 4 Di-OMe luteolin, and 4-OMe tricin in traditional recipes, indicate the chemo-preventive efficacy of pearl millet [71]. They may be inversely related to mortality from coronary heart disease and to the incidence of heart attacks in the pearl millet consuming belts of the world similar to lower incidence of diabetes reported in millet consuming populations [68]. 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. Among minor millets, foxtail and barnyard millet have low glycaemic index (40-50).

Traditional foods and beverages

Addition of finger millet as one of basic ingredient to the tune of 15-20% (w/w) along with other essential ingredients such as black or green gram, rice and spices has become a tradition in millet growing areas of South India [21]. Addition of finger millet up to 60% in papad is possible and practiced in some parts of Karnataka [72]. Vidyavati et al., [73] prepared millet papad (rolled, circular and thin sheets) by substituting 50% of mixture of black gram dhal flour and sago flour with finger millet flour and compared with black gram (Phaseolus mungo) dhal papad. The finger millet flour papad had higher sensory score of 4.7 on a five point hedonic scale and were rich in Ca (102 mg% in roasted and 109 mg% in fried) compared to black gram dhal papad (82 mg% in roasted and 99.6 mg% in fried).There was a slight reduction in nutrient composition but the protein quality improved due to supplementary effect of millet and pulse proteins. Consumer acceptability of finger millet Papad was very good after long storage and hence finger millet can be good substitute in traditional papad.

Sorghum and minor millets are poor source of protein which can be fortified by incorporating pulses or cereals. Badi et al., [74] tried to improve quality of Kisra, a staple food of Sudan, by addition of chickpea and peanuts. This type of kisra can be used as a well-balanced sorghum and millet based baby food for infants above the age of one year. This formulation and way of processing is well suited for commercial production of sorghum/millet based baby food.

Millets porridge is a traditional food in Russian, German and Chinese cuisines. In Southern Karnataka, both the rural and urban population consumes Mudde, a thick porridge of finger millet. Kodo millet is an important food crop for vast sections of the tribal community in Central India. The people in Himalayan foothills use millet as a cereal, in soups, and for making dense, whole grain bread called Chapatti. In Maharashtra state flat thin cakes called Roti are often made from sorghum/millet flour and used as the basis for meals. It is possible to incorporate 50–75% barnyard millet flour in preparation of rotis, idlies, dosa, chakli [75]; idli, pakora, vedai,adai and sweet halwa, kolukattai from finger millet;Navane sampali, huggi, burfi or kabab from foxtail millet; and Samai dosa, porridge, paddu and paysam from little millet as traditional recipes in different millet growing states in India. (Figure 15).

'Kodo ko jaanr' is the most common fermented alcoholic beverage prepared from dry seeds of finger millet in the Eastern Himalayan regions of the Darjeeling hills and Sikkim in India. Chhang is also a fermented finger millet beverage popular in Ladakh region in India. Koozh is another fermented beverage made with pearl or finger millet flour and rice, and consumed by ethnic communities in Tamil Nadu [76]. The traditional, naturally fermented finger millet product is called Ambali.Finger millet is the cereal of choice for the preparation of porridges for children and for the sick and old in India. Millet malt is also used to prepare beverages either with milk of lukewarm water with the addition of sugar since pretty old times. Mahewu is a non-alcoholic beverage prepared in Zimbabwe from finger millet (1/3) and sorghum (2/3) malt by traditional fermentation [77]. Some liquid foods with different local names prepared from millets are consumed in India. Ragi soup is also famous and prepared by mixing the ragi flour into water (one part ragi flour and 2.5 parts water). Vijayakumari et al. [36] made a scientific effort to develop finger millet based ethnic common recipes. Two types of beverages namely Ambli and malt were prepared and found a good score for appearance, texture and flavour with overall acceptability scores from 4.0-4.5 in sensory evaluation. There was a non-significant difference between the control and experimental products in all the parameters of sensory attributes. Modern products incorporating finger millet like ragi health drink (baby vita) are now available in the market. Extrusion of malted pearl millet grains can be used to prepare instant beverage powder from pearl millet and it reduces the peak viscosity of the starches significantly.

Figure 15: Breakfast cereal.

Nutritional Overview: Millet *vs.* Major Cereals

Millets-the 'noble grains'- comprise sorghum, pearl millet, finger millet and five small millets. Millets are good sources of carbohydrates (60-73%), proteins (6-13%), fat (1-5%), crude fibre (1-10%), and phytochemicals that have nutraceutical properties. Pearl millet is rich in proteins (11-13%) and lipids (4-6%); finger millet, on the other hand, contains proportionately less protein (6-8%) and fat (1.5-2%) [78]. Crude fibre content is 10–50-fold more in millets when compared to fine cereals, the highest being in barnyard millet. Millet proteins contain high proportions of essential amino acids, being 1.2–1.5-fold higher in essential amino acid content than rice (particularly finger millet). When compared to rice, the essential amino acid histidine content is 1.2-fold higher in sorghum, and the same in pearl millet and foxtail millet. Compared to rice, phenylalanine levels are 1.3-fold higher in pearl millet and methionine levels are 1.4-fold higher in finger millet. Cystine levels are 1.2-1.5-fold higher (or the same as) in rice for all the millets. Isoleucine levels are 1.3-fold higher in proso millet and finger millet. Lysine was always found to be the most limiting amino acid in millets as well as fine cereals. The amino acid presence in all the millets are 1.2-1.9-fold higher than in wheat. Millets also contain important vitamins such as riboflavin, thiamine, folic acid and niacin. When compared to rice, the vitamin riboflavin levels are 2.5–5.2-fold higher and folic acid levels are 1.1- 5.6-fold higher in all the millets, the highest being in pearl millet. Compared to rice, thiamine content is 1.4-fold higher in foxtail millet and similar in finger millet; niacin content in proso millet is similar to that in rice. All the vitamins are similar to the content present in wheat.

Hence, the development of millet products Ready-to-Eat (RTE) and convenient foods are to overcome cumbersome and time-consuming food preparation of millets. The value chain interventions were realized through realistic reassessment of crop research needs in terms of current and future demand, resolving specific production constraints, development of post-harvest processing, value addition technologies, and marketing strategies and policies that may result in additional income and employment without sacrificing the overall goal of attaining sustainable food and nutritional security, especially of the urban poor and millet producing farmers in dry regions.

Figure 16: Successful value chain of millets.

Technical Profile-Contours of the Value Chain

- Identification of the number of potential food products for wide-ranging and niche markets.

- Economic feasibility of products developed and studies on consumer acceptability and pricing strategies of millet foods.

- To develop appropriate strategies to promote and popularize millets and innovative approaches for commercialization through value-addition and branding as health foods

- Entrepreneurship development of stakeholders for intensive cultivation, product development and mechanization (on site and through demo units).

- Value addition through branding of millet-based recipes as health foods by training and popularization.

- Innovative approaches for popularization of millets.

- Assess socio-economic and environmental impacts of the interventions for plan uptake (Figure 16).

The Major Outputs

- Finished products, processes and protocols developed and/or adopted and to ready for commercialization

- Many more processing equipment have been retrofitted to make them suitable for millet processing, such as: pulverizer, destoner and grader, dehuller, hammer mill, chakki mill, roaster, edge runner, parboiling unit, roller flaking unit, semolina making machine, cold extruder, dough kneader, ribbon blender, sifter, homogenizer, convection oven, planetary mixer,automatic cookie cutting machine, popping machine, grinder, automatic sealing machine, nitrogen flux packaging machine, sealing machine, foot-operated roti-making machine, automatic roti-making machine, etc.

- Many more processing technologies (for ready-to-eat (RTE) and ready-to-cook (RTC) millet foods) have been developed, using with different types of millet such as sorghum, pearl millet, finger millet-etc and traditional rice such as red rice and black rice and pulses based products such as: flakes; vermicelli; pasta; gluten-free pasta (three varieties: xanthun gum, guar gum, carboxy methyl cellulose); Noodles, biscuits (many varieties: salty, sweet, groundnut, coconut, gluten-free salty and sweet biscuits (two types), transfat-free salty, sweet (two types), groundnut and coconut and low calorie salty, sweet, groundnut and coconut); RTE extruded snacks; gluten-free puffed snacks, ragi laddu, ragi pakoda. Instant health mix, flakes kheer mix and pasta kheer mix sorghum flakes; pops (three types: honey pops, choco pops and spicy pops); savouries, muesli, Nutribar, millet milk powder, etc were developed.

- Nutritional evaluation of millet is rich in complex carbohydrates, dietary fibre, folic acid, iron, calcium, zinc and magnesium, and can be consumed by all age groups.

- Millet products such as Flakes, Savouries, Nutribar, Pasta, Vermicelli, Noodles, puffed extruded snack (hot extruded snack), Health mix and biscuits) were successfully commercialized in market.

- Through entrepreneurial development programmes, more than 1000 farmers, self-help groups, small-scale processors, women groups and rural entrepreneurs were trained in millet processing, which resulted in the establishment of many rural industries to doubling the farmer’s income. Sensitization of policymakers was an important output, achieved through implement to exhibit the innovative food products which are creating awareness of millet nutritional superiority and to create demand for millets through processing and commercialization.

- Creating demand for millets and enhancing mainstream dryland agriculture is important for India’s sustainability, in terms of food, nutrition and livelihood security. To achieve this, the major challenge is to deliver millet-based technologies that are sustainable and market-oriented, aided by research that develops value-added products, new technologies, marketing strategies and policy measures in millet. Thus, a collaborative effort is needed to reduce those gaps that would help the millet ecosystem and all its stakeholders.

Conclusion

In conclusions, it may be stated that novel processing and preparation methods are needed to enhance the bioavailability of the micronutrients and to improve the quality of millet diets. Research is also needed to determine the bioavailability, metabolism, and health contribution of millet grains and their different fractions in humans. Making millet food products that deliver convenience, taste, texture, color, and shelf-stability at economical cost for poor people is needed. In addition, for promoting utilization of millet grains in urban areas to open new markets for farmers to improve their income, developing highly improved products from millet is needed. So to increase millet utilization and add to diversification in the market hence Entrepreneurship Development Programmes were developed for processing of millets and marketing of millet-based products. Processing millet products were demonstrated to farmers, and rural women and another self-help group (SHGs), farmers and urban entrepreneurs were trained in millet food processing technologies. One of the most relevant millet interventions was promotion; creating awareness of the invention of diversified products, value addition of millet food product, which is health, and nutritional merits of millet products and reinventing them as popular, convenient and healthy foods. This indicates that there is a growing tendency among the food players to invest more in the millet food business, and consumption of millets will once again be revived in India. With regard to horizontal expansion, it is envisaged that markets will be targeted across the country, even in non-traditional millet-consuming urban metropolises, such as Delhi, Bangalore, Chennai and Pune in phase I, expanding to other areas in phase II. Since the value chain model has proved to be successful and sustainable, it is ready for replication to the remaining millets and other crop commodities in India and across the globe.

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